Rice, weeds and shifting cultivation in a tropical rain forest

A study of vegetation dynamics

Anneke de Rouw

Stellingen

1

Het *Ars* element in de vegetatiekunde is zeer nuttig voor het succes van de *Scientia*.

2

De kennis van de ecologie van het tropisch regenwoud zal toenemen wanneer vegetatiekundigen niet alleen naar de planten boven hun hoofd kijken, maar vooral naar die op de grond.

- dit proefschrift -

3

In zuid-west Ivoorkust waar de vrouwen verantwoordelijk zijn voor de voedselteelt, heeft het naar school gaan van de meisjes de druk op het resterende regenbos verminderd.

- dit proefschrift -

4

Er is altijd een goede reden om niet te wieden.

- dit proefschrift -

5

Collectief determineren geniet de voorkeur boven individueel.

6

Het niet afsluiten van onderzoeksprojekten met een synthese is verspilling.

7

Positieve discriminatie ten gunste van vrouwen is niet nodig indien positieve discriminatie ten gunste van mannen ophoudt.

8

Na de "bevrijding" van de mens in Oost Europa zullen de varkens en de kippen wel achter de tralies komen.

A. de Rouw
Rice, weeds and shifting cultivation in a tropical rain forest.
A study of vegetation dynamics.

Wageningen, 21 mei 1991

Rice, weeds and shifting cultivation in a tropical rain forest

A study of vegetation dynamics

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Proefschrift
ter verkrijging van de graad van
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Abstract

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The study deals with the rain forest area in south-west Côte d'Ivoire (Taï National Park). Descriptions are given of the area's history, agricultural practices, geology, geomorphology, soils, flora and vegetation. The shifting cultivation system based on upland rice was studied as it is practiced without land shortage and under constraints. Possible adaptations of the system to the increasing population pressure have been tested on the fields of local farmers. Special attention was paid to the dynamics of the weed population and to the competition between rice and weeds. The classifications of primary forest, secondary forest and field vegetations are based on their complete floristic composition and was carried out by tabular comparison of plot-data.

Cover photography: A farmer of the Taï region weeding her rice field with a matchet.

A rice field in a valley bottom in the Taï region. Black *Raphia* dead palms and High Forest tree *Tarrietia utilis*.

A farmer of the Taï region sowing rice with a dibble and an achatine shell.

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à Pahi Djéa Yvonne

Contents

Résumé

La région de Taï n'est pas seulement l'une des dernières reliques de la forêt primaire, elle a également gardé un système de culture extensif, tributaire de l'environnement de la grande forêt tropicale humide. Tant les articles anciens que les récits des personnes âgées témoignent de l'étendue considérable des régions naguère cultivées selon les même pratiques (au Libéria, en Sierra Leone, en Guinée et en d'autres zones de Côte d'Ivoire). Dans la plupart des cas, la disparition de la forêt primaire s'est accompagnée de l'abandon d'un certain type d'agriculture. A Taï, une faible densité de population, et la proximité d'une forêt primaire conservée dans un Parc National ont permis le maintien d'un système de culture sans intrants industriels et à forte productivité (le peu de travail suffit à assurer la production vivrière). En dépit de la fertilité naturellement basse des sols, ce système reflète une société d'abondance. Le riz pluvial est destiné à être consommé, et non à être vendu. L'excédent ne se traduit donc pas en avantage monétaire, à peine en prestige. Ainsi, à quoi servirait de travailler davantage et de produire plus ? En sorte que les objectifs des paysans se résument à produire pour l'auto-consommation dans les conditions les moins pénibles possibles.

Les cultures exigent ainsi peu de travail. A chaque fois que c'est possible, le paysan tire profit de sa connaissance du milieu et met la nature à contribution. Il défriche les jachères forestières au moment où de nombreux arbres de forêt secondaire dégénèrent et s'abattent d'eux-mêmes. Il laisse les grands arbres, les plus durs, qui joueront un rôle important lors de la reconstitution après les culture. Au cours de la période de culture, il maintient les graines d'adventices au niveau qu'il peut les contrôler. Il n'enlève que les adventices vraiment préjudiciables aux cultures.

Les paysans ne sont pas prêts à fournir un travail supplémentaire malgré les risques de pertes dues aux mauvaises herbes ou à des attaques par des rongeurs. Ils abandonnent les champs s'il s'avère que le rendement sera trop bas. Ils ne prennent pas la peine de récolter tout le riz mûr si cela implique de revenir souvent sur un champ éloigné.

Si l'on demande à un homme combien lui ou sa famille compte produire, il répond que cela dépend de la surface que son épouse peut (ou veut) semer. Cela montre d'une part que c'est la femme qui décide de la surface à cultiver, même si c'est l'homme qui défriche ; d'autre part que c'est le semis qui est considéré comme limitant et non le sarclage. Un ou deux mois sont nécessaires pour le semis. Si la durée de sarclage excède un mois, la paysanne considère que c'est une charge trop importante. Peu de systèmes de culture accordent une part aussi faible au sarclage.

Par ailleurs, le Sud-Ouest ivoirien a fait l'objet, dans les années 1970 d'une politique gouvernementale de développement qui stimulait la production de cacao et de café. Depuis, la disponibilité en terres cultivables a fortement baissé à la suite de :

- l'accroissement de la population surtout liée à l'immigration de populations venues de la savane ;

- l'agrandissement du Parc National ;
- l'augmentation des surfaces occupées par les cultures pérennes, cacao et café.

Nous avons étudié, successivement le système itinérant de défriche sur brûlis avec de longues jachères (plus de 18 ans), et des courtes périodes de culture (6 mois), soumis à de faibles, puis de plus fortes contraintes. Dans ce qui est considéré comme non perturbé, ou Système Etabli, les paysans qui ont collaboré à cette étude ont gardé la liberté du choix des sites. Ainsi, seules ont été défrichées pour la mise en culture les forêts bien développées sur des sols de qualité bonne ou moyenne. De plus, les activités agricoles se sont déroulées pendant la période considérée comme la plus favorable. C'est dans ces conditions que nous avons apprécié la productivité plus ou moins maximale des cultures.

Malgré une diminution des terres disponibles pour cultiver le riz, les paysans gardent le même objectif : assurer la production avec le temps de travail minimum. Ils ont le choix entre :

- diminuer la durée de jachère,
- prolonger la durée de culture,
- mettre en culture des sites marginaux (sols très pauvres à carapace),
- adapter leurs techniques culturales.

Ces différentes solutions ont été testées en milieu paysan, en étroite collaboration avec 14 paysannes. Sur leurs champs de riz, des parcelles permanentes ont été suivies, depuis la période avant le défrichement jusqu'à la jachère, pour certaines pendant cinq ans, sur un total de 21 années de culture x parcelles.

De nombreux essais ont porté sur les conditions et les facteurs d'élaboration du rendement. Le modèle utilisé est adapté aux conditions du système. Le semis en poquets empêche la prise en compte des plantes individuelles. De plus, les paysannes récoltent seulement les panicules les plus lourds et délaissent ceux où le taux de graines vides est trop élevé, d'où la prise en compte des seuls caractères suivants : nombre de poquets/m^2, nombre de pieds productifs/m^2, nombre de panicules/m^2, nombre de panicules fertiles/m^2, poids de grains/panicule fertile. Les principales conditions étudiées sont :

- Le climat,
- L'état initial : durée de jachère précédente, durée de culture,
- Le sol : texture, teneur en gravillons, position sur le versant, fertilité chimique,
- Les techniques : intensité du brûlis, semis (technique et densité), travail du sol, sarclages (nombre et dates).
- l'envahissement par les adventices (couvert, hauteur, type).

La variété la plus courante "Demandé" a un maximum de production de 2 t/ha, dans les conditions optimales du système de culture. Ce rendement n'est possible que lors de la première année de culture si le champ a été bien brûlé, si la densité d'adventices reste faible et dans des conditions hydriques favorables. Cette variété est sujette à la verse.

Nous avons considéré l'influence de plusieurs niveaux de stress au cours des différentes phases de développement du riz.

Stress modéré pendant la période végétative

Dans la plupart des cas, la plante est soumise au stress dans sa phase végétative. Celui-ci peut être dû à la densité des adventices, à un stress hydrique (semis précoce, taux élevé de gravillons), ou à la compétition mutuelle avec un nombre trop élevé de graines dans le même poquet.

Au cours des phases de reproduction et de maturation, si les conditions sont favorables (sarclages, pluviométrie suffisante), la plante, même déjà soumise à un stress précédent, parvient à compenser : elle a produit moins de talles, moins de panicules, mais ces panicules sont plus lourds que les plantes n'ayant pas subi de stress au cours de la première phrase. En définitive, les plantes soumises à un stress modéré pendant la phase végétative peuvent fournir un rendement équivalent à une plante n'ayant pas subi de stress. Ces plantes, soumises à un stress modéré au cours de la phase végétative, sont les plus fréquentes, et les plus appréciées car elles nécessitent un temps de récolte plus réduit (moins de panicules).

Stress modéré en périodes de reproduction et de maturation

Des stress modérés, dus le plus souvent à la compétition avec les adventices, au cours des deux dernières phases, entraînent, en revanche, une diminution du poids de grains par panicule. Ces plantes, qui ont subi peu ou pas de stress au cours de la phase végétative, mais au contraire un stress plus marqué par la suite, sont abondantes dans les champs de première année non sarclés, et dans les champs de seconde année sarclés une seule fois.

Stress sévère en période végétative

Dans des conditions de stress plus sévères (sécheresse, enherbement) lors de la phase végétative, le riz ne produit que des talles peu nombreux et moins vigoureux. Même si les conditions ultérieures deviennent plus favorables, le riz produit un nombre plus élevé de panicules, mais avec de nombreux épillets infertiles, et des poids de grain limités. La période de maturation s'étend alors sur deux mois ou plus. Dans ces conditions, seuls les panicules les plus lourds sont effectivement récoltés. Ce cas est fréquent lors de la deuxième année de culture.

Stress sévère en période de reproduction et de maturation

Dans les conditions de stress sévère au cours des deux dernières phases, le nombre d'épillets infertiles augmente ainsi que les panicules à poids faible. Les pertes de rendement peuvent atteindre 100%. Ce type de conditions est fréquent en deuxième année de culture lorsque le champ est bien nettoyé lors du semis, mais négligé par la suite.

Ces études sur la compétition entre les adventices et le riz ont été complétés par des travaux portant sur la végétation. Ils ont démontré que la composition floristique de la forêt primaire est déterminée, en premier lieu, par l'humidité du sol. Celle-ci est étroitement liée à quatre facteurs : (1) le climat : les pluies augmentent légèrement du nord vers le sud, et surtout se distribuent plus régulièrement au cours de l'année ; (2) la position topographique : certaines espèces de bas-fond au nord de la région occupent des positions plus élevées sur le versant au sud ; (3) la roche mère : elle conditionne, par la texture et l'abondance en éléments grossiers, la capacité de rétention en eau. La simple composition floristique permet de déterminer la nature du substrat : les espèces du sud ne sont présentes dans le nord que là où les sols offrent les meilleures réserves en eau (schistes par opposition aux migmatites) ; (4) l'histoire culturale. En outre, la composition floristique peut servir d'indicateur à la présence d'alluvions, ou de roches sub-affleurantes, souvent peu perceptibles sur le terrain.

L'humidité du sol influence également la composition floristique de la forêt secondaire. Ainsi, une communauté de forêt secondaire de bas-fond au nord peut couvrir la plus grande partie des versants au sud.

Contrairement à d'autres systèmes itinérants sur brûlis en zone de forêt tropicale humide, la jachère forestière s'établit ici très rapidement. Les champs, en effet, ne sont cultivés qu'une année et seules quelque espèces rebelles sont sarclées, la plus grande partie des espèces forestières pionnières n'étant pas touchées. Toutefois, en marge d'un modèle "normal", plusieurs types de succession ont été différenciées à partir de longs suivis sur des quadrats permanents. En 1989, le type associé à une réduction des terres disponibles demeure néanmoins peu répandu. Par ailleurs, les champs abandonnés par les immigrants sont couverts, au moins pendant plusieurs années, de fourrés comprenant quelques arbres dispersés.

L'ensemble des traitements statistiques a bien mis en évidence que la composition floristique n'est pas le fruit du hasard. Les groupes correspondent à des conditions bien typées quant au climat, à la position topographique et à la place dans la succession. Il faut souligner que les meilleures espèces indicatrices de ces conditions de milieu ou de ces états appartiennent au sous-bois (herbes, lianes, fougères, ...).

Ce sont les sites qui présentent les plantes indicatrices de conditions favorables d'humidité du sol qui sont recherchés par les paysans en vue de la culture du riz.

L'étude des différentes composantes du milieu, du système de culture, les essais en milieu paysan ainsi que les travaux portant sur la composition floristique des champs, des jachères et des forêts primaires et secondaires nous conduisent à formuler les conclusions suivantes :

Dans un contexte de terres disponibles, le fonctionnement du système de culture repose sur :

- L'apport des éléments minéraux lors du brûlis. Les cendres relèvent le pH du sol. Les éléments nutritifs libérés peuvent être fournis par n'importe quelle biomasse brûlée (forêts primaire ou secondaire). Ainsi, ce type de culture peut être conduit indépendamment de la fertilité chimique naturelle du sol.
- La disparition des graines présentes dans le sol sous l'effet du feu.
- Le semis en poquets, accompagné du travail minimum du sol qui limite ainsi la germination des graines adventices.
- La durée de la jachère, au cours de laquelle le nombre de graines d'adventices diminue.
- La courte durée de culture qui permet aux adventices annuelles présentes de ne produire qu'une génération de graines.
- Le fait que la plupart des adventices sont des ligneux, moins agressifs que les herbes.
- La variété locale de riz, très compétitive de par sa haute taille (1,80 m) et sa forte production de feuilles.
- L'isolement géographique de la région. Un grand nombre de mauvaises herbes, fréquentes dans les autres régions, n'a pas encore infesté les champs de la région (à l'exception d'*Eupatorium odoratum*, survenue en 1980).

Ainsi, presque toutes les adventices sont issues du stock en graines présent avant la mise en culture. Elles germent au début du cycle cultural. Plus tard, leur nombre n'augmente plus. En d'autres termes, un seul sarclage suffit.

Dans un contexte de diminution des terres disponibles, le système répond par une dynamique différente des adventices :

- La diminution de la durée de jachère aboutit à une biomasse plus réduite qui, lors du brûlis, apporte moins d'éléments minéraux au sol. Dès lors, les contraintes liées à la fertilité du sol se manifestent davantage.
- Le brûlis, moins intense du fait de la plus faible quantité de combustibles, détruit moins de graines d'adventices.
- Puisque la durée de jachère est courte, le nombre de graines d'adventices ayant survécu est plus élevé.
- Les herbes (avec, en particulier, l'apparition des graminées) tendent à supplanter les ligneux.
- La prolongation de la culture d'un an à deux ans permet aux adventices à cycle court de produire continuellement des graines, d'où une croissance exponentielle du nombre de graines d'adventices dans le sol.
- Le riz, moins fertilisé par le brûlis, et soumis à une compétition des adventices dès la première phase, ne dépasse pas 1,20 m, et ne produit, au mieux, que la moitié du rendement de première année.
- L'effet du sarclage est plus limité du fait de la régénération continuelle des adventices.
- Au cours de deux ans de culture, le potentiel de recrû forestier est affaibli. La régénération sous forme de forêt secondaire est perturbée et remplacée par un fourré d'*Eupatorium odoratum* ou un tapis de graminées.

Samenvatting

Het zwerfbouw systeem van zuid-west Ivoorkust dankt zijn voortbestaan aan een ruime beschikking over bos. Elders in nat Afrika is deze, of een verwante vorm van voedselteelt, vrijwel verdwenen onder druk van bevolkingsgroei, of als gevolg van een degradatie van het milieu.

Deze zwerfbouw wordt gekenmerkt door een korte occupatieperiode van minder dan een jaar en een lange braakperiode van meer dan 16 jaar. De arbeidsproductiviteit is hoog ondanks de lage natuurlijke bodemvruchtbaarheid en het lage opbrengstpotentieel van de lokale rijstrassen. Dit is grotendeels het gevolg van het geringe aantal onkruiden. Al het werk, met uitzondering van kappen en branden wordt door vrouwen gedaan.

In de afgelopen tien jaar is de druk op beschikbaar land toegenomen door immigratie en door uitbreideing van het areaal koffie en cacao. Het oude, "Gevestigde" zwerfbouw systeem heeft zich moeten aanpassen, waardoor plaatselijk een "Afwijkend" zwerfbouw systeem is ontwikkeld. Dit proces is bestudeerd in drie fasen.

1978-1982 **Beschrijvend**, met behulp van veldwerk en oude luchtfoto's (1956).

1983-1987 **Experimenteel**, met behulp van proefplotten op de akkers van boerinnen die zich bewust waren van de naderende noodzaak tot aanpassing. Op de rijstakkers (16) werden veranderingen in het zwerfbouw systeem uitgevoerd, te weten: verkorten van de braakperiode, verlengen van de cultuurperiode, ontginnen van marginale gronden, extra branden, extra wieden en een lichte grondbewerking. De effecten voor rijst en onkruiden als ook voor de hergroei na de teelt werden bestudeerd in permanente quadraten gedurende twee tot vijf jaar. Er werd gezocht naar een aanpassing welke het minste extra werk opleverde en ecologisch gezien het minst belastend was.

1988-1990 **Beschrijvend**, met behulp van een satelietbeeld (1988) en verificaties in het veld.

Paralel met de landbouwstudies werden vegetatieopnamen gemaakt ter karakterisering van primaire bossen, secondaire bossen in verschillende successiestadia en van akkervegetaties.

Landbouwstudies

Het goed functioneren van het "Gevestigde" systeem berust op:

- Het vrijkomen van de noodzakelijke voedingsstoffen tijdens het branden. De as maakt de bodem minder zuur, deze is anders ongeschikt voor rijst. Elke grote hoeveelheid biomassa kan nutrienten leveren, zodat rijst geteeld kan worden bijna onafhankelijk van de natuurlijke vruchtbaarheid van de grond.
- De hoeveelheid kiemkrachtige onkruidzaden in de bodem vermindert als gevolg van het branden met ongeveer de helft.

- Zaaien met een pootstok verstoort de bovengrond minimaal waardoor zo weinig mogelijk onkruidzaden tot kieming worden gebracht.
- De lokale rijstrassen bezitten een grote concurentiekracht. Het zijn hoge planten (1,60 tot 1,80 m) die veel blad produceren. Door beschaduwing wordt de kieming van vele lichtgevoelige onkruiden verijdeld.
- Het gesloten bladerdek van de rijst wordt na de oogst meteen opgevolgd door een gesloten bladerdek van pionierboompjes. Alleen éénjarige kruiden die gelijk met de rijst zijn gekiemd en opgegroeid hebben rijp zaad kunnen produceren. Hierdoor blijft infectie van de bodem met onkruidzaden beperkt tot één generatie.
- Alle onkruiden kiemen vrijwel direkt na het branden. In de loop van de rijstcyclus komen er bijna geen nieuwe bij zodat één keer wieden voldoende is.
- De onkruidpopulatie bestaat hoofdzakelijk uit houtige planten, welke minder agressief zijn dan kruiden.
- Tijdens de lange braakperiode sterft een groot aantal onkruidzaden af in de bodem.
- Vanwege het geografische isolement van zuid-west Ivoorkust zijn vele gangbare pan-Afrikaanse of pan-tropische onkruiden afwezig.

Het gebrekkig functioneren van het "Afwijkende" systeem berust op:

- De geringe hoeveelheid biomassa die tijdens een verkorte braak wordt geproduceerd. Na branden komen er minder nutrienten ter beschikking van de rijst. De beperkingen veroorzaakt door variaties in natuurlijke bodemvruchtbaarheid komen meer tot uiting.
- Omdat er minder brandstof is, is het vuur minder intens en verbranden er minder onkruidzaden.
- Door de korte duur van de braak is een groot aantal onkruidzaden kiemkrachtig gebleven in de bodem.
- Het aandeel kruiden is groter dan het aandeel bomen waardoor de onkruidpopulatie moeilijker is te beheersen.
- Het verlengen van de cultuurperiode van één naar twee jaar impliceert een herhaald schoonmaken van de akker. Direct zonlicht op de bodem brengt lichtgevoelige onkruiden tot kieming. Het plaatselijk roeren in de bovengrond met een hak geeft extra kiemingen. De hoeveelheid onkruidzaden in de bodem neemt exponentieel toe want éénjarigen kunnen generatie na generatie rijp zaad produceren.
- De rijstplanten, minder goed bemest, concureren bijna niet meer met onkruiden en komen nauwelijks tot 1,20 m hoog. De rijst produceert op zijn hoogst de helft zoveel als het eerste jaar (0,5 t/ha).
- Het effect van één keer wieden is gering vanwege de continue zaadproductie van onkruiden.
- Het regeneratieve vermogens van de braakvegetatie zijn aangetast. De zaadbank waaruit het eerste jaar de pionierboompjes kiemden, is uitgeput. De vegetatie die na de oogst de akker bedekt is daarom geen jong bos, maar een struikgewas van *Eupatorium odoratum*, of een grasmat.

Vegetatiestudies

De vegetatieanalyse geschiedde op grond van volledige soortenlijsten van kleine plots (36 m^2 in bos, 9 m^2 op akkers and 18 m^2 op één à twee jaar verlaten akkers). Met behulp van vegetatietabellen werden sociologische groepen en plantengezelschappen geformeerd.

De soortsamenstelling van het ongestoorde bos reageert allereerst op vocht. Veelal is edafisch vocht en regenwater uitwisselbaar. Vooral onderbossoorten, kruiden, kleine lianen en varens zijn gevoelig voor fluctuaties in vocht. In de vegetatie op eendere bodems verspreid over het studiegebied, d.w.z. ontwikkeld uit hetzelfde type moedermateriaal en gelegen op dezelfde topografische positie, komt de noord-zuid regenvalgradient tot uitdrukking. Er werden zes plantengezelschappen onderscheiden.

Op eendere topografische positie, binnen één klimaatszone, komen bodemverschillen als gevolg van afwijkend moedermateriaal in de vegetatie tot uitdrukking. Aan de soortsamenstelling van de bosvegetatie ziet men met name de verschillen in watervasthoudend vermogen.

De soortsamenstelling van het bos verschuift met de positie op de helling. In het relatief drogere noorden zijn bepaalde soortengroepen beperkt tot de moerassen. In het nattere zuiden kunnen deze hun areaal uitbreiden tot groeiplaatsen hoger op de helling.

Op alluvium en dicht bij inselbergs is het effect van landvorm op vegetatie overheersend. Hier werden vijf plantengezelschappen onderscheiden.

In secundair bos werden acht plantengezelschappen onderscheiden. Vier in jong secundair bos, waaronder één op rivierafzettingen, vier in oud secundair bos, waaronder één op extreem arme bodems. In jong bos komen pioniers met een levensduur beneden 10 jaar voor, in oud bos niet. In oud bos beginnen primaire bossoorten het onderbos te koloniseren, terwijl deze niet voorkomen in jong secundair bos. Oud secundair bos op extreem arme bodems wordt gekenmerkt door de afwezigheid van kortlevende pioniers en van primaire bossoorten. De groep jong en oud bos zijn verder onderscheiden op topografische positie. De klimaatsgradient komt in zoverre tot uitdrukking dat de plantengezelschappen die in het noorden beperkt zijn tot moerassen, in het zuiden ook de helling kunnen bedekken.

Er werden dertien plantengezelschappen onderscheiden op rijstakkers. Er werden acht plantengezelschappen van het "Gevestigde" systeem onderscheiden en vijf behorende tot het "Afwijkende" systeem. De belangrijkste gradient is de mate van verstoring. De eerstejaars rijstvelden ("Gevestigde" systeem) verschillen in het aantal keren dat de plek al eerder in cultuur is geweest en in bodemverschillen (alluvium, moeras). Rijstvelden aangelegd in primair bos zijn het soortenrijkst. Wanneer de plek na een lange braakperiode opnieuw ontgonnen wordt, treedt er verlies aan primaire bossoorten op. Bij een tweede rotatie neemt het aandeel primaire bossoorten opnieuw af. Bij een derde rotatie gebeurt dit opnieuw maar de soortenrijkdom blijft bij volgende rotaties min of meer constant.

Akkers die voor een tweede jaar worden beteeld, of welke aangelegd worden na een te korte braakperiode ("Afwijkend" systeem), vertonen een enorm verlies aan soorten, vooral primaire en secundaire bossoorten. De akkersvegetaties van het "Afwijkend" systeem zijn uniform, en verschillen in cultuurgeschiedenis en bodem zijn grotendeels uitgevlakt. Op akkers aangelegd in moerassen kan het proces van degradatie versneld plaatsvinden.

Akkers die na één rijstcyclus verlaten worden ("Gevestigde" systeem) regenereren onmiddelijk terug naar bos. Vertegenwoordigers van jonge en oude successiestadia zijn reeds aanwezig op de akker. Akkers die na twee jaar rijstteelt worden verlaten ("Afwijkende systeem) veranderen in struikvegetaties (*Eupatorium odoratum*). De vegetatie op deze akkers bevat nauwelijks of geen vertegenwoordigers meer van oudere successiestadia. De snelheid waarmee deze afwijkende vegetaties ontwikkelen naar bos, is afhankelijk van het aantal houtige planten dat vegetatief de cultuurperiode heeft onderleeft en de kracht waarmee deze planten nog uitlopen.

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1 Introduction

1.1 GENERAL FRAMEWORK

Western Africa has only one large area of rain forest left, the Taï National Park and the forested land around (Fig.1.1). A fundamental feature is the great sparsity of population. Human impact on the environment had remained locally and temporally limited and so the forest recovered without scars from these slight injuries caused by agriculture, hunting and gathering. But geographic remoteness does not mean economic isolation. The inhabitants became involved in broader trading networks. The customary practices, including agriculture, did not alter much because land stayed in good supply. When plantation farming spread, combined with a population increase mainly through immigration, and the nearby National Park installed, the land problem finally became critical.

Abundant land or, on the contrary, land shortage can only be understood and defined in relation to environment and to systems of land use. This means that criteria for assessing whether land is not fully used or is overcrowded can only be laid down considering these two factors. Therefore, part of this study deals with the natural environment. In the Taï region, a wet climate, natural soil poverty, and the cost of the measures required to increase fertility set very definite limits to what can be done with the land. Another part of the study deals with systems of land use. We will see that the local practice of shifting cultivation, though it always involves a complex of motivations, is certainly a concession to the character of the environment. Only, shifting cultivation has difficulties absorbing a growing population. These particular difficulties are analysed in the final part.

Great issues as there are the perhaps irrecoverable forest destruction, the changes in regional climate, yield decline, soil loss, and the preservation of the National Park, all these things which menace the Taï ecosystem, have occupied numerous scientists and experts of many disciplines. The study of Guillaumet (1967) on the flora and vegetation of south-west Côte d'Ivoire has been a pioneering work. The Man and Biosphere programme of the UNESCO, which started in 1976 in collaboration with ORSTOM (Institut Français de recherche scientifique pour le développement en coopération), the IET (Institut Ivoirien d'Ecologie Tropicale) and other institutions, resulted in many articles and reports. A synthesis of research results was written in 1984 (MAB technical Notes No.15). Meanwhile the Taï National Park was inscribed on the UNESCO World Heritage List. In the 1980s the Agricultural University of Wageningen undertook a research programme "Analysis and design of land use systems in the Taï region". The results are currently being published. A Land Unit study (De Rouw, Vellema & Blokhuis 1990) as well as this study, were conducted as part of the programme. However, scientists from different disciplines may study the same subject, try to use the same type of methods, may work on the same scale in time and place and still essential functions of the system may remain hidden. The present study greatly benefits from the efforts of other workers, as it does from the knowledge of local residents. Aided by eleven years of personal contact with the Taï forest, the author, being a woman and an agronomist, was able to use other sources of information too. This book is an attempt to provide an integrated view of Taï and its problems.

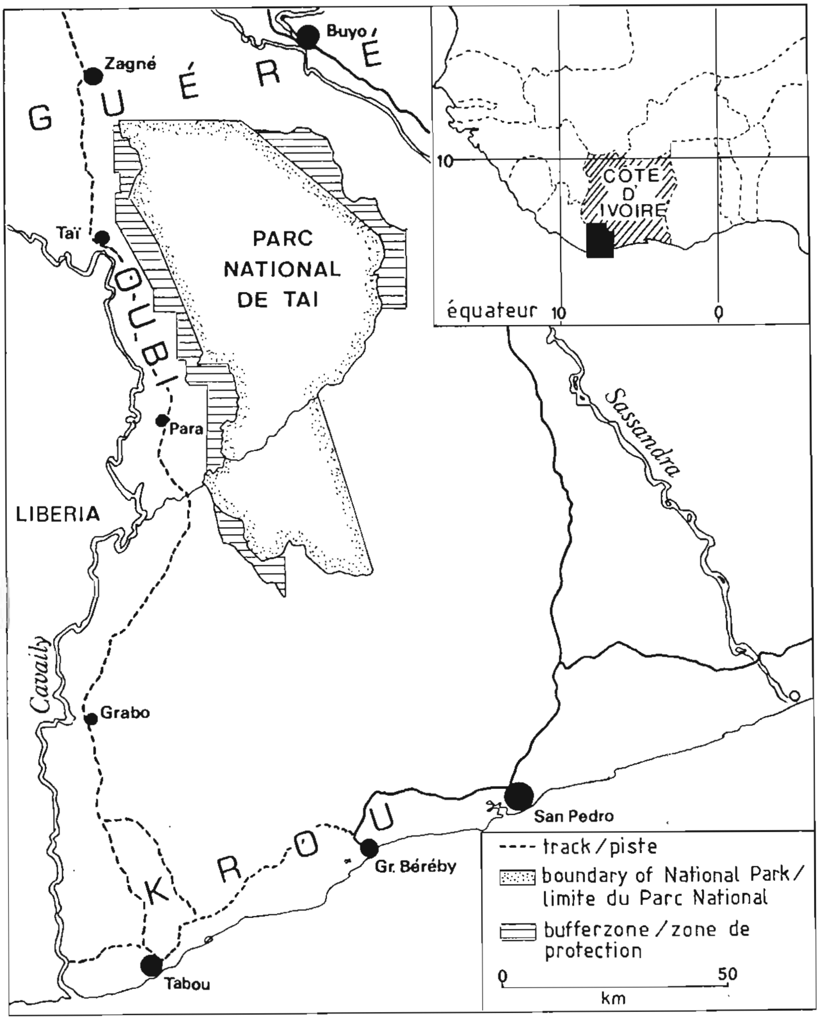

Fig. 1.1. Map of the south-west Côte d'Ivoire.

1.2 MAIN OBJECTIVES AND CONCEPTS

A farming system under pressure like the shifting cultivation system in the Taï region suffering from a growing population, seeks to adapt the current practices to the new constraints. In the beginning more land is put under cultivation. Then, as the land finally becomes scarce, there are various ways out:

- shortening the fallow period,
- prolonging the cultivation period,
- cultivating marginal sites,
- adapting the cropping techniques. There are many examples of this process throughout the Wet Tropics (Nye & Greenland 1960 p. 8-9, Geertz 1963 p.25-27, Ahn 1979, Toky & Ramakrishnan 1981, Hamilton 1984; Nakano & Syahbuddin 1989). A generally observed feature is that the old system passes through a period in which it has become an unproductive, ecologically damaging farming system. Broadly speaking we can say that the former, more or less "Established" system functioned with apparently satisfactory yields, good regeneration of forest and few weeds, and that the new, "Adapted" system has declining yields, poor regeneration and many weeds.

Our chief objective is:

- To describe the vegetation, the natural as well as the cultural and the processes there-in.
- To answer the question : what agro-cultural practices, in combination with environmental factors as climate, vegetation and soil, are responsible for the degradation of the "Established" system with few weeds, good regeneration of forest and acceptable yields, into an "Adapted" or "Deflected" system with many weeds, poor regeneration and low yields.

The objectives are approached in three main ways, reflected in three parts of the study.

1. Description of the environment, the people and the farming systems.
2. Trials with the principal food crop rice, performance of the rice and the weed population in the "Established" system and in the "Adapted" system.
3. Description of the vegetation, the natural and the cultural, succession and regression stages of secondary forest and weedy vegetation.

1.3 METHOD

1.3.1 Description of the environment, the people and the farming systems.

Extracting the knowledge from the people

The local people have acquired a working knowledge of the soil and vegetation they use, and a means of recognizing and distinguishing these. A method was used which extracts knowledge from these highly experienced people. This was translated into terms of science, western logic and common sense and incorporated in the study.

Work with the women

The question of gender is an important issue here because it has influenced methods and results.

The division of labour among the sexes, depends essentially on local customs. There are two patterns in subsistence farming, one in which food production is taken care of by women, with little help from men, and one where food is produced by the men with little help from women. Boserup (1970) names these two patterns Female and Male farming systems. Africa is a region of pre-eminently Female farming, where it is common in the wetter regions (Fig.1.2). Especially in sparsely populated regions, where shifting cultivation is used, men do little farm work, women do most (Boserup 1970).

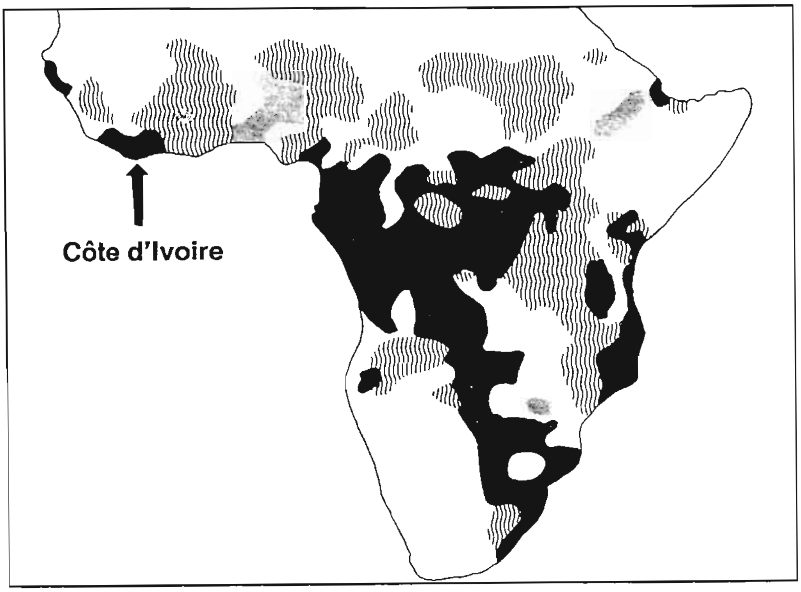

Fig. 1.2. Areas with Female and Male Farming Systems (after Boserup 1970).

Many examples can be given of agronomists who are unaware of sex roles in agriculture. In studies on subsistence farming the production unit is commonly seen as the male farmer assisted by family help. (Allan 1965, Spencer 1966, Boserup 1970, Bukh 1979, FAO 1985, many examples in Fresco 1986). The male farmer stands generally in the centre of attention and the tasks performed by women is obscured. In a region of Female farming systems this ignorance of sex roles in agriculture can have serious consequences, e.g. :

- Bottle-necks in labour during the cultivation period do not show up and in many cases the very seasonal nature of work in shifting cultivation is not recognized Schwartz 1972, Bognon 1988, Ruf 1979, 1984a.
- Yields of crops produced by women do not enter the national or regional records. Fresco (1986) demonstrated that the records of FAO and World Bank usually suggest a serious deficiency in food supply while food produced by women farmers in the region was largely sufficient.
- Those fields of knowledge where women are specialists because they do the work and have the experience, are reported in a fragmentary and vague way, probably because only men in the village are questioned (range of grown crop varieties, densities, intercrop patterns, staggered planting and harvesting techniques, and generally all local knowledge on weeds).

One of the many consequences of male-oriented outlook on food production is that one task, weeding, is hardly mentioned and most often fails to be considered as a constraint. Generally in tropical regions in subsistence farming, more energy is expended in weeding than in any other human task (Holm 1971), making weeding, in many cases the most expensive step in crop production. Yet, this is often overlooked. The extremely time consuming task of manual weeding is correctly valued if the subsistence farming system is modernized and the (male) farmer can no longer rely on "family labour". Then minimum wages have to be paid to a worker and this is in most cases an expensive operation (Moody & Datta 1982).

In the Taï region it is the woman's work to see there is food in the cooking pot every day. The task of food cultivation is left to her. What they harvest from those farms is their own property and the money they can get from selling the crops is their own. Husband and wife have separate economies and there are clear expectations as who should do, or pay for what.

As shall be demonstrated by this study, it is very constructive to consider this division of labour. Therefore the usual perspective is radically changed. The reader is invited to consider the farmer as a woman and the production unit as comprising the farmer, her husband and children.

Another particularity of the Taï farming system needs to be mentioned. Farming is an activity which provide both food and money to meet the current household expenses. It does not bring real prosperity. Everyone with more ambition in life is attracted by non-farming activities, although this does not always imply that the person leaves the region or stops farming altogether. The combination of part-time farming with a supplementary income by trading or a regular salary is often considered ideal. This attitude has important consequences. Because subsistence farming cannot make you rich, all elements of cropping are directed towards minimizing labour input. Secondly, children especially girls, are strongly encouraged to study. A demographic study by Schwartz & Capot (1972) demonstrated that the Taï region, despite its isolation, had the highest rate of school attendance of Côte d'Ivoire, i.e. 65,9 %. It further showed that nearly half of the school children were girls and this too, was exceptional for Côte d'Ivoire.

As a result children, especially girls are being pushed out of agriculture by their mothers in order that they may have an easier life. Hence there are few young farmers in the region as compared to older people.

1.3.2. Trials with rice.

On-farm trials

Detailed studies of the cropping system were implemented through field trials on the rice fields of local farmers. On their fields a number of practices were tested. The functioning of the "Established" system was investigated, the performance of the staple crop rice, and simultaneously the productivity of the weeds growing along with the rice. The interactions between the weed population and the rice crop received particular interest.

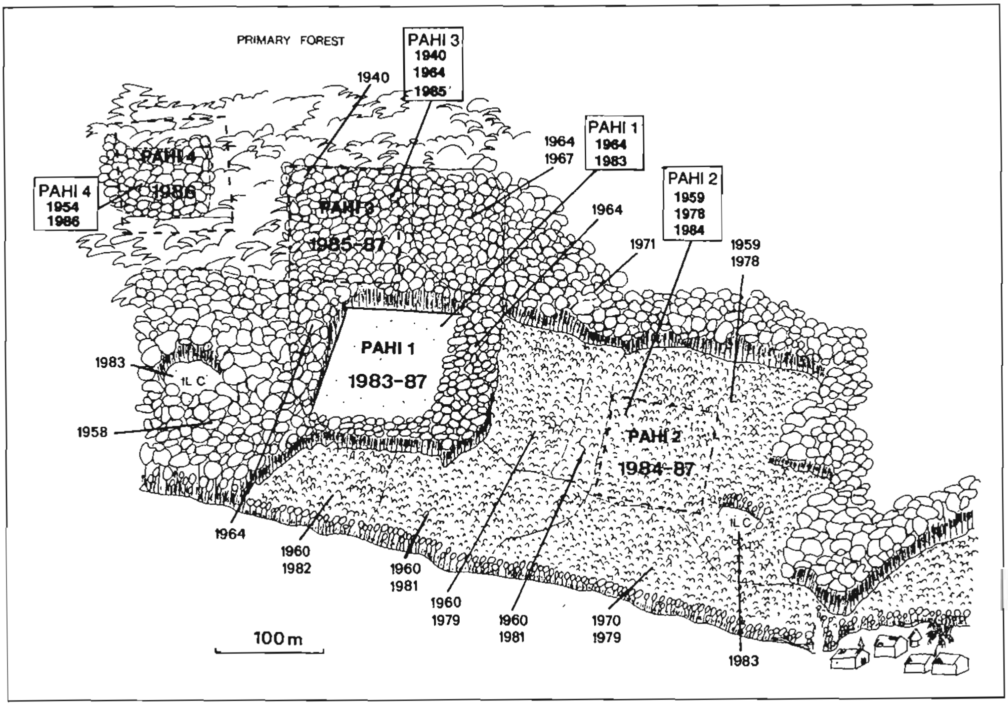

Fig. 1.3. Location of the Pahi experimental fields amid a forest mozaic of young secondary forest, old secondary forest and primary forest near the village Gouleako. The area represented is part of a 26 ha domain owned by one farmer. Years of observation : Pahi 1, 1983-1987 ; Pahi 2, 1984-1987 ; Pahi 3, 1985-1987 ; Pahi 4, 1986. Boundaries of former fields are enclosed by a line and dates indicate years of previous rice cultivation periods. il. c. : illegal clearing, no cultivation.

Secondly, the functioning of the modified or "Adapted" system is analysed in the same manner. The most obvious adaptations of the shifting cultivation system anticipating land scarcity were tested:

- shortening the fallow period,
- prolonging the cultivation period,
- cultivation of marginal sites,
- adaptation of cropping techniques.

Trials included different levels of weeding, burning, length of occupation period and duration of the fallow period. They were conducted on a variety of soils. They brought slight modifications of the traditional shifting cultivation pattern and were considered possible solutions farmers could adopt to cope with the growing scarcity of forest.

Site selection for field trials

Sites intended for prolonged and detailed study were selected first of all according to the farmers personal interest in the experiments. As social structure is weak among the forest people, the Oubi and the Guéré, no other authority than the farmer herself can decide what is to be done with her field. Indeed, no cooperation can be enforced by husband, village chief or money. Compliance and participation is essential to the success of on-farm trials, so farmers were chosen on these terms first. Secondly, we tried to cover all current combinations of history and soil.

Within our set of fields (16) all current combinations of soil and history are represented (Table 1.1). The cooperation with our farmers was such that we could ask for a field with a certain history and let them chose the location. After inspection of vegetation and soil we could, or could not, agree with the field.

Recordings before clearing

The forest designed to be cleared lies in a mosaic of other fields, fallows and patches of primary forest, usually owned by the same family being responsible for their arrangement. While visiting these vegetations, members of the family were asked to relate the cultural history of their property as thoroughly and as explanatory as possible. History and topography were united into a sketch. Fig.1.3 gives an example of such a land use mosaic including 4 experimental fields (Pahi 1, 2 3 and 4). Boundaries of old fallows never quite coincidence with those of new fields. The proximity of the village Gouléako makes the pattern even more complex for the farmer gave patches of young fallow vegetation away to elderly persons to grow food crops.

The next step is the cutting of a corridor which fixes the boundaries of the new field, for our experimental purposes always one hectare. Within these limits two homogeneous plots are laid out, each 18 m^2, after careful observation of vegetation and soil. Here surveys are made of the forest vegetation including descriptions of micro relief, soil profile to 1 m (auger), vegetation structure, height and cover. All plants are identified, and, as generally each species is represented by only a small number of individuals, these are counted. Phenological stage and vitality of plants is recorded. Girth (breast height) of the trees is measured in larger plot (1/4 ha).

A book is kept of all field activities and events.

Recordings after clearing

Number and species of trees left standing were recorded together with the motivation of the farmer for sparing each tree. The permanent quadrats for rice and weed studies (units of 9 m^2) were fixed and fenced after the germination of the rice, for crop conditions should be as uniform and representative as possible. The same common rice variety was always used : "Demandé". Different levels of weeding and different levels of initial burning were tested. There were three, two or one replication per field depending on our increasing experience with these kind of trials. At regular intervals during the cropping period surveys were made. Rice density per m^2 was counted, height and cover was estimated for rice and for the weed vegetation. Again, all plants were identified and counted. A distinction was made between plants present as seedling and plants appearing as coppice shoot or root sucker. In the beginning also dry weight of vegetation removed by weeding was recorded (24 h, 102°C, seedlings and coppice separately). Soil analysis (10 cm topsoil), before and after the cultivation period started from 1984 onwards. After the cultivation period, the same quadrats were used, sometimes during several years, for study of the regrowth. The fallow vegetation was surveyed in the same way at yearly intervals.

Estimation of the rice yield

The yield of a whole field was assessed to supplement the measured yields on the trial plots. However, sampling a field correctly is nearly impossible because of the uneven ripening of the rice, and because of the unknown percentage of

Table 1.1. Vegetation communities (see chapters 9,10, 11), landform and topographic position of the experimental fields.

Field name	**Topographic position**	**Landform**	**Forest community cleared**	**primary/ secondary**	**Field community first year**	**Field community second year**	**Field community third year**
Pahi 1	mid slope	upland	*Myr. & Pty.*	sec. 19 yrs.	*Tri. & Opl.*	*Age. & Eri.*	*Age. & Eri.*
Pahi 2	mid slope	upland	*Byr. & Rut.*	sec. 6 yrs.	*Age. & Eri./ Boe. & Cha.*	*Age. & Eri./ Cha. & Asp.*	
Pahi 3	mid slope/ lower slope	upland	*Myr. & Pty./ Dry. & Tri.*	sec. 21 yrs.	*Tri. & Opl.*	*Age. & Eri.*	
Presi	lower slope	upland	*Hun. & Chi.*	primary	*Cte. & Col.*	*Dim. & Mus.*	
Poyo 1	valley bottom	upland	not sampled	primary	*Cer. & Rap.*	*Vir. & Har.*	
Poyo 2	upper slope	upland	*Hun. & Chi.*	primary	*Cte. & Col.*		
Cavally 1		alluvium/ upland	not sampled	sec. 20 yrs.		*Age. & Eri.*	
Cavally 2		alluvium	*Cal. & Cos.*	sec. 6 yrs.	*Hib. & Mac.*		
Cavally 3		alluvium/ upland	*Cal. & Cos.*	sec.6 yrs.	*Hib. & Mac.*		
Cavally 4		alluvium	*Pla. & Pan.*	primary	*Hib. & Mac.*		
Suzanne	mid slope	upland	*Myr. & Pty.*	sec. 14 yrs.	*Tri. & Opl.*	*Age. & Eri.*	
Yai	upper slope	upland	*Myr. & Pty.*	sec. 30 yrs.	*Com. & Pol.*		
Djéa	lower slope/ valley bottom	upland	*Cle. & Bri.*	sec. 16 yrs.	*Cay. & Tra.*		
Joséphine	mid slope	upland	*Cle. & Bri.*	sec. 15 yrs.	*Cay. & Tra.*	*Age. & Eri.*	
Modeste	lower slope	upland	*Hun. & Chi.*	primary	*Cte. & Col.*	*Age. & Eri.*	
Hélène	lower slope	upland	*Hun. & Chi.*	primary	*Cte. & Col.*	*Age. & Eri.*	

field surface covered by dead wood. Also, ears of rice will disappear as soon as they are ripe, not only through the farmer but any visiting parent is often invited to "treat" herself. Finally, rice is not considered a commercial commodity, this also contributes to less attention paid by farmers to the actual size of the harvest.

However, to avoid many returns to a field in order to quantify the yield, we developed a procedure of collective estimation. Fields were visited just before the first ears were ripe, preferably many fields the same day and with the same group of people always including my assistant and myself. All members of the group separately ranked the fields visited in order of increasing yields. If the group comprised farmers who had on-farm trials in previous years, they were invited to rank those fields, among the fields visited. Discussions continued until everyone agreed. We gained sufficient confidence after an experiment in 1985 in which we estimated the yield of one and the same hectare of rice in three ways: by taking 72 samples of 1 m^2 randomly, by taking three samples of 16 m^2 each situated on one of the fields diagonals, by estimation as described above. All estimations ranged between 900 and 1000 kg of paddy. This procedure does not only help to improve the assessment of the rice yield outside the experimental plots, but also supplies information on rice yields on the surroundings fields and to compare yields of different years.

Study of the Pahi fields

The Pahi fields constitute the most thoroughly studied sites, from 1983 to 1987. Fig.1.4 illustrates the location of this group of experimental fields in a 1 km^2 landscape sketch. Those fields are of the commonest type with respect to cropping history and soil conditions.

Experiments on field Pahi 1 involved two factors: burning and frequency of handweeding. The field have been burnt in the conventional manner. Although the result was considered satisfying by the farmer, still about 10 per cent of the surface had received only a mild fire. We compared rice and weed growth on normally burnt places with growth on mildly burnt spots.

In the weeding test three levels were examinated:

- Two hand weedings, 2 and 3 months after sowing;
- One hand weeding, 3 months after sowing, which coincided with the weeding of the remainder of the field on initiative of the farmer;
- No weeding.

The field **Pahi 1** was prepared by clearing a 19 year old secondary forest of the community *Myrianthus libericus & Ptychopetalum anceps*. Observations on Pahi 1 started in 1983. Fig.1.5.No.1 gives the relative positions of permanent quadrats (four replications), trees cut during field preparation and trees left standing. In 1984, half of the field, including all permanent plots, was cleared for a second cycle of rice, the remainder of the field laid fallow. Trial procedure and observations procedure on the cultivated half of the field were exactly the same as the previous year (Fig.1.5.No.2). In 1985, a part of the field, including all the permanent quadrats, was cleared and burnt for a third rice crop. Again, observations on rice and weeds followed the same procedure as in previous years. Six permanent quadrats were installed in the sections of the field covered by regrowth, two plots in one year old stands, two in two year old stands (Fig.1.5.No.3). In 1986 the field was no longer cultivated. The field laid fallow but observations on all permanent plots continued (Fig.1.5.No.4). Observations could only partly continue in 1987 for immigrant farmers had destroyed most of the permanent

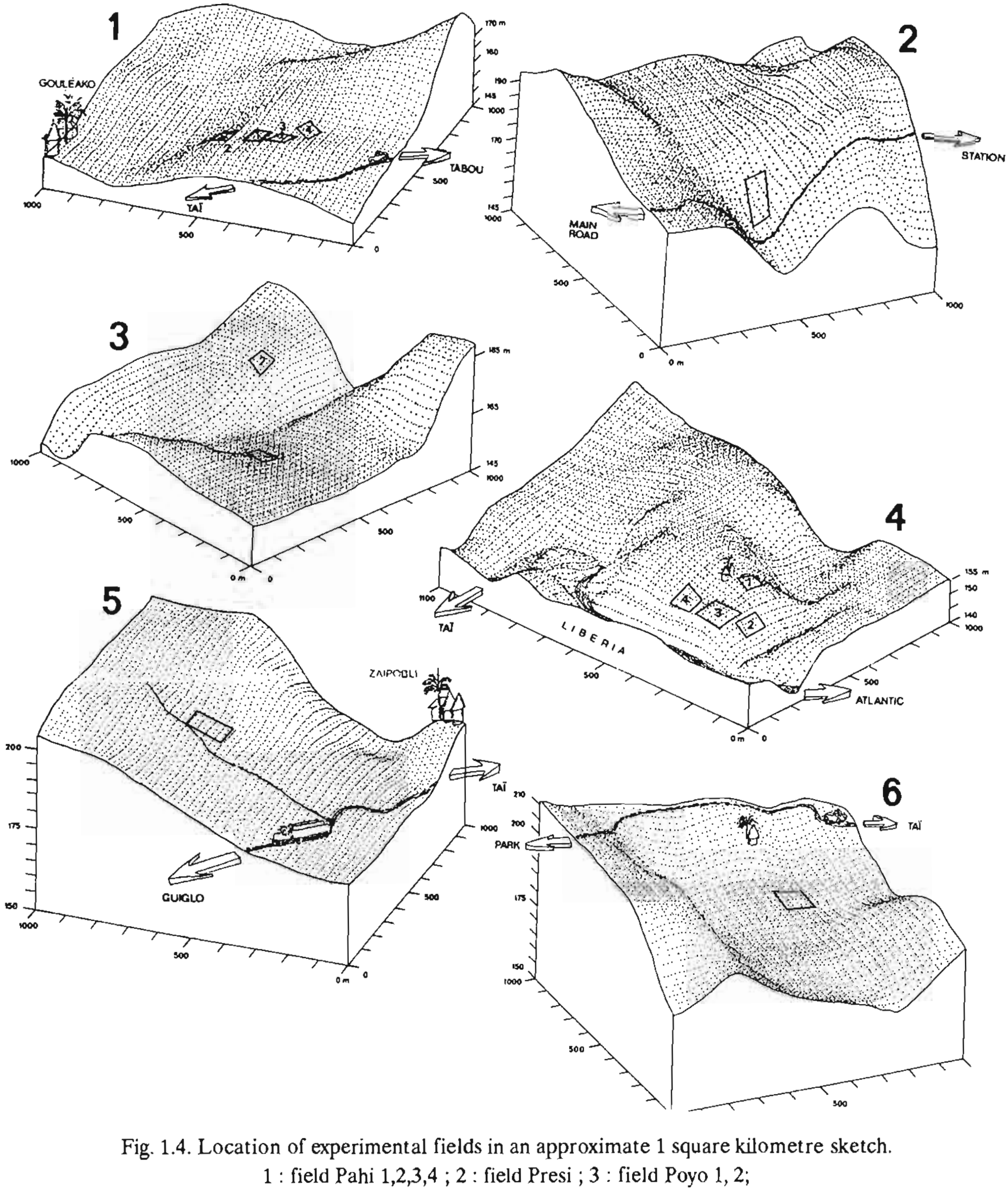

Fig. 1.4. Location of experimental fields in an approximate 1 square kilometre sketch.
1 : field Pahi 1,2,3,4 ; 2 : field Presi ; 3 : field Poyo 1, 2;
4 : field Cavally 1,2,3,4 ; 5 : field Suzanne ; 6 field Yai.

quadrats by their illegal attempts to grow foodcrops. (For details on rice trials see chapter 5).

Observations on **Pahi 2** started in 1984. For experimental reasons the last fallow period was deliberately shortened (6 years), a secondary forest of the

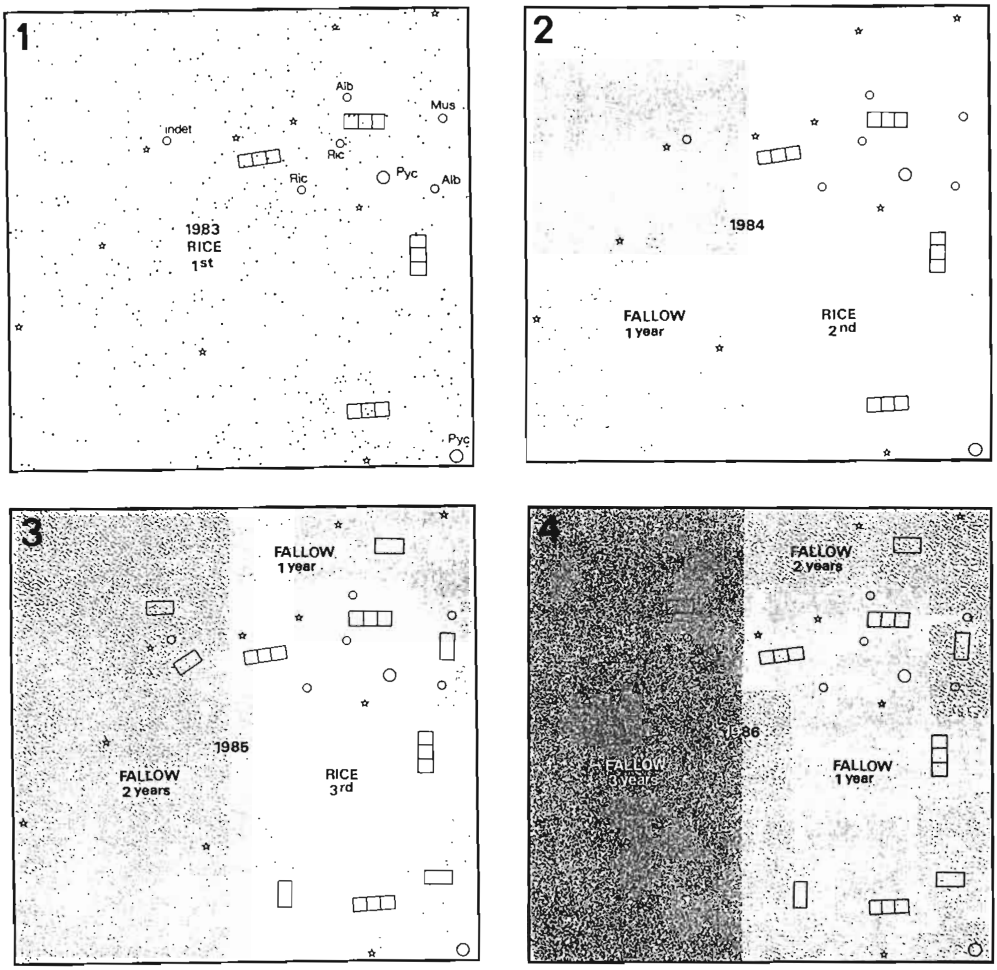

Fig. 1.5. The experimental field Pahi 1. Location of permanent quadrats and of the trees left standing during felling the forest (star ; adult oil palm, circle : other tree, Pyc : *Pycnanthus angolensis*, Alb : *Albizia adianthifolia*, Ric : *Ricinodendron heudelotii*, Mus : *Musanga cecropioides*).

No.1.First year. Forest is cleared and cropped with rice. Point : a felled tree with gbh over 20 cm.

No.2.First year. Half of the field is cropped with rice, half of the field lies fallow.

No.3.Third year. Part of the field is cropped with rice, the remainder lies fallow.

No.4.Fourth year and Fifth year. All of the field lies fallow.

community *Byrsocarpus coccineus* & *Rutidea parviflora* was cleared. The experimental layout was identical with that on Pahi 1.: all of the field was cropped in 1984 and four sets of permanent plots were laid out. The following year, half of the field, including the permanent plots, was cleared and burnt for a second rice crop, and the remainder laid fallow. Rice cultivation stopped after two cycles and in 1986 observations continued on the various fallow regrowth vegetation. In 1987 all permanent plots became useless because of illegal clearing by persons not informed of the experiment.

Pahi 3 was installed in 1985. The last fallow period had lasted 21 years. The main difference with Pahi 1 was its undulating relief, resulting in a secondary forest community *Myrianthus libericus* & *Ptychopetalum anceps* covering the greater part of the slope (80 %) and the community *Drypetes gilgiana* & *Triphyophyllum peltatum* covering the lowest part. The permanent quadrats were laid down in such a way as to study best the effect of slope. During the first year of cultivation, besides the current observations as were done on Pahi 1 and Pahi 2, trials on seedbank and sowing technics were also executed. In 1986, most of the field was used for a second year of rice cultivation, except for a strip of land descending the slope used for regrowth studies. Observations on permanent plots continued in the usual way. In 1987 all of the field laid fallow and final observations on permanent quadrats were made.

Field **Pahi 4** was installed in 1986 by clearing a 32 year old secondary forest. The field was used for observations on fire and seedling emergence. (Details of trials are given in chapter 5).

Study of other sites

All other experimental fields (Fig.1.6) carried permanent quadrats for observations on weed and rice during the cultivation period. Rice cultivation continued for one or two years and the subsequent fallow vegetations was followed for one or two years in the same permanent quadrats. The site characteristics of these fields are summarized in Table 1.1.

1.3.3. Description of the vegetation.

The functioning of the "Established" and of the "Adapted" system was not only investigated on an agronomical level but also on a ecological level. This was done through the analysis of the plant population in fields and abandoned fields (field scale) and by means of surveys on a much larger area (regional scale).

Field scale

The assumption is that the response of the vegetation will indicate the possible success or failure of the tested agricultural variation. Measures, or combinations of measures, which result in massive weed growth are apparently so destructive that a serious degradation of the vegetation sets back or slows down the process of succession, are considered ill-adapted to be incorporated into the current shifting cultivation practice for they may compromise the rain forest environment in the long run. Measures, or combinations of measures, which are followed by a moderate weed growth, or a rapid passing of the consecutive seral stages, are therefore considered preferable. Of course, other aspects of changes are considered too, for example labour effort, yield, time and money involved.

Short-term changes up to five years were observed directly on permanent plots. Forecasts of long-term changes (up to 30 years) were based on observations of spatial sequences on adjacent sites.

Regional scale

On the whole there is an impression of uniformity yet the Taï rain forest is not an homogeneous vegetation type. It shows on the contrary considerable physiognomic and floristic variation. The same can be said for disturbed forest, being a type of vegetation not uniform either, and even for weedy vegetations

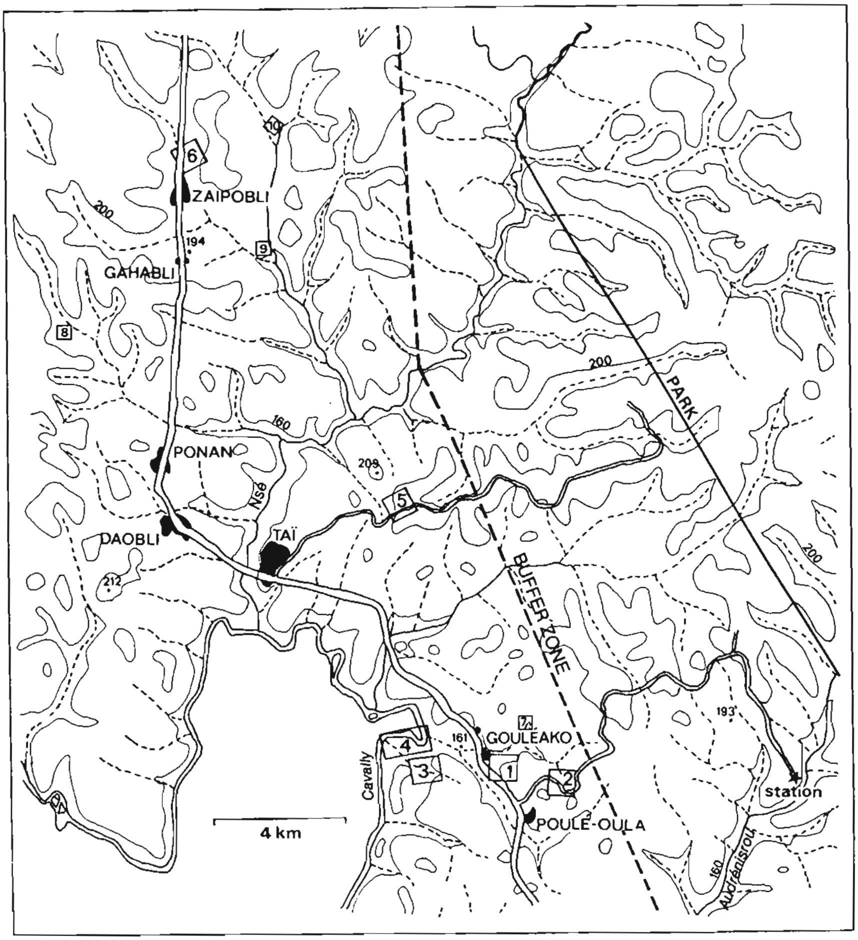

Fig. 1.6. Location of the experimental fields. 1 : fields Pahi , 2 : field Presi, 3 : Fieldds Poyo, 4 : Cavally fields, 5 field Suzanne, 6 : field Yai, 7 : field Djéa, 8 : field Joséphine, 9 : field Modeste, 10 : field Hélène.

in fields. The forested landscape may seem undiversified, but really it is divided into countless little patches, some fertile, some swampy, some truly primary[1], others disturbed.

In a region with a general lack of field experiments and no exhaustive soil surveys, it is often the natural vegetation which is the best indicator available of the potential of any area of land because it results from the sum of effects of rainfall, soil type, drainage etc. (Trapnell 1959, Allan 1965 p.3-35, Küchner & Zonneveld 1988, chapter 34-37). Because many species within the study area exhibit some sort of site preference, we can make the study of vegetation an excellent tool to detect quickly and accurately alterations in the environment.

1 Primary forest is forest lacking secondary forest species as listed in Appendix 1 and 2.

As this study is primary concerned with agriculture, we will focus on two questions :

- which plant combinations (sociological species groups) indicate important ecological variance: climate, soil, geology etc, and where can they be found;
- which plant combinations (sociological species groups) indicate more or less severe human impact and how does disturbed or degraded vegetation develop over time, and in what patterns they occur.

In order to provide an answer to these questions one needs a classification, according to which the subject, the vegetation is systematically subdivided into units that are described according to composition and structure, so that correlations with the environment can be established. A systematic description of these units can be detected, delimitated and mapped.

For the present study it was necessary to develop our own classification, not because the existing ones proved inferior, but because of the scale and the special purpose of this study. The method used takes into account the full floristic composition and the sampling is largely based on the landscape ecology approach. This method has been described in detail by Zonneveld (1989) and also by Touber *et al.* (1989).

Land Unit Survey

Parallel to this study a Land Unit Survey was conducted (maps 1
in the area indicated in Fig.1.1 The survey was carried out in order to provide a general framework for this and other studies in the area (De Rouw, Vellema & Blokhuis 1990). Land Units are tracts of land which are considered ecologically homogeneous at the scale level concerned. They provide a proper basis for ecological description of an area and for land evaluation (Zonneveld 1989). In chapter 10 we will deal with some of the results.

1.4 CONCLUSION

The results of this study, agronomical and ecological, together with observations on the human environment, should make it clearer whether a shifting cultivation system thus modified is worthwhile or not.

The productivity of local practice food cropping will be determined mainly by trials in the fields of farmers. The productivity of the region is estimated mainly by the study of vegetation, natural and human-modified, in relation to climate, soil, and other environmental factors. A classification of plant associations in accordance with these factors aims to provide a practical, single guide to agriculture and forestry potentials.

2 The physical environment

The physical environment has been described comprehensively in the Land Unit Survey (De Rouw, Vellema & Blokhuis 1990, chap.3, 4, 5, and 6). Here we will briefly indicate the main characteristics of climate, geology, geomorphology and soil. On the other hand, studies on microclimate, erosion and water dynamics not considered in the Land Unit Survey, will be discussed more extensively. Vegetation, part of the physical environment too, will be dealt with in chapters 9, 10 and 11.

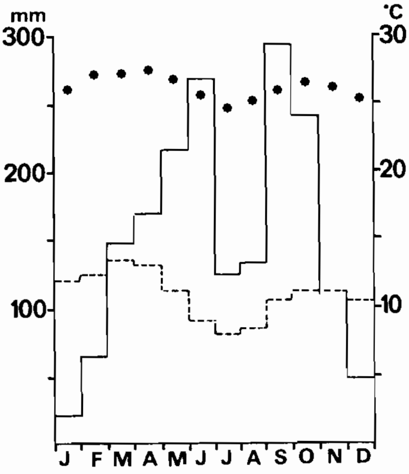

Fig. 2.1. Average monthly potential evapotranspiration rainfall and temperature (MAB station, Taï, 1978-1982, after Monteny 1983).

2.1 CLIMATE

The tropical location of the Taï region (5°57'-5°20' N latitude and 7°30'-7°14' W longitude), has resulted in a monsoon climate characterized by continuous heat, uniformly high relative humidity and abundant precipitation. The climate is determined by the seasonal north-south movements of two air masses with distinctly different moisture conditions. The frontal separation between these two air masses is known as the Inter Tropical Convergence Zone. The temperature is high throughout the year, about 26°C with diurnal variation superior to seasonal variation and weak irregular winds. A constant high humidity is only interrupted by the presence of the occasional Harmattan winds. They bring coolness and dust from the Sahara desert during a few days or a few weeks in the main dry season.

The study area has a "Aw climate" according to the classification of Köppen (1936): a tropical rainy climate with a main temperature in the coldest month >18 °C and a distinct dry season. Average rainfall data are presented in Fig.2.1. The study area has a mean annual rainfall that increases from about 1800 mm in the north to about 2100 mm in the south. The rainfall data (Fig.2.2) allow a distinction of four seasons. There is a relatively long rainy season from March through June, with a maximum towards the end of the period; this maximum is most clearly expressed in the south; a shorter rainy season is concentrated in September and October. The dry season is from November through February, but it is to be noted that there are only three relative dry months (December, January and February) in Taï and further north, and two (January and February) in the south, near Grabo. In Grabo, August is relatively dry, in Taï and further north, both July and August (Fig.2.2). Monteny (1983), however, tells the small dry season chiefly by changes in solar radiation, which is higher than usual, and considers the variation in rainfall insufficient (Fig.2.3).

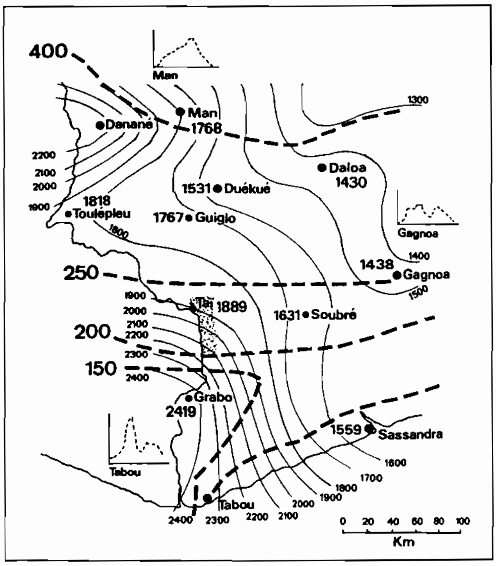

Fig. 2.2. Annual rainfall in south-west Côte d'Ivoire (isohyets, thin line) and number of days per year with hydric deficiency (thick broken line). Three stations with different rainfall distributions are presented. Study area indicated as stippled area. (Source Eldin *et al.* 1971.

Bioclimatological studies were carried out by ORSTOM in Taï between 1978 and 1982. Most observations were made in primary forest and in gaps of different sizes. As these circumstances have affinities with field and secondary forest conditions, we will see to them more closely. Evaporation exceeds rainfall for about one month a year, but variability between years is great. Monteny (1983) compares the diurnal microclimate of a two hectare gap with a 40 hectare clearing. Diurnal variations in air temperature and air humidity are more acute in the small gap than in the large clearing, due to superior turbulence in the latter. In the small gap, great daily changes in humidity produce a heavy dew, especially in the dry season. In the rainy season, solar radiation is less intense producing less daily variation. In the large gap microclimate is more uniform during the day and during the season and no dew is produced. The well known issue of climatic changes caused by deforestation exists on several scales. On a very detailed scale, the local Oubi and Guéré farmers are convinced that where the forest has been felled, the weather becomes drier. The effect can be tempered by leaving a few large trees in a field during cultivation, which "attract" rain and produce moisture. Cutting all high trees without exception "dries" the environment, so they say. On a continental scale, most metereologists agree that if the remainder of the west African High Forest is cut, serious ecological consequences are to be expected for the Sahel and the Savanna zone. Monteny in his thesis (1987) is one of the rare scientists to pronounce a judgement on a regional level. He states that the Taï forest largely contributes to a climatic equilibrium which is maintained by the general atmospheric circulation. Due to aerial and underground vertical structure of primary forest trees, about 55 % to 70 % of the annual rainfall is recycled into the atmosphere, thus the physical characteristics of the humid air masses from the ocean are preserved. In the southern part of the study area, where rainfall is more evenly distributed over the year, recycling is best. In the dry season large trees with their deep root system continue to evaporate as usual. As a result nearby vegetation on fields and other low vegetation does not warm up as much. He also observed that young secondary forest, even only 3-4 years old, could evaporate almost as much as High Forest, but only if water conditions were good. During dry spells and in the dry season these stands transpire far less. He concluded that large scale clearing of this High Forest would alter the energy equilibrium seriously and the impact would be observed on the region situated a few hundred kilometres north of the Forest zone. (Example the elaborate farming system in the densely populated Senoufo land would be seriously affected, and probably the now prosperous teak (*Tectona grandis*) plantations in the north of Côte d'Ivoire, too. B. Monteny pers. comm.)

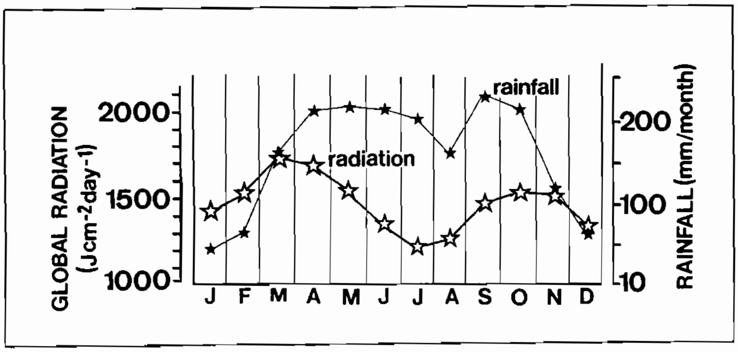

Fig. 2.3. Average monthly global radiation and rainfall (MAB station, Taï, 1978-1982, after Monteny 1983).

2.2 GEOLOGY

The most accurate and recent geological map of south-west Côte d'Ivoire was produced by Papon (1973) at a scale of 1:500,000. Development and Resources Corporation (DRC 1967a) prepared a generalised geological map of south-west Côte d'Ivoire from information accumulated during soil investigations. In the Land Unit Survey (De Rouw, Vellema & Blokhuis 1990) these studies were supplemented with our own observations and the map Fig.2.4 was produced, which is to a large extent a simplified map of Papon (1973).

The underlying geology of most south-west Côte d'Ivoire belongs to the Precambrium Basement Complex that consists of granites and associated metamorphic rocks, mainly of gneissic character. The formations belong to two different systems, the "Libérien", of Archean age (3000-2300 million YBP) and the "Eburnéen" of Proterozoic age (2300-1500 million YBP) (Tagini 1972). After the last orogenic event (2090-1830 million YBP) only minor and local geological events took place. The south-west of Côte d'Ivoire is characterized by a rectilinear structure of parallel bands of either Liberian or Eburnean formation. The oldest formation, mainly granites and migmatites is intersected by a younger complex, consisting of schists and micaschists. The main trend of the rocks orientation is reflected into the relief for the principal faults run in the same direction (Bos 1964). These faults are carved by perpendicular faults of more recent origin (Fritsch 1980).

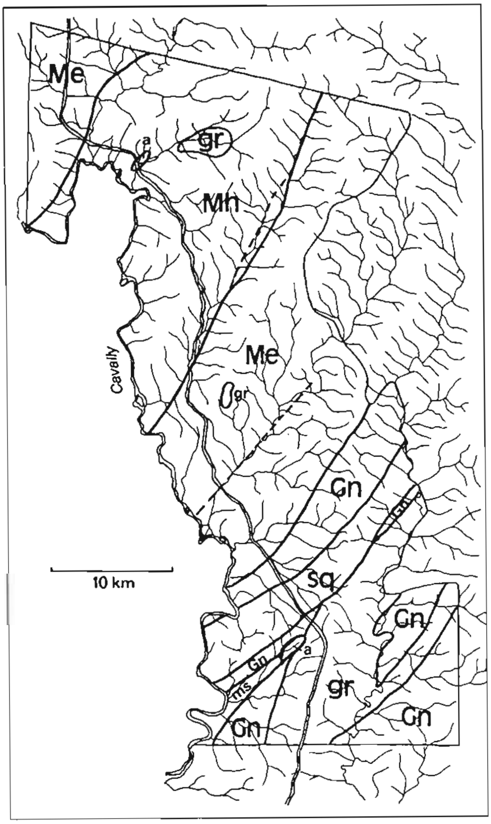

Fig. 2.4. Geological map of south-west Côte d'Ivoire (slighly modified after Bos, 1964).

Eburnean formations:

ms = mica schists

sq = schists - quartzites

gr = granite

a = amphibolite

Liberian formations

Gn = gneiss

Mh = heterogeneous migmatite

Me = homogeneous migmatite

-- = fault

2.2.1 Geology and soils

Soils of migmatite-gneissic origin

The mapping and naming of geological distinct units has been, and is, a particular knotty problem in the Taï region. Some of the difficulties in interpretation are commented on in the Land Unit Survey. In Fig.2.4 large units are mapped as migmatite. Migmatite is per definition a rock of mixed composition. Migmatites of the study area are characterized by lithological differences over short distances due to precisely that mixture of rock. Most of this change is produced by the variable amount of granite in the rock. The more granitic the original parent material, the sandier is generally the soil texture. The differences in "mignatites hétérogènes" and "mignatites homogènes" distinguished by Bos (1964) is that former are more granitic and the latter tend to be more gneissic. It should be evident that the gneiss Units in the map have much in common with the gneissic mignatites (Fig.2.4). Apart from these discrepancies in naming, it was often difficult to identify the different geological formations in the field. One reason was the obvious scarcity of exposures, another reason was that the landscape is so old that changes in parent material are not distinct in landform, and, if they are, the limited visibility in a forest may leave this unnoticed. In fact, most soils derived from more or less granitic migmatite, or from more or less gneissic migmatite, or from gneiss, have many common features and those could be easily checked by auguring. They constitute a soil type which is widespread and very common throughout the study area. All soils have a very gravelly to gravelly topsoil, consisting mainly of ironstone. The thickness of the gravelly layer is more than 50 cm, but usually over 100 cm. The layer begins within 20 cm from the surface. The soils are brownish to reddish clayey soils to yellowish-brownish loamy soils with some quartz fragments. All soils are well drained.

Soils of granitic origin

The soils that have developed over a granitic rock have some clear features which makes them distinct from those of migmatite-gneissic origin. Granite is dominant in one Land unit in the southern rainfall zone, but granite inclusions occur in a number of other units. The soils differ from those derived from migmatite in being much coarser-textured. Soils are yellowish-brown rather than reddish coloured and the surface soil contains far less ironstone gravel. Fragments of quartz often occur below 50 cm. Soils may be loamy sand to sandy clay but loamy soils are most common. They are well drained.

Soils derived from schist

Occasionally, the texture of migmatite tends towards schists, as it does sometimes towards granite. In the study area schistose layers were most of times so small that typical schist-derived soils could not be identified, but in some cases, the intrusions were of sufficient extent to allow the development of a specific soil. The schist-derived soils differ from the migmatite soils (upper slope and crest) in having less ironstone gravel and quartz and containing much mica. The soil is red to yellowish red and has a clayey texture. Soils are well drained. By their clayey texture and lack of gravel these soils are obviously better suited for water storage than most soils derived from migmatite, gneiss or granite.

Soils in inselberg landscapes

Some of the crests and upper slopes on sites where migmatite forms the underlying rock have characteristic small domed inselbergs (bornhardts) or boulder inselbergs (tors). The occurrence of these inselbergs is restricted to a few areas which have been mapped as "Association of uplands and small inselbergs" (Land unit map). Places far from rock outcrops had the characteristics of a normal gravelly, clayey, migmatite derived soil. Yet the forest composition was very different so it must be concluded that something in the parent material continued to be different.

2.3 GEOMORPHOLOGY

Over 80 % of the study area consists of a dissected peneplain with remnants of an ironstone capping on the now highest terrain exposures, the crests. Most of the study area is situated between 100 and 240 metres above sea level (topographic maps 1:50,000).

The major part of the landscape is moderately dissected (0.4-0.6 km/km).

The distance between successive crests is about 1000 to 1500 metres; the difference in elevation between crest and valley bottom is about 15 to 40 metres. (Collinet 1988, Guillaumet, Couturier & Dosso 1984).

Crests are flat-topped or have a convex cross-sectional profile. Over their length the have slope gradients of 0 % to 5 %. The valley sides have a convex upper slope, merging into a straight or concave middle slope that passes either concave or steeply convex into the valley bottom. The majority of the slope gradients range between 2 and 15 %. Valleys become narrow upstream, often forming short but very steep abrupt ravines. This occurs especially in the northern part of the study area, where deep gullies have dissected some of the lower slopes. All through the study area rivers ramify strongly downstream, following no preferable direction and may become almost stagnant in valley bottoms 100 to 150 m wide (Van der Gaag 1989).

2.3.1 Geomorphology and soils

Soils of the uplands

Soils on crest, upper slope and middle slope have usually develop "in situ". These sites are subject to soil erosion. Lower slope soils are developed in colluvial material that has been eroded from higher positions. Valley bottom soils have developed in a mixture of colluvial and alluvial material.

Soils developed "in situ" are very old in Taï. They are strongly weathered, depleted of bases and relatively enriched is sesquioxides - mainly of iron and aluminium - and quartz.

The clay contents in soils that have formed "in situ" increases with depth. It is interesting to note that in the Taï area plinthite formation is not restricted to lower slope soils, but occurs frequently in midslope positions and even at upper slope and crest sites.

Association of uplands and small Inselbergs

In part of the uplands some of the highest landscape positions have the characteristic of small inselbergs. They differ from other crest sites in being asymmetrical with some steep slopes. These crests have a convex profile, a circular plan, and a smooth rock-paved surface. The middle and lower slopes are not different from those below non-inselberg crests and upper slopes (De Rouw, Vellema & Blokhuis 1990).

Alluvial landscapes

The alluvial landscapes consists of the foodplains of the Cavally river and of the smaller floodplains along the lower courses of the Audrénisrou, the Méno, the Gô and the Nsé rivers. These are all tributaries to the Cavally (De Rouw, Vellema & Blokhuis 1990).

Soils of the alluvial plains

Only the alluvial deposits alongside the river Cavally extend to some width (2-10 ha). The terraces are flooded in exceptional wet years, about twice in five years. The texture of the deposits may change from one place to another, but remains remarkably constant throughout the profile. The clayey soils hardens in the dry season, only to soften slowly in the rainy season. Water retention is low, topsoil is acid, between pH 4 and 5.5 (Leneuf 1956), getting less acid down the profile. Drainage is good in the topsoil, becoming moderate in soil layers underneath. The deposits occupy only a small area in the study area.

2.4 SOIL CHARACTERISTICS OF A TYPICAL TOPOSEQUENCE

Several surveys and other investigations have been carried out to study the soils in south-west Côte d'Ivoire (Leneuf 1956, Riou 1960, DRC 1967a, Perraud 1971, Fritsch 1980, 1982).

The soil map produced by Fritsch (1980) gives a good illustration of the way soils change along a toposequence from crest to valley bottom . Especially his soil survey of 1600 ha on a scale of 1:15,000 gives insight into the variability over short distances.

In Fig.2.5 cross-section of a catena is represented, being an example of a typical toposequence on the slope of the small hills around Taï. The differentiation of sequential soils is described as follows.

- From the hilltop to the midslope (slope gradient 0-20 %) the topsoil is built up by gravelly layers about 70 cm deep, of which 50 % of volume consists of coarse fragments. The gravel is embedded into a red clayey, fine fraction. Underneath, between 70 and 180 cm, the clayey layers become softer and receive a fine, subangular blocky structure. The granite saprolith occurs between 180 and 200 cm. These soils are classified as "sols ferrallitiques fortement désaturés, remaniés modaux" or as "Ferric Acrisols". They are well drained, acid, with low organic content, low CEC and base saturation (Table 2.1).

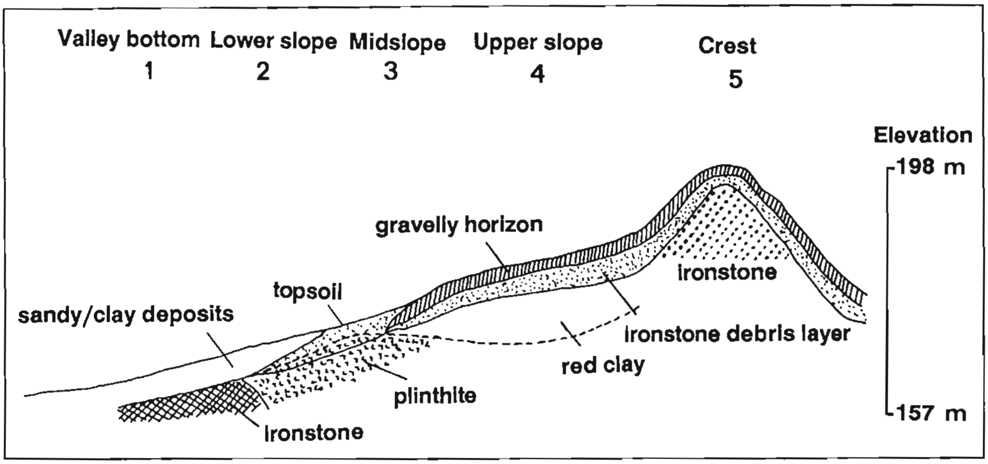

Fig. 2.5. Typical toposequence in the Taï region (details see 2.4), after Fritsch 1980.

- From midslope to one third lower slope, extending over 100 to 150 m, the slope gradient is decreasing from 20 to 5 %. The gravel layers become less thick, 20-30 cm, and they are generally covered with 10 to 20 cm thick yellowish sandy loam. Underneath, mottled clayey layers continue to the saprolotic layers which occur at about 200 m depth. These soils are classified as : "sols ferrallitiques fortement désaturés, remaniés à recouvrement apprauvris", or as "Plinthic Acrisols" or "Plinthic Ferralsols". They are moderately vertically and laterally drained, very acid with very low base saturation, but if a correction is made for the gravel content, relatively moderate organic matter content (Table 2.1).
- The lower one third slope, extending over 100 to 120 m, has yellow, sandy topsoil layers and more clayey layers below. In the first 100 cm no gravel occurs. The structure is massive but faunal activity has introduced large pores. In the lower part, about 120 cm depth, the mottled layer may be hardened to a petroplinthic layer (carapace). Saprolith rarely occurs within 200 cm of the surface. These soils are classified as :"sols ferrallitiques fortement désaturés apprauvris indurés", or as "Xanthic Ferralsols", or "Plinthic Ferralsols". They are moderately drained, mainly superficially and laterally, very acid with even less organic matter content and CEC (Table 2.1).
- In the valley bottoms the soils are hydromorphic with gley. They represent strong variations passing vertically and laterally from coarse, white sand to greyish clay loam. They are classified as : "sols hydromorphes minéraux à gley d'ensemble", or as

Table 2.1. Analytical data of topsoil under the primary forest of a typical toposequence in the Taï region (after) Fritsch 1980. Gravel content as percentage of whole soil, other analysis on fine earth fraction only.

		Crest	Upper slope	Mid-slope	Lower slope	Valley bottom
Gravel						
	0-7 cm	76%	75%	3%	0%	0%
	7-20 cm	75%	71%	56%	0%	0%
pH - H2O						
	10 cm	5.9	5.6	4.5	4.3	4.2
	20 cm	4.9	4.7	4.7	4.4	4.4
pH - KCl						
	10 cm	4.8	4.2	3.6	3.8	3.7
	20 cm	3.8	3.8	3.8	3.8	3.9
CEC (meq./100g)						
	10 cm	8.9	9.6	6.2	2.3	4.7
	20 cm	5.1	5.4	4.7	3.0	3.2
Base Saturation (%)						
	10 cm	73	53	16	23	37
	20 cm	28	15	11	6	55
Org. matter (%)						
	10 cm	3.11	3.45	1.78	0.93	1.57
	20 cm	1.32	1.08	0.89	0.65	1.18

"Dystric Gleysols". They are poorly drained, extremely acid with moderate organic matter content (Table 2.1).

2.5 SOIL AND WATER

ORSTOM carried out various erosion and runoff experiments in the area near the research station in Taï. They used rainfall simulation and natural rainfall and studied the soil under untouched forest and under local cultivation practice.

All soils in Taï become quickly saturated. It appears to be rather unimportant whether they are initially moist or rather dry. The soils with a gravelly layer in the topsoil infiltrate always better. Casenave *et al.* (1982) removed the understorey from a primary forest and also, delicately, removed all litter from small plots which he used for 1 m^2 rain simulation. The bare soils gave 64 % run-off on the upper slope, 75 % on the mid-slope with a gravelly layer under the surface and 88 % run-off on the hydromorphic lower slope soils.

Compared with two other Ivorian soils under high forest, studied in the same manner, the Taï soils are exceptionally quickly saturated. Collinet & Valentin (1979) studied erosion under natural rainfall and under a 50 m^2 rainfall simulator. Under natural rainfall, with no understorey and no litter removed, runoff is limited to 20 % for the soils with a gravelly layer (upper- and mid slope), but runoff increased spectacularly to 50-60 % on the hydromorphic soils lacking gravel. Under these natural conditions erosion is limited to 150 to 300 kg/ha/year. The undergrowth and litter breaks the kinetic energy of raindrops and the soil is further protected by a strongly developed rootmat and, on the upper slope, also by gravelly layers. If the forest is felled , burnt and cultivated with rice in the autochtoneous manner with no tillage done and with masses of unburnt debris on the field, runoff increases considerably in mid slope and lower slope fields. However, erosion stays at a level comparable to forest soils : below 0.5 t/ha/year. But runoff and erosion increases dramatically if the field is cultivated by immigrants, which means that all the debris is burnt, small moulds are elevated for yam, and the rootmat is destroyed. Under these circumstances - the yam is only slowly covering the ground- erosion is at least 25 times that under rice cultivation; one shower of 120 mm on 50 m^2 caused 800 kg/ha of erosion (Collinet 1984).

2.6 CHEMICAL AND BIOLOGICAL FERTILITY (Literature review)

2.6.1. Nutrient cycling

Ever since scientists have been confronted with the apparent paradox of a "luxuriant" rain forest growing on a poor soil, the issue of nutrients comes up. The resolution of the paradox was sought in the theory about nutrients stocked in the above-ground biomass and in almost "closed" nutrients cycling (Richards 1964, p.219-226). When the above-ground biomass is destroyed, not only the nutrient capital is lost, but also the system of tight nutrient cycling is attacked. It was generally believed that shifting cultivation in the "Established" way, is an appropriate farming system because nutrient losses per unit time and per unit area were small relative to the total stock of nutrients immobilized in the ecosystem. Many aspects of nutrient stocking and cycling in rain forests, whether intact or damaged, have been studied since. Recent reviewers (Harcombe 1980, Whitmore 1989) expressed the necessity to reconsider the matter per site. No matter how, a long term success of shifting cultivation, however modified, depends on the recovery and maintenance of soil fertility. In a hot and humid climate this is a serious problem.

Nutrients in a rain forest

Let's see what happens or what is supposed to happen with nutrients in a mature rain forest, during the cropping period and during fallowing. In a rain forest under low natural fertility conditions a large proportion of the plant nutrients is stocked in living organisms. Continually large quantities of plant tissue die, are decomposed and return their supply of nutrients to the soil. The reabsorption of nutrients is so rapid that the available supply in the forest soil is permanently kept at a very low level. This is how a rain forest ecosystem limits losses of nutrients by leaching or fixation (Bartolomev *et al.* 1953). No data are yet available for the Taï forest but an account on macro-element cycling have been given by Bernard-Reversat & Huttel (1975) for the Banco and the Yapo forest in Côte d'Ivoire.

Nutrient cycles do not work without gain or loss (Snedaker 1980). Losses in the Taï forest are balanced by nutrient addings from several sources this being chiefly soil weathering, precipitation and dust. The rates of supply remain to be quantified but are probably low. Erosion, even under intact forest exists (Collinet 1984, De Rouw, Vellema & Blokhuis 1990) and brings saprolitic rock within reach of tree roots. The mineral weathering of mica's (Potash), not seldom found in the surface layers of the soil constitute a nutrient input. Rain input of nutrients is reported to be low, though not as low as in Amazonia (Bernard-Reversat 1975). Dust may be a far more important source. Nye (1961) in Kade, Ghana, reports a substantial input of NO_3-N, P, K and Ca during the period the Harmattan wind blows from the Sahara carrying dust in the air. Bertrand, Baudet & Drochon (1974), unlike the statements of McTainsh (1986), showed that the Harmattan dust feeder zones for Côte d'Ivoire are situated in the Ténéré, near Bilma, and those for Ghana more eastward, in the Chad Basin. Mineral composition of dust is bound to vary according to entrainment zone. The principal components of the dust deposed in Abidjan is quartz and kaolinite clay and about 5 % consists of phytolithes (mainly petrified wood) and 3 % are fossils of sweet water organisms (Folger 1970). Harmattan dust haze frequencies vary considerably from year to year so amounts of deposits too. A problem rarely mentioned is how the dust comes down (Maley 1981 p.501-503). The Harmattan dust comes rarely in contact with the wet air masses of the F.I.T. so the dust can not rain out. Another inconvenience is the dust being so small. Particle sizes in Abidjan are mainly between 0.3 and 0.5 l, a rare maximum being about 10 l (Bertrand, Baudet & Drochon 1974. Though the aerosols of the Harmattan, being dry and hygroscopic, do attract some water in the humid air of the High Forest zone, this forms only mist (Malay 1981). Only aerosols in the size range between 1 and 40 l in the presence of clouds, can be associated with rain (Mason 1962).

In the hot, humid climate the ancient rocks have weathered in situ to depths of 3 to 20 m. The end product of millions of years of softening are severely leached poor, acid soils with kaolinite as the main clay mineral, low CEC, low organic matter content and much sesquioxides. On places with locally and seasonally insufficient drainage, a redistribution of Fe and Mn occur, which, together with the sesquioxides, work as a kind of cement between soil material. In case of dissecation of this material, it hardens to plinthite. If the soil is eroded and this horizon appears on the surface, the plinthite will harden irreversibly to a crust of ironstone (called laterite or carapace). For this last process a drier climate is needed (Tagini 1972). Collinet (1984) situated the last relative dry period about 30,000 years ago.

In subsequent humid periods this crust becomes subject to renewed weathering. Nowadays remnants of unbroken crust are still visible as well as the erosion product, ironstone gravel.

In an interesting experiment in the rain forest near Divo, Côte d'Ivoire, Scaetta (1941) demonstrated that the dust-laden mist can be captured by vegetation only if the latter has an outstanding irregular surface, like the rain forest canopy or a field with remnant trees, and no dust is caught if the surface is low and smooth, like a grass field or a thicket. He further demonstrated that the dust was often enriched by ash parts from the burns in the savanna and that those emergent trees with most leaves captured most dust. Epiphytes and lianas are probably the first organism to benefit from this nutrient source. Via stemflow the dust eventually comes to the soil.

Nutrients during the cropping period

The agricultural use of a forest soil requires the removal of a rain forest to be substituted by crop plants. The felling of the forest results in the liberation of large quantities of mineral nutrients to the soil. In most cases, burning is the only devise for clearing away vegetation. The effect of burning is very complex. There is a loss of Nitrogen and Sulphur due to volatilization and an instant mineralisation of organic matter. This leads to an accumulation of all kinds of minerals but especially Phosphorus and Potash. Burning produces a marked decrease in acidity. Most of, of only part of, the soil flora and fauna is destroyed (Nye & Greenland 1960 p.67, Maggi *et al.* 1990). Then crops are planted which grow currently with the decomposition of the forest residues. They highly benefit from the short-term fertility brought by the ash of the burned trees. A quite complete burn of a Costa Rican rain forest brought 670 gram ash per m^2 (Ewel *et al.* 1981), a normal burn in Amazonia, Peru, deposed about 400 gram ash per m^2 (Seubert, Sanchez & Valverde 1977). Ash input after burning a primary forest in Taï was valued 242 and 208 gram ash per m^2 (Guillaumet, Couturier & Dosso 1984). The same field had an important fine litter adding, estimated at 0.5 kg per m^2, which disappeared completely within four months. In Taï, no decline of humus was observed as a result of the firing but rapid decomposition of unhumified material was reported elsewhere (Ghana, 30 year old forest, Nye & Greenland 1964). So in short, burning promotes the rapid turn-over of nutrients. Furthermore, the release of bases is stimulated by an increase in soil pH. With most of the nutrients accumulated over many years present in the ash, it is not surprising that the first crop after burning is good. In northern Thailand (Sabhasri 1978), in Para State, Brazil (Salati & Vose 1984) and in Amazonia, Peru (Sanchez *et al.* 1982) the first harvest was almost entirely derived from the ash. The thoroughness of the burn had a most strong influence on fertility level in Sarawak (Andriesse & Schelhaas 1987b).

The increase of non-biological mineralisation during the first year after felling releases approximately 5 ton of Carbon per hectare and 2 ton of Nitrogen, resulting in a slight decrease in soil organic matter (Taï, field in primary forest, Fritsch 1982).

During the cultivation period nutrients are not released at the same rate. Usually an increase in the available Calcium and Phosphorus is much slower than that of Nitrogen or Potash. The availability of the latter may reduce quickly after clearing leading to a drop in agricultural yield (Adedeji 1984, southern Nigeria, Nye & Greenland 1964, Ghana). During cultivation there is a danger of important nutrient loss before the cultivated crop is sufficiently large to immobilize most of the nutrients because the mineralisation of forest residues is too quick.

Nutrient cations, especially Potash and Magnesium, but also nitrate and sulphate may have leached out. Fixation by clays and soluble irons may severely affect Phosphorus availability. Hence the possibility of excessive nutrient loss almost simultaneously with cultivation (Jordan 1988, review). A striking loss of all nutrients was recorded in Ghana, after clearing a 30 year old forest, especially the first year (Nye & Greenland 1964). Idem, but limited to the upper soil levels in northern Thailand (Sabhasri 1978) and San Carlos, Venezuela (Herrera *et al.* 1981). Of course we should also account for nutrients removed by the crop harvest. These were measured for a first rice crop (0.75 ton per hectare) in a primary forest field in Taï, 10 kg of Nitrogen, 1 kg of Phosphorus and 2.5 kg of Potash (Jaffré 1985).

On the other hand, Vitosek & Walker (1987) puts forward that the lack of extreme nutrient losses in many disturbed areas is due to the dual role of micro-organisms. They break down organic components but are at the same time also major consumers. Golley (1983) remarked that the nutrients stored in organic matter like humus, partly burned boles etc. are usually not easily liberated. The soil microflora, largely destroyed by land clearing, has to re-build complicated food chains in order to be able to decompose different kinds of debris. In Taï, for example, the decomposition of unburnt wood by termites needs, among other things, the re-establishment of a pre-digesting fungus population (M. Lepage pers. comm.).

Forest removal results in loss of organic matter due to the cessation of input and to the accelerated decomposition. Organic matter is concentrated in the top few centimetres and sharply decreases with depth (Taï, Fritsch 1980). It makes the largest contribution to the exchange capacity of the soil for the CEC of the subsoil is and because the predominance of kaolinitic clay minerals. So, in those soils chemical fertility is most closely related to organic matter content (Fritsch 1982, Nye & Greenland 1964, Ghana). Though the rate at which the stable humus fraction of the organic matter disappears can vary widely according to site, all places where a conversion took place of forest to field suffer from a, mostly steady, decline of organic matter (Krebs 1975 volcanic soils Costa Rica, Herrera *et al.* 1981 San Carlos Venezuela, Salati & Vose 1984 Para State Brazil, Sanchez *et al.* 1982 Peru Amazonia, Brams 1971 Sierra Leone, Harcombe 1980 review).

Nutrients in the fallow period

After the area has been cropped for some time the release from the organic residues further slows down and crops suffer. Liberated nutrients are used up, removed with the harvest, fixed by colloids or are lost by leaching (Nye & Greenland 1964). In such soils the supplying capacity of the soil is not sufficiently large to continue cropping. Secondary forest species can apparently absorb nutrients at lower ranges of availability than crops.

Some of the functions of fallows have been summed up by Nye (1958) : storing nutrients thus preventing them from leaching, withdrawing nutrients from the subsoil and releasing them at the topsoil, increasing the level of organic matter content in the topsoil thus increasing the capacity to hold nutrients. Other beneficial effects are listed by Ahn (1979) : fallows protect the soil by lowering soil temperature so reducing oxidation of organic matter, it also improves physical and biological properties of the soil, and, constitutes a "weed break". Of course nutrient accumulation by the fallow vegetation depends very much on the density and extent of the root system. Fallows growing rapidly with deep roots are surely best (Ahn 1979). Large trees left standing during the cropping period are probably crucial for the prevention of leaching nutrients (Aweto 1981, south Nigeria, Andriesse & Schelhaas 1987a, Sarawak).

The litter of early successional pioneers is higher in Nitrogen and can be low in phenolic compounds and lignins than are later successional plants. So they decompose and release nutrients more rapidly (Vitosek & Walker 1987).

Nutrients stored in typical Taï fallows have been studied by Jaffré & De Namur (1983) and Jaffré (1985) and those data have been compared to other findings elsewhere. Nutrient accumulation in successive stages of forest succession can be quite impressive. On sites with comparable poor levels of soil fertility, Zaire (Bartolomev *et al.* 1953), Colombia (Folster, De las Salas & Khanna 1976) and Taï, the differences in capacity of nutrients uptake by the natural vegetation per time unit depends merely on the plant species composing the fallow (Jaffré 1985). First this variation in floristics gives a difference in biomass. Jaffré & De Namur (1983) have demonstrated that the annual increase in biomass in Taï succession lags behind that of Zaire due to a difference in dominant pioneer tree : Musanga cecropioides in Zaire grows faster (15.2

ton per hectare per year) than Macaranga hurifolia in Taï (5.9 ton per hectare per year). Secondly, some pioneers prove to be better accumulators than others. Compared to Zaire and Colombia, Taï forest fallows have particular high Nitrogen and Calcium concentrations in their plant tissue. In the first stages of succession, in spite of the differences in biomass produced, the Musanga cecropioides dominated fallows and Macaranga hurifolia fallows stock about equal amounts of Potash and Magnesium, the latter accumulates only slightly less Calcium and Nitrogen and superior amounts of Phosphorus (Jaffré 1985).

Fritsch (1982) estimates that almost all of the nutrient input supplied by the felling and burning of the (primary) forest was re-used within two or three years. This means that crops and the young fallow mainly grow on the nutrient stock liberated by the initial forest.

2.6.2 Two kinds of forest ecosystems

It is generally considered that a regeneration of site fertility during the course of succession is also perceptible in the soil (Fig. 3.5 p.59 in Ruthenberg 1976). But Ripley (1975), especially for Ghana states that it is not at all likely to expect any difference in chemical properties in the soils of different length of fallow periods. Cultivation alone is sure to bring along a degradation. In Columbian Amazonia uplands, (Eden & Andrade 1988), and in San Carlos Venezuela (Uhl 1987), the nutrient levels in fields, in fallow vegetation and in mature forest were equally low in absolute terms. The same was reported by Fritsch (1982) for the topsoil of primary forest, fields and fallows of different ages in Taï.

In fact, literature data fall into two groups. The first comprises ecosystems where cultivation and fallowing does not bring any substantial change in measurable soil nutrient levels which always remain very comparable to those of primary forest. Observations concerning this group are often made in rain forest of low natural fertility levels, where primary forest is not rare and where old secondary forest or primary forest are used for cultivation. The second group contains those ecosystems where fallowing does result in a recovery of fertility which stock is depleted during cultivation.

A net recovery of soil fertility is usually perceived in somewhat drier areas where almost all primary and secondary forest has disappeared. Shifting cultivation consist of a more or less careful management of forested fallows not allowed to grow very old. Examples are given by Sabhasri (1978) north Thailand, who reports that fertility of the upper soil is reduced in the first few years of forest regrowth but that it takes a subsequent six to eight years for the supply of nutrients in the soil to return to pre-cultivation levels. Depletion of nutrients continues through early successional fallows up to five years due to low returns of litter of the dominant cover plant Eupatorium odoratum. Low-growing fallow proves to be inefficient in restoring soil fertility. Observations of the same kind were made by Ramakrishnan & Toky (1981) in north-east India, Wadsworth *et al.* (1990) in Mexico, Aweto (1981) in north-western Nigeria, and by Nakano & Syahbuddin (1989) for most shifting cultivation systems based on rice in south-east Asia and by Werner (1984) in an eutrophic ecosystem ("La Selva") in Cost Rica.

It might well be possible that relative densely populated regions with shifting cultivation are so because the soil there was initially better. Although the land is being cropped intensively and fertility level has dropped low, the capacity of regeneration during fallowing may testify a remnant of a superior soil. Inversely, regions which have remained very sparsely populated up to now, may count the infertility of the soil under virgin forest as one of the reasons explaining this.

To conclude, two examples of careful management of soil fertility in a shifting cultivation system. In both cases the soil fertility maintenance on soils deprived of unweathered minerals. In eastern Nigeria, Vine (1954), the tree *Acioa barteri* (also present in Taï) has been planted in high densities, grown from seed. During the cropping period which does not exceed eighteen months, it serves as yam stakes. The fallow vegetation consist mainly of freely coppycing *Acioa barteri* trees grows for four to eight years. The cycle is only made possible by the scrupulous preservation of stumps of trees during land clearing and the abstinence from firewood collecting during the fallow period. The system does not work on sandy soils. Another description of a strictly regulated shifting cultivation system apparently pushed to a limit comes from the Lua' in north Thailand (Zinke, Sabhasri & Kunstadter 1978). It is a ten year cycle made possible by the preservation of trees which are not killed during cutting and burning.

Continuous cultivation or abusive forms of shifting cultivation carry along an inevitable decrease of productivity. Nutrients may simply not be present in the soil or may be released at a rate inadequate to allow crops to grow. (Brams 1971 Sierra Leona, Uhl 1987 San Carlos, Krebs 1975 Costa Rica, Sanchez & Nurena 1972 somewhat better soil in Peru, Sanchez *et al.* 1982 Peru, Ramakrishnan & Toky 1981 north-east India, Taï this study etc). Next to a decrease in nutrient supply, physical conditions, often excellent after a forest fallow, degenerate (for Taï Collinet 1984, Moreau 1983).

2.6.3 PHOSPORUS

Special attention deserves Phosphorus. Nutrient cycling patterns of this element have similarities throughout the rain forest sites because every where it is essentially biologically controlled (Golley 1983b). Availability of the element is reported to be the limiting factor for cultivation and fallow development in many regions (Arnason *et al.* 1982 Belize, Brams 1971 Sierra Leona in more intensive shifting cultivation, Sanchez *et al.* 1982 Para State Brazil and Yurimaquas and in Peru already so the first year of cultivation, Ahn 1979 west Africa in shifting cultivation, Tergas & Popenoe 1971 Amazonia, Folster *et al.* 1976 Columbia, Wadworth *et al.* 1990 Mexico, Van Reuler & Janssen 1989 Taï).

Zinke, Sabhasri & Kunstadter (1978) contributes the success of the Lua' farming system to the management of available phosphorus in the surface soil layers. Pumping up of phosphorus during fallowing has also been reported by Nye & Foster (1961), Ramakrishnan & Toky (1981) north-east India, Sabhasri (1978) north Thailand. No correlation however, was found between extractable phosphorus in the soil and total phosphorus content of the vegetation, but some pioneers were good phosphorus accumulators (Tergas & Popenoe 1971 Guatamala), while other (planted) fallows are not (Cornforth 1970 *Pinus caribbea* in Trinidad). Data from Ghana (Nye & Greenland 1960) and from Taï (Fritsch 1982) indicate that total phosphorus is very low but the rate of leaching is very low as well. The problem with phosphorus is not so much loss but the availability for plant uptake (Nye & Greenland 1960). Under natural conditions (Banco, Yapo forest) mineralisation of phosphorus is a very slow process and all released phosphorus was immediately immobilized by soil organisms (Bernard-Reversat 1975). She concluded that the phosphorus cycling was almost "closed". Nye (1958) could describe fallows as systems absorbing phosphorus at a low level of availability in the soil, to release it in an easily available form, eventually after clearing and burning or after mineralisation of litter.

2.6.4 Mycorrhizae, literature review

Ecologists in a rain forest environment and specialists of fungi in their laboratory seldom meet. Not rarely they stay unacquainted with each others findings. Although the case of mycorrhizal associations has often been mentioned as an important one, even essential to the functioning of the rain forest ecosystem, a lack of empirical data is evident (Whitmore 1982 p.29, Richards 1964 p.220). Detailed ecological studies of mycorrhiza in rain forests started to come off in the late seventies, in Costa Rica, in Venezuela and in Taï. Data from the rain forests were compared with the results of earlier laboratory work and with field work from temperate regions.

Mycorrhizal fungi have a mutual relationship with host plants, chiefly woody plant species. Host plants "give" carbon compounds and "take" nutrients, mainly phosphorus. The fungi display little host specificity.

Went & Stark (1968) introduced the term "direct mineral cycling" for what they considered to be the greatest asset of mycorrhizae in rain forest: the almost closed cycle of minerals to microflora to tree roots. Stark (1971) further proposed a direct mycorrhizal recycling mechanism in the forest litter in the Amazon basin. Mycorrhizae were supposed to decompose litter in situ and furnish the host plant with a mycelial structure for transport of nutrients immediately into the root system.

Mycorrhizae in rain forest

Nowadays, many rain forest tree species are supposed to have mycorrhizae associations (Stark & Spratt 1977 San Carlos Venezuela, Janos 1983, Alexander 1989, and Golley 1983a). A mycorrhizal association has a variety of beneficial effects of which many aspects remain only partly understood. Fitness of the host plant is improved because the external hyphae greatly increase the absorbing surface of the feeder roots thus limiting the plants expenses seeking out nutrients (Janos 1980a). Since the phosphate anion will not go far to the root, than the root has to go to the phosphate anion. So adequate phosphorus uptake depends very much on a well-developed root system.

Hyphae extend much farther than root hairs and some mycorrhizae-dependent rain forest trees have no root hairs at all (Janos 1983). Vitosek & Walker (1987) observed that nitrogen-fixing organisms required a large amount of phosphorus and Janos (1983) stated that the formation of a mycorrhizae-association is a prerequisite for nodulation of many Legume trees. In the Miombo woodland Zambia, all Legume trees with active root nodules had also an mycorrhizal association (Högberg & Piearce 1986).

Estimation of the amount of mycorrhizae present, varies widely, from a maximum of 10 km length of the fungal mycelium per gram soil substratum (Witkamp 1971) to 1.4 m external mycelium to every cm of root infected (Harley & Smith 1983).

Mycorrhizae and crops

The possibility to form mycorrhizal associations have been demonstrated for many useful plants and crops. Here we just mention cacao (Laydock 1945 and Nadaradja 1980), coffee (Janse 1896) and oilpalm (Nadaradja 1980). Most experiments demonstrating a superior performance of infected plants were conducted in pots (Janos 1983). However, cocoa is likely to carry reasonable amounts of mycorrhizae in the field for Janos (1980b) used field-collected chopped cocoa roots as inoculum in his laboratory experiments.

Mycorrhizae and land clearing

Together with the awareness of the significance of mycorrhizae for rain forests the question raised : what happens if the forest is disturbed? Fungi cannot live without hosts. In the absence of a host mycorrhizae persist as spores, deposed underground or in litter. These spores are large and not adapted to wind-dispersal, moreover they are subject to intense parasitism and predation (Janos 1980a). In contrast with temperate regions, humid tropical soils contain very few spores (Janos 1980a Costa Rica lowland rain forest, Rambeli *et al.* 1984 Taï forest). Whereas infection in temperate regions occurs chiefly by spores, infection of new plants in tropical rain forests happens from living root to living root (Janos 1980a). Alexander (1989) suggested the possibility of inoculum staying available as infected dying root fragments up to 6-9 months in dead roots(experiment by Tommerup & Abbott (1981). Anyway, spores being rare, it is now generally accepted that non-infected plants get infected in the proximity of the rooting zones of mycorrhizae-carrying trees. Logically, infection becomes a problem if the forest is removed. Removal of the topsoil containing litter and roots creates a mycorrhizae-free soil (Alexander 1989). If the soil is less disturbed, prolonged cultivation with non-mycorrhizal crops, stump removal and clean weeding brings about the decomposition of litter and the root death of pre-existing roots. The area is likely to lack seriously mycorrhizae inoculum, too. Ramakrishnan & Toky (1981) suggested that productivity decline in subsequent years of cultivation may be due to destruction of the mycorrhizae population this being accentuated under shortening shifting cultivation rotations.

Mycorrhizal infection was reported for a successional stand in San Carlos, Venezuela (St. John & Uhl 1983), and mycorrhizal fungi could live over shifting cultivation periods in a Miombo woodland (Högberg & Piearce 1986). Ewel *et al.* (1981) demonstrated that mycorrhizae survived heavy burning in Costa Rica.

Mycorrhizae and plant communities

Research has revealed three degrees of dependency of plants and mycorrhizae. Species can be wholly dependent which implies they cannot survive or reproduce if uninfected (obligatory mycotrophic species). Species can live without mycorrhizae but once infected, produce better (facultatively mycotrophic species). Species can refuse a mycorrhizal association (non-mycorrhizal species). Janos (1980a) has designed a theory relating these species groups to soil fertility and to competitiveness of communities. At low natural fertility levels, in the absence of mycorrhizal fungi, only species that do not need them will be able to grow. Here, colonization of non-mycorrhizal plants tend to continue for re-inoculation is difficult. It was suggested by Janos (1980a) that heavily disturbed areas in Asia (Whitmore 1982 p.131-132) and Africa (Nye & Greenland 1964) now covered by a permanent layer of grasses and sedges - known to be non-mycorrhizal - can be explained by a fungus-free soil. The vast stands of rattan shrubland persisting in west Java on places where the ash layer of the Krakatau eruption has sterilized the soil could be explained in a similar way (Hommel 1987 p.141-143).

On the other hand, obligatory mycotrophic species are most likely to dominate plant communities on poor soils and here large mycorrhizal fungal populations are retained. Many primary forest woody species are supposed to be obligatory mycotrophic. Long-lived pioneer trees and secondary forest trees of late successional stages are believed to be facultatively dependent on mycorrhizae for mineral uptake. This group competes successfully with non-mycorrhizal communities provided they are duly infected, and considerably less so, if not infected. Field studies supporting this theory are scarce, so much remains to be confirmed. The assumption that primary forest trees are mainly obligatory mycotrophic, seral species facultatively mycotrophic, and weeds non-mycorrhizal, has recently been refined. The weed *Sida rhomboidea*, also frequent in Taï, was facultatively mycotrophic in laboratory experiments (Janos 1983). Some secondary species proved to be extremely efficient at concentrating phosphorus (Lambert, Arnason & Gale 1980) and this ability to mobilize P was thought to be owned to mycorrhizal fungi (Arnason *et al.* 1982). Rambeli *et al.* (1984) screening some plant species of the Taï forest environment for mycorrhizal symbiosis, found the weed *Tristemma coronatum*, the grass *Streptogyna crinita*, and the herbs *Marantochloa cuspidata* and *Geophila afzelii* infected. The woody primary forest species he found to be mycotrophic were : *Craterispermum caudatum*, *Memecylon guineense*, *Ouratea* sp, *Plagiosiphon emarginatus*, *Xylopia quintasii*, *Berlinia occidentalis*, *Dialium aubrevillei*, *Ouratea duparquetiana*, *Scytopetalum tieghemii*, *Triphyophyllum peltatum* and *Popowia mangenotii*. He did not mention the 5 plant species which failed to have mycorrhizae.

An other important study was conducted by Rambeli *et al.* (1984) in four permanent plots in the Taï forest. The fungal population of soil and litter was examined during the recovery of the forest in two recently abandoned fields. Both fields[1] had been prepared (local practice) in primary forest, with intact primary forest around. One of them, studied by Collinet and Moreau during the rice cultivation period in 1978 and 1979 was insufficiently burned. The fungal communities in the cultivated plots evolved towards conditions similar to those previous to cultivation because of the rapid reappearance of primary forest species, the accumulation of organic matter during the first three years of abandonment and the rapid acidification of the soil. Rambeli *et al.* (1984) further concluded that the shifting cultivation period hardly dad affected the fungi population for the recovery of the forest in the disturbed areas was very fast.

2.6.5 Conclusions

It seems quite probable that the Taï forest growing on a nutrient-poor soil carries a capital of mycorrhizae treasured mainly in the woody component of the vegetation, especially in primary forest species. In the traditional shifting cultivation system sufficient inoculum remained present to infect the seral vegetation throughout succession. If the woody component is lost due to recurrent slashing and burning much of the mycorrhizae capital gets lost also. On sites now covered by old cocoa, especially those plantations of many square kilometres deprived of trees this may

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1 Mr. S. Olfreda kindly supplied the information concerning the exact location of the plots.

become a big problem. J. Slaats (pers. comm.) observed (1989-1990), in the vicinity of Taï village an attempt to replant an ageing cocoa plantation. The plantation was cut, food was cropped for a short period and the subsequent replanting of cocoa was an utter failure. The vegetation which covered this site contained only grasses and low-growing herbs and apparently succession was non-existent. It seems possible that the decline of the mycorrhizal population ever since the site was under cultivation had fallen to such low numbers that no mycotrophic plant species could invade.

Though relative field data are rare, Janos (1980a) justly put forward that those agricultural- and agroforestry systems that were successfully employed for a long period are those which favour the maintenance of a large mycorrhizae population. Leaving some rain forest trees standing in shifting cultivation fields, permitting coppicing forest stumps to grow over cultivation periods, the occupation period itself being short followed by a rapid return to a forest, are certainly practices least disturbing the pool of pre-existing inoculum.

3 The inhabitants of the study area

3.1 EARLY TIMES

In ancient times the thick forest of west Africa was extremely thinly populated. As for the rain forest of actual Côte d'Ivoire, it may well have stayed without permanent inhabitants until, in the eleventh to the fourteenth century, the rise of organized Mande kingdoms in the Sudan affected more southerly living peoples. These peoples expanded southwards and displaced earlier inhabitants of the lands in which they settled. Finally, the most southern living people like the Wè and the Bété, who inhabited the fringe of forest and savanna, were forced into the forest. Emigration occurred by little groups and stretched over many generations.

As in the mid-eighteenth century the Ashanti kingdoms fell apart, peoples who formerly inhabited modern Ghana, like the Agni and the Baoulé, were pushed westward, into actual Côte d'Ivoire. The newly arrived forced the already present peoples to move westward (Fage 1978).

Under influence of both pressures, the slow Mande pressure southwards, and the more sudden pressure of Ashanti origin westward, the peoples of this study were obliged to make their home in a rain forest environment. Schwartz (1971 p.15) estimates this occurred some five hundred years ago.

Meanwhile the forest had become a more livable environment for farmers, since a wider range of crops, above all the south-east Asian cultigens, were available (Fage 1978).

Schwartz (1971) study on the Guéré and Lena *et al.* (1977) on the Bakwé tried to trace the history of ethnic geography in the land which is now the south-west Côte d'Ivoire. My own results were acquired during eleven years of patiently recording all sorts of stories told by Oubi and Guéré[1].

A story about Pygmee, living in the Taï forest prior to the migration of the present peoples, continues to crop up (Mangenot 1956, Aubreville 1957, Guillaumet 1967 p.31, Alexandre 1989a p.65), but we never came across any indication confirming this.

The first farming people advanced into the forest about 500 years ago. Regarding the great many mutually unintelligible languages spoken by forest people nowadays, these people have lived in small groups and stayed very isolated from each other (Person 1964). They congregated around the best sources of permanent water. The interior of the forest was constantly travelled over, but at an extremely slow pace. Settlements moved up and down the larger rivers but it took, for example, several generations to "cross" from the river Sassandra to the river Cavally (Lena *et al.* 1977). We should therefore not consider the Taï forest as an absolutely virgin forest. However, these first farming inhabitants were very few, and other subsistence activities, gathering, fishing etc, were

1 This would never have been possible without my assistant Yvonne who proved still more curious and passionate to solve the puzzle of Taï history. As a rule only identical information supplied by two or more persons questioned independently of each other, was considered. Informants were mostly old people, not speaking French and a fair amount of resistance had to be overcome before stories would be told to us.

probably more important than agriculture was (Lena *et al.* 1977). Guillaumet (1967 p.21) states that no traces what so ever of their activities remain perceptible in the forest vegetation of the interior of the Park.

Of all groups who are now considered autochthonous forest peoples of the south-west Côte d'Ivoire, the Guéré, Oubi, Bété, Krou and Bakwé and others, the Bakwé stayed the most isolated of all Ivorian societies. (Anonymous 1979) They preserved an example of a society which spends a minimum effort on agriculture compared to time devoted to other forms of subsistence (Lena *et al.* 1977).

The Oubi split from a Bakwé group about 200 years ago as a result of a quarrel. (Lena *et al.* 1977) dates the event not before the middle of the 18th century. Although the Bakwé did not tell him the full story, he noted it was something about a whetstone. Our ears were probably considered less prudish for on two occasions Oubi gave us an extensive account on the "whetstone" affair[2]. The group of migrants whose departure was directly caused by the whetstone fight, left the region of Soubré and after having followed the Meno to the north, travelled westward and crossed the Cavally. The Oubi of the actual villages Gouléako and Poulé-oula descend from them. A second group of people whose migration can not be traced back to the whetstone affair directly, arrived later in the same land. This group, coming from the south-east (San Pedro) were the ancestors of the actual villages Taï, Zriglo and many settlements in Liberia. Finally, with the coming of a third group, also from the south-east the ancestors of the Oubi population of Diéré-oula, Tiéoulé-oula, Sakré and Port Gentil settled in the region and also in Liberia. All these people lost their original Bakwé language while mixing with the Gli people of Liberia and became Oubi[3]. The former "whetstone" Bakwé, who stayed behind, mixed in such a way with the Bété, that they too lost their language and are now called the "Bété of Soubré".

The Oubi settled on both sides of the Cavally, but they crossed frequently. They preferred to build villages on the borders of the smaller rivers like the Méno, Andrénisrou, N'zé rather than along the Cavally.

Schwartz (1971 p.15) traces the precolonial migrations of the two groups of Guéré who moved from the north into the study area also about 200 years ago. One group, called the Daho-doo, settled mostly in Liberia and only few came to live in Côte d'Ivoire (Daobli). They preserved their slightly different dialect. The descendents from the other group, the Gnéo, the inhabitants of the villages Ponan, Gahabli and Zaipobli speak the common form of Guéré.

Essential information could recently be verified with the book of Bouys (1933)[4]. I will enlarge the topic of local history for three main reasons:

- exact historic data on the south-west Côte d'Ivoire are rare, it allows oral history to be tested,

2 The young man Glaro seduced the wife of his elder brother Tou-omlè-gnawa, the village chief. At first his brother forgave him. Later, all Glaro's friends came to sharpen their knifes on the village whetstone in front of Tou-omlè-gnawa's door, and imitated, one after another, in a obscene way the crime of Glaro. The chief got so angry that Glaro and his friends had to leave the country. He prosecuted them through the forest, asking "Wou pi?", meaning "(where are) there traces?". (account by the chief of Gouléako, 1986 and by the chief of Sakré, 1989).

3 The language of the Oubi is called "Gli-ouwee" which means "language of the Gli people".

4 Dr Bouys who lived in Tabou from 1905 until 1927 knew most explorers and administrators personally. I an very fortunate to possess a personal copy of the author (1933).

- it is generally constructive to consider the origin of problems,
- it makes us understand why precisely the Taï forest has survived as the only remnant primary rain forest of some extent, in west Africa.

3.2 EXPLORATION OF THE BAS-CAVALLY

The estuary of the Cavally has been rather well known from the mid-fifteenth century, but very few ships used to call in because of the dangerous surf and the almost empty land improper to forage.

At the end of the nineteenth century the French, well established in west Africa, increased their interest in the region of the Bas-Cavally mainly because the border between the newly created Liberia and the French colony was still unclear. A Franco-Liberian convention decided 8 December 1892 that the river Cavally was to be the border between both countries. It was the governor Binger (1893), upon his arrival in Côte d'Ivoire, who decided that the Bas-Cavally should be explored and occupied by the French. French administrators were send to San Pedro, Béréby and Tabou, but colonial presence became only permanent in Tabou, from 1889 onward, with the functioning of regular boat and mailing services.

In the meantime, the first explorers of the hinterland, the mission Quiguerez-Segonasz (1891) ascended the rio San Pedro but were forced to withdraw due to hostilities of the inhabitants causing the death of Mr. Quiguerez. A second mission, Decressac-Villagrand, explored in 1894 the Cavally up to the village Tiboto some 15 km south of Grabo. They met, however, with constant hostilities of inhabitants. In 1895, the naturalist Pobéguin was sent to explore the lower reaches of the Cavally. He travelled on the Liberian side up to about 75 km into the interior, and, on his return, told Mr. Bouys that he had been well received by the nicest cannibals he knew. The administrator of the "cercle de Tabou", Mr. Ed. Hostains set out 13 February 1897 to make contact with the people living in the interior. He was forced to return rapidly to Tabou, after only 20 km, for the town was being attacked. In the same period, 28 July 1897, a mission of lieutenant Blondiaux, tried to reach Tabou starting from the north, in Touba. He was stopped near Man because of hostile Guéré. Blondiaux persevered his plans somehow for he was to be the second white man to visit the Oubi in Taï, many years later between 1908 and 1910. Another mission started from Tabou, in 1898, travelling on the Cavally. Both Frenchmen, Bailly and Pauly were killed in Zogou, Liberia. A second mission Hostains, this time with the lieutenant d'Ollone set out in 1898. They did not follow the Cavally, considered too dangerous, but proceed into the interior using an old path Béréby-Patokla which had been used to drive Sudanese slaves to the coast. The plan was to travel north and meet the mission Woefel-Mangin somewhere half way. The latter party was travelling south, starting in Touba. Unfortunately, the mission Woefel-Mangin had to retreat after lieutenant Mangin had been hit by four bullets. Their southernmost point had been the village Logoualé, between Man and Diékoué. The progress of the mission Hostains-d'Ollone was also stopped by hostile inhabitants but also because of the many swamps. Their northernmost point was the village Patokla, near the actual village Djiroutou.

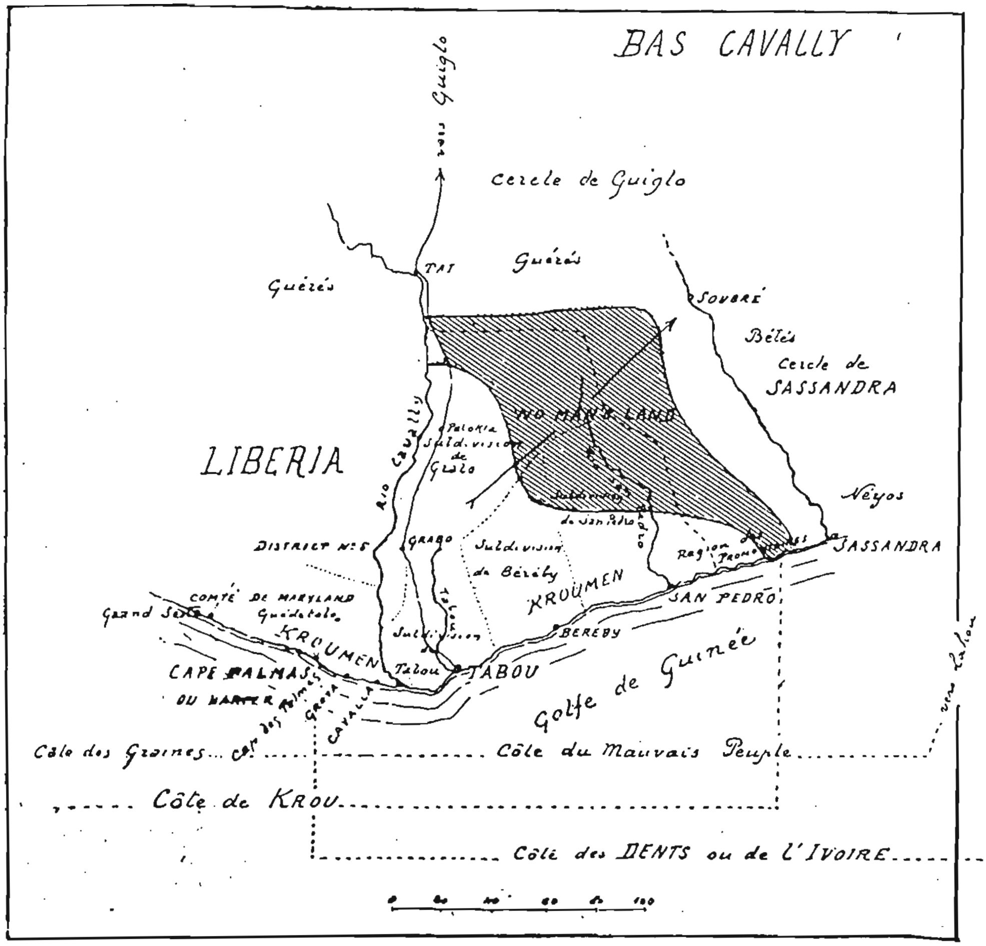


Fig. 3.1. Map of south-west Côte d'Ivoire in the thirties (Bouys 1933).

The administrator Mr. Penel was ordered, in 1898, to enlarge the path Tabou-Grabo to, what was called, a "piste cavalière". Very soon he had to suspend all activities for all villages 20 km north of Tabou up to Grabo, were revolted against the French. Military aid had to come from Grand Bassam to suppress the rebellion (1901). Under Jules Repiquet, at that time the administrator of the cercle Tabou, the "piste cavalière" was prolonged to Patokla. A military fort was build in Grabo (Fort Dromard 1902) and in Patokla (Fort Binger 1906). Mr. Jolia, stationed in Fort Binger, was to explore the country north of Patokla which had remained utterly unknown. In 1906 he reached the village Sakré, being the first settlement after 50-60 km of "no man's land" (Fig.3.1). The next year, December 1907, he starts a second journey, this time with two interpreters. They visit some

Oubi villages[5]. The naturalist A. Chevalier was certainly the first botanist to become acquainted with the Taï forest, though he did not visit the Oubi. In 1906 and 1907 he ascended the Sassandra up to Soubré, then crossed to Patokla and finally reached Tabou (Guillaumet 1967 p.4.).

From 1908 onward the French colonial power demonstrated less and less interest in the Bas-Cavally, to the benefit of regions more populated, closer to the capital and less dangerous. A second period of regional instability started in 1910 and continued until 1930. Travelling on the Cavally was most of the time impossible. In 1917 and 1918 cases of anthropophagy were recorded in San Pedro (Bouys 1933).

Renewed interest came after the governor Reste, in 1931, travelled from Guiglo to Tabou. (He was the only governor to make such a hard journey). Reste declared afterward that without a road Man-Guiglo-Tabou the region of Taï would be lost to France.

The first contact of the Oubi with the colonial world was established via the south, starting with the visit of Mr. Jolia and ending with the removal of the military fort near Daobli by troupes from Fort Binger stationed in Patokla[6]. The Oubi land was the furthest point the French reached. After a period of enforced isolation, new contact was established from the north. Again, the region of Taï constituted the last frontier of colonial influence. From now on Taï would be commonly reached by the north and the transect Taï-Grabo remained the least developed up to now. The little interest the colonial power demonstrated for the Bas-Cavally is explained by the obvious difficult access which made e.g. timber extraction impossible, the repeated problems with the inhabitants, and the little benefit these few people could provide. Only small quantities of oil palm kernels, rapphia, latex and ivory[7] could be extracted with relative ease (Bouys 1933).

Other important events are related in Table 3.1 for so far as they could be dated with precision. Most facts concern the descendants of the first group of Bakwé ("whetstone" people). The penetration of the French into the Taï region was part of the pacification of central-west and south-west Côte d'Ivoire which started in 1906 and was more or less completed in 1913 (Schwartz 1971 p.17-19).

5 (account by inhabitants of Gouléako). Mr. Jolia was the first white person seen by the inhabitants. He had a mirror, a magnifying glass, a tinder-box and some petrol. No one could understand him. He poured the petrol on some dry wood and stroke fire from his flint. With his magnifying glass he made a caterpillar look big and he manipulated the mirror. He managed to make clear that if the people would not obey him he would set the village on fire. He could still see them if they hid themselves far in the forest and he could see behind him.

6 A military camp was constructed in 1910 along the stream Gbolo, a few kilometres north of Taï (Fig.3.2). In 1911 the camp was attacked by a band of Liberian Gli. The leader, Glè-ouli or Saou-o, was killed by the only Frenchman present (name approximadly "Jean To"). Three African soldiers ("tirailleurs sénégalais") also defended the camp. Two of them already dead, the third soldier tried to persuade the Frenchman to flee, but he would not leave French property. Just before he was shot, he managed to give a letter to his servant François Tsajo, the son of Taré. The boy delivered the message to the French in the nearest camp in Patokla. (Account of inhabitants of Zaipobly, 1985 and Gouléako, 1986).

7 The Oubi employed elephant tusks for decorating the house and as a platform in the bathroom to avoid muddy feet.

Table 3.1. Chronicle of the Tai region.

1908 The first European visits the region, the Frenchman named Jolia (among Oubi remembered as "Joliot").

1910 A group of French military meets the man Taré, who lives in Taré-oula (No.1, Fig.3.2, Table 3.2), then they meet Baly, the father in law of Taré, the chief of the Oubi. The French persuade Baly, who lives in Balydiawo (No.1), Liberia, to come and live in Côte d'Ivoire. So Balydiawo (No.2) is founded and Baly is appointed the first "Chef du Canton". The French built a military camp nearby, on the borders of the river Gbolo.

1911 The village Taré-oula (No.1) is moved to the path Guiglo - Patokla and administrative buildings are constructed (Taré-oula No.2). The military camp is raided by Liberian Oubi and all foreign occupants are killed. As a result the French post is abolished. The inhabitants of Balydiawo (No.2) flee into the forest and found the village Bowaigwo. All Daho and other Guéré flee to Liberia.

1912 Baly dies and Taré becomes Chef du Canton.

? Peace returned, the inhabitants of Bowaigwo and many others, also Liberian Oubi, come out of the forest and found the village Bélébo along the path Guiglo - Patokla.

1915 Bélébo is considered too big. Baly Gbamlin, Baly's son, founds Baly-oula (No.1) and Ouwèlè founds Poulé-oula (No.1), a village named after his son Poulé. Later, Baly Gbamlin became the third Chef du Canton, and still later, Poulé the fourth.

1932 A French military party under command of lieutenant Lafourcade persuaded the Gnéo, who live in the forest and in Liberia, to install themselves along the path Guiglo - Taï (Taï being a the corrupted name of Taré-oula (No.2)).

1933 Most of the Daho come back from Liberia and install themselves in Ponan (No.1), along the path Guiglo - Taï.

1935 Primary school in Taï.

1937 Beginning of the construction of a road Guiglo - Taï - Djiroutou (= Patokla).

1940 The road is finished.

1946 Yvonne is born, the great-granddaughter of Baly.

1947 To punish the Oubi who would not give up moving their households into the forest, the French burn the already deserted Baly-oula (No.1). Most former inhabitants construct Baly-oula (No.2), others join Gbamlin Pahi, the son of Baly Gbamlin and settle in Diéro-oula (No.1).

1949 First Yacouba immigrants settles where once Bélébo stood.

1952 Gbamlin Pahi founds the village Pahigbario, where once stood Baly-oula (No.1).

1953 Yvonne, the daughter of Gbamlin Pahi is the first girl in the Canton Taï to go to school.

1962 Kouadio, the first Baoulé immigrant arrives and construct with a second Baoulé named Kwamé and their families the village Kouadiokro.

1963 Ndri, a third Baoulé is lost in the forest for 8 days, returns and dies.

1964 Sangbé, a fourth Baoulé arrives and founds the second village Sangbékro.

1965 Poulé-oula (No.3) moves to Poulé-oula (No.4).

1967 The inhabitants of Baly-oula (No.2) join the people in Pahigbario and the name changes into Gouléako.

1968 A third Baoulé village Port Bouet is build. Pierre Béoutis, the last French sous-préfect in Taï leaves and the first Ivorian sous-préfet is invested.

1974 The first Mossi immigrants arrive.

1976 Gbamlin Pahi, the grandson of Baly, with J.-L. Guillaumet, chases the evil spirits from the place where the UNESCO research station is to be build. He dies soon after.

3.3 SETTLEMENTS PATTERNS

In many societies practicing shifting cultivation the continuous movement of cropping is accompanied by a slow migration of the population. A modest part of a study on shifting cultivation is usually devoted to this topic : where people settle, how long they stay and with how many people they are. Also in the Taï region whole villages have moved, split up, resettled and moved again (Bouys 1933, Holas 1957, Schwartz 1971). To study settlement patterns through time is recognized as a very complicated matter for objective data like old maps, old aerial photographs etc. are scarce or non-existent, whereas the information given by local informants most often lacks precision. Moreover, when informants are consulted as to why a village has moved, a wide range of motivations can be given, none of which really satisfies the investigator. The latter (geographer, agronomist etc.) tends to stuck on but one hypothesis : what is the role of resources in determining settlement patterns ?

A fruitful contribution to the theory of settlement patterns comes from anthropologists, especially those involved in cultural ecology. A settlement pattern has three elements, Mobility, Size and Location (Hames 1983). Mobility has two components: a Macro-movement which relates for example, a people's historic migrations, and a Micro-movement which concerns frequent small scale movements (Chagnon 1973).

3.3.1 Macro-movements

The people, now considered the "autochtonous people", or "original inhabitants", Oubi and Guéré, came to live in the study area by a macro-movement. It has been observed by Hames (1983) that macro-movements are usually caused by internal disputes according to informants accounts, though environmental motives may be hidden. However, in his study of non-acculturated Amazonians, no empirical evidence could be supplied in order to establish a causal link between limiting resources and macro-movements. Lena *et al.* (1977) for his part, seems to be convinced that the forested land of the Bakwé had been exploited by gathering, fishing and hunting at greater rates than the natural rates of recovery. The whetstone provocation[2] obscured this real reason, which was resource depletion. He admits however that very little evidence exists that the Bakwé had saturated their environment. Other reasons, not mentioned by Lena *et al.* (1977), like the stringent regulation on exogamy in a thinly populated land, may have their say in macro-movements. As Hames (1983) acknowledges in his conclusions: not only the stomach but also the sex needs to be considered.

3.3.2 Micro-movements

Micro-movements are considered to occur as part of the ecology of shifting cultivation, rather than caused by political reasons. Hence underlying economic and ecological motives should be strong (Chagnon 1975). The Amazonian Indians demonstrated micro-movements of 50 m to 1 km every 4-5 year (Chagnon 1973). But again, evidence that the efficiency of gathering, hunting, agriculture etc. had diminished with resident time, is very sparse. Perhaps leaky roofs and vermin infested villages were sufficiently powerful incentives to move (Hames 1983) ?

Next to nothing can be said about the micro-movements of the Oubi before colonial contact as they "travelled" through the forest, because moving frequency and moving distance is un-

Fig. 3.2. Locations of former and actual settlements.

known. Concerning two other aspects of settlement pattern, Size and Location, we can be less speculative. Location was very probably on the borders of the larger rivers and Size was certainly not over fifty persons per village. Of all Ivorian societies the Bakwé are the most loosely organized politically (Anonymous 1979). The time Lena *et al.* (1977) did field work in isolated Bakwé villages, something of this way of life could be recorded. Population density was about 0.5 person per km^2, settlements contained less than 50 people. The population was more engaged in gathering, fishing etc. than in agriculture. There was a story of two settlements along the river Hana, 12 km apart who knew nothing of each other existence until a third party had met them travelling up the river.

Though Oubi and Guéré communities presumingly have lived continuously in the Taï region upon their arrival, they certainly did not stop shifting residence regularly. Moving continued under French colonial rule though the French tried hard to discourage them. A second objective of the French was to make as much people as possible leave Liberia for Côte d'Ivoire.

If we limit our attention to the migrations of the villages Baly-oula, Poulé-oula and Diéré-oula, a conservative estimate of their mobility would be every 15-25 years (Table 3.2). These displacements are real micro-movements, a few hundred meters to a few kilometres, except for the relocation resulting from the Liberian raid of 1911 (Fig.3.2). Another feature of these micro-movements is the frequent return to old sites. Looking at the map we see that villages prior to French penetration were located along rivers, and after the French had made attempt to concentrate settlements along the main road we see that the inhabitants have moved to the nearest point where a river cuts this main road. People build their houses a little to the north and a little to the south, but were confined to the same water source. Micro-movements of this kind can no longer be "explained" as a possible move into an area with higher abundance of game, fish, gathering products or good soil. Village movements seems to be rather a remedy against sorcery,

Table 3.2. Movements of the villages of the three groups whose descendants are the actual Ivorian and Liberian Oubi population. Records of second and third group are incomplete. Names of actual villages in bold.

Period	First group	Second group	Third group
before the arrival of the French (1908)	Balytebo Balydiawo No.1 (Liberia)	?	?
after 1908	Balydiawo No.2 Bowaigwo (= under the Uapaca trees) Belebo (= many people living together) Baly-oula No.1 (1915); Poulé-oula No.1 (1915) Baly-oula No.2 (1947); Pahigbario (1952); Poulé-oula No.2 Poulé-oula No.3 **Gouléako** (1967) **Trois cailloux** (1986); **Poulé-oula** No.4 (1965)	Taré-oula No.1 **Taré-oula** No.2 (= Taï) **Zriglo**	Troya Diéré-oula No.1; Tiéoulé-oula No.1 Diéré-oula No.2 (1948); Sakré No.1 **Diéré-oula** No.3 (1960); **Tiéoulé-oula** No.2; **Sakré** No.2; **Siéblo-oula**; **Port Gentil** **(= Paul gentil)**

unexplained deaths and other mischiefs. Informants consulted on movements always converge on motivations related to internal conflicts or a desire to avoid illness.

Our inquiry should not stop here. We have strong evidence that families kept moving for still other reasons, much to the dissatisfaction of the colonial power. Part of the population would live in the villages as they are located on the map, or would live there during part of the year, and an unknown number of families would live dispersed in the forest, in so-called campements. As late as in the fifties Holas (1957) observed that only the recent popularity of growing coffee together with the necessity to register these plantations at the local authorities, made up the strongest incentive yet experienced for people to live in fixed villages along the road, stronger than the French colonial pressure had ever been. Other evidence comes from small patches of very old secondary forest situated deep into the Bufferzone and Park (also located by Jaffré & De Namur 1983 and A.P. Vooren pers.comm.) These rice fields would have required uncomfortable long travels for people living in villages along the road. The aerial photographs of 1956 (Fig.3.3 interpreted by H.C. Vellema) showed the existence of rather extensive clearings as well as the occurrence of stretches of disturbed forest far from the road. Finally, the survey team of DRC (1967b), quite by accident, discovered large recent and abandoned clearings north of the village Taï, on the borders of the Nzé. Former dwelling places can often be recognized by the presences of bamboo persisting in the forest. Bamboo was introduced by the French.

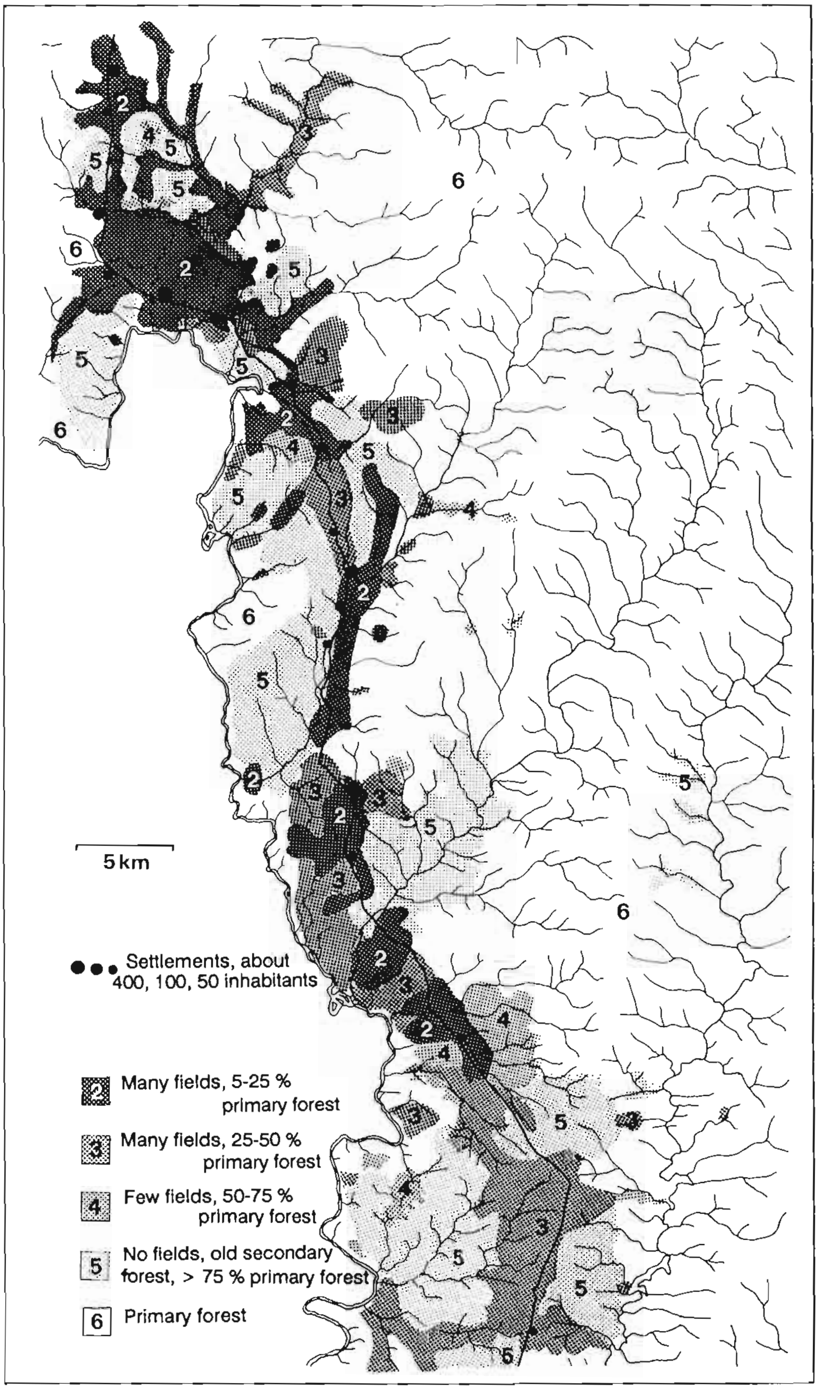
Some of these movements into the forest and certainly many during the period 1940 - 1944 are explained as a reaction to French demands. Families withdrew into the forest to avoid conscription of labour and tax. During World War Two taxes tripled and an "effort de guerre" was claimed in the form of rubber (latex of wild trees and lianas). The necessary labour for the construction of buildings and the road had also to be provided by local residents. Making people work without remuneration proved to be extremely difficult. Unlike elsewhere in Côte d'Ivoire in more densely populated regions (Schwartz 1971 p.23), men in Taï were not seldom paid. Men who built the military camp and other buildings in 1910 were paid with firearms, pagnes, salt and machetes. Workers who constructed the road between 1937 and 1940 were paid rather well : 25 CFA a month[8].

It is very probable that the attractiveness of moving decreases sharply with brickstone houses, roofs of corrugated iron, schools, modern wells (from 1977 onwards) etc.

Although changing of habitation can be induced by a variety if human motivations, the act of moving to locations with large stands of undisturbed forest actually does open up new potential resources of game, fish etc. This does not mean automatically that such moves are, or partly are, adaptations to scarce subsistence resources.

Fig. 3.3. Different intensities of land use in 1956 (aerial photographies). Only indigeneous people inhabit the land practicing shifting cultivation (photographies kindly interpretated by H.C. Vellema). ▶

8 For 5 CFA you could buy 12 yards of cloth (pagne).



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Settlements, about 400, 100, 50 inhabitants
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2
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4
2 Many fields, 5-25 % primary forest
5
3 Many fields, 25-50 % primary forest
3
3
4 Few fields, 50-75 % primary forest
4
3
5 No fields, old secondary forest, > 75 % primary forest
5
5
6 Primary forest
5

3.3.3 Settlement patterns and resources

Recent studies in cultural ecology have stressed the importance of three factors which were often neglected in the study of settlement patterns (Hames 1983, Vickers 1983, Gross 1983) although their relation with land use is obvious.

- the possibility of people to adapt themselves to new situations should never be underestimated,
- large stands of relatively undisturbed forest can not be assumed as being a relative homogeneous environment,
- the distribution of resources like good soils, can not be supposed to be erratic.

The Bakwé society (as described by Lena *et al.* 1977, Anomymous 1979) and the Oubi who fissioned from them, show some remarkable differences. Oubi (and Guéré) make larger fields, they cultivate a wider range of crops, the stock of rice seed have been enriched by new varieties through contact with other cultural groups, they have practiced the "double field cultivation"[9], also reported from Guéré living further north (L. Bonnehin pers. comm.). So with changing agricultural customs, other settlement habits have probably prevailed, for example new crop varieties may require particular soils etc.

The heterogeneity of the Taï primary forest has often been observed, documented and mapped. The Land Unit map, the result of a Land Unit Survey, is an efficient means to provide a rather small-scale inventory of natural resources of an area. Within the accuracy of the map scale (1:100,000) each Land Unit has a certain uniformity as far as land characteristics and land use potential are concerned. Such a map can be interpretated in terms of suitability, rating for different kinds of land uses and management. The abiotic aspects of the Land Unit map are presented in Fig.3.4.

The aerial photographs of 1956 allowed to locate settlements, recent fields, abandoned fields, secondary forest and undisturbed forest. An interpretation of the photographs (Fig.3.4) shows the extension of farming. The relative intensities of farming are indicated as percentage of undisturbed forest left. At that time agriculture was virtually limited to shifting cultivation for rice by Oubi, Guéré and Krou. All villages border the main road, whereas part of the population, probably temporally, lives in "campements" built for the sake of easy access to far-off fields. These remote lying "campements", fields and abandoned fields border rivers. Large areas remote from the road appear undisturbed and uninhabited. The area close to the road is not exploited uniformly because greater pressure is placed on land nearest to settlements.

It is interesting to detect a relation between the abiotic aspects of the Land Unit map (Fig.3.3) and patterns of land use and habitation in 1956 (Fig.3.4). The Alluvial landscape bordering the Cavally is not used for cultivation. This may be due to a combination of difficulty of clearing (hard wood of the dominant tree *Plagiosyphon emarginatus*), adverse soils (often sandy) and flooding hazards. The alluvial plaines of the middle and lower reaches of the Nsé, Audrénisrou, Gô are often cultivated. The tree *Plagiosyphon emarginatus* is here restricted to the narrow well-expressed natural levees bordering the main stream. Settlements and cultivation does not occur in the landscapes which is an association of uplands and low inselbergs (UB). This in

9 In January a small clearing was made in young secondary forest in a valley bottom for short-cycle rainfed rice. A few months later a larger clearing in older forest situated more up hill was made, intended for long-cycle rice.

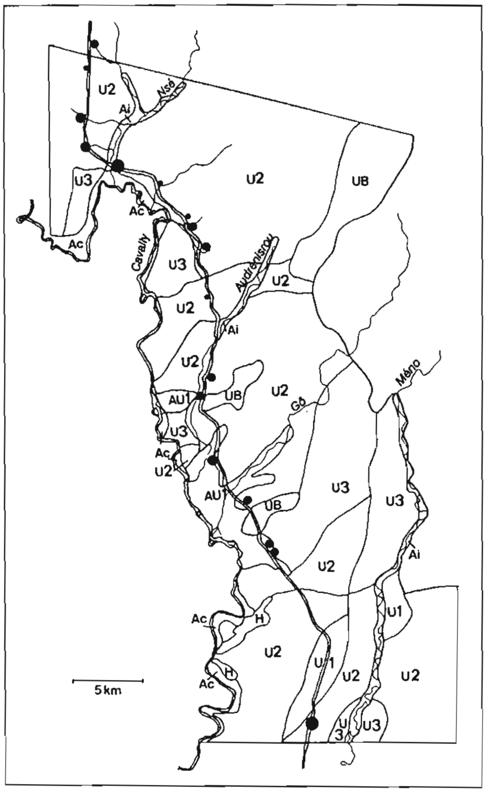


Fig. 3.4. Simplified version of the Land Unit Map (De Rouw, Vellema & Blokhuis 1990).

U : Uplands

AU : Association of alluvial plains with uplands

AC : Alluvial landscape of Cavally deposit

Ai : Alluvial landscape of other river deposits

UB : Association of uplands and low inselbergs

H : Steep-sided hills

1 : almost flat

2 : weakly dissected

3 : moderatly dissected

spite of the sometimes superior quality of the soils observed here. The only relation, though weak, is between drainage/topography and settlement/agriculture. This is most pronounced in the central and southern part of the area mapped. In the region south of Diéré-oula we find the heaviest concentration of housings and of farming in weakly dissected landscapes (<0.4 km/km^2) which are almost flat (slopes not steeper than 2 %).

A striking feature of the SPOT imagery (1988) are the many small bright red dots. Repeated checks in the field demonstrated that most often these spots were produced by a huge umbrella-shaped crown, about 40 m wide, of one tree of the species, *Piptadeniastrum africanum*. We did not find other species capable of producing such a flat-topped crown large enough to give a red dot on the SPOT imagery. It turns out for reasons we do not yet understand that the distribution of large *Piptadeniastrum africanum* trees follows, roughly the areas of recent and ancient habitation. Red dots are concentrated along the main road and in zones where shifting cultivation was practiced in 1956. Red dots are absent or occur in very low densities in the Park and in the Bufferzone, regions without traces of disturbance in 1956.

3.3.4 Land rights

With almost fixed villages and a growing number of people sharing the same territory, the pressure on scarce commodities, good soil, fish, game etc. increases. We will concentrate now on one resource, suitable soil for cultivation, and see how the social regulation of rights develops.

The precolonial period

Land rights were initially acquired by virtue of felling a forest. They extend to the secondary regrowth which followed each cropping. Rights were held by individual households and they were attributed to the chief male member. Although land rights are endowed to men, both men and women executed these rights with equal authority. The wife (or wives) continue to exert these rights when the husband is deceased or in his absence. Land rights were essentially household rights, permitting the owner to do with the land whatever he wished, and prohibiting anyone else to touch it without his permission. However, permission to others was easily granted, e.g. for purchasing firewood, or poles to construct houses, or medical plants, or for laying traps. Each year a household could extend its domain, if it so wished. However, all land acquired by a man during his lifetime devolves to the community when his household is broken up, so that other Oubi or Guéré can use it. It is curious that land claims are not transposed to sons or other heirs. This absence of inheritance of claimed land demonstrates the individuality of shifting cultivator, and the abundance of forest.

The colonial period

The French colonial government obliged the people to help to construct and maintain the main road. Each village was responsible for half the distance to the next village north and half the distance to the next village south. The manner in which the road was thus divided, and responsibilities separated between villages remained after the colonial period. Gradually these boundaries developed into borderlines to mark the forest land left and right of the road section that belonged to each village. Boundaries between village territories were rather arbitrary since the number of inhabitants per village did not affect the extent of the territory. This also reflects the abundance of forest.

The period since independence

At this time the situation was such that each village held rights to a distinct territory. This is not a communal land tenure, as land rights of shifting cultivating societies are often considered, but simply the right to prohibit any outside person from farming within the village territory. Within the village territory individual claims continued and households were free to use the land as they liked.

Village rights were further developed in the period of the first (Baoulé) immigrants during the sixties. Households started to record officially at the sous-préfecture ("Juge de Paix") the position of all forest traditionally claimed. The land was attributed to individuals, making it possible for men and women alike to lawfully own land. Most persons became owner of 15 or 30 hectares of secondary forest and fields and almost every one added also patches of primary forest. The domain itself was marked with cemented boulders. Portions of forest claimed by no one stayed in "reserve". From this pool land could be taken and given to absent parents and children. The creation of the National Park interfered with the land rights of the Oubi, since large portions of their forest became part of the Park. During the last enlargement of the bufferzone, in 1982, it was still possible for farmers deprived of their land to purchase some 15 to 20 hectares of forest elsewhere within the village boundary.

When immigrants arrived they were conducted to villages that had relatively much land and few people. The Baoulé, who came first, were sent to areas with few claims. Obstacles were overcome with presents (beer, wine etc.) and the immigrants acquired rights to use the land. Many Baoulé families settled between the villages Taï and Gouléako, and those who had arrived first, received sometimes fifty or more hectares. Baoulé who came later, and foreigners, most of them Burkinabé, received far less land, 4 to 10 ha, and they were directed towards remote places which were still unoccupied, or to land close to the main road where the forest was less high and the soil often swampy and considered less suitable for the cultivation.

Immigrants, Baoulé and Burkinabé in search for land to plant cash crops, first "saturated" other forested areas in Côte d'Ivoire before reaching Taï. In those areas they often arrived so suddenly and in such large numbers that the indigenous farmers did not have enough time to validate their traditional land rights at the sous-préfecture, and so they lost much forest (Lena *et al.* 1977 for the Bakwé, Chaveau & Richard 1977 for the Gban, Affou 1978 for the Akye). In the Taï area, however, immigrants arrived at a much slower pace, and so the Oubi and Guéré managed to keep part of their traditional territory for their own use.

The Oubi stopped giving large portions of land to newcomers rather suddenly. Gouléako, as one of the first villages, dropped in 1972 from 10 hectares per family to 2 or 3 hectares (Ruf 1984a). Other villages followed and after 1978 it was no longer possible in the sous-préfecture Taï to obtain large stretches of any kind of forest. No distinction was made between Baoulé or foreigners. Some Baoulé even departed considering Taï saturated.

In the eighties the competition for land becomes rather severe. People start selling forest, which was up to then not a marketable commodity. Many illegal fellings occur and disputes about territorial boundaries are frequent.

First existed a land use right per household. In colonial times a land use right per village was added which developed into individual rights. Dove (1983) gives examples of land use rights per household and per village in Kalimantan (the Banjarese and the Kantu).

With a population superior to that of the Oubi, (about 8.8 persons per km^2 in 1970), the Guéré living north of Guiglo acquired land claims by felling a forest too, but these rights expired after 6 or 7 years, this being the regular length of a fallow (Schwartz 1972).

3.3.5 Extension of the cultivated land

The SPOT imagery of 1988 allows to identify the location of settlements, the extent of agricultural activity and the relative intensity of land use. It allows also to distinguish the land use of indigenous people and that of immigrants (explained in chapter 4). Intensity of land use is represented in a similar way (Fig.3.5) as in Fig.3.4). In a separate map (Fig.3.6), areas indicated with a "M" are occupied by immigrant settlers exclusively. Here land use is largely out of control of the indigenous people, Oubi, Guéré or Krou. Land indicated with "A" is cultivated by the indigenous people, or by a mixed population of indigenous people and immigrants. In both cases the indigenous people still hold some sort of control over the land.

A comparison between the maps Fig.3.4, Fig.3.5 and Fig.3.6, allows some interesting conclusions on the development of land occupation the last 30 years. The original inhabitants continue to occupy the land bordering the road, but much primary forest has been cut. Land that was in use for shifting cultivation in 1956 and that is located near the main road, or situated between the road and the Cavally, is still controlled by them. Slightly disturbed primary forest in 1956 near the main road, too. On the other hand, land that was used for rice cultivation, or had been used previously, located far from villages, is now in the hands of immigrants alone. Generally, land covered by undisturbed primary forest in 1956 is now either farmed by immigrants, or, if located in bufferzone or Park, has remained forest. The total territory cultivated by Oubi, Guéré and Krou has hardly increased.

In the mixed Alluvial-upland landscape (Fig.3.3) which was rather intensely used for rice cultivation in 1956 (less than 25 per cent primary forest), no primary forest is left in 1988 for all is used for shifting cultivation. As for the uplands some distance east of the road, rice cultivation was concentrated along the rivers, whereas the land between rivers was less frequently cultivated. In 1988 the situation has unversed. The slopes are cultivated at the expense of the forest close to rivers. This is the immediate result of the change in dominant crop: cocoa and coffee do not grow well in swampy or periodically waterlogged soils, but the rice varieties used do not mind. In the region north-east and east of Taï this was observed best.

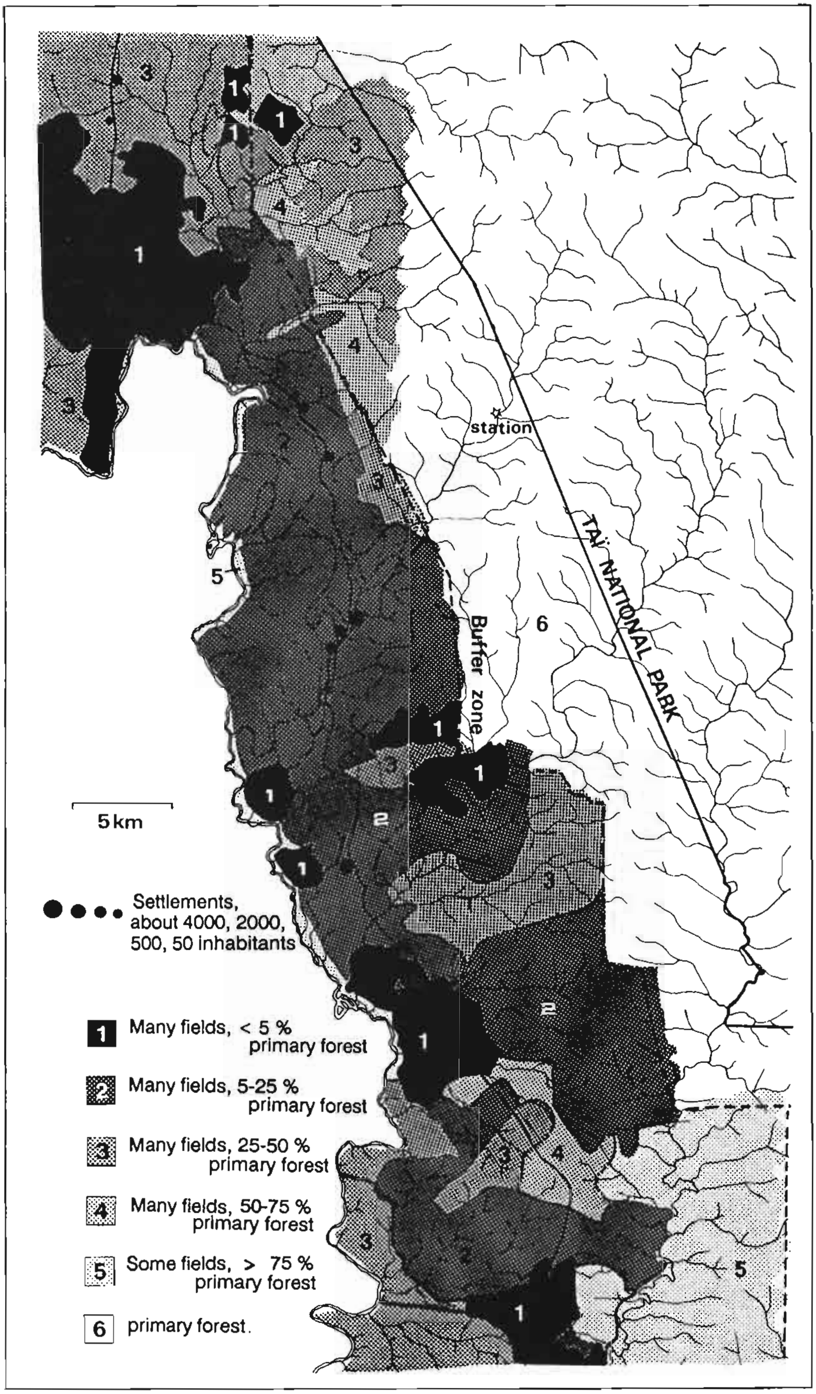
3.4 DEMOGRAPHY

It is obvious that the south-west Côte d'Ivoire is a thinly populated land. The custom to live in villages along the main road had "emptied" the interior of the Taï forest (Guillaumet 1967 p.21). The Guéré population living in the country is estimated the 180,000 persons (Anonymous 1979), of which less than 1500 inhabit the study area. About 1000 Oubi live in Liberia (11 villages) and about an equal number of them in Côte d'Ivoire. At least a quarter of the Ivorian Oubi are permanent residents of Abidjan, leaving about 700 Oubi to live in the study area. The number of Krou who inhabit Côte d'Ivoire is estimated 18,000, but most of them live along the coast and only a few hundred inhabit the south of the study area.

In 1965 the Government of Côte d'Ivoire decided to promote the development of the south-west, especially the production of cash crops coffee and cocoa. As the region was considered under-populated immigration was propagated. (Guillaumet, Couturier & Dosso 1984). Immigration was slow at the beginning, not only because Taï was far away and roads were bad, but also because of a persisting echo of anthropophagy. It was only after a speech on the radio in which the President declared that all people in Côte d'Ivoire were civilized, that the first Baoulé immigrants ventured into the Taï region. Attracted by local conditions such as abundance of forest, many immigrants, usually from savanna regions, settled in this area and started crop plantations.

A demographic study was carried out in 1970 in the sous-préfecture Taï (Schwartz & Capot-Rey 1971). The data represented in Table 3.3 exclude a floating population of 521 mainly Burkinabé employed in seven logging firms operating in the area. Also absent are 383 Oubi and Guéré who have migrated to the cities. The population density is 3.3 persons per square kilometre, but if abstraction is made for the land occupied by the National Park, density increases to 7.8. Another correction needs to be made: the northern part of the sous-préfecture is more densely populated and falls outside

Fig.3.5. Different intensities of land use in 1988 (SPOT image, February 1988). Land inhabitated by indigeneous people and immigrants, practicing shifting cultivation and coffee-cocoa cropping. Bounderies of National Park and Buffer zone indicated. >



station
TAÏ NATIONAL PARK
Buffer zone
5 km
Settlements, about 4000, 2000, 500, 50 inhabitants
1 Many fields, < 5 % primary forest
2 Many fields, 5-25 % primary forest
3 Many fields, 25-50 % primary forest
4 Many fields, 50-75 % primary forest
5 Some fields, > 75 % primary forest
6 primary forest.

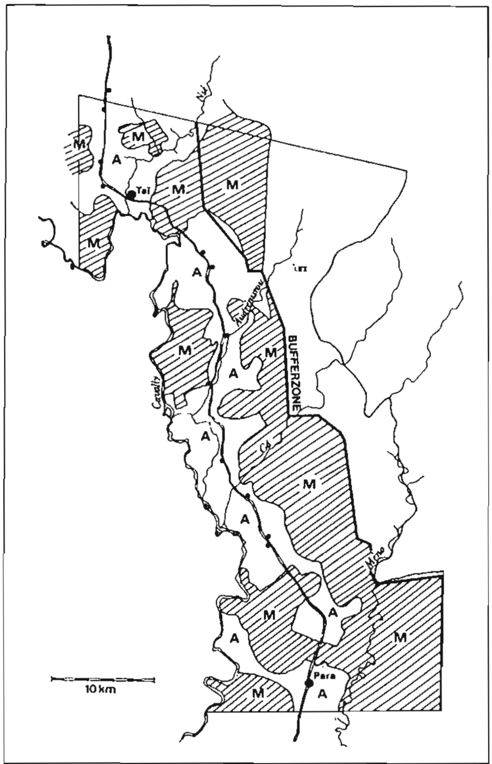


Fig. 3.6. Land occupied by the different population groups (SPOT image February 1988). M : immigrants exclusively. A : mixed population of immigrants and indigeneous people or by indigeneous people above.

the study area. The Guéré population was spread over ten villages along the road (average number of inhabitants per village 200 persons) and 28 campements (average 8 persons) disseminated in the forest interior. The Oubi lived in six villages along the road (average 62 inhabitants per village) and nine campements (average of 14 persons). The Baoulé were living in 15 campements near the road or in the forest with an average population of 14 persons per campement, but one settlement, Kouadiokro, counts 82 inhabitants. The Baoulé preferred to live separately in campements. The figures which the sous-préfet kindly placed at our disposal (Table 3.3) demonstrate an influx of Baoulé before 1979, and, while immigration by Baoulé continues, an increase of foreigners thereafter. After Ruf (1984a) a maximum of Baoulé arrived in 1979, rapidly levelling off the next years and ceasing after 1984. This was a direct result of Oubi and Guéré ceasing to give large portions of forest to immigrants. The population in the study area, outside the Park, increased to about13 persons per km^2 in 1985, only 22 per cent were indigenous. In addition, the sous-préfet provided some demographic data of individual villages in 1978 (Table

Table 3.3. Inhabitants of the sous-préfecture Taï with percentage of indigeneous people, immigrants form Côte d'Ivoire (Baoulé) and other immigrants.

Year	Total number	Oubi & Guéré	Baoulé	Other immigrants
1971 *	3288	83%	7%	9%
1979 **	6000	55%	30%	15%
1985 **	11185	22%	41%	37%

* source: Schwartz & Capot-Rey 1971
** source: sous-préfecture Taï

Table 3.4. Number of inhabitants belonging to different ethnic groups,living in the villages of the study area in 1978 (no data from the villages Zaipobli, Gahabli, Siéblo-oula and Para - Source : Sous-Préfecture Taï).

Village	**Oubi**	**Guéré**	**Baoulé**	**Other Ivorians**	**Foreigners**	Total
Ponan	0	259	76	11	75	421
Daobly	0	218	0	3	20	241
Taï	147	107	192	196	64	706
Kouadiokro & Sangbékro	0	0	162	0	0	162
Gouléako	121	0	0	6	1	128
Poulé-oula	137	0	70	1	7	215
Diéro-oula	87	0	84	0	4	175
Tiéoulé-oula	71	0	29	0	7	107
Sakré	150	0	6	5	30	191
Zriglo	81	0	18	0	1	100
Total	794	584	637	222	209	2446

3.4). We see that in 1978, the total population of the sous-préfecture is estimated at about 6000 people (Table 3.3) but less than half of that number actually lived in the study area. Since then the number of foreigners, which followed the wave of mainly Baoulé immigration, has turned some Oubi and Guéré villages for a large majority into Burkinabé. Though exact data are not available for all villages, Ponan had over 2000 inhabitants (census Janmaat & Schrikkema 1989) and Sakré about 2100 in 1989 (De Rouw, Vellema & Blokhuis 1990). The villages Daobli and Taï also strongly increased their number of inhabitants since 1978, but other settlements did not grow much. The Liberian civil war in 1990 brought many refugees in the Taï region. The number of inhabitants, approximately 29,000, has been increased with about 17,000 registered refugees (source sous-préfecture de Taï, February 1991).

4 Farming systems

4.1 ANALYTIC FRAME

Shifting cultivation has often been described as some kind of a system (De Schlippe 1956, Conklin 1957 and many others). In shifting cultivation this seems a very natural thing to do because the way farmers farm is so obviously related structurally, temporally and functionally with other things, notably the environment. A system approach can be a suitable tool for analysing agriculture in the present case too, therefore we have to straighten our terminology. We will follow Fresco (1986), inspired by Ruthenberg (1976), who has developed a system-directed methodology. This study integrates three kinds of systems which can be ranked in a hierarchical order.

1. The **cropping system** is situated on the lowest level. Its object is the field and its function is the transformation of plant material and soil nutrients into useful biomass. The systems components are: crops, weeds, pathogenes, insects). In this study different cropping systems coincides with different field types (rice fields, cocoa plantations etc.).
2. The **farming system** is on the intermediate level. Its object is the farm. It functions as a decision-making unit as it transforms land, capital, knowledge, labour into useful products that can be consumed or sold. One of its components is the cropping system. In the Taï area different farming systems corresponds to the farming activities of the different ethnical groups (the indigenous population, Oubi and Guéré, and the immigrant groups).
3. The system on the highest level is currently called "**regional system**". Its object is a certain region, landscape, large watershed. The system components are divers but include farming systems, climate, geology natural vegetation but also the service sector, roads etc. In the present study the regional system is rather a "lump" system, it comprises all organization above the level of farms but inside the study area. Preferably we will use other terms which are more precise, Land Unit, village territory etc.

4.1.1. Shifting cultivation systems

Shifting cultivation systems are farming systems. They are widespread and very variable. Shifting cultivation has been subdivided and classified according to intensity of rotation (Nye & Greenland 1960, Spencer 1966), according to crops and animal activity (Ruthenberg 1976), to tools used, degree of commercialisation (Fresco 1986, Ruthenberg 1976), and many other criteria. Here it is the classification of Conclin (1957) which suits best because it emphasises the fundamental differences among the farming systems operating in Taï.

A. Partial systems, which has two variants,

A1. Supplementary farming. A permanent field cultivator, devotes part of his agricultural efforts to shifting cultivation through necessity.

A2. Incipient farming. A cultivator, often with little knowledge of shifting cultivation techniques and usually from a crowded agricultural region, moves into an upland area as a resettler or a squatter and devotes all his agricultural efforts to shifting cultivation.

B. Integral systems, which has two variants,

B1.Pioneer farming. Significant portions of climax vegetation are cleared each year.

B2.Established farming. Relative little climax vegetation is cleared each year, trees and tree crops are plentiful.

The Oubi and the Guéré farming systems are Integral systems of the Established type.

This form of shifting cultivation includes long fallow periods and short cultivation periods, hence requires much land. A veru comparable system has been described (Sevin 1983, the Dayak, Indonesia). Rice cultivation in such a way is rare now but there are many indications that once it was widespread among people in western Africa who subsist on rice (Lelong 1946, Guinea; Paulme 1970, Sierra Leone; Ripley 1975, Ghana; Mouton, 1959 for the region of Man, Côte d'Ivoire; Bognon 1988, Côte d'Ivoire). Most of these farming systems have been adjusted under population pressure or the spread of tree cash cropping.

4.2 SHIFTING CULTIVATION IN TAI, EARLIER STUDIES

Some of the particularities of the Oubi and Guéré system have been studied in detail.

4.2.1 Erosion

A general feature of soils near Taï is a marked susceptibility to erosion, already observed by the "Mission militaire" (Riou 1960, Adjanohoun & Guillaumet 1960-1961) and experimentally studied by ORSTOM (Guillaumet, Couturier & Dosso 1984). Physical properties and changes in soil were studied in recently cleared primary forest. Local practice includes no soil disturbance other than by the planting stick and leaves the soil covered by a multitude of unburnt wood, followed by a rapid cover by the vegetation. These methods do not modify soil surface properties and do not bring about more erosion than under untouched forest (50 to 300 kg/ha/year Collinet 1984). Surface structure middle slope was better than lower slope and resisted better to various impact due to cultivation (Moreau 1983 ; Guillaumet, Couturier & Dosso 1984). Other sowing and planting techniques, especially moulding the soil surface to plant yams, seriously damaged the surface structure and induced an erosion twenty five times as much (Collinet 1984). Erosion continues as long as the soil remained bare, a period which is much longer in the case of yam cultivation.

4.2.2 Soil fauna and myciflora

Macroporosity greatly develops as soon as the ground is covered by vegetation. Earthworms and other soil fauna reconstitute an excellent soil structure during the first years of succession while incorporating the large mass of forest debris into the soil (Collinet 1984).

Fritsch (1982) found a good relation between number of worms and amount of casts on the surface, the chemical fertility of the casts being very superior to the surrounding soil. The activity of earthworms is closely related to the quantity of litter available, which in secondary forest increases dramatically in periods the pioneer trees die off. The same has been recorded from shifting cultivation ("Jhum") in northern India (Bhadauria & Ramakrishnan 1989) where the mucus produced by earthworms is evaluated at 15 tons/ha/year of a five year old forest fallow.

The recovery process of the soil fungal community, including mycorrhizae populations was studied under the Oubi shifting cultivation conditions in a primary forest environment. This type of cultivation was not found to have destructive effects on the soil mycoflora, but other types of disturbance and a greater extension of the same type would not necessarily demonstrate a similar good recovery process (Maggi *et al.* 1990, Rambeli *et al.* 1984).

4.2.3 Insects

The absence of serious pests is illustrated by the nature of indigenous knowledge. Knowledge of the insect world is sometimes considerable as was proven by various tests in Taï (Couturier 1985, unpublished data). Remarkable details were told about many conspicuous and odd insects, but even the most common feeders on rice were ignored and had no name. The okra, (*Abelmoschus esculentus*) cultivated by almost every farmer, is attacked by *Alcidodes* species (Couturier & Perrin 1982). The population can be easily controlled by manual destruction, asking not much time and effort, as was explained by ORSTOM workers to farmers in Taï. However, this was not considered worthwhile, not even by those women involved in the commercialisation of okra (G. Couturier 1985 pers. comm).

4.2.4 Rodents

The geographical isolation of the Taï region and the high levels of forest cover kept the population of rodents, especially the locally called "agoutis" (*Thryonomys swinderianus* Temminck) very low so that farmers were not used to take effective measures against them. In a study of rodents in Taï (1974-1981) very few agoutis were captured, either in primary forest, secondary forest or in fields (Guillaumet, Couturier & Dosso 1984). The species was not mentioned as a pest. A survey on rodents in Taï demonstrated a dominance of *Mus minutoides musculoises* in the period two to three months after planting the rice. In more disturbed areas, this was *Mastomys erythroleucus* (Koyate & Dosso 1981). At that time, farmers on the other side of the Park (Ottawa, Broudoumé) were already obliged to defend their rice field against agoutis.

4.3 DESCRIPTION OF THE SHIFTING CULTIVATION OF THE OUBI AND GUERE

4.3.1. Site selection

If we suppose a farmer has retained freedom of choice by site selection, for land is in good supply, then he or she will show an appreciation of two physical factors, the forest and the soil. Practical and cultural considerations may be very important too, travel distance, former yields, religious taboos, etc.

Forest age

A secondary forest is build up mainly by pioneer trees which are roughly even-aged for all have sprung up since the last period of cultivation. Most pioneer trees have a limited life-span which is genetically controlled. The forest succession in Taï has two periods of strong decline of pioneer trees. The first occurs after seven to nine years when the *Macaranga hurifolia* stand breaks up. A second period of decline occurs after sixteen to twenty years of fallowing and this time trees of many species are affected. Much work can be saved if the moment of felling coincides with one of the periods of decay. A farmer does not "use" the first period of decline, chiefly because too many weed seeds are still present in the soil. He rather benefits from the second period of degeneration. This time the forest fallow is considered to have restored the land to a state in which it can be farmed again. If a secondary forest gets older, besides all trees growing thicker, the pioneer trees are succeeded by trees with often much harder wood.

A primary forest is still more troublesome to fell. Size of the vegetation, hardness of the wood and the difficulty to get rid of the most of the debris cause such problems that a good rice yield is not guarantied.

Forest quality

Quality of a forest is judged after two criteria : structure, or merely "health" of a forest and floristic composition. If a farmer gets the impression that the trees are too small for their age, he estimates that no good crop is to be expected. The floristic composition is unimportant. In the opposite case, a vigourous regrowth will promise a satisfying yield, even is some undesirable species occur.

Floristic composition can be valued "good" or "bad". A plant can be qualified as "bad" for two reasons. It is difficult to cut, or it is difficult to control because of coppice growth. The plant can also be called "bad" if it refers to environmental conditions which anticipate a bad crop. Places with "bad" plants usually have a sandy topsoil with low organic matter content and low pH. "Good" plants usually indicate no such conditions. The Oubi have a word for "good place to grow rice" (Ferraclao) which is the name of one plant species *Millettia rhodantha*. The occurrence of *Millettia rhodantha* was found to be related to rock outcrops, low inselbergs (De Rouw, Vellema & Blokhuis 1990), ancient riverbeds and other anomalies in the landscape induced principally by geology (De Rouw, vellema & Blokhuis 1990). Guillaumet (1967 p.25) observed a prominence of *Millettia rhodantha* in secondary forest and in fields. Going to the north, the occurrence of *Millettia rhodantha* becomes more and more erratic while extent of growing places is greatly reduced. Below the village Diéré-oula in contrast, *Millettia rhodantha* may be widespread over several hectares or Even Square Kilometres (De Rouw, Vellema & Blokhuis 1990).

A strong presence of *Marantaceae* is equally appreciated, especially those species which constitute the "Gbarou" forest type (Table 4.1). *Marantaceae*, as a group, are mainly moisture indicators.

A forest type indicated with "Powi-kla", characterized by a dominance of *Scaphopetalum amoenum*, has often been cleared for cultivation to a point that it has become rather rare. Guillaumet (1967 p.80) states that occurrence of *Scaphopetalum amoenum* is always related to schist and micashist, but, in the Land Unit Survey we could not confirm this.

Table 4.1. Types of soil and types of vegetation distinguished by Oubi and Guéré.

Name Oubi	Name Guéré	Translation
torro ko-oo	blo-djéré kohou-o blo	black soil
torro so-oo	tchéa blo	red soil
torro po-oo		
	binlin blo	soil sandy
pla-lè	kranlin blo	swampy soil
	daman blo	gravelly soil
klouha	koula	all sorts of forested land
kparo	koulahé	primary forest, upland
gboma	gboho	primary forest in swamps
sahii kloa	sahan	primary forest on alluvium
pohé kloa	vahin koula	very old secondary forest, changing into primary forest
gbahé	hoila	secondary forest with dense underwood
gbarou		"horizontal forest"
piri	peli	herbaceous vegetation

Soil

Oubi and Guéré in the study area use similar criteria in their judgement of the soil. The surface ten to fifteen cm is examined for colour and texture with the help of a matchet and by squeezing a handful of earth. The kneaded soil is dropped on the ground from some distance (about 30 cm). If it falls apart, the site is to be rejected. Three classes of texture are distinguished: clayey, sandy and intermediate, and three categories of colour: blackish, reddish and pale. The darker the colour and the more clay, the better the soil. A red clayey soil is considered superior to a dark-coloured sandy soil. Presence or absence of gravel is not considered to be important except in two circumstances. On crests and upper slopes a too thick layer of gravel enhances the risk of lack of water (most farmers), and gravel in lower slope soils is generally desirable because of better drainage (some farmers). Softness of the topsoil is sometimes tested by putting one's bare toe into the ground.

Farmers throughout the study area mention the importance of earthworms for the quality of the soil. Activity of earthworms is estimated by the number of casts ejected on the surface.

Compacted soil under former timber extraction roads, even those more than twenty years abandoned, is to be avoided. Maize and rice plants will turn yellow, stay small and are greatly hindered by abundance of weeds.

Travel distance

Land close to dwelling places is more intensely cropped than forest at some distance. This implies that soils of lesser quality and young fallows are cultivated for the benefit of lying nearby. New cultivation sites are rarely selected further than three or four kilometres away from the village. Far off fields all have some modest buildings to cook, store field products, to rest and if necessary, to pass the night (campement Fig. 4.2).

4.3.2 Definite survey and marking of site

A definitive survey is followed by marking off the new field. Now decisions are made on actual size, shape, spacing in relation to other fields, in relation to the slope, and to the position to very large trees, or useful trees intended to preserve.

Size

The size of a cultivable area varies with age, ambition and responsibilities of the people in the household. In fact it depends on how large a surface a woman is prepared to plant, which is usually not more than one hectare per year.

Shape

A field may have all kind of angles but if hired labour is to be recruited, a more or less rectangular, is preferable because these people are paid for their work per hectare and the exact surface of the field needs to be known. Hired workers are present during the delimitation and marking of the site. For this purpose the village standard measure, a rope of 25 metres is borrowed.

Relation to other fields

The boundaries of the fresh clearing will not necessarily coincide with those of previous ones (Fig.1.3 is an illustration). Often a new field is joined to the one cultivated the previous year if the latter has a campement and a garden which can be used and harvested another year.

Relation to the slope

A field should have a clear uphill-downhill dimension. A slope implies differences in soils and, related to this, a variation in moisture regime during the cropping season. These micro-variations are used primary as an adjustment to the peak labour period which is sowing the rice, and secondly as an adaptation to special demands of crops (Table 4.2 for rice varieties).

Position of large trees

Very large trees, especially trees with wide-spreading buttresses are, where possible, confined to the field edge.

4.3.3 Cutting

Method

Men start cutting the understorey of a secondary forest in January or February, a primary forest in December. For this a matchet is used, a cut-lass with a single edged blade, about 50 cm long and 5 cm wide. A new three-square file is taken to the site where it is kept in almost constant use. Herbs, saplings, vines and small trees with a grith below 20 cm, all this is cut close to the ground to reduce coppice growth and to circulate more easily in the field. Depending on the density of the forest and the skill of the man, this work takes between 7 and 12 days per hectare. Trees with a girth between 20 and 40 cm, or still bigger trees with soft wood, are felled with a heavier matchet. They are felled well above the ground where it is easier to use force. This work takes another 7 to 12 days. The upright leafy branches are chopped off in order to facilitate rapid drying. The shade cast by the trees still standing forms no objection. Finally, after 4 to 6 weeks of drying out, the largest trees are felled with a steel axe, taking 6 to 12 days. Where possible smaller trees are notched with several deep incisions so that with the felling of larger trees, they will be knocked down. Trees may be pulled over by lianas too. Not much use is made of scaffolds to cut buttressed trees. A further 6 to 12 days are employed cutting the wood to pieces to allow better drying. Burning is a necessity and the success of the burn is largely determined by the thoroughness of this cutting activity. Workers with no direct personal interest in the field (hired labour) often lack enthusiasm for this onerous and less spectacular task. No special effort is made to spread the cut debris evenly over the forest floor.

Work, clearing an old secondary forest	Tool	Gender	Month	Days/ha /person
Cutting the understorey and small trees (girth < 20 cm)	light matchet	M or F	Jan.-Febr.	7 - 12
Cutting the larger trees (girth 20 - 40 cm)	heavier matchet	M or F	Febr.	7 - 12
Felling the large trees	axe	M	Febr.-March	6 - 12
Cutting the wood to pieces	matchet, light or heavy	M or F	Febr.-March	6 - 12
Total				**26 - 48**
Felling the large trees and cutting the wood to pieces	chain saw	M	Febr.-March	1/2

Fortunate people may hire a man with a chainsaw for one day to cut the largest trees, especially if a primary forest is to be cleared. Additional Burkinabé workers are often recruited to slash the underwood but they are criticized for not cutting close enough to the ground.

Most man work alone on their field but occasionally, may ask other Oubi men to help. Men, not belonging to the household are remunerated in cash or in the form of reciprocated labour on a strict man-day for man-day basis.

Felling is considered men work but during my stay I observed women, often widowed or divorced, engaged in any work of felling except cutting the large trees with an axe.

Different types of forest

If the clearing period is well planned in relation to the dry season the felled vegetation dries rapidly and rots but slowly. If the clearing period is less well planned, with the rainy season starting, the debris dries slowly and rot becomes a problem. There is no limit to the period in which a felled primary forest is allowed to dry out. The leaves being generally hard and contain a great many chemical substances preventing them to be rapidly attacked by micro-organisms. Thus they takes some months to moisten and rot. The main reason for which a primary forest is often poorly burnt, is the great mass of wood, drying slowly, and the many trees left standing, preventing the sun to reach all of the material. The trash of a secondary forest is much quicker attacked by insects and micro-organisms. Here the main danger putting the whole burning at risk, are layers of moist trash starting to rot. Care is taken not to cover the first layer of felled vegetation by fresh material before it has sufficiently dried out. The younger the secondary vegetation, the shorter the period the debris is allowed to dry.

The secondary forest called "Gbarou" (Table 4.1) is quick to clear. It usually consists of a 3 to 5 metres high thicket of lianescent *Marantaceae* (*Hypselodelphys* *violacea*, *Trachyphrynium brachystachys* etc.) and the scrambling tree *Alchornea cordifolia* mixed with some outstanding trees 15 - 25 m. The continuous layer of leaves can be cut in 5 or 6 days. This is, however, not easy. With one hand one has to lift the thick layer of Marantaceae leaves, while with the other hand the stems are cut. A second inconvenience is that the debris should be burnt within 3 or 4 days because underneath the layer of leaves, the litter starts to rot, thus preventing correct burning. Plenty of very large, edible snails (*Achatina achatina*) can be found in this kind of vegetation.

Differences between clearing a primary forest and a secondary forest regard, the date field preparation starts, the tools used, the period needed for adequate desiccation and the number of days work.

Twice we could determine the exact number of hours needed to clear one hectare of forest. A nineteen year-old forest was cleared in 76 hours. The trees with a grith under 20 cm, about 600, were felled in 42 hours, a further 34 hours were used felling the larger trees and cutting the debris to pieces. Almost a similar number of hours was needed (72) to clear a six year-old fallow. The extremely dense stand of *Macaranga hurifolia* demonstrated no signs of decay and the spiny trunks were interlaced with a dense mass of vines. After cutting a tree refused to fall down and had to be cut several times over and pulled to the ground.

Special tree species

There are trees which have to be cut and thoroughly burnt for they will damage the crop if surviving. *Alchornia cordifolia*, *Griffonia simplicifolia* and *Sterculiaceae* in general, except for the useful *Cola nitida* which is often preserved for its seeds, must be eliminated because of their vigourous coppice growth. The fruits of *Discoglypremna caloneura* will attract birds also feeding on rice.

Work, clearing a "Gbarou" forest	**Tool**	**Gender**	**Month**	**Days/ha /person**
Cutting the understorey of Marantaceae climbers	light matchet	M or F	March	5 - 6
Cutting the trees	matchet, light or heavy	M or F	March	2 - 7
Cutting the wood to pieces	matchet, light or heavy	M or F	March	2 - 3
Total				**9 - 16**

Trees left standing

Oubi and Guéré fell all but 2 or 3 very large trees per hectare, relicts of the rain forest. These trees are usually left standing as their removal is not thought worth the considerable effort involved, either for the extremely hard wood (*Dialium aubrevillei*, *Erythrophleum ivorense, Klainedoxa gabonensis*, *Lophira alata*, *Samnaea dinklagei* and *Chidlowia sanguinea*), or for the large buttresses (*Ceiba pentandra*, *Bombax buenopozenze* and *Piptadeniastrum africanum*). A variable number of smaller trees are left untouched. Either a poor developed crown makes them harmless to the crop, or the wood is hard (*Diospiros* spp) or the tree belongs to a species which hardly survives exposure to full sunlight. Some trees are preserved for their useful seeds (*Irvingia gabonensis*, *Ricinodendron* *heudelotii*, *Coula edulis* and oilpalm) or for religious reasons. The foliage of oilpalms should be removed if they are under five meters high in order that they may survive the fire. After the burning the tree grows out again without further attention. Up to 19 trees over 15 m high per hectare were counted in fields, and the number was not considered exceptional. The trees are appreciated by workers in the field for the comforting shadow. Finally, Oubi and Guéré suppose the trees contribute to re-establish the forest once the field is abandoned. Especially the emergents are thought to attract rain and thus to help a quick return to forest humid environment, hence large forest trees are considered a guarantee against drought (more details in De Rouw 1987).

Turtles and snails take shelter between the stiltwoods of relics (*Uapaca* spp and *Ficus lyrata*) in the period the vegetation dries out where they are fetched to eat.

4.3.4 Burning

Burning is a decisive factor which controls future yield and work involved. Farmers discriminate at least four beneficial effects from burning:

- it cleans the field, making it thus accessible to planting crops,
- it eliminates many weed seeds and limits coppice growth,
- it makes the topsoil soft and friable so dibble planting is easy,
- the ashes fertilize the soil.

Burning is also a delicate work. Success depends on the correct timing of cutting activities, a proper use of the weather conditions and adequate firing techniques.

Burning is done at the end of the dry season, in February or March, on a windy afternoon. The best time is the hottest part of the day between one and three p.m. The preceding days have to be dry. If the vegetation is very dry, burning can be delayed into the rainy season without serious consequences. The moment of burning is decided by the individual farmer who owns the field.

Farmers in Taï are not used to take precautionary measures against unintentional fires. There is no danger of flames escaping into the forest bordering the field because of constantly moist conditions. However, during an exceptional dry year, 1986, fire ran into surrounding cocoa plantations and caused much damage.

The midribs (rachis) of the dry leaves of the *Raphia* palm are split and tied together with lianas, to form torches about 2 or 3 m long. 8 to 12 torches, locally called "bambous", are needed to burn a hectare. Immediately following a ritual consideration, firing starts. The burning end of the torch is thrust into the dry vegetation every 3 or 4 m. The person makes sure that the fire has caught at each point of contact. The man works against the wind, covering all of the field by walking zig-zag. In average to large fields, there may be two torchmen. The work takes less than an hour. Setting fire is men's work. If a woman does not have a man to burn her field, she has to do it herself secretly.

Quality of the burning

Burning is never complete. Logs of wood will still cover part of the field. Places with too thin a layer of trash or patches covered by moist material, especially the field margins, will be incompletely burnt. As for these reasons, the burning will not be repeated. Unburnt logs and stumps are left as such. The reason for which a burning may be repeated - but this is rare - are large unburnt trees, felled but not cut to pieces, which prevent with their branches access to part of the field. This wood is cut, piled and burnt in small heaps, while the sowing of another part of the field has already started. The deposit of the ashes forms an irregular pattern, but ash is usually not re-distributed over the field. Incomplete, spotty burning is quite common. It is mainly due to the patchy distribution of dry vegetation over the field. A poor, overall burning is less frequent. The chief reason is the felled vegetation being still moist. In the latter case, piling of the material followed by a secondary or even tertiary burning does not bring the beneficial effect produced by a correct first burn. Because of the rainy season approaching, re-burning is not considered worth the trouble.

4.3.5 Planting

Rice

Seeding a field is done by women who consider this the most tedious work in cultivation. Rice is the only crop which is maximally planted, in every new field and in every square metre of suitable surface space. But it is not cultivated in pure stands. In a rice field different crops are mixed, some cultivated simultaneously, others in a overlapping fashion.

Farmers seek to plant rice immediately after burning but this is only possible if the soil contains sufficient moisture. Successful rice planting requires some heavy rain if a gravelly soil is seeded. A valley bottom soil can have sufficient residual water to allow immediate planting. The time interval between the firing and the first day of rice planting is usually less than a week.

Sowing-seed

Oubi and Guéré estimations on the quantity of rice seed needed for sowing are very approximate. Quantities are measured in "tin" or in "dourou" (Oubi). Both words indicate a metallic box of 8 litres. Two or three tins will do for a hectare. We determined quantities of sowing seed twice, 15 kg/ha and 20 kg/ha. (Guillaumet, Couturier & Dosso 1984 measured 28 kg/ha).

Seed is saved from the previous harvest by collecting perfect paddy ears from sound plants. The ears are dried and stored separately from the rest of the harvest. No effort is made to select early or even ripening plants. Different varieties of rice are kept well apart.

Just before sowing these selected rice plants are trashed. This means that the straw is separated from the grain by gently pounding with a pestle a bundle of panicles in a mortar.

Rice varieties

A mixture of rice varieties are sown in the same field but separately. Distinctions are made on length of growing cycle, ranging from three and a half to five and a half months, on resistance to stress, like dry spells, weeds and pests, on taste and on size of the paddy. The sowing period and the distribution of short and long cycle rice in a field is thus organized that the period of harvesting is spread over two or more months. In Table 4.2 twenty three rice varieties from ten household spread over six villages are listed with some characteristic features. Identification, which is only possible after the complete ripe plant was made collectively, but one woman presided at all sessions to prevent duplications.

Table 4.2. Rice varieties (*Oryza sativa*) cultivated by Oubi and Guéré in the Taï area. Arranged in decreasing order of importance.

Local name *	Gloss	Life cycle **	Grain characteristics	Stature ***	Weed tolerance	Miscellaneous remarks
Rice varieties cultivated in large quantities						
Demande (O), Marie (O), Gadebly (G), Fassa (D), or Mou-i (M)	"riz bordel" name of the Yacouba woman who introduced it	long	large	tall	very good	Taste, average.Robust security rice, by far the most common variety.
two under-varieties						
Fee-ko (O)	"beard of the wild hog"	long	large, with awn (5-10 mm)	tall	very good	Taste average.Awn sometimes effective against birds and monkey pest.
Koloa–u (O)	"sweet success"	long	large, with black mark	tall	very good	
Nennou (O,G)	"eczema"	long	large, with brown and white spots	tall	good	Taste good.Sensible to drought.
Assi	name of the boat wh brought the rice	short	large	medium	average	Taste average.
Rice varieties cultivated in small quantities						
Clemensi (O,G,B	Yacouba name	long	small	tall	good	Taste very good.Sensible to drought.
Tatje (O)	"come and have a look"	medium	large ,with black mark	tall	good	Taste average.
Kwoo-ko (O), Satmaci (O)	name of the extention office	medium	large	medium	bad	Taste average.Improved variety, vigoreous growth but low stature makes harvesting tedious.
Boro-ko (O)	"dark beard"	long	large, with long awn	tall	good	Taste average.Awn sometimes effective against birds and monkey pest.
Sa-ko (O)	"sweetheart rice"	long	small	tall	good	Taste excellent.Only for your best friends.
Karen sa-ko (O)	"the Karen people's sweetheart rice"	short	small	medium	average	Taste excellent.Only for your best friends.
Kok-pin (O) ; Tchinlantan (G)	"three seasons"	long	large, red	tall, many tillers	good	Taste average.In swamps, after the main harvest a second ratoon crop 3 months later.
Nima (O,G)	village in Liberia	long	large, red	tall	good	Taste good.
Pellegna (O,G)	village "Pelle" in Liberia	long	large	tall	good	Taste average.Rodents are supposed to dislike the taste.
Souwako-ko (O)	name of the Yacouba woman who introduced it	long	large	tall	good	Taste average.Difficult to tresh.
Ban-ko (G)	Dyula name	-	-	-	-	Taste average.In swamps, of all varieties least resistent to drought.
Dadje (O,G)	"my mother gave it to me"	long	large	tall	good	Taste average.Introduced by a Bété woman.

Table 4.2. cont.

Local name *	Gloss	Life cycle **	Grain characteristics	Stature ***	Weed tolerance	Miscellaneous remarks
Dodi (O); Tehe-zaekloa (G	"elephant has eaten a rice field" "Tehe has found it in the forest"	long	-	tall	-	Taste average.Seeds are said to be found in the stomach or droppings of a elephant by the hunter Tehe.
Dwohobli (O)	"you must respect me"	medium	-	medium	average	Taste average.From Liberia.
Vlajondou (O)	"you are lazy"	long	large	tall	good	Taste average.Easy to tresh.

Notes:
* O = Oubi; G = Guéré; B = Bété; D = Dyula; M = Moré (language of Mossi people from Burkina Faso)
** long = 150 days or more; medium = about 130 days; short = 120 days or less.
*** tall = between 1.50 and 1.80 m; medium = between 1.20 and 1.50 m.

"Demandé"[1], or "Marie" was introduced by a Yacouba woman named "Marie" who followed her husband to Tiéoulé-oula probably in the fifties. It spread rapidly among rice farmers to become the first rice variety cultivated in the region. The rice is commonly known as "riz bordel" after the african expression "c'est un bordel", meaning "it is a mess" (in the field). "Demandé" resist weeds better than any other variety hence it can often be seen growing in unweeded (messy) fields. Varieties with awns are said to resist bird attack because birds have difficulties reaching the grains. The rice is sometimes planted where monkeys are liable to enter the field (border with High forest). Monkeys always sniff at any food before eating it. Awns are supposed to hurt their nooses and so they are discouraged from eating rice in the field. The variety "Assi" was introduced in the thirties or forties. It spread over all south-west Côte d'Ivoire for short cycle rice was almost unknown. The existence of a boat "Asia", operating a service with Tabou, which gave the variety its name, was confirmed by Bouys (1933). Generally at least one short cycle variety is sown first in order to eat as soon as possible from the new harvest. Three to five varieties are sown each year. The greater part of the field is occupied by a variety which provides a reliable and substantial yield. In Taï this is most often "Demandé" and more seldom "Nennou" and "Assi". A smaller portion is reserved for varieties yielding high under favourable conditions (like "Kwookwoo" in weed free fields, and "Tjerrenjeko" under excellent moisture conditions). Finally some spot is retained by delicate varieties, appreciated for taste or for the small size of the paddy ("Klemensi" and "Sako" are common).

Most rice varieties are long grain, long cycle and long straw plants. They tiller profusely and produce tall, rather weak stems with many large dropping leaves, giving a dense crop canopy but also a

1 Some varieties are found throughout south-west Côte d'Ivoire under the same name ("Assi", "Klemensi", Nennou", "Sako") others, like "Demandé" or "Kwookwoo" are probably equally widespread but they change names from one ethnical group to another, or from one village to another. Varieties spread through the custom of exogamy as can be traced by many names, later they are exchanges among parents and village members. The multiple comings and goings of people since colonial times is also responsible for the spread of rice varieties (Schwartz 1971 p.203).

proneness to lodging. They are able to outgrow and shade weeds, to withstand some flooding, dry spells. They produce a crop under poor standards of management and low soil fertility. It is possible that the rice varieties in Taï are adapted to low levels of solar radiation.

Cultivation of *Oryza glaberrima* is infrequent in Côte d'Ivoire (Bezancon *et al.* 1978) but the crop continues to hold a modest place by Oubi, Krou and Guéré who cultivate for ritual and religious reasons (Pham and De Kochko 1983; Bognon 1988).

Mixing seeds of different crops

Rice seed is often mixed with small quantities of seed of other crops. One or two handful of seeds are thoroughly hand-mixed with the rice and all is transported to the field. Almost all farmers mix okra (*Abelmoschus esculentus*) seed with rice. Less frequent but still widespread is the mixture jute (*Corchorus olitorius*)-rice, or the mixture jute-okra-rice. Mixtures do not include climbing legumes yet may include creepers like the mix pumpkin (*Cucurbita moscata*)-okra-rice. Maize occupies a special place. About 1 kg seed/ha is currently mixed with rice seed and sown together but only if sowing is possible just after the burn. If the soil is considered to dry, maize is sown alone, hence it is always the first crop in all fields. Maize, as a hardier crop can be planted right after burning. It is sown all over the field in the same manner as rice (see below). Two seeds are placed per hole and holes are made every two to four metres. One or two varieties are planted in any average field. No difference in treatment was noticed (location, period, care) except for "Sakpahou", an old variety now rare which was planted on old termite moulds. Table 4.3 gives characters of seven maize varieties cultivated in Taï by Oubi and Guéré.

Work, planting food crops	**Tool**	**Gender**	**Month**	**Days/ha /person**
Sowing rice and maize; clean to rather clean field (well burnt)	planting stick	F	March-May	14 - 24
Sowing rice and maize; field with much unburnt wood lying about	planting stick	F	March-May	30 or more
Sowing vegetables	planting stick, matchet	F	May-June	1 - 2
Planting cassava and bananas, taro	hoe, matchet	F	June	2 - 3
Total				**17 - 35 +**

Seeding

From a seed container carried to the field small quantities of seed mix are put in a shell (*Achatina achatina*) which is easy to hold in one hand. The other hand holds a planting stick or dibble called "baoulé" in Oubi (Fig. 4.1). With the dibble, holes are made averaging from three to five cm in depth into the topsoil which has become soft and sticky after the fire. With a small finger movement of the hand holding the shell a controlled quantity of seeds is allowed to fall into the hole. A second movement with the planting stick covers the seeds with earth. Sowing starts in the lowest part of the field and a woman works uphill until the whole field is planted.

Number of seeds per hole and average interval between holes seems to be a personal character for it hardly changes with the physiognomy of a field. Nine women participated in a sowing test and seeded 54 m^2 each. Mean number of

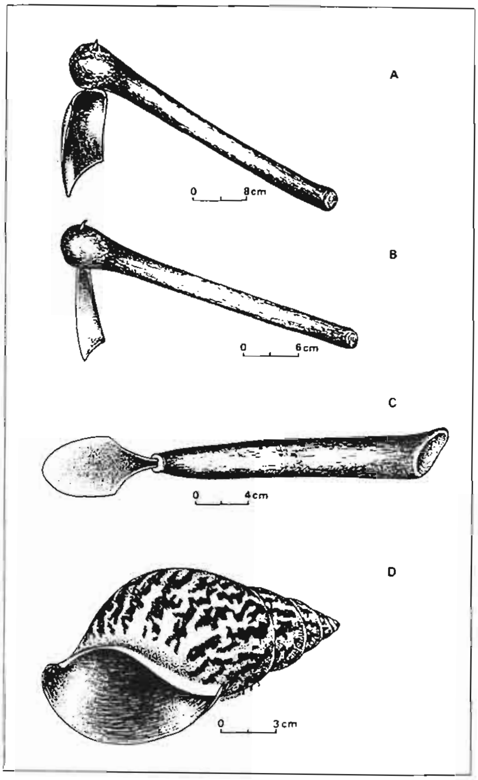


Fig. 4.1. Agricultural tools of Oubi and Guéré.
A. medium sized hoe "daba";
B. small hoe "petite daba";
C. planting stick;
D. shell to stock rice seed while sowing "achatine".

germinating seeds in a hole was 5.10. The mean number of holes was 8.61 per m^2.

Planting of rice is possible until mid-July. It takes a minimum of 14 days to seed a well burned field (116 hours work/ha), but if a mild fire has left many obstacles, 30 days or more may be needed. Patches where the rice is poorly established may be reseeded. Crop failure is rarely due to delayed monsoon rains, but more often caused by pests, birds who eat the grains, buffaloes or agoutis who eat the fodder. Though gaps in crop stand are frequent, reseeding is not very common. Reseeding may be attempted as late as July.

Crops growing simultaneously with the rice in no particular arrangement

The vegetables okra, jute and pumpkin grow all over the fields for their seed has been mixed with that of the rice. Other vegetables which occur disseminated over the field are most of the time not deliberately planted but have arrived spontaneously. We will call them semi-domesticates for they are just preserved and protected. Important semi-domesticates are the numerous local "aubergines" (*Solanum* spp)[2], chilly pepers (*Capsicum annuum*) and also oilpalm (*Elaeis guineensis*).

Maize, okra, chilly peper, aubergines and oilpalm are crops well represented in all rice fields.

Crops growing simultaneously with the rice in special areas

A number of crops are planted in well defined places. Climbing legumes (*Phaseolus lunatus*, *Vigna unquiculata*) and creeping Cucurbitaceae are planted in sole stand near a physical support,

2 Schmelzer (in press) made a revision of cultivated, semi-domesticated and wild *Solanum* taxa in the Taï region. The most common semi-domesticate *Solanum*, known all over Côte d'Ivoire as "Gnangnan", is *Solanum anguivi* Lam., a synonym with *Solanum indicum* L. It is supposed to be a wild ancestor of the cultivated *Solanum aethiopicum* L. In Taï two subspecies described by Jaeger (1985) occur, *S. anguivi* ssp anguivi Lam. with curved spines, and *S. anguivi ssp distichum* Schum. which is spineless. Two types are distinguished by the inhabitants, on fruit size independent of Jaegers's subspecies. *Solanum anguivi* easily hybridizes with the domesticated *Solanum aethiopicum*, producing another two local varieties, both semi-domesticates. One group of semi-domesticated "aubergines" is immediately recognized by its quaterny flowers - possibly a local mutation - ,all other *Solanums* have the groundnumber five. These are identified as *Solanum anomalum* Thon. Finally, leaves and sometimes fruits of *Solanum americanum* Mill (resembling *S. nigrum* L. and *S. nodiflorum* Jacq.) are regularly consumed.

in sole stand near a physical support, most often unburnt branches. Tobacco (*Nicotiana tabacum*) is planted where ashes have accumulated. Other crops, aubergine (*Solanum macrocarpum*), domesticated varieties of chilly pepers and sesame (*Sesamon indicum*) and more okra, are just planted along pathways in the field so that they can be protected and harvested with ease. All okra plants are of the "Guinéen" type (Siemonsma 1982) distinct from the international cultivars for their long vegetative period and their capacity to produce fruits during a lond period. Okra, fruits and leaves, is the most important vegetable in Taï.

All plants are seeded directly, except for tobacco which is pre-seeded in a moist area and transplanted when 3 cm high, and aubergine (*Solanum macrocarpon*) which is sometimes transplanted as well.

Planting time is not only conditioned by the rainy season, but also by the desire to stretch the period of harvest over a long period. Nevertheless vegetables should be planted not later than July.

Table 4.3. Maize varieties (*Zea maïs*) cultivated by Oubi and Guéré in the Taï area. Arranged in decreasing order of importance.

Local name *	Gloss	Miscellaneous remarks
Daloa-kpassié (O), Banpkalou (G)	"maize from Daloa" (O)	Stout plants, large cobs, introduced by Dyula.
Vinplou-okou (G)	"beard stays with me"	Styles (beard) are still visible although the cob is ripe.
Kou-ec-pkalou (G)	"calao maize"	Small narrow cobs.
Ciéglé (O)	"stay in the field"	Plant does not outgrow the rice.
Colowô-kpassié (O),	"cowrie maize"	Multicoloured, mealy grains, from Katiola,
Némé-kpalou (G)	"centipede maize"	North of Côte d'Ivoire.
Diélédjè (0), Yréyé (G)	"monkey can not see me"	Plant does not outgrow the rice.
Sak-pkalou (G)		Small narrow cobs, sweet taste, planted preferably on termite moulds.

Notes:
*O = Oubi, G = Guéré.

Crops growing with the rice in an overlapping fashion

Rice shortage is always possible, therefore cassava (*Manihot esculenta*) is planted as an adequate, though less desirable food supply. Cassava is not planted in all fields, but every household has disposal of a fair quantity of cassava plants (about 50), distributed over several fields. Most of these plants will never be harvested, but instead, eaten by animals or choked in the fallow vegetation. Local prices are low and this makes the transport of the (heavy) tubers not worthwhile. Most of the varieties identified in Oubi and Guéré agriculture are hardy cultigens which grow without any attention paid to them. The recently arrived variety "Aboré" in Oubi, or "Bonoua baha" in Guéré, enjoy a growing popularity because other, more tasty dishes can be prepared from them cultivation takes. The list of 10 cultivated varieties with characteristic features is given in Table 4.4.

Cassava is propagated by stem cuttings which have been allowed to dry out for some days. Planting of cuttings can start as soon as the early maturing rice can be harvested, from May on. A small circular place is freed from weeds. In the middle a shallow hole is made with the help of a small hoe (Fig. 4.1) and a matchet, about 50 cm in diameter. Two or three stem cuttings, 20 cm long and 2 cm diameter are placed parallel in the hole, then covered by a thin layer of soil. The distance between planting holes is at least 2 metres, this to avoid neighbours being damaged during the harvest.

Sandy soils or soils which have become "hungry" (local expression indicating that a series of short fallow periods s deteriorated the soil) are best suited for cassava cultivation. Although a difference is made between soil appropriate for rice and those best for cassava, never a fallow is cleared for cassava culture alone. Often places from which already tubers were taken are planted anew.

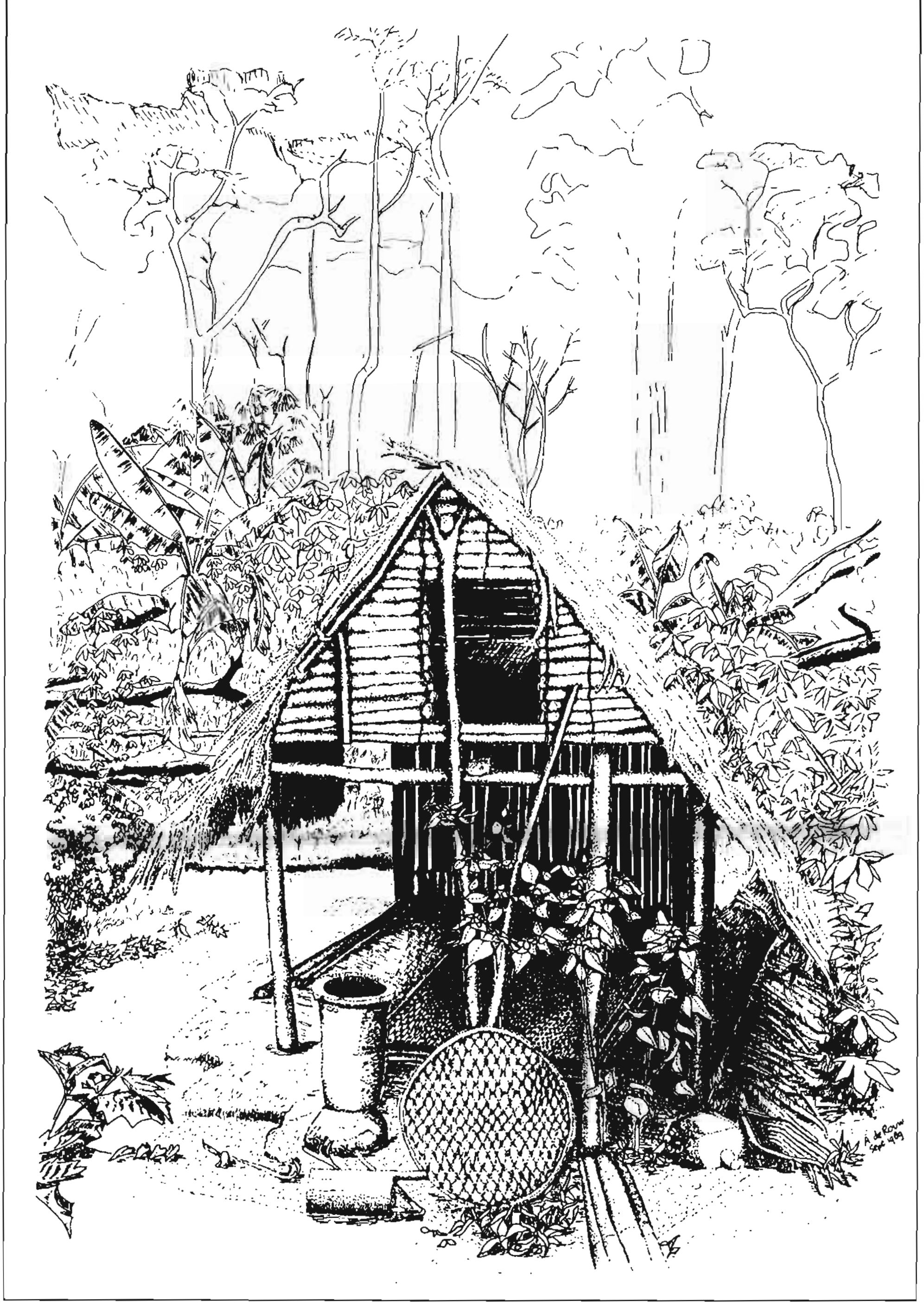
Usually not more than one or two days are spent on cassava planting.

Crops grown around the campement

The best way to introduce the widely used concept "campement" is to look at Fig. 4.2. Oubi and Guéré call all house-like structures outside the village "campements". Every two, three years structural decay of the campement requires near re-building. Campements are preferably build close to permanent water and in or very near a cultivated field. In Fig. 4.2 we see that rain water falling from the roof has caused erosion round the building. From this and from the age of the crops growing around we can conclude that the campement is probably two years old. Under the roof harvested products and planting material can be stored. In front, various utensils are exposed, making it evident that the campement is used to prepare the mid-day meal and to rest during the hottest part of the day. Typical crops planted near all campements are bananas, cassava, chillies, aubergine (*Solanum macrocarpon*), and sweet potato (*Ipomoea batatas*). Not represented in the drawing, but commonly cultivated are taro (*Xantosoma sagittifolia*), pineapple (*Ananas comosus*), and papaya. Depending on the ambition and the energy of the woman, many more crops can be planted, groundnuts (*Arachis hypogaea*), beans (*Vigna unguiculata & Phasaeolus lunatus*), sugar cane (*Saccharum officinale*) etc. Large campement which are used during many years have fruit trees besides a simple but permanent garden which receives all sorts of waste and trash.

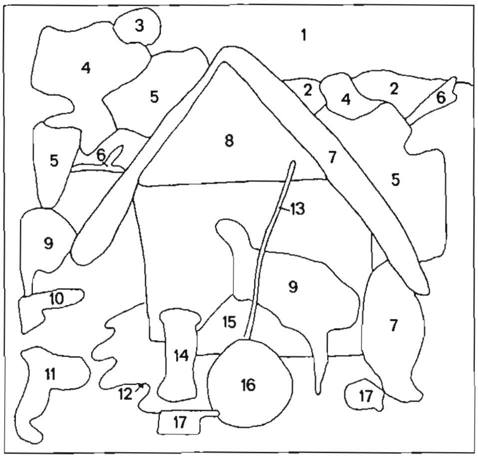
The farmer starts to look after the campement garden after she has completed the sowing of the rice. As long as a reliable succession of rain is to be expected, planting can continue, yet top months of planting all sorts of secondary crops are June-July.

Oubi and Guéré are conscious of the fact that the soil in Taï is less suitable for the cultivation of bananas than in other regions, still bananas are always planted close to a campement. Both "banane plantain" and "banane douce" are usually present. Bananas are propagated by suckers from which roots have been trimmed and leaves have been cut back. The rather large suckers, seven to ten cm in diameters are buried with the bud or eye upward, 5 to 10 cm below the soil surface. Like this the watery tissue easily


A. de Rouw
Sept 1989

survives dry spells and even some burning. Household dispose of an average of 40 banana trees which may be disseminated over several, also abandoned, campements. The same as with cassava, the majority of the 12 bananas varieties identified in Oubi and Guéré fields are very hardy trees with rather unpalatable fruits being able to persist for a long time in a forest fallow. The now common varieties are much more tasty but need more care.

Fig.4.2. Drawing of a typical Oubi (or Guéré) campement.
1 High Forest, 2. *Macaranga hurifolia* pioneer vegetation, one year old, 3, *Musanga cecropioides* pioneer tree, 4 banana trees, 5 cassava, 6 unburnt wood, 7 roof of the campement made out of *Raphia sassandrensis*, 8 under the ceiling paddy and other crops are stocked, 9 chillies, 10 sweet potatoes, 11 aubergine (*Solanum macrocapon*), 12 erosion features, 13 pestle of *Baphia* spp wood, 14 mortar made of *Nauclea diderrichii* wood, 15 rattan bed, 16 winnowing basket, 17 stool made of *Musanga cecropioides* wood.



The planting of bananas may easily take two to four days.

Bulbs of taro are often planted in somewhat shady place where is grows slowly but does not need any care. It is often mixed with a variety of other crops, notably bananas. Taro is even less appreciated as cassava, not so much because of taste but because pounding the tubers is hard work. Taro is merely grown to meet rice harvest shortfalls.

Sweet potato is propagated by stem cuttings. Most often it is planted well separated from other crops in full sunlight, occasionally it was observed mixed with cassava. There is hardly a fixed period for planting. Harvesting of leaves and tubers is continuously. Three varieties are listed in Table 4.5.

Yam (*Dioscorea alata*), always the variety Bete-bete, enjoys some popularity since the arrival of Baoulé farmers in the region. Contrary to the Baoulé way, yam is cultivated on the flat.

Sugar cane, represented by a few plants, grow almost unattended mixed with banana, taro, cassava. Stem cuttings which have dried out for some days are superficially buried in furrows.

A variety of minor crops, beans, pumpkins, groundnuts etc. may be added to the campement garden, in separate patches (Tables 4.6 and 4.5). These annuals are seeded directly without any soil preparation. Papaya seeds are simply scattered around without working the ground, on the spot where a fruit has been eaten.

In Fig. 4.3 the principal crop sequences in a field and near a campement are shown.

4.3.6 Fencing

Because goats, sheep, pigs and in some Guéré village cows, are allowed to run loose, all fields close to villages have to be protected against domestic animals. Goats venture as far as 200 m into the bush and up to 500 m if the animals can follow a well-kept path. Coarse fences

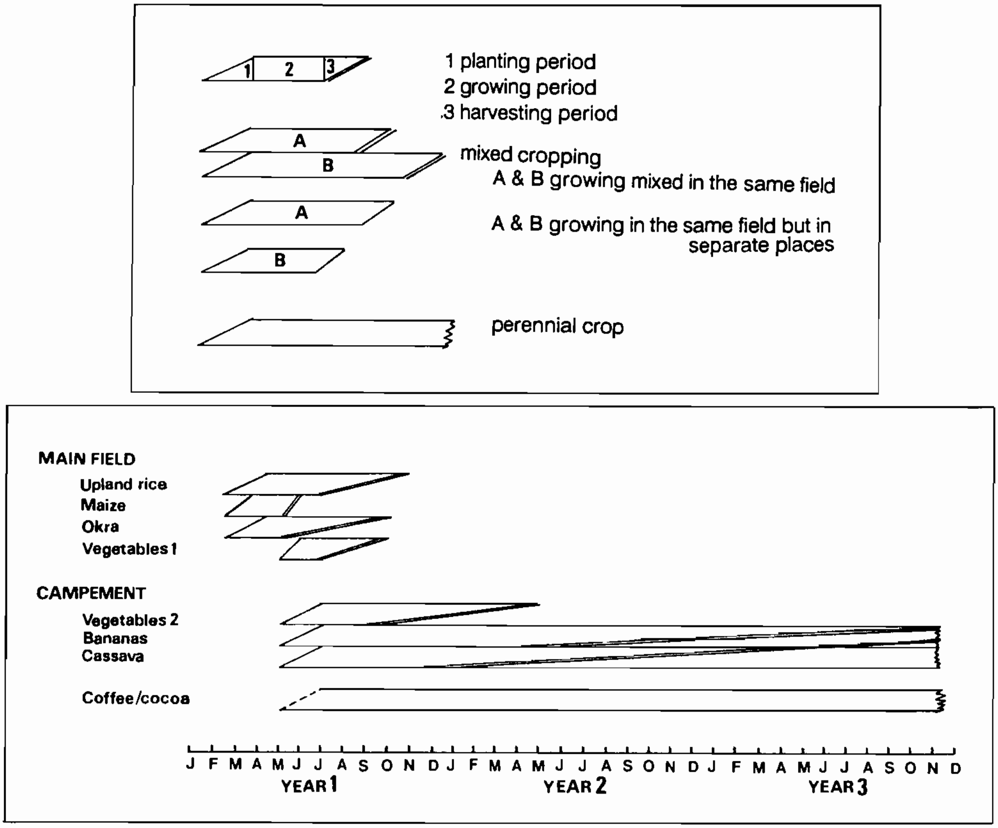


Fig. 4.3. Cropping schedules and crop combinations on main field and in campement garden of Oubi and Guéré shifting cultivators. Cocoa/coffee is volunter crop.
Vegetables 1, beans, tobacco, aubergines (*Solanum* spp), pumpkin.
Vegetables 2, chillies, aubergines, aubergines (*Solanum macrocarpon*), sweet potato.

made out of bamboo can be constructed in one or two days. Three or four horizontal bamboo rails are fastened to thin widely spaces bamboo stakes. Complete fencing is often not necessary for most fields are (partly) bordered by forest. Goats are rapidly discouraged if they have to seek their way in some sort of forest. The necessary material is cut from the village bamboo groove which usually offers a abundant supply of bamboo.

These barriers are useless against the most important animal pest at the moment, commonly called "agouti" Agoutis are rodents with the size, breeding habits and the taste of rabbits. They populate all human-modified environments in Côte d'Ivoire.

Table 4.4. Cassava varieties (*Manihot esculenta*) cultivated by Oubi and Guéré in the Taï area. Arranged in decreasing order of importance.

Local name *	Gloss	Miscellaneous remarks
Aboré (O), Bonoua-baha (G)	"cassava from Bonoua"	Selected in the region of Bonoua, near Abidjan. Introduced in Taï in 1964. Rather a small plant. In contrast with older varieties, a limited lifespan. Best for the preparation of attieké.
Koko-kparo (O), Baha-na (G)	"I do not die" "cassava of the anchestors"	Old, robust variety, perennial, used for the preparation of tapioca.
Glao-baha (G)		Old variety, commonly cultivated, tuber has white skin.
Glémé-baha (G)		Old variety, from Liberia, red stem.
Kolouyou-baha (G)	"taro-cassava"	Tuber has white skin.
Saboubly (G)		Tuber has fine white skin, difficult to ground.
Djô-baha (O,G)	"fromager-cassava"	Leafs resemble those of Ceiba pentandra.
Gbas-baha (G)		Old variety, stem zig-zag.
Oula-baha (G)	"daman-cassava"	Old variety, short stem and rounded leaflets.
Tchanmin-baha (G)		Old variety, flesh turns yellow when cooked.

Notes:
* O = Oubi; G = Guéré.

In Taï these rodents gained the reputation of a pest from 1984 onwards for all fields visited were more or less attacked. Fencing newly cleared fields was generally felt as a necessity in 1985 and after, but still many such fields stayed unprotected or were fenced to late in the season. By 1986 half of the fields in relatively densely cropped areas were fenced, but far-off fields were not enclosed.

Sometimes a type of fence is made which does not resist well to burrowing animals. It is made out of tightly woven palmleaves supported by a frame of split bamboo or pole timber. Most often a fence is constructed by firmly introducing into the ground some thousands of poles. The result is a continuous wall, 60 - 70 cm high of poles along the margin of the field which completely encloses the area. The structure is rarely strengthened by vine lashing. Unburnt wood in the field provides most of the fencing timber. Because fencing is a tedious and new task added to agriculture, a large variety of hastily fashioned substitutes can be observed, most of them ineffective to keep out rodents.

Fencing is usually done by men, the woman being occupied by planting the field. Not seldom the job is put out to Burkinabé men. Often, the work is accomplished intermittently over a relative long period. Depending on the size and amount of wood supply in a field, fencing can easily take two to three weeks work. Adjoining fields are enclosed by a single fence to save time and effort.

Table 4.5. Varieties of beans cultivated by Oubi and Guéré in the Taï area. Arranged in decreasing order of importance.

Local name *	Gloss	Miscellaneous remarks
Phaseolus lunatus		
Dirri poho (O)	"white bean"	Thick beans.
Badwee dirri (O)		Thick white and black beans.
Diou (O)		Thick white and orange beans.
Vigna unguiculata		
Dolo-nilli dirri (O)		red and white cowpea
Dirri-ko (O)	"bean-rice"	black cowpea.

Notes:
* O = Oubi; G = Guéré.

4.3.7 Guarding

Watching rice field to prevent faunal damage is an uncommon activity, although fields close to dense forest areas (bufferzone) prove to be vulnerable to destruction by buffaloes, monkeys and other animals. Elephants, since poachers killed most of them in 1980, are no longer a danger. The common practice of setting traps (snares) in the surrounding forest is primarily intended to provide meat, and only secondly considered a technique for crop protection. An exception are traps incorporated into a fence structure. The animals, mainly rodents, living inside the enclosure, are driven into the traps by a dog. Monkeys attack the rice in the milky-stage period. They operate in large bands but if one of them is shot or trapped, the rest of them will go elsewhere.

The only systematic guarding activity sometimes exerted is against birds. The first rice crop in a region which reaches maturity (milky-stage) is attacked by flocks of birds, commonly called "oiseaux gendarmes" which drink the milk directly from the stalk. The field has to be watched continuously until fields closeby are covered by an equally attractive crop. The flock breaks up and no more attention is paid to the birds. If outside labour is contracted to plant the rice, which is currently done by Burkinabé (men and women) who sow broadcast followed by a superficial tillage, more attention is paid to birds. Even if the work is done with care, some seeds remain uncovered. Birds eat not only the uncovered seeds but also, while walking on the soil surface, they dig up many other seeds and eat those too. This is one of the Oubi arguments against sowing broadcast. The field has to be guarded until the rice has two leaves.

The only scarecrows observed were rather awful looking masks hung in cocoa and coffee trees, obvious put there against humans.

Table 4.6. Sweet potato (*Ipomea batatas*) varieties of beans cultivated by Oubi and Guéré in the Taï area. Arranged in decreasing order of importance.

Local name *	Gloss	Miscellaneous remarks
Bassi pli (G)		White skin, mealy tuber, leaves with five fingers.
Tchesson bassi (G)		Tuber less mealy, yields after three months.
Zro-you bassi (G)	"brown bracelet potato"	Tuber mealy, petiole brown, leaves rounded.

Notes:
* O = Oubi; G = Guéré.

4.3.8 Weeding

Fields are weeded to keep the rice from being choked by faster-growing plants. In addition it serves to make harvesting easier. An other motive, though not expressed by every farmer is that a clean field controls a rodent population for the animals do not like to nest in exposed areas. Other women objected because clean weeding will oblige the rodents to feed on crops exclusively.

Undesirable growth is extracted in several ways. Weeds arisen from seed have still such a limited root system that they can be pulled out completely by hand. Larger plants which cannot be pulled out are controlled with a matchet. Plants resprouting from underground buds are partly uprooted. The plant may be twisted so that it is uprooted, or the plant is cut up so that the knife gets under much of the root. Stems and roots are cut close to the ground, while the blade of the matchet is kept flat and parallel to the ground surface. The uprooting of the complete plant is usually not done for the root system can be very extensive. Stump coppice shoot, developed from buds above the ground, are cut off as closed to the stem as possible. A handful of pulled-out weeds is placed on stumps or unburnt branches or any exposed area well above the ground where they may dry out. If no such place is available, accumulated weeds are thrown into the nearby forest. Cut off coppice shoots are left where they have fallen down.

A more or less systematic weeding covering most of the field starts after the rice planting is completed, but often not immediately afterwards. Most weeding is done in the second and third month after burning, and, as planting is spread over more than a month, weeding occurs in one and two months old rice. Some preliminary weeding is accomplished, this means alternating with rice planting, as coppice shoots are cut off whenever they are found. The fast growing shoots form the greatest threat to early rice growth. The field is never weeded more than once.

Weeding is entirely women's work.

The older the secondary forest and the better the cut vegetation had been burnt, the less time is needed for weeding. Weeding is always very time-consuming if a young fallow has been cleared, and, in addition, elimination of weeds should start earlier. Tree seedlings are dominant in fields made in primary forest or in old secondary growth. They are much easier to combat than herbaceous weeds. The very small seedlings are left untouched because juvenile growth of many pioneers is rather slow and is further checked by the vigour of the rice crop. An exception is the tree *Alchornea cordifolia* which grows fast and must be eliminated. Fields made in not so old secondary forest carry much more representatives of sedges and herbaceous weeds. Grasses, however, are not very numerous. This makes the field more troublesome to weed. Clean weeding is never practiced and very small weeds are left untouched. Some semi-domesticates (*Solanum* spp, *Capsicum frutescens* and others) are left to grow. Sedges (*Mariscus alternifoilius*, *Scleria* spp) are known as noxious pests and should be extracted in any stage of development. *Triumfetta rhomboidea* is a difficult broad-leave herb, and coppice growth of the woody climbers *Pyrenacantha vogeliana* (underground buds) and *Griffonia simplicifolia* (above ground buds) has to be cut back carefully.

The time spent on weeding under the Established shifting cultivation system is between 0 and 18 days.

Work, food crop care	Tool	Gender	Month	Days/ha /person
Fencing	matchet	M	April-May	14 - 21
Guarding				0 - 3
Weeding, field in secondary forest, first year of cultivation	matchet, hand	F	May	12 - 18
Weeding, field in primary forest, first year of cultivation	matchet, hand	F	May	0 - 7
Total				**14 - 49**

Attitudes towards weeding

Patches in a field particularly infested by weeds caused by insufficient burning or by previous logging activities are readily given up for weeding is not worth the trouble. Little or no weeding is done if the rice is diseased or ravaged by rodents. There is an interesting psychological aspect concerning weeding. Weeding is not done if too many weeds are already established the time planting is completed. The threshold lies about 90 weed plants per m^2 three months after burning. A greater density of weeds or the same density reached earlier in the season frustrates all weeding attempts. If more than a quarter of seedlings are sedges, no matter the density of weeds in the field, though a multitude of sedges go usually with a high number of weed plants too, no weeding is done. If the yield of paddy is expected to be below 500 or 400 kg/ha, whatever being the reason and irrespective of weeds present, weeding is no longer considered worthwhile. No weeding is done either, if number of weeds per metre three months after burning is below about 40 plants. No matter how much weeding is considered a good thing to do, women are rarely prepared to spent more than one month work on weeding. The qualification :"not much weeds so no weeding is needed" and "hopelessly invaded so weeding is no longer worthwhile", both qualifications resulting in unweeded fields, are decisions which can be taken few weeks after one another concerning the same field.

4.3.9 Other crop care

Insects

Clearing and burning eliminates most of the original forest insect population. Rapidly a new, very heterogeneous and probably very complex population is established of which not much is known yet. Densities remain low throughout the cropping period and do no substantially harm the crops (Couturier *et al.* 1984).

Of all insect attacks, post harvest losses are the worse. They occur if part of the cut off rice stays in the field awaiting transport to the village. The traditional way of storing the harvest in a smoky place above the cooking pot is a very efficient way of protecting the rice against insects (Guillaumet, Couturier & Dosso 1984).

Diseases

Rust attack on rice in known under two names "gado-ha" and "galba" (both Oubi names), but the distinction remains unclear. It occurs mainly on rice cultivated on soil that have been overworked. Nothing is done against it, its occurrence is merely a sign to leave the field. Rust is a poor-farmers disease, opposite to Green Snot commonly called "tồ" in Oubi, or Faux Charbon (caused by *Ustilaginoidea virens*[4]) is considered a rich-farmers sign. The conspicuous attacks are compared with the pustules on the face of a fat person, the pimples do not affect his well-being, nor does "tồ" influence the yield level. Losses due to Green snot are negligible, only heavily attacked ears are put aside during the harvest. A field with serious symptoms of Green snot carried nonetheless only one attacked panicle on 100 sound ears.

The fact that the disease is propagated through seed seems to be unknown by the population.

4.3.10 Harvesting

Maize

The first crop to harvest is the short cycle maize (3 months) followed by the ripening of the later variety, if such a type has been planted (4 months). Many cobs are removed before the grain has hardened, this allows the maize to be consumed immediately, grilled as a snack. Part of the maize is allowed to harden on the stalk for storing purposes or because the grains will serve to prepare maize flour. After harvesting, the maize plant is somewhat cut back or cleared away to maintain sufficient sunlight during the maturing of the rice.

Only cobs which are thoroughly dried, still enclosed in the husks, are stored. No special place is reserved for maize storage, other than the granary destined for the paddy. Anyway, by the time the rice harvest is in, much of the maize has been consumed.

Rice

Rice harvesting begins if at least one variety has fully ripened. The first to touch the new crop is the farmer herself and generally no one dares to cut any ear in the field before. The early variety in the lower section of the field is being harvested first. Harvesting is done by hand and each ear is cut off separately with a small knife, 20 or 30 cm below the lowest grain. In the other hand the cut panicles accumulate until the hand can hold no more rice. The last panicle to be added to the bunch is cut off with a much longer stem, about 70 cm. It serves to tie the rice firmly together so the bunch can be manipulated with ease. Such a bunch, or "botte" is placed on overhanging unburnt branches, stumps or any exposed place well above the ground. Unripe panicles are left to ripen more fully. Headless stems which have been reaped completely, are pressed on the base of the clump with the foot so that the whole plant is somewhat pulled over and out of the way. Some farmers say that this trampling of roots into the ground stimulates regrowth resulting in a minor, second harvest three months later, though they rarely take the trouble to

4 Dr S. Savary kindly identified the pest.

harvest them. Two varieties planted in wet places are particularly suited to ratoon cropping (Table 4.2).

A "botte" can weigh up to three kilograms. During a days work at least seven "bottes" are harvested. As much as possible of the cut panicles is transported to the village the same day, in headloads of 20 to 35 kg, depending on the strength of the woman, the distance and other commodities like vegetables, firewood etc. needed to be transported too. The "bottes" awaiting transport are put on the roof of the campement, if there is any, or left on stumps and branches, or simply piled on the ground.

Work, harvesting food crops	Tool	Gender	Month	Days/ha /person
Picking the maize ears	hand	F	May-June	1/2
Cutting back the maize plant after harvesting	matchet	F	May -June	1/2
Cutting the rice panicles; clean to rather clean field (well burnt)	small knife	F, help from M	July-Oct.	50 - 60
Cutting the rice panicles; field with much unburnt wood lying about	small knife	F, help from M	July-Oct.	60 - 70
Carrying the harvest home (depending on distance, yield)		F	July-Oct.	5 - 20
Total				**56 - 91**

The tall varieties have weak stems and have therefore a proneness to lodging. If a plant grows taller than 1.8 m, being no exception for the variety "Demande", and there is no forest regrowth, or unburnt wood, or tall weeds to support the ripe ears, all rice will fall down forming a thick layer of material. Often the plants are capable of lifting a few panicles from the ground. These are generally the only ones which are harvested. The covered grains start to rot, and at the same time, rice is carried of and eaten by animals. Lodging is not so much felt as a loss of yield for it is at the same time a sign of prosperity. Short-stem varieties are unpopular because harvesting requires a bend down position.

A staggered harvest is possible even within a single variety. The main harvest extends from July to September, if the field had been sown in March and in April. However, the current trend to plant late, as late as May and June, results in a equally late ripening of the rice, which is complicated by the onset of the small rainy season. The rice plants left standing during the first paddy cutting period, are harvested informally during the next weeks or months. They can increase the yield by 50 or 100 kg, depending on how carefully the first harvest was done.

Yields

It is very difficult to estimate average yield per hectare, or the average number of days work needed to harvest and to transport the rice because of the considerable variation in field sizes, density of rice stands, field surface remaining unused for trunks and unburnt wood lying about, the number of trees left standing, the vigour of coppice shoots etc. The total area planted is never the total area harvested due to many hazards. Because ripe rice is cut over a long period of time, this would mean repeated surveys in often remote lying fields. The visible supply in the granary after the harvest is not a reliable determination of the yield. Part of the harvest will be immediately eaten, while an unknown part will disappear with any person from outside the household, as a compensation for helping with the harvest. Three "bottes" as a harvest share for a day's effort of seven or eight "bottes" cut is generally acceptable pay. The more a harvest is plentiful, especially those early in the season, the more a farmer is obliged to share meals prepared from the new harvest and to give away part of it to visiting parents. Recognizing these difficulties a number of ways to estimate yields were elaborated (explained in chapter 1). The following estimates were derived from this method. The measurements in kilogram dry paddy refer to rice after trashing, winnowing and thorough drying; it is the dry unhusked paddy ready for storage or hulling. An average hectare of rice yields between 750 and 1000 kg of dry paddy. The actual range is very great from almost nothing to as much as 1300 kg paddy/ha. The minimum average labour needed to harvest and transport the rice to the village varies between 50 and 70 days per hectare.

Harvesting the rice is a woman's responsibility, though men may participate in the cutting of the ears. Labour from outside the household usually works against part of the daily harvest.

4.3.11 Processing

Rice

Before the new harvest can be stored or eaten a series of time-consuming and elaborate manipulations are required. Drying of the cut panicles starts as soon as possible, in the field, on the roof of the campement or in the village, on the roof of the house. If flat cemented floors are used (constructed for cocoa and coffee drying), or woven rattan mats, someone must guard the rice constantly against chickens and other domestic animals. Several days of exposure in full sunlight are necessary to dry out the rice sufficiently so it can be processed further. All rice destined for storage or for sowing seed is dried, tied up in "bottes". The rice meant for immediate consumption is released and to hasten the process of drying the loose panicles can be spread out in a thin layer on any flat exposed area in the village. After a period of drying, the part of the harvest which is to be stored, is parboiled. This means that the "bottes" are steamed and boiled for some minutes in large cooking pots. Women do this, as they say, to reduce breakage and to attain better storage qualities. A clear day in the sun is sufficient to make the thus handled "bottes" ready for storage. The most appropriate structure for this are four-posted granaries, at least 1.5 m from the ground. They are build very near the house for convenience. Underneath, the meals are prepared so all products in the granary, rice, maize, tobacco etc, are permanently smoked through.

Further processing is needed in order to ready the stored "bottes" for consumption. The rice is trashed in wooden mortars. Unwanted broken husks, stem panicles are removed by pounding with a pestle until the empty rice panicles are freed from any remaining grain. The rice is winnowed to separate unfilled grains, pieces of straw and other impurities from the developed grains. This dry, clean, unhusked rice is generally called "paddy". In this book, the thus prepared paddy, expressed in kilogram paddy per hectare, or gram paddy per metre, is the measurement for crop yield. Preparing the paddy for food involves hulling with wooded pestles in a mortar, or milling by a machine (available in some villages). Both processes remove the outer layer of the grain, leaving the white kernel. During subsequent winnowing the grain is further cleaned and the rice is ready for cooking.

The more or less formal consumption of new rice is generally celebrated. The tasty rice is eaten "pur", just with some palm oil and chillies. In the Taï region rice is destined for consumption by the own household and not for the market. Only small quantities of new rice (paddy) are sometimes sold for they make five or ten times the prize of normal rice.

If there is plenty of rice, it is the staple of every meal. The daily rate of consumption is easily half a kilogram of paddy per adult. Oubi and Guéré speak of "famine" if they run out of rice. If possible, the household will change to imported rice for cassava is associated with mourning and poverty and other tuber crops are not very tasty either.

Oil

Palm oil is part of almost all meals. The extraction of palm oil is another time-consuming work done by women. First palm nuts have to be harvested. This work is not seldom done by men The nuts have to be cleaned from the husk. Red oil, the most common type, is made from the flesh of the palm fruit. The fruits are boiled, pounded in a mortar and the fibbers strained off with water. The red oil is skimmed off and boiled and becomes a very tasty and nutritious edible oil. Occasionally a woman, or a group of women prepare a great quantity of oil in an old oil drum for selling purposes. Kernel oil is only made if the kernels can be milled in a machine. The process involves cracking of the nut residue with the hand on a stone, roasting and milling the kernels. The kernel flour added with water, has to be kneaded to drive out the oil. Finally all is boiled and the oil skimmed off.

4.3.12 Remaining plants in the field

There is a gradual transition from the cropping stage when the field is no longer weeded but still being harvested, to the early stages of regrowth. The temporary stubble field is still frequented during the following months, though the circulation inside the field becomes the more and more restricted to the pathways. Only the crops around the campement are regularly freed from regrowth. As long as the field is penetrable some of a rice ratoon crop is harvested, disseminated okra fruits with ripe seeds for planting are gathered, the usually abundant fruits of the semi-domesticates aubergines and chillies is harvested, oil palm nuts are cut off, and fire wood is collected. Some six months after the harvest of the rice only the path leading to the campement and the campement garden is kept open.

In the period in which most of the observations on subsistence agriculture were made (1978-1987) it was uncommon to recultivate a field a second year, though it was a rather widespread practice to plant extra banana suckers, root crops, tubers and even groundnuts on small patches in the rice field of the previous year. A small space, often an enlargement of the campement garden was recleared, cut back and reburnt. Before planting the crops the soil surface had to be cleaned completely with a matchet or with a small hoe (Fig. 4.1) especially if grasses had invaded the field. These subsidiary gardens are mainly considered as an insurance against need. The planter of each producing tree or other crop remains the undisputed owner of it, until it ceased to be productive or until he or she gives an other person permission to harvest it. Nevertheless, people who happen to pass a campement garden, especially those remote from a village, feel free to take a pineapple, a papaya, dig up a tuber and eat it on the spot. Only if large quantities are taken, disputes over harvesting rights arise. Many campements are protected by magical devices, as are sometimes individual trees. All bunches of firewood awaiting further transport carry property marks tied to them.

4.3.13 Changes in the system

Before coffee growing interfered with rice cultivation, the practice of the "double field" was widespread. Two rice fields were cropped in a year. A moist place is chosen, not exceeding a quarter of an hectare, covered by a young secondary forest (about six years old). Cleared in January, these small fields were cropped with short cycle rice. The crop used the residual water in the valley bottom soil. Harvest was in April. The latest recording of the practice in the Taï region dates from the fifties. The same practice, now disappeared, has been observed by the Guéré of Guiglo Toulepleu, and Man, (L. Bonnehin, pers. comm., Bognon 1988,), by the Dan of Danané (Guinard 1961).

The main rice field was located more uphill and was prepared later in the season. In former times fields were located on lower slopes and parts of valley bottoms. The study of the aerial photographies showed this. The intention to use a field not only for rice but also for a subsequent cash crop, coffee or cocoa, has prompted many farmers to fell primary forest, although the clearing of secondary forest was rather their custom. Coffee and cocoa were said to need "fresh" soils. Because of diseases, other difficulties or overoptimism not all primary forest was indeed planted with cash crops, but these intentions have determined the field locations for at least a decade. As primary forest grew scarcer, forest classified as second rate (e.g. lower slopes with layer of hardened plinthite in the topsoil) were also converted into tree crop plantations.

The growing popularity of coffee and cocoa planting among men has produced a labour bottleneck. The more a man is occupied with harvesting and processing his cash crop the less he is disposed to clear a forest for rice at the most appropriate time. A farmer in a hurry easily stints on chopping the felled trees in smaller pieces and this greatly hampers the debris to dry out. Furthermore, the period in which the vegetation is allowed to dry out is shortened and, as the rainy season sets in, the risk of a poor burning is still increased.

There are indications that the practice of campement gardening has developed over the last decade. A greater variety of crops are grown, they receive more attention, more plants are grown in a garden, and the same place is longer used. At least three factors have stimulated this type of gardening. Coffee or cocoa is now being cultivated by every household. These permanent fields have campements which are permanent too. Thus most households have one permanent campement, associated with a tree crop plantation and sometimes one non-permanent campement, associated with shifting cultivation. The opportunity to grow, especially long-term crops like fruit trees, has increased. More important is the second factor. Immigrants have introduced a wide range of new crops and new varieties of which many are well adapted for cultivation in gardens. Thirdly, immigrant women, especially Baoulé receive a substantial part of their income by cultivating, processing and marketing garden products. This example has been followed by some Oubi and Guéré farmers. Together with a growing population in Taï which is not, or only part time, engaged in farming (personal of schools, hospital, family of police, customs, National Park employees), garden product are increasingly marketed. These recently introduced varieties of other staple crops, have enriched the local "cuisine" with more tasty recipes as an alternative for rice.

Table 4.8 compiles traditional and recently introduced crops with characteristics of cropping pattern, occurrence and abundance as well as other information.

The increasing population pressure have made the preferential judgements about forest and soil less obvious. Farmers living in the larger villages, Taï, Ponan, Sakré are largely restricted in their choice. They might have little alternative other than cultivating the ground with the longest fallow.

In chapters 6 and 7 we will see that the slightest intensification of the current shifting cultivation practices, is accompanied by an explosive development of weeds. At the same time the weed population has profoundly changed into a much more aggressive one. Under these conditions the traditional attitude towards weeding becomes problematic.

Work, planting or sowing cocoa and coffee by Oubi and Guéré	Tool	Gender	Month	Days/ha /person
Making holes 40 x 40 x 40 cm and transplanting treelets from the nursery into the field	small spade	M	May-June	12 - 14
Direct seeding	planting stick	M	May-June	2 - 3

4.4. FARMING SYSTEMS WITH TREE CROPS

4.4.1 Short history of coffee and cocoa planting

It is not clear when exactly coffee (*Coffea canephora*) and cocoa (*Theobroma cacao*) were introduced into the south-west of Côte d'Ivoire, but certainly both crops were known before 1920. Cocoa arrived via Liberia and was usually cultivated because the sweet pulp of its fruits could be fermented into a fresh, lightly alcoholic beverage. The oldest, very small cocoa plantation (a "Ferreclao" site) still producing stands near the former village Diéré-oula No.1 and dates from the thirties. The economic (and demographic) map (Fig. 4.4 Bouys 1933) locates the main producing areas of cocoa and coffee and other cash crops of the south-west. The northern most plantations destined for export are situated near Grabo. There is little reason to think cocoa and coffee were being planted for export from the Taï region at that time. Coffee cropping in the Taï region started later than cocoa planting and remained at a very low level until 1954, when coffee prices were high and the production of coffee was propagated (Schwartz 1971 p.24). Holas (1957) mentioned a growing popularity for coffee among Oubi and Guéré and the existence of a small promotion and distribution centre in Keibli, a village 10 km north of Taï. He described the serious disruptions coffee planting caused in family life but failed to mention the true reason. As a matter of fact, men are always the ones contacted by extension offices because the European administrators are accustomed to the male farming systems of their home countries. Above that, inspired from that same point of view, African men were considered to have "not much to do" in regions of female farming. The men, attracted by the profit from coffee cropping, but unfamiliar with or otherwise not prepared to do agricultural work other than the usual field preparation, tried to make women work in their plantations. The women refused to work in the fields of the men, as they continue to do so, up to now, without being paid. Coffee planting was however widespread but fields were very small. The government distributed coffee seedlings (old "Robusta" varieties) free of charge and supplied subsidies during the first two years, in proportion to the surface planted (Schwartz 1971 p.24). In the Taï region old coffee trees dating from this period can still be observed in old forest fallow. World prices started to fall in 1956 and this was followed in 1960 by the withdrawal of price guarantees by the government.

New interest in coffee and cocoa farming by Oubi and Guéré farmers arose with the arrival of immigrants and with the modernization of the extension office in the late sixties and seventies. Attracted by local conditions such as abundance of forest, many immigrants, usually from savanna regions, have established themselves in the south-west to grow tree crops. Cocoa requires less work than coffee and the profit per kilogram yield is almost the same. As a result most immigrants chose cocoa. However, in the Taï region cocoa culture is hazardous, and therefore some farmers, mostly Oubi and Guéré, prefer to cultivate coffee. Most coffee and cocoa planters are men. Women, when questioned, are willing to cultivate coffee or cocoa too, but are often much too occupied with subsistence farming, domestic chores and child care.

Cocoa planting began on a large scale in 1973 as new, early yielding varieties called "Ghana" were distributed. They replaced old varieties, commonly called "Côte d'Ivoire", which produced only after 8 or 9 years. The new varieties are preferably transplanted into the field after 6 months spent in the nursery. These trees may start to produce two years after. The old varieties were seeded directly into the field.

In about the same period the coffee varieties known as "Kouilou", the oldest, and "Robusta" somewhat more recent, were replaced by more modern cultivars, locally indicated as "Satmaci".

4.4.2 Farming systems of the immigrants

In general terms, the Established shifting cultivation system, as described above, applies to the indigenous population and by comparison, are quite unlike those of immigrants. In the classification of Conclin (1957) immigrants are, in part, Incipient farmers because they are people arriving in a new area as settlers. In part they are Supplementary farmers, because all immigrants cultivate permanent crops. Only as far as they leave temporarily overworked land, they are shifting cultivators. Here we will describe the practices of the two main immigrant groups, Baoulé and Burkinabé.

4.4.3 Earlier studies

The farming system of the different immigrant groups in the south-west of Côte d'Ivoire has been studied rather thoroughly, especially by social scientists. The main feature of all immigrant farming is that cocoa planting and food cropping are tied together. Most of the agro-economic and demographic studies concentrate on land occupation patterns, income, labour and yield from cocoa (Lena *et al.* 1977, Schwartz 1979, Ruf 1984a, Lesourd 1988). The colonization of notably Baoulé cocoa farmers is generally reported as a success-story (Ruf 1984b, Lesourd 1988,). Most agro-economic analysis assume that cocoa trees produce for 25 to 30 years and take for granted that old cocoa farms can be replanted with about equal success. Budelman & Zander (1990), describing the same land-use strategy in the Taï

Table 4.8. Cultivated plant species in the Taï region, in relation to ethnic group, frequency, cropping pattern and abundance.

Crop, scientific name common local name *	Ethnic group	Occurrence per household	Planting zone and year	Quantity per household	Crop pattern and uses other than food
Abelmoschus esculentus gombo	Oubi,Guéré, Baoulé, Mossi Baoulé, Mossi	all all most	field, 1st yr. field, 1st yr. field, 2nd yr.+	> 100 plants > 100 plants > 100 plants	mixed intercropped with rice mixed intercropped with yam mixed intercropped with other food crops
Allium ascalonicum échalote	Baoulé, Mossi	some	field, 1st yr. field, 2nd yr.	10-100 plants 10-100 plants	sole stand sole stand, in field with other food crops
Amaranthus hybridus brôhon-brou (Dyula)	Mossi	some	home garden **	1-10 plants	
Anacardium occidentale noix de cajou	Baoulé	some	home garden	1-10 trees	
Ananas comosus ananas	Oubi, Guéré Baoulé, Mossi	all all	campement *** field, 2nd yr.+	10-100 plants > 100 plants	may also indicate field bounderies often indicates field bounderies, also inter-cropped with cocoa and coffee
Annona muricata corossol	Baoulé	some	home garden	1-10 trees	
Arachis hypogaea arachide	Oubi, Guéré Baoulé, Mossi	some all	field, 2nd yr. field, 2nd yr.	> 100 plants > 100 plants	sole stand, in field with other food crops sole stand, in field with other food crops
Artocarpus communis fouloutou (Oubi)	Oubi, Guéré	some	campement	1-10 trees	two varieties
Basella alba mali (Moré)	Mossi	some	home garden	10-100 plants	
Cajanus cajan pois d'Angole	Baoulé	some	home garden	1-10 plants	
Canavalia ensiformis haricot	Baoulé	some	home garden	10-100 plants	

Capsicum annuum	Oubi, Guéré	some	campement	1-10 plants	semi-domesticated varieties are favourite
piment	Baoulé, Mossi	most	home garden	10-100 plants	
Carica papaya	Oubi, Guéré	most	campement	1-10 trees	
papaye	Baoulé	most	home garden	1-10 trees	
	Baoulé, Mossi	most	field, 2nd yr.+	10-100 trees	mixed with cocoa, coffee, food crops
Cassia occidentalis	Baoulé, Mossi	most	home garden	1-10 plants	from leaves tea is made
kinkeliba (Dyula)					
Celosia argentea	Oubi	some	campement	1-10 plants	ornamental, from Liberia
Citrus aurantifolia	Oubi, Guéré	most	campement	1-10 trees	
citron	Baoulé, Mossi	most	home garden	1-10 trees	
	Baoulé	most	field, 2nd yr.+	1-10 trees	mixed with cocao, coffee
Citrus paradisi	Oubi	some	campement	1-10 trees	
pamplemousse	Baoulé, Mossi	some	home garden	1-10 trees	
Citrus limon	Oubi, Guéré	most	campement	1-10 trees	
citron	Baoulé, Mossi	most	campement	1-10 trees	
	Baoulé	some	field, 2nd yr.+	1-10 trees	mixed with cocao, coffee
Citrus reticulata	Oubi, Guéré	some	campement	1-10 trees	
mandarine	Baoulé, Mossi	some	home garden	1-10 trees	
	Baoulé	most	field, 2nd yr.+	1-10 trees	mixed with cocao, coffee
Citrus sinensis	Oubi, Guéré	some	campement	1-10 trees	
orange	Baoulé, Mossi	some	home garden	1-10 trees	
	Baoulé	most	field, 2nd yr.+	1-10 trees	mixed with cocao, coffee
Cocos nucifera	Oubi, Guéré	most	campement	1-10 trees	also in village
noix de coco	Baoulé, Mossi	most	home garden	1-10 trees	
Colocasia esculenta	Mossi	some	field, 2nd yr.+	10-100 plants	mixed with cocao, coffee, food crops
taro					
Corchorus olitorius	Oubi, Guéré	some	field, 1st yr.	> 100 plants	mixed intercropped with rice
kerolla (Baoulé)	Baoulé	some	home garden	10-100 plants	
	Mossi	most	field, 1st yr.+	> 100 plants	sole stand, in field with other food crops
Crescentia cujete	Oubi, Guéré	some	campement	1-10 trees	calabash-tree
bwitou (Oubi)					

Crotalaria sp massélébri (Moré)	Mossi	some	home garden	1-10 plants	medicinal plant from Burkina Faso
Cucurbita maxima potiron, ver (Dyula)	Mossi	some	field, 1st yr. +	10-100 plants	sole stand close to support, in field with other food crops
Cucurbita moschata potiron	Oubi, Guéré Oubi, Guéré Baoulé	some some some	field, 1st yr. campement home garden	10-100 plants 1-10 plants 1-10 plants	mixed intercropped with rice or sole stand
Cucurbita pepo potiron, mdon (Moré)	Mossi	some	home garden	10-100 plants	
Cucumeropsis edulis nvielet (Baoulé)	Baoulé	all	field, 1 st yr. +	10-100 plants	mixed with other foodcrops
Dioscorea alata igname	Baoulé Oubi, Guéré Mossi	all some most	field, 1st yr. field, 2nd yr. field, 1st yr. +	staple food 10-100 plants 10-100 plants	on moundls, principal variety 'Bete-Bete' flat, in field with other food crops on mounds, in field with other food crops
Dioscorea bulbifera igname	Oubi, Mossi	some	campement	1-10 plants	also semi-domesticated varieties
Dioscorea cayensis igname	Baoulé Oubi, Guéré	all some	field, 1st yr. campement	> 100 plants 10-100 plants	on mounds, principal variety 'Lokpa' flat
Dioscorea dumentorum igname	Baoulé	some	field, 1st yr.	10-100 plants	on mounds, principal variety 'Akolloko'
Elaeis guineensis palmier	Oubi, Guéré Oubi, Guéré Baoulé, Mossi	all some all	field, 1st yr. + campement field, 1st yr. +	10-100 trees 1-10 trees 10-100 trees	mostly semi-domesticated, also in fallow mixed with cocoa, coffee, food crops
Hibiscus sabdariffa dah (Dyula)	Mossi	some	home garden	10-100 plants	
Ipomoea batatas patate	Oubi, Guéré Mossi	most some	campement home garden	10-100 plants 10-100 plants	
Lagenaria siceraria calebasse	Baoulé	some	home garden	1-10 plants	mainly used as calabash-plant

Lycopersicon esculentum	Baoulé	all	field, 1st yr.+	10-100 plants	mixed with other food crops
tomate	Mossi	most	field, 2nd yr.	10-100 plants	mixed with other food crops
Luffa cylindrica	Oubi	some	campement	1-10 plants	also on carbage in village, used as sponge
Mangifera indica	Baoulé	all	field, 2nd yr.+	1-10 trees	mixed with cocoa, coffee
mangue	Baoulé, Mossi	all	home garden	1-10 trees	
	Oubi, Guéré	some	campement	1-10 trees	
Manihot esculenta	Oubi, Guéré	most	field, 1st yr.+	10-100 plants	relay intercropped with rice
manioc	Oubi, Guéré	all	campement	10-100 plants	
	Mossi	all	field, 1st yr.+	staple food	in field with other food crops
	Baoulé	most	field, 2nd yr.+	10-100 plants	in field with other food crops
	Baoulé	all	home garden	1-10 plants	
Musa spp	Oubi, Guéré	most	field, 1st yr.	10-100 trees	relay intercropped with rice
banane douce and	Oubi, Guéré	all	campement	1-10 trees	
banane plantain	Baoulé	most	field, 2nd yr.+	10-100 trees	in field with other food crops
	Baoulé	all	home garden	10-100 trees	
	Mossi	all	field, 1st yr.+	10-100 trees	in field with cocoa, coffee, food crops
Nicotiana tabacum	Oubi, Guéré	some	field, 1st yr.	10-100 plants	sole stand in ashes
tabac					
Ocimum gratissimum	Oubi, Guéré	some	campement	1-10 plants	leaves for skin care
vlahan (Oubi)					
Oryza glaberrima	Oubi, Guéré	some	field, 1st yr.	> 100 plants	only people who have O. sativa as taboo
kodje (Oubi)					
Oryza sativa	Oubi, Guéré	all	field, 1st yr.	staple	dibbled, principal variety 'Demandé'
riz	Mossi	some	field, 1st yr.	staple	dibbled
	Baoulé, Mossi	some	field, 1st yr.	> 100 plants	seed is broadcast, lower slope
Pennisetum typhoides	Mossi	some	field, 1st yr.+	10-100 plants	poor yield, in field with other food crops
san-njon (Dyula)					
Persea americana	Baoulé, Mossi	most	home garden	1-10 trees	
avocat	Baoulé	some	field, 2nd yr.+	1-10 trees	mixed with cocoa, coffee
	Oubi, Guéré	some	campement	1-10 trees	
Phaseolus lunatus	Oubi, Guéré	some	field, 1st yr.	10-100 plants	sole stand
haricot	Oubi, Guéré	some	campement	10-100 plants	

Psidium guajava	Baoulé	some	field, 2nd yr.+	1-10 trees	mixed with cocoa, coffee
goyave	Baoulé	some	home garden	1-10 trees	
Saccharum officinarum	Oubi, Guéré	some	campement	1-10 plants	
canne à sucre	Baoulé, Mossi	most	home garden	1-10 plants	
Sesamun indicum	Oubi	some	field, 1st yr.	10-100 plants	sole stand
sésame	Oubi	some	campement	10-100 plants	
Solanum aethiopicum	Baoulé	most	field, 1st yr.+	10-100 plants	in fields mixed with other food crops
gnangnan (Baoulé)	Oubi, Guéré	some	campement	1-10 plants	
	Mossi	most	field, 1st yr.+	10-100 plants	in field mixed with other food crops
	Mossi	some	home garden	10-100 plants	
Solanum anguivi	Oubi, Guéré	all	field, 1st yr.	10-100 plants	mostly semi-domesticated varieties
gnangnan (Baoulé)					
Solanum anomalum	Oubi, Guéré	some	field, 1st yr.	10-100 plants	mostly semi-domesticated varieties
pouleplou (Oubi)					
Solanum macrocarpon	Oubi, Guéré	most	campement	1-10 plants	
aubergine	Baoulé, Mossi	all	field, 1st yr.+	10-100 plants	
	Baoulé, Mossi	all	home garden	1-10 plants	
Sorghum bicolor	Mossi	some	field, 1st yr.	10-100 plants	only for beer, poor yield
sorgho					
Talium triangulare	Oubi	some	field, 2nd yr.	10-100 plants	also semi-domesticated varieties, sole stand
water-glin (Oubi-Liberia)	Oubi	some	campement	10-100 plants	
Tephrosia vogelii	Oubi	some	campement	1 tree	leaves are fishpoison
nrehe (Oubi)					
Trichosanthes sanguinea	Baoulé	some	home garden	1-10 plants	recently introduced from Liberia
gourge					
Vigna unguiculata	Oubi, Guéré	some	field, 1st yr.	10-100 plants	sole stand
haricot	Mossi	some	field, 2nd yr.	10-100 plants	mixed with maize
Voandzeia subterranea	Mossi	some	field, 2nd yr.	10-100 plants	sole stand in field with food crops
gloklo (Dyula)					

Xanthosoma sagittifolium	Oubi, Guéré	some	campement	1-10 plants	
taro	Baoulé, Mossi	all	field, 2nd yr.+	> 100 plants	mixed with cocoa, coffee
	Baoulé, Mossi	all	home garden	1-10 plants	
Zea mays	Oubi, Guéré	all	field, 1st yr.	> 100 plants	seeds mixed with rice seeds
maïs	Baoulé	some	field, 1st yr.+	10-100 plants	sole stand, in field with food crop
	Mossi	all	field, 1st yr.+	staple	in field with food crops
Zingiber officinale	Oubi, Guéré	most	campement	1-10 plants	mainly for beverage
gingembre	Baoulé, Mossi	most	home garden	1-10 plants	mainly for beverage

Notes

* if not French, language indicated as Dyula (vernacular), Oubi, Guéré, Baoulé or Moré (spoken by Mossi).

** housing which is used year-round.

*** housing which is not permanently used .

region, are far less optimistic. The latter study does not only incorporates soil fertility aspects and food cropping performances into the analysis of the Baoulé system, but more important, it views cocoa planting also on the long run, and demonstrate that problems are created for the future by those who seek after quick profit. In the Taï region the economic life of cocoa is much shorter as expected and replanting the square kilometres of ageing cocoa seems to be questionable. This matter has also been discussed in Guillaumet, Couturier & Dosso (1984), De Rouw (1987), Alexandre (1989b), , De Rouw, Vellema & Blokhuis (1990) and by others.

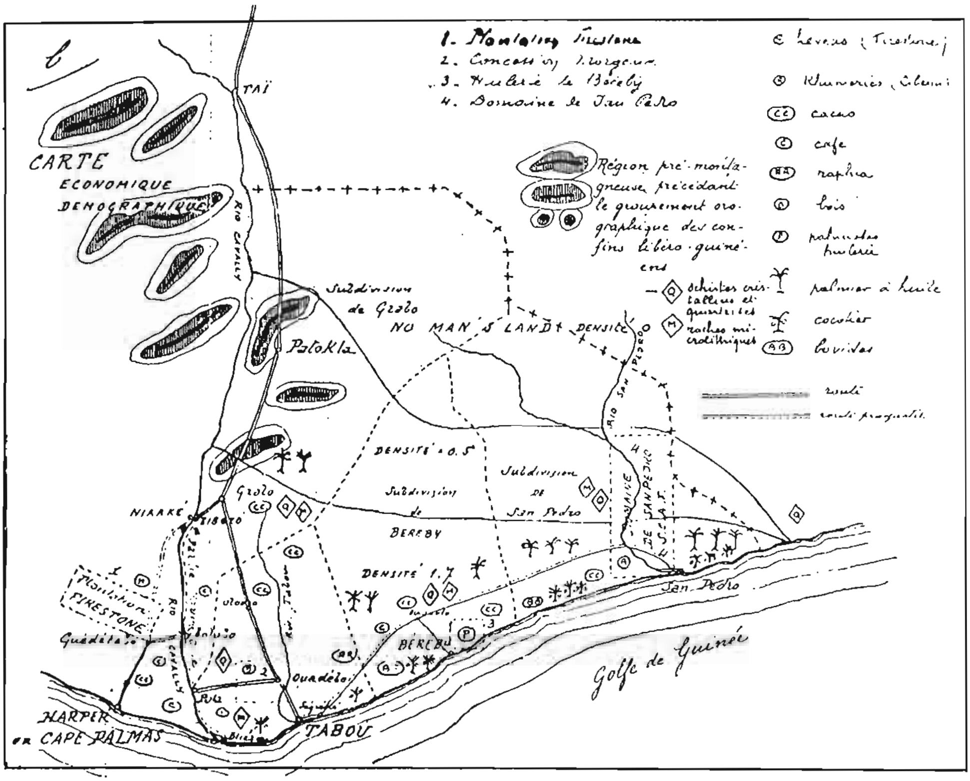


Fig. 4.4. Land use in south-west Côte d'Ivoire and population density in the thirties (Bouys 1933).

4.5 DESCRIPTION OF THE FARMING SYSTEM OF BAOULE IMMIGRANTS.

4.5.1 Arrival

The first large group of farmers to arrive in Taï were Baoulé, inhabitants of the savanna of central Côte d'Ivoire. After Ruf (1984a) a maximum of Baoulé immigrants came to Taï in 1979, rapidly levelling off the next years and ceasing after 1984. Baoulé, mostly men, arrived well prepared, alone or in two's with an average of about 100.000 CFA capital to start with. They brought their own food crop planting material (yam) for this was expensive and scarce in Taï. New arrivals stayed with family or other Baoulé friends until the immigrant had been granted a piece of forest where he could exploit for himself. He paid his host back, in labour, for the services received, and, if he is married, he asks his family to join him. Most Baoulé families live in small settlements, alone or with other Baoulé families close to their plantations. The first four years are the most difficult.

Baoulé men are mostly engaged in cocoa farming in addition to field preparation for foodcrops. Baoulé women are important traders who market an important part of the crops they grow, vegetables and fruits, on their own account. The staple crop yam is male property.

4.5.2 Site selection

A Baoulé immigrant will start with choosing the land he considers most suitable for cocoa planting, this means a soil not too swampy, not too gravelly and preferably close to a road. Most of the land he has received is under primary forest. He will expand his plantation until, eventually, every possible place has been planted and replanted by trees.

4.5.3 Land preparation

The men cut down most of the undergrowth and the smaller trees. After a period of drying out, much of this material is burnt. The remaining debris is collected and burnt in piles, packed around the bases of the larger trees to kill them . Burning is repeated until all firewood is spent. Though no tree is tolerated because of its too strong competition with the crops, some large trees enjoy a narrow escape due to lack of firewood or to a thick and watery bark (*Pycnanthus angolensis*, *Anthocleista* spp).

The period of felling coincidences with that of the Oubi and Guéré, but burning, cleaning and reburning the field continues far into the wet season and this extra work takes at least one month (per hectare). The size of the field is largely dictated by the quantity of labour available, but usually does not exceed one hectare per household per year (near Gouléako and Taï, average of 0.8 ha measured by Budelman & Zander, 1990, in Diéré-oula).

Work, planting of food crops by Baoulé immigrants	Tool	Gender	Month	Days/ha /person
Cleaning, moulding, planting the yam	matchet, hoe	M, help from F	March-May	36-56
Sowing vegetables	matchet	F	April-June	3-Jun
Planting of taro	matchet	M and F	April-June	4
Total				**44 - 66**

4.5.4 Planting, first year, food crops

The Baoulé are used to subsist on yam and they continue to do so in a forest environment, not changing much of their cultural habits (Blanc-Pamard 1979). In the topsoil, which has become bare for the disappearance of all wood lying about, moulds are made and yam is planted. In Taï, the men prepare the moulds, scraping the soil of about 1 m^2 into heaps initially 50 cm high with the help of a hoe. This working of the top soil strongly affect the soil structure and destroys much of the root mat. Moulds are arranged side by side in a way resembling a draught-board. A piece of yam tuber, about 200 gram is buried. The top is often capped by some litter, but this is only a poor protection against erosion. Usually only part of the clearing will be cropped by yam. Examples of surfaces, covered with a mixture of yam and associated crops are given by De Vries (1984): 6600 m^2 and 4550 m^2 where a secondary forest was cut, 2200 m^2 and 3500 m^2 in the case of a primary forest. In the secondary forest fields, about 300 moulds were made, and on the foot of each heap taro was planted. The primary forest fields carried about 400 moulds and no taro. Vegetables, gombo, tomato, *Cucumeropsis edulis* and a great variety of other crops, accounted for 172 and 106 plants in two the yam-taro fields, against 441 and 296 plants in the two pure yam fields. Vegetables are planted on the mould hills or in the depressions between heaps. For all the preliminary fieldwork, the planting of the yam, and the vegetables can only start in April to May. Only maize is sown at the onset of the rainy season. It takes about a month for the yam to appear above ground. By the time foodcrops constitute some sort of a cover but the soil has been lying unprotected for the greater part of the rainy season.

Raising of the yam mounds takes 12 to 28 days of labour/ha, depending on the "cleanness" of the field, plantation of taro takes an additional 4 days/ha and a same number of days can be counted for the planting of vegetables.

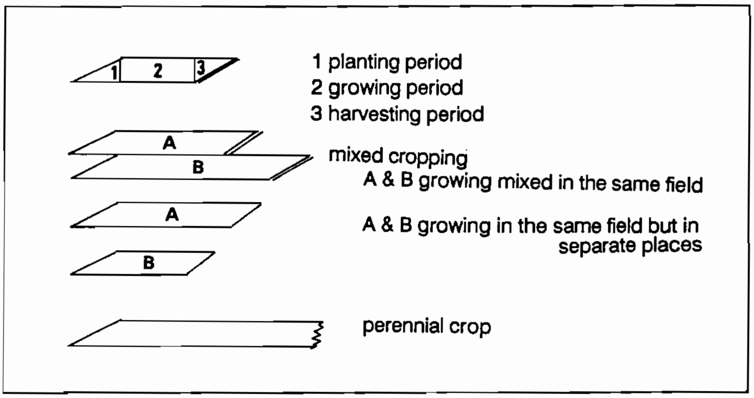
4.5.5 Planting of the cocoa, coffee, harvest food crops

Seedlings of cocoa (or coffee or a mixture of both) are planted all over the field, in densities often exceeding the 1350 per hectare advised by the extension office. A quarter of the farmers questioned by Holtland (1986) seeded directly into the field, the remainder planted treelets of about a year old. Making holes and planting the trees occupies a man for about 14 days per hectare. Bananas suckers are often planted mixed with the cocoa. In this first year the trees are favoured by two weeding rounds, in addition to a very clean start in June. The first occurs in September as a short cycle yam is harvested, the second in December as the long cycle yam is taken out. Short cycle yam, mainly the variety "Lokpa" (*Dioscorea cayensis*) is subject to rapid detoriation once harvested, thus part of the harvest is immediately replanted, but not in a field where cocoa has been planted. The remainder of the "Lokpa" yield is eaten or sold. Long cycle yam, most often the variety "Bete-bete" (*Dioscorea alata*), is more suitable for storing. The tubers are attached to a trellis most often built in the field. Depending on the extent of the cultivated area, harvesting the yam takes between 6 and 20 days, while two weeks should be added for cleaning the field (per hectare). De Vries (1984) measured yields of 75 and 60 kg of yam per 100 m^2. Budelman & Zander (1990) recorded average yields of 6 ton per field (0.8 ha) or about 1.6 kg of yam (Bete-bete) extracted per mould. We should keep in mind that 0.7 ton is needed for planting material and losses during storing may easily attain 25 per cent. Carrying the yam to places where it is consumed or sold is very hard work and usually not taken into account.

Rice is sometimes cultivated in small, swampy patches, which are too wet for cocoa. Rice is sown broadcast and lightly worked under with a hoe. It takes 4 days to sow an hectare.

4.5.6.Planting, second year and onwards

If forest, labour and money is available, a Baoulé family will spent all their energy opening up a new field the following year, and cultivating it in the same way. If the pace of extending the plantation is slowed down, some foodcrops will be planted the second year in the same field in addition to the bananas and taro plants already present in the field. The latter are often replanted as soon as a tuber is taken out. Only on the rare places where no cocoa has been planted, yam moulds can be made. Mixed with the other crops a variety of vegetables are grown, but the most important activity is replanting tree seedling everywhere one has died.



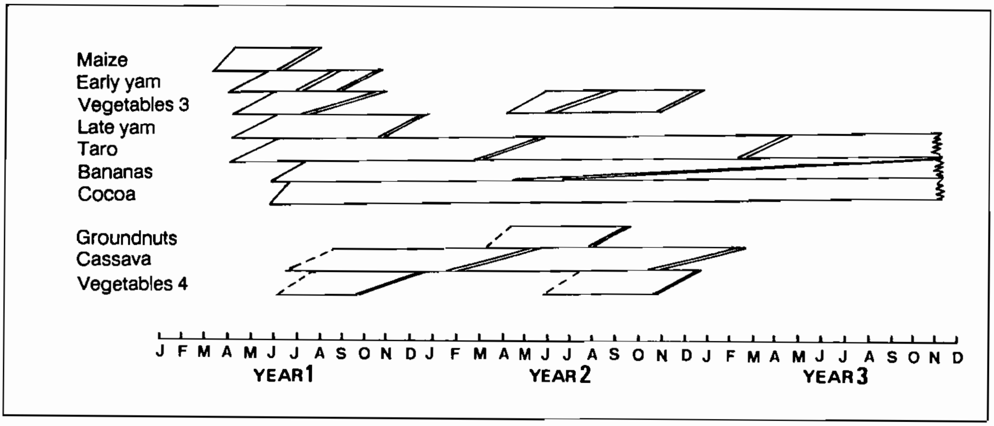


Fig. 4.5. Cropping schedule and combination of crops on main field of Baoulé farmers.
Vegetables 3, okra, tomatoes, aubergines (*Solanum spp*), *Cucumeropsis manii*.
Vegetables 4, onions, beans, aubergines (*Solanum macrocarpon*).

The third year only taro stays for it thrives in shade of the cocoa trees, with an occasional group of bananas.

Baoulé fields produce vegetables and fruits in large quantities, for subsistence and for the market. Round their habitations many fruit trees are planted, even trees from the savanna (*Nauclea latifolia*). Though the settlements of immigrants are commonly called "campements" we shall distinguish their gardens from the Oubi and Guéré campement garden by calling them "home gardens" for they are kept close to permanent habitations. Baoulé are often keen on collecting and growing unfamiliar varieties experimentally in the house gardens. Fig. 4.5 shown the crop sequence on a typical Baoulé farm.

4.6 DESCRIPTION OF THE FARMING SYSTEM OF BURKINABE AND MALINESE IMMIGRANTS

4.6.1 Arrival

Foreigners, mainly Burkinabé from the Mossi group, arrived later than the Baoulé but large groups of Mossi continued to settle in the region long after the influx of Baoulé had ceased. Throughout the study area they outnumber any other cultural group. Although usually called foreigners, they are most often long-time inhabitants of Côte d'Ivoire and have simply re-migrated into the Taï area from a more crowded region. They usually came in small groups of four or six adult men with one woman relative to prepare food and do other domestic work. Arriving without capital, they sell their labour to any farmer who needs someone to clear a forest, weed a plantation, to fence a field or to harvest coffee. If he is employed over a long period, his patron, cedes a small portion of the land to grow his own food. As soon as he disposes of a piece of forest of some extent, usually primary forest, he will sent for his family and he will start his own tree crop plantation (Lena *et al.* 1977). Burkinabé generally work very hard. The women grow and sell part of the vegetable and fruit production on the market, but usually her husband acts as her "banker" so, in contrast with Oubi, Guéré and Baoulé women, she has less possibilities of getting direct income. Many Mossi live amidst their plantations, but some large villages as Daobli, Ponan, Taï and Sakré have extended quarters entirely composed by Burkinabé.

4.6.2 Planting first year

Clearing and burning a forest is done like the Baoulé do, but Burkinabé tend to fell even less and burn even more standing trees. Rice is often the first crop, sown with a digging stick. If no rice seed is available, maize or yam is cropped, the latter only rarely on mounds. Man or woman or both plant the staple crop. After this, the woman starts weeding, while she adds vegetables and other secondary crops. Climbing vegetables and crops demanding special care (tobacco) are planted separately or near the habitations,in home garden. These are generally well developed like those of the Baoulé, and enriched with typical savanna crops and medicinal plants.

Work, clearing a primary forest by immigrants	Tool	Gender	Month	Days/ha /person
Cutting the understorey and small trees	matchet	M	Dec.-Jan.	4 - 8
Cutting the larger trees up to girth 60-100 c	matchet, axe	M	Jan.	15 - 25
Cutting the wood to pieces, burning, piling, re-burning, cleaning	matchet, axe	M	Febr.-Avril	25 - 45
Total				**44 - 78**

While the woman weeds the field and cares for the vegetables, the man makes a fence and plants seedlings, mainly cocoa from the nursery into the field, or sows the seeds directly. The first year the rice fields carried also cassava, bananas, taro, maize and aubergines in quantities of 3 to 13 individuals per 100 m^2 of each crop. Rice yields are comparable or slightly lower than those obtained by Oubi, but the reason is that here, far more crops are produced on the same surface (Dekker 1986, sample of 20 Burkinabé families).

The field is weeded at least twice, in June and in August while harvesting. Fifteen days are needed each time, but if the first round was not done for too few weeds were present, the second takes at least 25 days.

4.6.2 Planting second year and onwards

Because the Burkinabé have generally less opportunity to expand each year, (the Burkinabé in the sample of Dekker 1986 had between 1.5 and 10 ha of land) at least part of the field is cultivated with foodcrops the second year. Rice is not common because it is difficult to mix it with the cocoa trees. Maize takes its place as the main crop. Dekker (1986) measured densities to 480 plants per 100 m^2. Taro, cassava, bananas and pineapple fill up all available place. Vegetables become more and more concentrated in the home garden and dead cocoa seedlings are replaced by coffee. The field is weeded twice or three times a year.

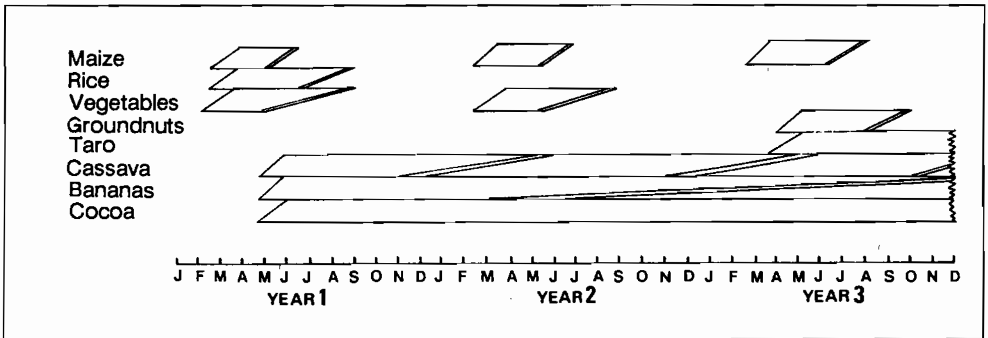


Fig. 4.6. Cropping schedule and combination of crop on main field of Burkinabé farmers. Vegetables, okra, tomatoes, aubergines (*Solanum spp*), beans.

Food cropping continues a third year if land is really scarce. Maize can be mixed with groundnuts, the latter in densities of about 400 plants per 100 m^2 (Dekker 1986) on places where cocoa or coffee has failed. Though cropping patterns vary greatly from one farmer to another, all fields cultivated for three years or more carry taro as the main crop because it tolerates the growing shade of the tree crops. Everywhere the cocoa trees had died, a mixture of cassava, bananas and other crops is grown to fill in the open space. Fig. 4.6 shows typical crop sequences on Burkinabé fields.

4.7 DIFFERENCES BETWEEN INDIGENOUS AND IMMIGRANT CULTIVATION PRACTICES CONCERNING COFFEE AND COCOA PLANTING

4.7.1 Field preparation

Most households is the Taï region, whether Oubi, Guéré or immigrants, have a cocoa or coffee farm of some extent. All groups use preferably primary forest while the tree crop is planted or seeded the first year of occupation during the harvest of the staple crop, rice, yam, or maize. Though all are cocoa or coffee farmers, forest people and immigrants differ greatly in cultivation methods, especially in the way they manage the original rain forest.

A striking feature of the immigrant planting system is the practice of clearfelling. The Oubi and Guéré on the contrary never turn to eliminate all forest trees. The land occupied by Oubi and Guéré is immediately recognized by the presence of scattered large trees, whereas the land cultivated by immigrants is either deprived of all large trees, or there are only trees left standing as dead timber. This difference in cultivation practices allowed a differentiation on the SPOT image between areas with indigenous and with immigrant farms.

A second distinction between the two systems is the degree to which the soil surface is disturbed.

4.7.2 Shade to nurse the young crop

It is a well accepted fact by both groups that shade is needed to nurse a young plantation. However, the relicts on the Oubi fields are unfit to serve this purpose. Instead, among the fast growing pioneer trees, overgrowing the rice stems after the harvest, certain species are selected, suitably spaced, to protect the coffee and cocoa. Undesirable trees as well as vines are removed. The best pioneer trees are those whose natural decline after a couple of years coincides with the crops diminishing needs for protection.

Work, coffee and cocoa crop care and harvesting by Oubi and Guéré	Tool	Gender	Month	Days/ha /person
Weeding three months after transplanting	matchet	M	Aug.-Sept.	0 - 2
Weeding six months after transplanting	matchet	M	Nov.-Dec.	5 - 18
Total first year				**5 - 20**
Weeding a coffee field while harvesting	matchet	M	Oct.-Jan.	25-50
Harvesting of the cocoa pods	matchet	M	Sept.-Jan.	5-10
Processing of the beans		M	Sept.-Jan.	20-25
Total cocoa harvest				**25-35**

The Oubi farmers suppress *Macaranga* spp because of its large spines on the trunk and the habit of gregarious growth. Removal is simple for the germination tends to be synchronous and after some weeding rounds no further germinations occur. The pioneer *Trema guineensis* is considered most appropriate in the opinion of almost all farmers. Its growth is encouraged by thinning the fallow population until the crowns of *Trema guineensis* cast a regular shade. Where *Trema* is lacking, *Musanga cecropioides* takes its place. The usual abundance of seed of *Trema* and the property of *Trema* and Musanga to overcome repeated weeding, facilitate the installation of the desired canopy. Besides, *Trema* starts to degenerate after 3 years and 5-year old die-hards are easily disposed off by girdling. A stand of *Musanga*, being a more massive tree, is more difficult to control. In general little weeding is done. There is sufficient shadow to prevent the crop being choked by heliophyle weeds but the development of the crop is probably slowed down by the vigour of the regrowth trees. A well-kept 2-year old plantation contains an average of 10 shadow trees per 100 m^2 and 8 cocoa or coffee plants, but most plantations carry more pioneer trees (Fig. 4.7 is an example of a common 2-year old cocoa field).

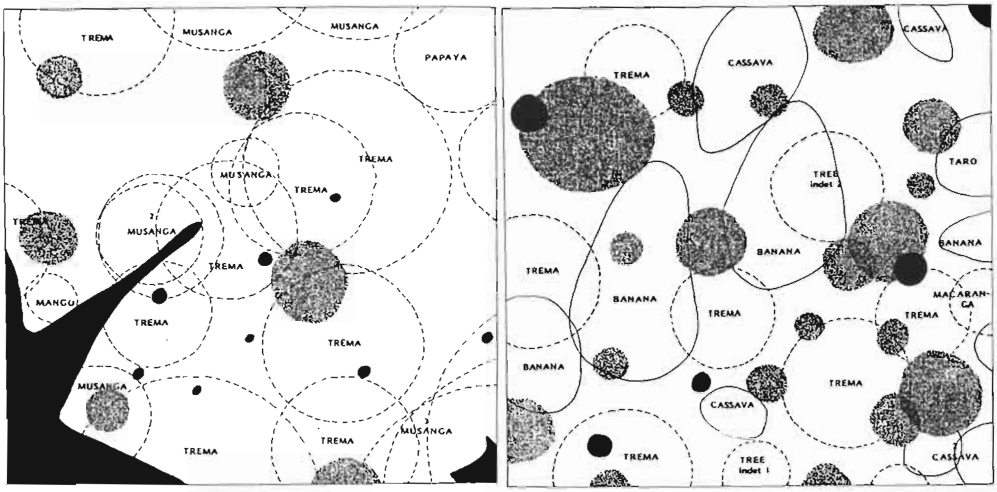


Fig. 4.7. Left : two year old cocoa plantation of Oubi farmer. Cocoa trees are between 1-2 m high, shade trees between, 6-8 m high. Perpendicular projection of cocoa trees, shade tress and dead wood. *Trema guineensis*, *Musanga cecropioides*, *Carica papaya*, *Mangifera indica*. 7x7 m.
Right : Two year old cocoa plantation of Burkinabé farmer. Cocoa trees are between 0.5 and 2 m high due to repeated by-planting. Shade trees between 1.5 and 7 m high. *Macaranga hurifolia*. 7x7 m.

The Baoulé, after the yam crop, have to cope with many heliophyl forbs, grasses and vines which have rapidly invaded the plots being rather open due to repeated burning, weeding and some soil tillage. The Burkinabé, though no yam farmers, re-burn and weed so thoroughly that most pioneer seedlings are lost too. It is no longer possible to raise fallow trees according to one's wishes. Bananas, taro and some fruit trees replace most of the pioneers. As free space is continually replanted, a young cocoa or coffee plantation may carry a double amount of crop trees: an average of 13 foodcrops and 3 fallow trees per 100 m^2 protect the crop. Fig. 4.8 is an illustration of a typical 2-year old Burkinabé plantation. It is noteworthy that nor the district market, nor the local population can possibly work up this food production, especially the quantity of taro. The surplus is left on the field. The Baoulé are liable to look upon each fallow or High Forest tree as a possible rival to the cashcrop and the young tree is disposed off as soon as the crop expresses the slightest sign of suffering. Generally, Baoulé farmers, by working hard, one or two rounds of weeding a year, successfully get rid of the weeds. Their efforts result in better and earlier yields.

4.7.3 Forest trees mixed with the adult tree crop

It is noticed by forest people and immigrants that adult coffee and cocoa trees tolerate some foreign trees among them, and that the crop may benefit from certain species. Thus after the disappearance of the pioneer trees and the food crops, seedlings of appropriate species are favoured to establish themselves. They are raised either for their proper usefulness (oilpalm, avocado, *Funtumia elastica*, Makoré[5] etc.), or to sustain the coffee and cocoa production (legume trees).

A piece of forest cleared in the Oubi way, often becomes too crowded in the period the pioneer trees nurse the tree crop. Many trees take root due to lack of attention paid to the plantation. Some plots may even resemble a fallow in the normal course of succession. *Alchornea cordifolia*, *Fagara macrophylla* (spines) and *Ficus capensis*, once established, are particularly difficult to get rid off as they regenerate by stump sprouts. The situation gets worse, when an insufficient burn has permitted an abundant development of primary forest coppice shoots. Less choice is left to install a profitable mixture of forest trees and crop. Therefore, many trees appear spontaneously and densities from 8 to 20 non-crop trees per hectare were observed.

The Baoulé and Burkinabé, having finished with the mass of vines and shrubs, are further troubled with the falling down of the dead trees. Meanwhile care is taken to select seedlings of tree species ranging from rather harmless to beneficial with respect to the crop. A rather dry site may turn a tree into a severe competitor, while the same species, growing under more humid conditions, is rendered harmless (*Coula edulis*). An exception is made for the oilpalm. Though admittedly held responsible for yield reduction, the palm is tolerated in small numbers, its products, oil, construction material and palmwine being indispensable. Sometimes useful trees (*Coula edulis*) are destroyed in order not to attract visitors.

Some mutual influence exists between Oubi and Guéré on one side and immigrants on the other. The numerous spontaneous trees in an Oubi plantation can not be felled without damaging the crop. Usually they are killed the immigrant way, by small fires lit at the base of the trunk or by girdling, thus simultaneously avoiding the development of shoots. When burning is difficult, a Baoulé may resort to felling a tree, at times hiring an Oubi to do so. Lastly, immigrants are held responsible for having introduced and spread many fruit trees, some of which are intercropped with cocoa and coffee (avocado, *Citrus* spp).

An adult Oubi plantation may carry an equal number of forest trees as a immigrant field (5 to 8), but usually the former shows a more forest-like appearance. With 600 to 1000 cash crop trees per hectare the Oubi do not reach the densities advised by the extension office of 1350 /ha. The immigrants, for their habit of filling each gap with new plants, often create to thick a stand. Fig. 4.8 gives densities of trees on a typical Oubi and Baoulé plantation.

4.7.4 Maintenance, weeding

As long as food crops other than taro are intercropped, a field of a man may receive some weeding by women tending the food crops, after that, weeding becomes men's work. A young cocoa or coffee plantation is cleared with a matchet, once or twice a year. With the trees growing older, the need to weed and the work involved, diminishes.

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5 Tieghemiella heckeli is a very large primary forest tree highly prized by Oubi and Guéré for an edible fat made out of the seeds. The tree has become rare outside the Park due to logging. The tree is sometimes planted (Bonnehin 1989).

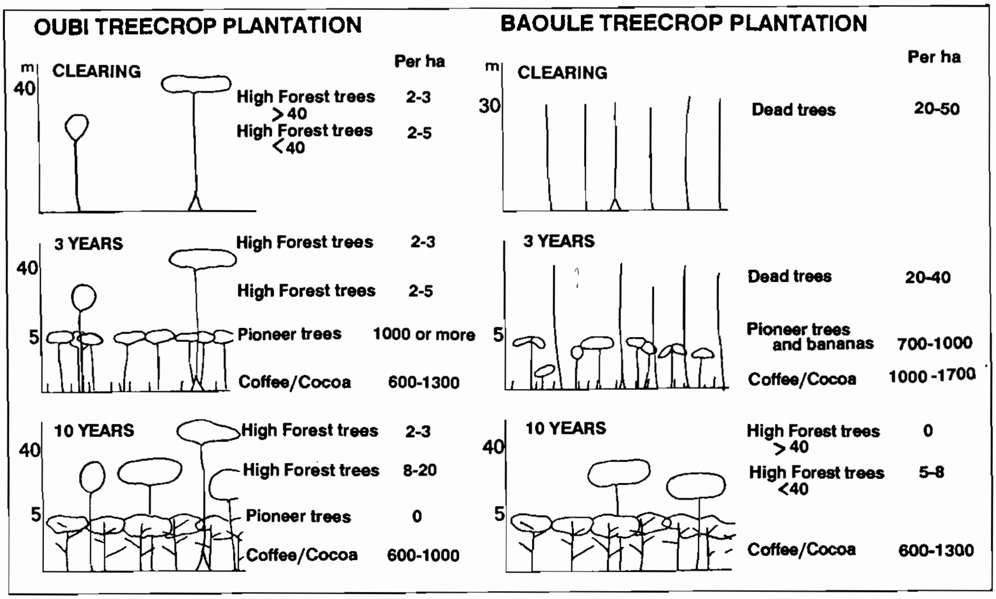


Fig. 4.8. Density of trees on a typical Oubi and Baoulé holding, after land preparation, in a young plantation, in an adult plantations.

4.7.5 Pruning, pests

Although it is recommended to cut back coffee trees almost completely every five or six years, it is rarely done. "Pruning" consist merely of removing occasional branches which are in the way. In cocoa farms, branches close to the ground are generally cut off, perhaps more to facilitate access than to improve deliberately free circulation of air and thus limiting some pests, notably "pourriture brune" caused by *Phythophthora palmivora* (Butl.) Butl.

Work, cocoa crop care and harvesting by immigrants	**Tool**	**Gender**	**Month**	**Days/ha /person**
Weeding three months after transplanting	matchet	F	August	7 - 14
Weeding in young cocoa, by-planting	matchet	M, help from F	mainly Sept.-Jan.	20 - 30
Spraying insecticides	sprayer	M		1
Pruning	matchet	M		1 - 2
Total young cocoa				**29 - 47**
Harvesting and processing the cocoa beans	matchet	M, help from F	Sept.-Jan.	30 - 45

Cocoa plants prove to be far more delicate than coffee. Plantations are therefore regularly sprayed, once or twice a year from the fourth year onward. In spite of the general practice of spraying pesticides, the die-back of young shoots, and also of complete crowns can often be observed. An evaluation of cocoa performance in the region has been given recently (De Rouw, Vellema & Blokhuis 1990).

4.7.6 Harvest, processing

Coffee harvest occurs once a year, starting in October and continuing until January. Men usually wait to weed the plantation until harvest time, so the field has to be made accessible before picking of the ripe cherries is possible at all. Later, the cherries are dried during 2-4 weeks, often spread out thinly on cemented floors in the village. All damaged and unripe cherries have to be removed and the good cherries are hulled before being sold.

Most cocoa pods are harvested between September to January, the variety "Ghana" produced some ripe fruits afterwards. Less time is spent opening up the plantation because the crowns of cocoa trees often form closed canopies, in contrary to the shrub-like coffee plants. The pods are opened and the beans ar allowed to ferment in the field, under banana leaves for three to five days. In the mean time a sweet drink is prepared from the pulp. Afterwards the beans are dried on bamboo and rattan platforms well above the ground.

4.7.7 Yield

Very little yield data come from actually measured harvests. Judging the yield from what the farmer says about his or her production is rather arbitrary. Firstly, the precise extent of the area under crop is rarely expressed. Secondly, there are strong psychological motives which determine some answers. In household (Baoulé), where all income from the members accumulate with the chief, who later will re-distribute the revenue among the different members of the household as he thinks proper, the exact volume of the profits may be kept imprecise on purpose. Households where every coffee or cocoa grower works on his own account, answers may be strongly influenced by the persons present, who could get jealous, or who, on the contrary need to be impressed. Finally, data on yield may vary according to the interviewer's own possibility of checking in the field. Therefore much of the yield data should be considered imprecise (Ruf 1984a p.71). Holtland (1986) gives average yield from 28 visited plantations : 220 kilogram of dry, hulled coffee per hectare, and 350 kilogram of dry cocoa beans per hectare.

Fig. 4.9 illustrates the development of a typical Oubi and Baoulé holding. Densities of trees are given alongside.

4.7.8 Changes in the system

A great question is what are immigrant farmers doing when they have used up all the land? All the forest given to them, or bought, is felled and attempts to plant coffee and cocoa has turned the land into a complex mozaïc of more or less successful plantations It is not unusual that farmers re-clear a 3 to 8 year old regrowth on places where cocoa had failed. These patches are small, irregular and of variable quality. The usual pattern of foodcrops is grown, but cassava, more vegetables and sometimes groundnuts take the place of bananas and taro. These patches are, however, limited too. Farmers who have got on well, may buy other forest to expand. Another possibility observed among Baoulé, is that they re-migrate to places where there still is forest and leave their plantations in the hands of a tenant.

Most immigrants, convert their land into plantations, after which more forest is needed to plant food crops. The land will inevitably be transformed into tree cropped land. Having received less forest from the start, for they arrived late, the Burkinabé have the most acute land problem. After 1986 the Burkinabé developed the habit of clearing an Oubi or Guéré rice field after the harvest to grow maize and cassava a second year. Sometimes this is done without the owners consent. They count on soft feelings with the owner who often gives part of the field for the time of one harvest. Already before 1987 a great deal of illegal felling went on. Oubi and Guéré inhabiting villages where forested land was relatively scarce and who did not watch his or her fallow or primary forest during the dry season, could be sure to loose some forest to immigrants.

In the Land Unit Survey all areas thus "saturated" could be detected with the help of the SPOT imagery. A special study was made on agricultural problems in those areas. Here cocoa plantations over 7 years were generally in a better condition than younger ones. The more recent plantations were, apparently, installed on less favourable sites. The oldest cocoa (and coffee) plantations were on upper and middle slope, on both sides of the timber extraction road that usually follows the crest. Later the lower slopes had been cleared and planted, followed by the crest. Finally, valley bottoms are planted and these youngest plantations are in a deplorable state. Food cropping within the territory has become difficult. Many degraded cocoa plantations have been abandoned and these are now covered by grasses, sedges and thicket forming weeds (*Eupatorium odoratum*), being unsuitable places for food cultivation. Some farmers will ask Oubi farmers permission to use their rice fields for food cropping at the moment they leave it. This is usually after one rice crop as the Oubi consider the land to be too heavily infested by weeds for further cultivation. However, in the opinion of the immigrant farmer, there is not yet a serious weed problem. If cultivation continues on those fields for one or two years, those areas develop into degraded thickets, similar to those in their own territory. This practice of letting the immigrants "finish off" a field worries many Oubi. In the villages Siéblo-oula and Zriglo attempts are now made (1989) to prohibit all immigrant farming on recently abandoned fields within the Oubi shifting cultivation zone. In other villages, Sakré and Poulé-oula, such decisions were already taken in 1986 and 1988 by several individual farmers.

But most forest farmers are conscious of the fact that Burkinabé farming spoils the fallow by the habit of recultivating and cleaning the ground from weeds very thoroughly with the help of a hoe.

5 Growth stages and yield components of rainfed rice

The chapters 5, 6 and 7 deal with vegetation changes during the cropping period and with interactions between the weed population and the rice crop. First we will present the rice variety used and we will analyse the performance of rice with the help of yield components. secondly the relation weeds and rice is discussed. Finally, particular aspects of the weed vegetation will be treated.

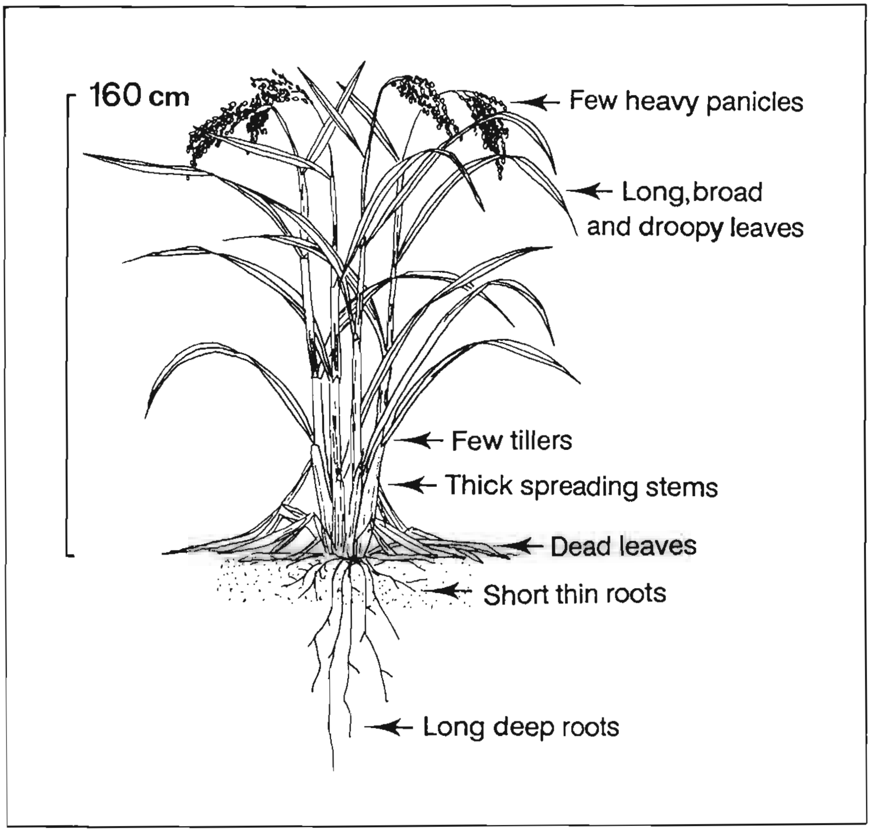


Fig. 5.1. Typical tall "traditional" rice variety (*Oryza sativa*, "Demandé"). Plant in ripening phase.

5.1 MAIN CHARACTERS OF THE RICE VARIETIES

5.1.1 The rice varieties of the Taï region

Upland rice, also called rainfed rice, pluvial rice or dryland rice is cultivated in many parts of West Africa, Latin America and south-east Asia. In many regions, locally selected so called "traditional", "unimproved" or "primitive" varieties occur. Most of these rice varieties are low yielding but well adapted to the, usually poor, environment. All current rice varieties in the Taï region would be classified as very primitive by any plant breeder.

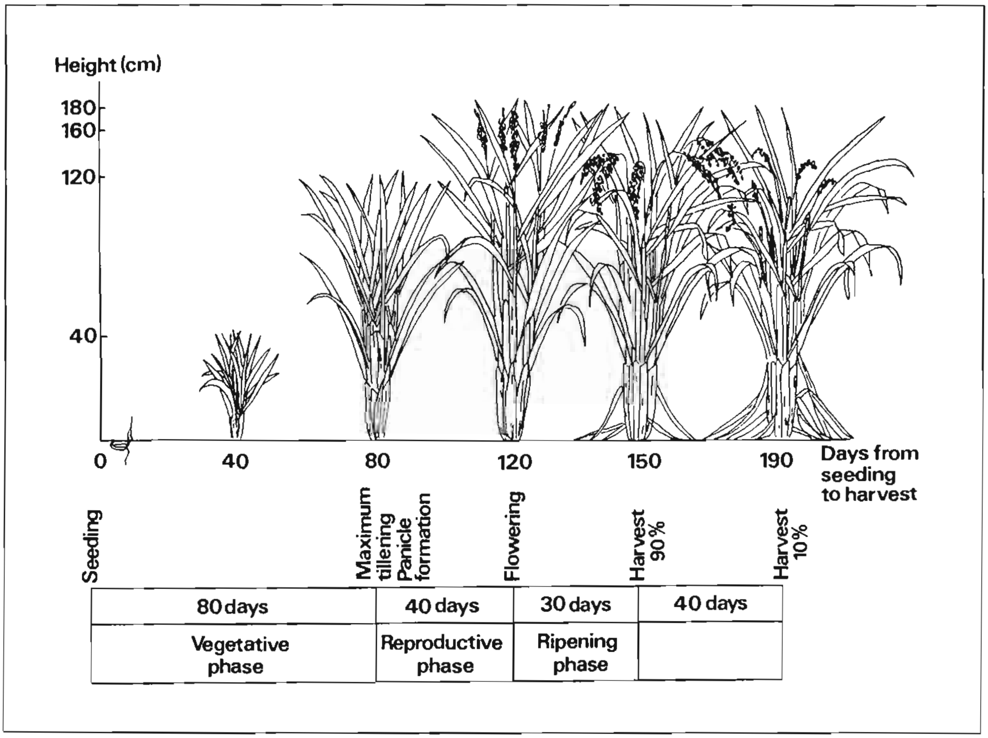


Fig. 5.2. Growth phases of the "traditional" upland variety "Demandé".

5.1.2 The most common variety: Demandé

Plant type

The rice "Demandé" is cultivated in large quantities by almost all rice farmers in the Taï area. In Fig.5.1 a rice plant is represented in the ripening phase. All other long cycle rice varieties have a similar appearance. Rice plants are tall, with broad droopy leaves. Stems are thick and resist lodging under normal management, but lodging of the crop occurs when growth conditions are exceptionally good. Few, but vigourous tillers are produced. The harvest is concentrated in a few very heavy panicles.

The plant has both short superficial roots and long thick deep roots and is fairly resistant to drought.

Growth stages

"Demandé" rice has a long life cycle because of the length of the vegetative period, being 80 days under normal circumstances but can be prolonged with up to 20 days or more under stress. After a period of maximum tillering at the end of the vegetative phase, panicle initiation starts (Fig.5.2). The end of the panicle formation period, usually called the booting stage (about 100 days after sowing), is characterized by the bulging of the leaf sheath and the farmer says the rice is "pregnant". Height is maximum during flowering, followed by a gradual decline of old leaves. At harvest time, dead leaves form a thick mulch layer. The main harvest, about 150 days after sowing, produces few and heavy panicles. The late harvest, one or two months later, gives small panicles. The latter are often considered not worth the trouble to harvest. Demandé recovers from severe stress (drought, weeds, rodents) by a prolongation of the life cycle, but instead of few heavy panicles, many light panicles are produced.

5.2 YIELD COMPONENT ANALYSIS

5.2.1 Usual model

The factors commonly taken into account are:

number of plants/m^2, number of tillers per plant, number of panicles/tiller, number of spikelets/panicle, fertility of spikelets, weight of a single grain.

A study of the different components contributing to grain yield can reveal why yields are high or low (Matsushima 1966, Forestier 1979).

5.2.2 Adapted model

Because a variable number of seeds are dibbled in one hole it is impractical to distinguish the number of tillers of an individual plant. Instead, we considered the number of dibbled holes per m^2, commonly called "hills" or "pieds" and the number of productive hills. Number of hills/m^2 are important for still another reason. As was said earlier, rice cultivation in the Taï region is orientated towards labour reduction. The number of hills per unit area is directly related to work input, hence in the cultivation system this is an important factor. Another factor, in a similar way related to labour, is number of panicles. Each panicle has to be cut off separately so the number of panicles per unit area is very important too. In fact, not the weight of the grain is considered but only the weight of the panicle. During harvest three types of panicles are distinguished:

- Panicles heavy with many ripe grains which are harvested immediately,
- Panicles with many unripe grains which will be harvested later on,
- Panicles with few unripe grains and many empty spikelets which will never be harvested.

The first two types of panicles were incorporated in the yield determination, and the number of panicles of the third type were recorded.

The yield component model used is:

Total number of hills/m^2
x Rate of productive hills
x Number of panicles/hill
x Rate of fertility of the spikelets
x Weight of the grains/fertile panicles

The main recordings are:

- total number of hills/m^2

- number of productive hills
- total number of panicles/m^2
- number of fertile panicles/m^2
- weight of grains per fertile panicle.

These recordings were supplemented with: height and ground cover of the rice plants during the different growth phases, length of the cycle, occurrences of pests and diseases, straw weight at the main harvest period, and number of rice plants/hill (some fields).

The environmental and technical factors taken into account were: climate, initial stage (length of the previous fallow period, length of the cultivation period), soil, burning, sowing technique, tillage and weeding.

5.2.3 General presentation of trials

Rice trials were conducted during four growing seasons, 1983, 1984, 1985 and 1986 in the fields of 14 local farmers. One field was studied during three successive rice cycles (Pahi 1), three fields during both the first and the second year of rice cropping (Pahi 2, 3 and Poyo 1). Six fields were studied during the first year of rice cultivation, and six years during the secend year. The common methods on all rice experimental fields has been described in chapter 1. Table 5.1 summarizes the allocation of rice trials over the different fields and years. All counting and measurements on rice were made in plots of 9 m^2, the number of such units per fields is given in Table 5.1. The performance of the rice outside the plots, notably the yield, was determined as explained in chapter 1. The actual yield of the whole field was always below that in the plots because of space occupied by unburnt wood, unburnt spots where the rice did not grow well, space occupied by other crops, and shading by remnant trees. Yields of rice fields in the neighbourhood were determined in the same manner in order to compare the yield of experimental fields with the general yield level of rice crops in the region. All experimental fields had trials on rice-weed competition, but in some fields additional trials were performed (Table 5.1).

Plot data were analysed statistically with variance analysis and simple and stepwise multivariate regression.

5.3 ANALYSIS OF THE FACTORS AFFECTING YIELD COMPONENTS

5.3.1 Climate

5.3.1.1 Rainfall

Part of the popularity of the variety "Demandé" is certainly explained by its superior resistance to drought, compared to most other rice varieties cultivated in the region (Table 4.2). This is particularly appreciated since cultivation is no longer restricted to wet places but has moved up hill as a result of tree cropping (chapter 4). Nevertheless the year of cultivation was very significantly related to yield (n=52, sign. level 0.003). Rainfall quantity and distribution was normal during the seasons 1983, 1984 and 1985, but in 1986 the small dry season in August was unusually severe and affected the rice on some fields. No yield reduction in 1986 was observed in fields sown very early (February) for the dry spells in July and August were avoided. Fields prepared in valley bottoms and those in deep clayey alluvial soils were not affected either.

The year of cultivation was significantly related to length of the cycle (n=52, sign. level 0.02). All rice fields which suffered from the dry weather in 1986 had an average growth cycle of 170 days instead of the usual 150 days. Absence of precise pluviometric data (in the period 1983 - 1986 the meteo station near the I.E.T. station did not work permanently) forces us to limit the interpretations of the results to a description of the typical response of the rice variety "Demandé" to drought. The factor water stress is further analysed in relation to gravel content in the section Soil. With relatively little water stress, growth is not delayed and grains are ripe in the appropriate period.

With severe water stress, growth stops. The rice in those fields affected by drought, were at the end of the vegetative phase. After the rains, the plants recovered by forming new tillers and leaves but the period of panicle formation had already started. The growth of the last tillers competed with the development of the panicles, resulting in weak tillers and poor panicles. Low yield was caused by a low average weight of panicles and by a high proportion of infertile spikelets. The number of panicles/m^2 was not affected.

Table 5.1. The experimental fields and the year in which the different trials were conducted.

Field name	**Years of rice trials** first year	second year	**Number of plots (units of 9 m2)**	**Trials**
Pahi 1	1983	1984 1985	12 12	biomass, height, cover of rice and weeds, type of weeds, weed plants/m2, sowing density, burning
Pahi 2	1984	1985	12	biomass, height, cover of rice and weeds, type of weed, weed plants/m2 , short fallow period
Pahi 3	1985	1986	72	height, cover of rice and weeds, type of weeds, viable seed stock in the soil before and after burning, sowing technique, soil variability along slope.
Presi		1985	6	height, cover of rice and weeds, type of weed, weed plants/m2
Poyo 1	1985	1986	4	height, cover by weeds and rice, weed type
Poyo 2	1986		4	height, cover by weeds and rice, weed type
Cavally 1		1986	4	height, cover by weeds and rice, weed type
Cavally 2	1986		2	height, cover by weeds and rice, weed type
Cavally 3	1986		2	height, cover by weeds and rice, weed type
Cavally 4	1986		2	height, cover by weeds and rice, weed type
Suzanne		1985	6	height, cover of rice and weeds, type of weed, weed plants/m2
Yai	1985		6	height, cover, of rice and weeds, type of weed, weed plants/m2
Djéa	1986		2	height, cover by weeds and rice, weed type
Josephine		1986	4	height, cover by weeds and rice, weed type
Modeste		1986	4	height, cover by weeds and rice, weed type
Helene		1986	4	height, cover by weeds and rice, weed type

5.3.1.2 Light

The importance of sunshine on rice yield is well known (Robertson 1975, Graf *et al.* 1990). The low solar radiation in August is a far more constant feature of the Taï climate than the actual drier weather in that month (Monteny 1983). Fields sown late in the season (April or

May) may suffer from lack of sunshine in a period (flowering) when photosynthesis peaks. Most of our experimental fields were sown early, in February or March so the month of low radiation corresponded with the ripening phase. Again, precise metereological measurements are lacking. Besides the climatic factor, the question of light availability is highly complicated by the variable number of large trees left in the field.

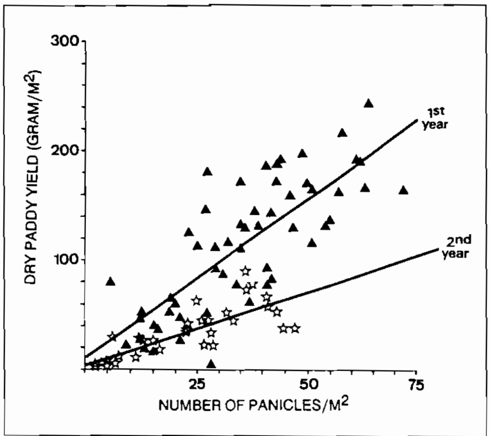


Fig. 5.3. Relation between number of panicles and paddy yield for the first and the second year of cultivation.
Triangle: first year. n = 55, $Y = 10.82 + 2.90 X$, $R^2 = 0.62$
Star: second year,n = 31, $Y = 3.13 + 1.35 X$, $R^2 = 0.63$.

5.3.2 Initial state

5.3.2.1 Duration of the fallow period

The length of the previous fallow period, ranging from 14 to 30 years, had only very little influence on yield components. It did not affect yield, number of hills and number of panicles significantly. The fact that the field had formerly been primary forest had no influence either.

5.3.2.2 Duration of cultivation period

A field being cultivated for the first year, or for a consecutive second year had an important influence on many yield components. It affected:

- Number of hills. Second year fields were seeded somewhat denser than first year fields (slightly significant, n=52, sign. level 0.028).
- Number of fertile panicles. First year fields had very significantly more fertile panicles than second year fields (n=52, sign. level 0.004).
- Weight of grains per fertile panicle. First year fields had much heavier panicles than second year fields (highly significant, n=52, sign. level <0.0001)..
- Lodging. Flattening of the rice plants occurred more in first year fields than in second year fields (very significant, n=52, sign. level 0.0078).
- Height of rice plants. Except for the first two months rice plants were taller the first growing season compared to the second year of cultivation. (highly significant, n=52, sign. level <0.0001).
- Yield. High yields were very significantly related to first year fields and low yields to second year crop (n=52, sign. level 0.0027).

The relation between number of panicles and yield for the first and for the second year of cultivation is presented in Fig.5.3. We see that yields are cut the second year to roughly half. A second year field comprises many light panicles which are not considered the trouble harvesting.

.3.3 Soil

5.3.3.1 Land variability along a toposequence

Soil features can change markedly over small distances and very different soils can be found in one field (hectare) especially if the slope is rather pronounced (Fritsch 1980). This was investigated in relation to rice performance on a upper slope to lower slope sequence. Prominent typical features were: decline of gravel content of the topsoil down the slope and changes in texture from a more clayey middle slope to coarser material down hill. The main objective of the experiment was to study a water stress-gradient by means of a gravel-gradient.

Methods

A 21 year old secondary forest was cleared and 6 blocks were laid out along the slope. Gravel content of the topsoil in the blocks (0-20 cm) was 68 %, 67 %, 63 %, 39 %, 0.12 %, and 0.10 % respectively. Simultaneously, texture of the topsoil changed gradually from upper slope (0-10 cm sandy loam, 10-20 cm clay loam) to lower slope (0-10 cm loamy sand, 10-20 cm sandy loam). All of the field was sown early, between 14 and 21 February. Under local practice only the lower part of the slope would have been sown and the very gravelly part of the field would have been planted about a month later. Generally, the more the rainy season advances, the more gravelly a soil can be planted with rice. In our trial, by seeding all of the field in the same period, we had the possibility to study the rice reaction to water stress. At the main harvest period, six random 1 m^2 samples from continuously clean-weeded plots were taken from each of the blocks.

Results

Yield was very significantly related to topographic position (n=36, sign. level 0.0009), but number of panicles/m^2 less so (sign. level 0.0146). The plots with intermediate gravel and clay content yielded most (average of 148 g dry paddy/m^2; average panicle weight 2.97 g). The plots with no gravel and the very gravelly plots had lower yields. Rice plants had two main ways of responding to stress. If yield was only slightly lower (80 %), the weight of individual panicles was slightly lower too (2.67 g). Yield reduction was due to reduced weight of panicles. If the yield was much lower (70-60 %) than panicles were few but about twice as heavy (4.17 g). Yield reduction was due to a reduced number of panicles. In the very gravelly plots the yield reduction due to a small number of

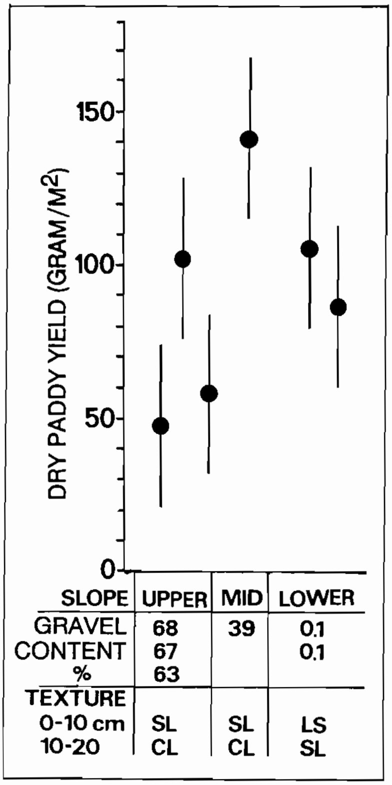
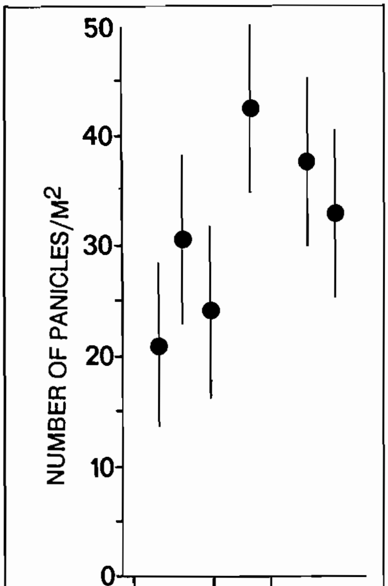


Fig. 5.4. Paddy yield of six blocks located on the same slope (field Pahi 3, first year of cultivation). Mean of six sample plots per block is indicated with a dot and 95% confidence limits with a line.

panicles was most pronounced. (Fig.5.4 and 5.5). In some cases of very low grain yield, both panicle weight and number of panicles was low. How to explain this in terms of water stress and water availability? A gravelly topsoil favours infiltration, whereas a gravelfree topsoil is subject to runoff, as was demonstrated in Taï with rainfall simulation (Collinet 1984). Slightly gravelly soils have highest clay content, while gravelfree soils are often coarser textured. Few gravel and much clay causes slightly gravelly soil to have best waterholding capacity. The superior yields on slightly gravelly soils



SLOPE	UPPER	MID	LOWER
GRAVEL CONTENT %	68 67 63	39	0.1 0.1
TEXTURE 0-10 cm	SL	SL	LS
10-20	CL	CL	SL

Fig. 5.5. Number of panicles of six blocks located on the same slope (field Pahi 3, first year of cultivation). Mean of six sample plots per block is indicated with a dot and 95% confidence limits with a line.

are partly explained by this. Because gravelly soils have less waterholding capacity, rice plants on gravelly soils are probably more readily affected by water stress. Drought during the vegetative phase due to a sandy, crusted soil or to an excessively drained gravelly soil, induces the plant to make less tillers. Number of tillers is directly related to number of panicles. In the reproductive and ripening phase, with the rainy season well advanced, the plant compensates the lack of panicles by producing very heavy panicles. Very gravelly soils have an even smaller capactiy of waterstoring. Under heavy water stress in the vegetative phase growth slows down or stops. The plant recovers by forming many weak tillers and the result is many light panicles and low total yield. The yields on the gravelfree soils are low for a variety of reasons. The sample contained lower slope soils with low clay content. These soils have the lowest natural fertility too (Table 2.1), so part of the low yield can be explained by these poor properties.

Number and weight of panicles is very important to farmers. The yield in the slightly gravelly plots was appreciated by the farmers in two ways: total yield was highest, and the concentration of the paddy in rather heavy panicles made the work, cutting them off, more productive. Some very gravelly plots were appreciated too, because paddy was in a few very heavy panicles making harvesting easy and efficient, but total yield was low. Those plots with many, rather light panicles were least appreciated, although total yield may be higher.

5.3.3.2 Topography, all fields

Considering the experimental fields which were sown in the appropriate period, we find that topographic position proves to be very significantly related to number of hills (n=52, sign. level 0.018).

spaced in lower. This could be the result of a decision of the farmer to sow less densely in very gravelly upper slope soils. It could also result from hills having disappeared due to water stress.

5.3.4 Techniques

5.3.4.1 Burning

All fields are burnt prior to cultivation. The burning is far from uniform because of the irregular patterns in which trees came down and have or have not been consumed by the fire.

Methods

The effect of initial burning on rice development and yield was tested once in field Pahi 1 (1983). Two levels of burning were compared. Shortly after the fire, normally burnt areas have charred trunks and stumps and show other visible traces of fire like black coal and white ashes. Slightly burnt areas are characterized by the absence of the above mentioned features and by the presence of twigs, branches and an occasional living leaf. Six plots (units of 9 m^2) on normally burnt places were compared with six plots on mildly burnt places.

Results

The effect of burning proved to be so obvious that the trial was not repeated in other fields. The mildly burnt places yielded only 5 to 10 per cent of the normally burnt plots where between 150 and 180 g paddy/m^2 was harvested. The number of rice seeds which germinated in a hill was greatly reduced, too. Hills in normally burnt plots had a average of 6.18 rice plants/hill (mean of 264 hills sown in 36 m^2), while hills in mildly burnt plots had an average of 3.83 rice plants/hill (mean of 233 hills sown in 36 m^2). Height was greatly reduced, the maximum was 1.20 m instead of 1.60-1.80. Only one hill out of two had ripe panicles, this in contrast with the normally burnt plots where all hills had ripe panicles. The average panicle weight was around 1g and such light panicles are never harvested. In addition, 35 % of all panicles formed was infertile, against only 4 % in the normally burnt plots.

Acid soil, lack of fertilizing ashes and absence of other beneficial effects of burning, resulted in total yield loss on those places. Quality of the burning can easily be assessed during the first month after the fire as the field is largely uncovered. The surface of the field which is unburnt or only mildly burnt can be considered wholly unproductive. In most of our experimental fields this was about 5 per cent of the surface, but fields cleared too late in the season are difficult to burn properly and 20 to 40 per cent of the field may be lost. Fields prepared in primary forest have rather high rates of unburnt or slightly burnt areas (10-30 %).

5.3.4.2 Sowing density

A farmer drops some five to ten seeds in a hole bored with a pointed stick. Spacing between holes averages around 40 cm. Density of rice plants thus depends on number of seeds buried together in a hole and number of such holes per unit area. Number of seeds per hole seems to be rather a personal characteristic of the person sowing because it remains constant whatever type of field at hand. Fig.5.6 gives an example of two women with distinct sowing habits. Number of seeded holes, (hills), per field depends largely on the proportion of soil occupied by tree trunks and partly burnt branches. Those places occupied by wood, obviously cannot be planted. As long as densities remain at a normal level - between 50 and 90 hills/9 m^2 - the number of hills per m^2 is not related to paddy yield. Generally we can say that a high number of seeds per hole not always compensates for wide spacing, nor does close spacing make up for a few seeds per hole. However, if not much weeds are present, widely spaced hills favour a profuse tillering and yields are not inferior to those sown in normal densities (40 hills/9 m^2 gave a dry paddy yield of 850 g/m^2). Narrow spacing, together with many seeds per hole, brings mutual competition and hinders the process of tillering, hence sometimes reduces yields. Number of hills or

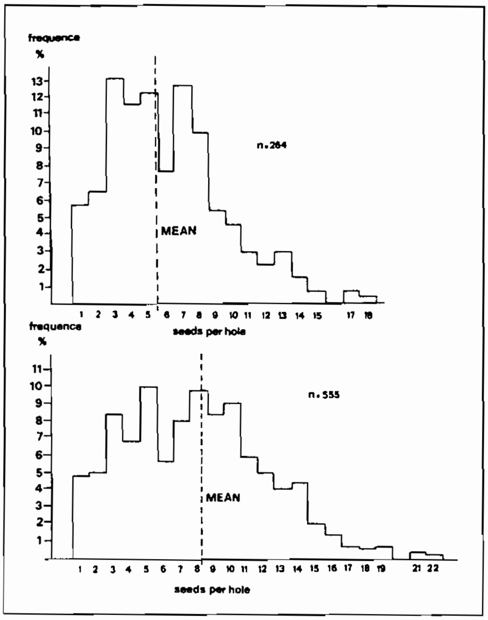


Fig. 5.6. Examples of sowing patterns of two women farmers.

number of seeds per hill was not statistically related to yield components. The number of seeds per hill does not seem to limit production.

We should bear in mind that sowing is considered the most tedious task in rice cultivation and labour is here directly proportional to number of holes. Hired labour, who does not benefit from the harvest, usually sows in lower densities than the woman farmer directly concerned. This can lead to yield reduction.

5.3.4.3 Sowing and tillage

Oubi and Guéré in the study area drop seeds in a hole, then crumble the soil on top of the seeds. The surface is not otherwise disturbed. Guéré who live further north (Guiglo), Bété living east of the Park (Soubré and Gagnoa) and Yacouba near Diéoukoué, sow rice while scraping the soil surface with a small rake, then dibble the seeds and cover them with the same instrument. This way of sowing implies that most of the soil surface is touched, though very superficially. People living still further north, the Guéré near Toulepleu (Bognon 1988) and near Man (Mouton 1959), the Dan (Guinard 1961), the Baoulé, the Kissi in Guinea (Paulme 1970 p.29) do not dibble the rice but broadcast the seeds and then work the surface with a small hoe. Now all of the surface is superficially disturbed. It is noteworthy that the lower limit of tillage is found in the wettest type of forest and that gradually going towards a drier climate, the soil is more and more disturbed.

Methods

In an experiment in field Pahi 3, first year of cultivation, these different techniques were tested:

- minimal tillage, dibbling of seeds
- dibbling with scraping the surface
- broadcasting the seeds and hoeing the surface.
- broadcasting without any disturbance of the soil.

The latter technique, though not practiced in the region, was added mainly to study weeds.

The test was conducted in 6 replications and included three weeding levels: no weeding, clean weeding, and one weeding which coincided with the weeding of the remainder of the field (between the 55 and the 75 day after sowing).

Results

The different sowing techniques varied greatly in labour required: dibbling took 140 hours per hectare; dibbling with scraping needed 200 hours per hectare; broadcasting and hoeing required 90 hours per hectare. Broadcasting the seeds took 45 kg of seed per hectare against 30 kg of seed needed for dibbling.

Effect on yield

The effect of sowing technique on yield was significant (sign. level 0.035) and this was best observed if combined with clean weeding. (Table 5.2). Broadcasted rice without tillage yielded lowest, independent of weeding. The unburied rice seeds were readily eaten by animals, mainly birds. One of the reasons why Oubi and Guéré carefully bury the rice seeds is that seeds lying on the surface attract animals, who, while eating those seeds, work the soil surface with their feet and so uncover other seeds which are inevitably eaten too. In our case it was noticed that birds could dig up seeds that were broadcasted and covered with help of a hoe too, but they could not uncover dibbled in seed.

Table 5.2. Effect of four methods of sowing on paddy yield (t/ha).

Sowing technique	Dibbling	Dibbling and scraping	Broadcast and hoeing	Broadcast and no tillage
Three weedings	1.04	1.22	1.23	0.38
One weeding	1.03	0.80	1.00	0.59
No weeding	0.73	1.17	0.82	0.73

A field sown broadcast is difficult to enter and to weed without damaging the plants. Rice sown with a digging stick grows in bunches, thus the field remains accessible.

It was probably worthwhile to weed the field. The 60 hours of extra work which cost the scraping of the soil were probably better employed by an equal amount of time spent on weeding and sowing in the conventional way. One weeding round was sufficient.

Though Oubi farmers provide arguments in favour of the common practice in Taï, the experiment did not explain why the rice shifting cultivators in a somewhat drier environment sow differently.

Influence on weeds

Cultivation is reported to bring dormant seeds nearer to the surface, hence triggering germination (Moody 1975, Whitmore 1983). Scraping and hoeing the top soil resulted in a slight increase in germination of broadleaved herbs and a slight decrease in tree seedlings. This was only noticeable during the first months after sowing. More tree seeds however, germinated during the following months in these disturbed soil surfaces so the net result was much the same. *Trema guineensis* was the only tree where scraping or hoeing the soil surface stimulated germination (doubled).

There was no noticeable difference between the various techniques regarding cover by weeds and cover by rice.

Rodents

Seeds sown broadcast were often buried to shallow and had difficulties to take root. Rodents did more damage in broadcasted rice than in dibbled.

5.3.5 Weeds infestation

Weeds are reported to limit rice production in dry land areas (Merlier 1973, Carson 1975, Kundstadter 1978, Akobundo & Fagade 1978,). Though rice is one of the food crops most thoroughly studied, only a few studies sufficiently apply to our situation and are contributing to our understanding. In fact these studies in order to be useful, should deal with:

- Upland rice cultivation where hand weeding is important;
- Weed trials in a tropical humid environment in order to have some similarities in weed flora;
- The rice cultivars used should bear some resemblance to the ones used in Taï.

5.3.5.1 Critical period

A key concept in rice versus weed research is the idea of "critical period for weed competition". This is defined as the number of days weeds are in harmful competition with the rice. The period lies between early growth during which weeds can grow in the rice field without affecting crop yield, and the point after which weed growth does no longer affects yield (Zimdahl 1980). To pinpoint the optimum weed-free period has been the aim of much research. The "critical period" was found to vary mainly according to the length of the life cycle of the rice and according to the regional weed flora. The number of days weeds can be left in competition after the rice emerges, is usually no longer than 20 days (Sharma, Singh & Friesen 1977, Nyoka 1982, Sankaran & De Datta 1985,), though 40 days has been mentioned by Carson (1975) for Ghana and 30-45 days in Sierra Leone (Sahai, Bahn & Balyan 1983). Where hand weeding is most widely used, weed control starts not later than three weeks after sowing the rice and a second weeding is needed two weeks later (Akobundo & Fagade 1978). Delaying hand weeding beyond 25 days sharply decreases yield (Sankaran & De Datta 1985). A major difference with Taï is that all rice-weed trials as far as known to the author were conducted in environments much more infested by weeds. The rice had to compete with current pan-tropical and pan-African weeds, essentially broad-leaved herbs, sedges and grasses of which many species are still absent in Taï, though they may be common in other parts of Côte d'Ivoire. Those species mentioned in literature which are present in the Taï region, occur at very low densities. Often a species is marked as dangerous in other studies but in the Taï area is not considered so. If we look at the weed population in Taï in the current shifting cultivation system, it simply cannot produce a weed crop of similar dimensions in such a short time. Another aspects which makes the weeds in Taï different, is the growth form of weeds. Weeds described in literature have scrawling growth habits with strong lateral extension and give a rapid low cover (Merlier & Montegut 1982, Jones, Mahapatra & Raymundo 1978). This in contrast with Taï where the weed vegetation is far more varied including many seedlings of tree species and a large variety of woody coppicing plants. Apart from a rather slow juvenile growth, trees grow upright and thus cover less. In weed trials elsewhere, almost all weeds are herbs and stands are very uniform comprising only a few species. Though the weeds are very different in traditional Taï shifting cultivation as compared to the usual populations described in literature, they tend to be less so if cultivation continues in the same field. In addition, the recent invasion of *Eupatorium odoratum* (1980) has doubtless worsened the situation (De Rouw 1991). But still, weeds in rice fields, for example near Abidjan, resemble far more those described in literature, as do those fields most infested in Taï.

The "critical period" is further defined by some characteristics of the rice cultivar used. Rice plants have a period during which they tiller and each tiller will produce inflorescences and eventually ripe grain. Number of tillers is strongly related to number of inflorescence and to paddy yield. If a cultivar has been selected on evenly ripening of the grains, tillers will be produced in a well-defined period and late tillers will no longer produce inflorescences. This is largely genetically controlled. During the period effective tillers are produced, the rice is highly susceptible to weed competition. If a field is weed-free during that time, the rice tillers freely, and if there are many weeds, the rice does not tiller much. This period of maximum tillering roughly covers the "critical period". The chief difference with the Taï rice varieties is that they do not seem to have been selected on evenly ripening of the grains. Tiller production is stretched over a long period which can continue beyond the harvest of the first ripe grains. Many rice varieties can produce even a ratoon-crop. It is obvious that where the period of tillering is very long, the sense of the "critical period" is changed too. A second particularity of the most important Taï rice varieties is their extremely long cycle, at least 150 days but extending considerably under unfavourable growing conditions. This in contrast with so called "long cycle" cultivars tested in literature which have usually a cycle of about 120 days. Those extra "long cycle" rice in Taï are bound to delay or stretch the "critical period", as well. Finally, rice varieties in Taï, especially the widely cropped "Demandé" can grow excessively tall, 1.80 m is no exception. In literature rice cultivars over 1.50 m are hardly considered. In short, rice-weed trials discussed in literature generally deal with improved varieties, high yielding, evenly ripening, short cycled and short statured. On all these points the locally selected varieties of Taï are very different.

To conclude, in Taï rice seeds are dibbled into the soil in an irregular pattern, whereas most rice-weed trials have rice seeds drilled in rows or, occasionally, broadcasted rice. The latter two ways of sowing allow a better control of stand densities.

Few studies consider the long cycle varieties. Moody & De Datta (1982) state that late maturing cultivars compete better because by growing longer, they have more ability for compensation for weed competition. Only one study, found until now, applies to Taï rice cultivation. Somewhat similar rice varieties, grown in Peru, were tested on their ability to resist weeds (Kawano, Gonzales & Lucena 1974). Tall, vigourous genotypes with a long growth duration (about 160 days) proved to be well adapted to extremely primitive agronomic conditions. They perform better under low Nitrogen availability, prefer wide spacing and have a high tolerance to weeds. Vegetative development, especially plant height growth is most significantly related to competition ability. No significant relation was found between tiller activity and competition, nor between tiller activity and response to spacing. Kawano, Gonzales & Lucena 1974) concluded that the evolution towards more "modern" cultivars should be accompanied by the evolution of cultural methods, including fertilizers. Shorter cycle and shorter stature etc. implies a loss in weed tolerance and a less good competition for Nitrogen, but the possibility of higher yields.

It should be evident that the particular weed flora and rice varieties in Taï need a series of preliminary trials in order to know them better, before something can be said about critical period or a comparison can be made with trials elsewhere.

5.3.5.2 Cover by weeds

In the following trial an attempt was made to determine at what period the rice crop is particularly susceptible to weeds

Methods

In field Pahi 3, during the first year of cultivation, 48 permanent plots of 4 m^2 were laid out. Cover of weeds was estimated in the plots 25 days, 55 days, 80 days and 120 days after sowing. Paddy dry grain weight was determined 165 days after sowing by taking a sample of 1 m^2 rice in each plot. Weeding took place, inside and outside these plots on the farmer's own initiative. She spent 12 days work (per hectare), between 55 and 75 days after sowing).

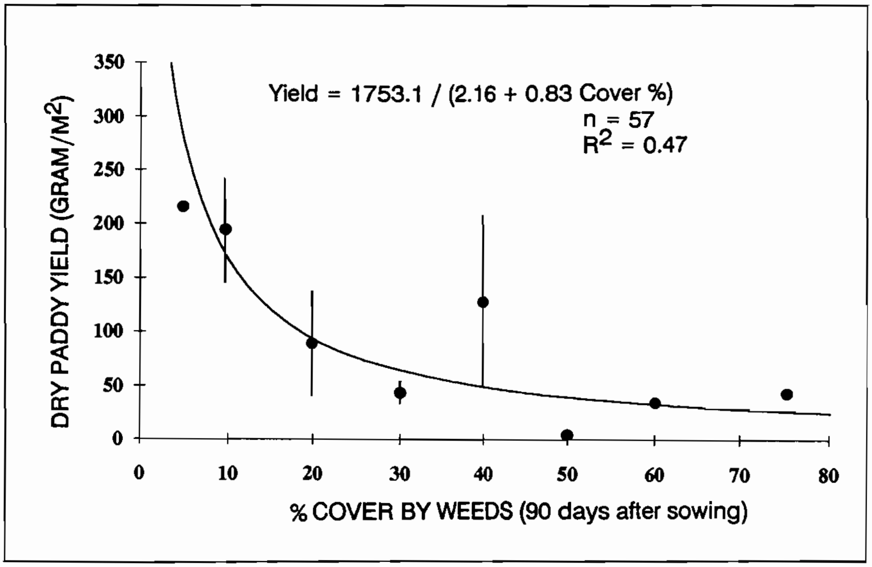


Fig. 5.7. Paddy yield *versus* cover by weeds, three months after sowing, first year of cultivation.

Results

Cover by weeds, 25, 55 and 120 days after sowing had no relation or a very weak relation with yield components. Cover by weeds 80 days after sowing showed a rather strong relationship, notably with yield. Places where weed covered 30 per cent or more stayed under 70 g paddy/m^2. Places with 10 per cent weed cover yielded well above average. Most samples had around 20 per cent

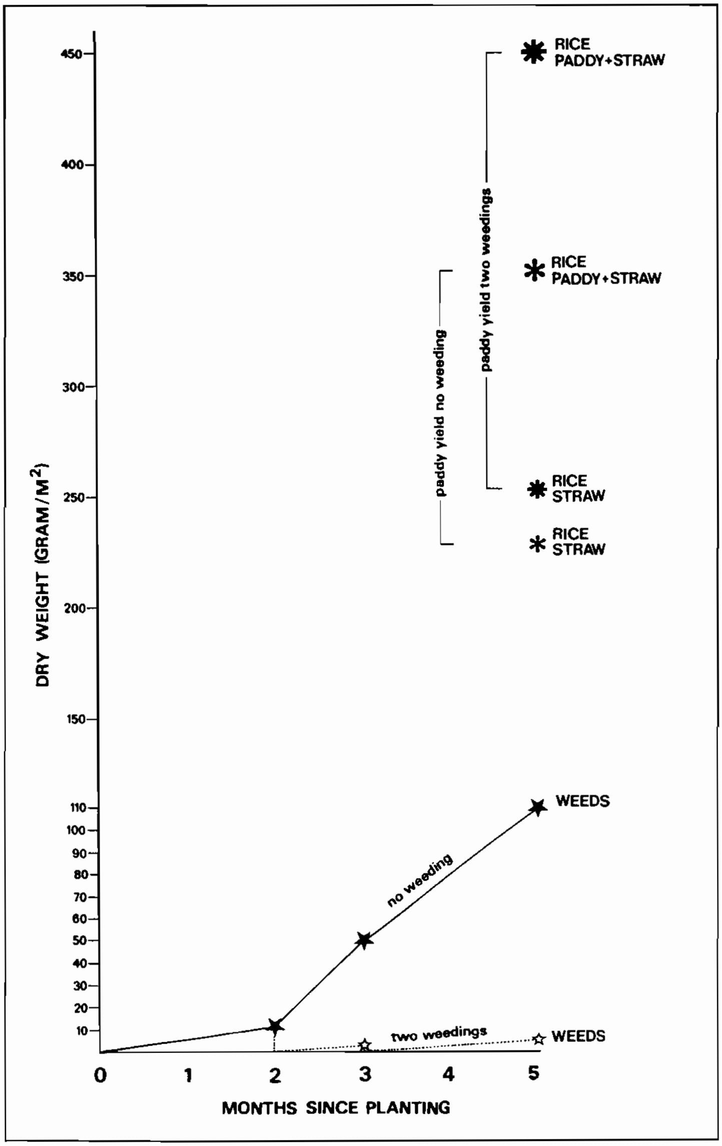


Fig. 5.8. First year of cultivation. Dry weight of biomass produced by rice plants (paddy and straw) and by weeds. Plots having received no weeding and plots which were weeded twice.

weed cover 80 days after sowing and here paddy yield could be either high or low (Fig.5.7). We concluded that weeding should be done before the 80th day and should start shortly after the 55th after sowing. Weeding as it was done by the farmer had probably been in the correct period but it had not been enough. An experiment in the same field, the same year, demonstrated that one weeding round had increased yield to 1.03 t/ha, whereas no weeding gave 0.73 t/ha (Table 5.2). If the farmer would have spent more time on weeding, she had a chance of increasing the general level of the field to 0.9 t/ha of dry paddy.

Though the farmer recognized that weed infestation was such that extra weeding would have increased yield, she did not weed more. This was justified by the following argument. More weeding would have been worthwhile if the field would have been better shielded from "agouti" pest. The field was enclosed by a fence with traps incorporated into it. Inside the fence a fair amount of rodents lived. The farmer however strongly preferred to keep the rodents inside the enclosure in order to kill one or two of them each day and this continued during 26 days. "Harvesting" the animals took a few minutes per day. A dog chased the agoutis until they ran into one of the traps. Extra weeding in this case would have enlarged the agouti damage because the weeds in the field avoided that the animals fed on rice exclusively.

So we should judge this rather poor weed management in a wider perspective. The field yielded not only paddy but also some maize (outside the plots), vegetables and ...meat. The allocation of working hours (productivity), in this particular case, had been advantageous.

Weed cover, all fields

Considering the results from other fields cultivated the first year, it is evident that the weed cover two months after sowing does not affect yield components significantly. Three months after sowing, the influence of weed cover was considerable, (Fig.5.7) as shall be explained in the next section. Five months after sowing the relation with yield components was again weak.

Weed height

Weed height, whether two, three or five months after sowing did not affect yield components.

5.3.5.3 Competition: biomass of weeds and rice plants

Weed competition is often studied by means of biomass production of rice and weeds as they grow together during a certain period. Generally, data with heavy and data with light weed infestations are compared. If the rice produces far more biomass with few weeds present than it does with more weeds, than competition by weeds is imminent. Next, we can study how the extra biomass produced without weeds has been "used". Has it resulted in more paddy yield or merely more vegetative growth?

Methods

In field Pahi 1, during the first and the second year of cultivation dry weight of weeds was determined from permanent plots (six units of 9 m^2), two, three and five months after sowing. Dry weight of rice plants was determined at harvest time, five months after sowing. Three weeding levels were tested: one weeding, two weedings and no weeding. There were two replications.

Results

The first year of cultivation standing biomass (dry weight) in the unweeded plot at the end of the season consisted of 110 g/m^2 of weeds, and 360 g/m^2 of rice plants (Fig.5.8). 36 per cent of the plants dry weight is paddy and this would have given a yield of 1.3 ton per ha. The difference between one weeding round and two weeding rounds was slight, so in Fig.5.8 only the results of the plots weeded twice are represented. At harvest time the weeded plots carried 6 g/m^2 dry weight of weeds and 450 g/m^2 dry weight

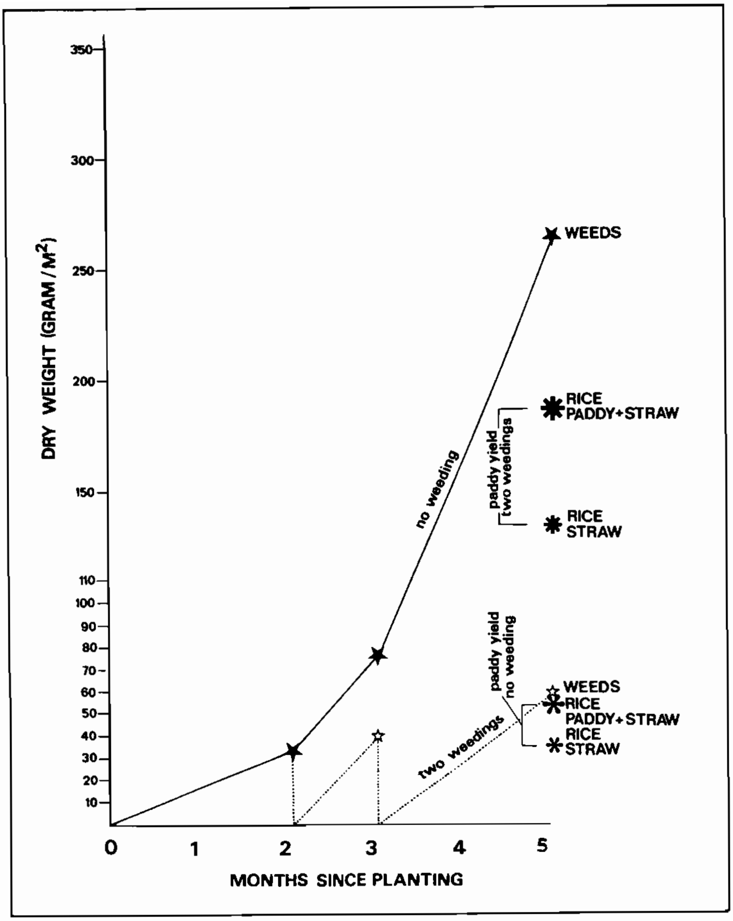


Fig. 5.9. Second year of cultivation. Dry weight of biomass producted by rice plantes (paddy and straw) and by weeds. Plots having received no weeding and plots which were weeded twice.

of rice. Now 43 per cent of the plants dry weight consisted of paddy, which corresponds to a yield of almost 2 t/ha.

These results give the impression that absence of weeds increases paddy yield. The difference between weed biomass produced in weeded and unweeded plots is about 100 g/m^2. The difference in rice biomass produced in weeded and unweeded plots is almost 100 g/m^2 as well. So the net production of biomass produced during the season (rice + weeds) is almost the same, independent of weeding. We can see that the extra biomass the rice produces in weeded plots is very well used: it greatly increases yield.

The experiment was repeated the following year on the same plots. The results are presented in Fig.5.9. In the unweeded plots rice plants produced about 50 g dry weight/m^2 and this included 15 g dry paddy. This corresponds to a yield of about 0.15 t/ha.

Weeds produced more than five times as much biomass if they were allowed to develop freely. 28 per cent of dry weight were from grasses. Grasses were absent the first year. The plots that were weeded once (three months after sowing) showed a comparable allocation of biomass over rice and weeds and yield was equally poor. But also in the plots weeded twice crop condition could hardly be considered satisfactory. Although 180g dry weight was produced, only 25 per cent was stored in dry paddy, this being comparable to 0.45 t/ha.

If we compare the quantity of weeds in the unweeded plots during the first year of cultivation with the amount of weeds in the weeded plots during the second year of cultivation, we observe that in both cases levels of weed infestation are about the same if we limit ourselves to the "critical period" two to three months after sowing. Yet the performance of the rice is very different. With about the same amount of weed biomass present two and three months after sowing, the rice produces 0.8 t/ha more than in the first year of cultivation. We are inclined to think the declining soil fertility is an important constraint in the second cropping year.

The experiment was repeated in the same field, (Pahi 1) during the first year of cultivation on spots which had been burned only slightly. The biomass produced by weeds in the weeded and in the unweeded plots was very similar to the biomass on normally burned places. Yet the rice crop grew very poorly, stayed below 1.1 m high and yield was around 0.1 t/ha. Here too, soil fertility is likely to be the chief factor because slightly burned places lack the fertilizing input of ashes and soils are more acid.

The same experiment was performed in field Pahi 2 during the first year of cultivation. The field's last fallow period had been short (6 years) in contrast to those of field Pahi 1 and 3 where fallow had been of normal length (19 and 21 years). As a result of rodents no reliable rice biomass data could be gathered. Weeds were far less affected. The dry weight produced by weeds 5 months after sowing was 300 g/m^2 in unweeded plots and 65 g/m^2 in weeded plots. The dry weight production by weeds proved as high as in Pahi 1 during the second year of cultivation. This was mainly due to the short fallow period which caused many weed seeds to survive in the soil.

It is very likely that biomass production by weeds is much higher nowadays for the invasion and firm establishment of *Eupatorium odoratum* has occurred since.

5.3.5.4 Compensation

During the first year of cultivation weed infestation stays at such a low level that the difference in yield between plots weeded once and plots weeded twice is not perceptible. Fig.5.8 demonstrates that once weeds are eliminated two months after sowing, hardly any new ones appear. Why do farmers not weed after two months (about 10g dry weight biomass/m^2), but after three months (about 50g dry weight biomass/m^2, which means more work)?

In Table 5.3 the results of a rice-weed trial are represented, conducted the first year of cultivation (Pahi 1). We present the results of only three plots although the same phenomenon has been observed on other occasions too. In these three plots (A1, A2, A3), growth conditions were better controlled which allowed to draw some interesting conclusions. The three plots lay adjacent, so on the same type of soil. Number of hills in the plots is almost the same. The rice had grown free of pests and diseases. The only difference was a difference in weed management, as indicated in the Table 5.3. The data in the Table demonstrate what happens at low levels of weed infestation. The more weeding is done, the more panicles are formed and inversely, the more weeds are present, the less panicles are produced.

If weed infestation stays at a very low level (A2), panicles are heavier and total yield is high. If weed infestation is somewhat more important (A3), panicles are lighter and total yield suffers from this.

Table 5.3. Number of hills, dry paddy yield, number of panicles and level of weed infestation under different types of weed management (plots of 9 m^2), first year of cultivation.

Treatment (A1, A2, A3)	Number of hills	Dry paddy yield	Number of panicles	Level of weed infestation (5 months after sowing)
Weeding 2 and 3 months after sowing	67	1776	440	density : 20 plants/m2 cover 5 %
Weeding 3 months after sowing	67	1690	390	density : 25 plants/m2 cover 10 %
No weeding	72	1162	324	density : 65 plants/m2 cover 40 %

The number of tillers determines the number of panicles. If during the vegetative phase weeds are present, less tillers are formed and subsequently less panicles. If weeds are left untouched, they will continue to compete with the rice, mainly for nutrients as was explained above. Yield is lower as panicles are both few and light (A3). If weeds are removed two months after sowing, weeds are so few that the rice plants can tiller up to a maximum. Yields are high due to a large number of panicles of average weight (A1). If weeds are left to grow up to three months, this means throughout the vegetative period, then competition with weeds reduces tillering and number of panicles. Subsequent removal of weeds at the onset of the reproductive period, induces the rice plants to compensate the small number of panicles by making them heavier (A2). The number of spikelets per panicle is determined at the panicle formation stage (Fig.5.2). The rice, free from competition, is able to form a large number of flowers. A second opportunity of compensation occurs half way the reproductive phase, at the moment of reduction division. A weed free environment allows the grain envelope to be large.

Apparently, the harm caused by weeds is limited. We could even say that farmers use weeds to reduce work. They tolerate a modest quantity of weeds during the period of tillering, which reduces the number of panicles. One weeding at the onset of the reproductive phase, permits the compensation. The work of harvesting is reduced but not the yield.

However, comparing plots weeded once with those weeded twice (which can be considered as clean-weeded), an important question remains. Why are the rice plants grown without weeds (A1) not capable of producing panicles as heavy as those produced by plants under light weed stress during the vegetative period?

It is a question of economics and merely of economics of products of assimilation. It is easier for a rice plant to develop a certain number of spikelets located in one panicle than the same number of spikelets distributed over many panicles, as it is easier to fill the grains in the same panicle than a similar number of grains distributed over many panicles, and it takes less effort to fill one large grain than two small ones. This concept of economy is part of the theory of Sources and Sinks (Munch 1930). Rice plants growing without weeds tiller profusely, which means that a large number of Sinks is produced. During later stages of development, the plant has difficulties filling all these Sinks appropriately, hence panicles of average weight. A light weed stress during the vegetative period limits tillering and thus reduces the number of Sinks. This small number of Sinks is easily filled, hence heavy panicles and a sometimes superior total yield.

We are inclined to think that conditions of upland rice cultivation, in spite of the relative good circumstances - long forest fallow period, first year of cultivation, good burn - are nevertheless often marginal. Not because of weeds, for they are easily controlled, but because of nutrients. Late weeding can be interpreted as a manipulation of the nutrient capital. The small amount of food available is directed to places of optimal use.

As we have seen in section 5.3.3.1 on gravelly soils, moderate water stress during the period of tillering produces the same effect. Light stress can be induced by early sowing, by a very gravelly soil or by too many seeds sown in the same hill. Provided light stress is limited to the vegetative phase, compensation can take place and yields do not suffer.

During the second year of cultivation or during the first year of cultivation but after a short fallow period (less than 6 years), no such manipulation of weed population is possible. One reason is that weeds appear in such large numbers already during the first month of rice development, that tillering is greatly reduced.

5.3.5.5 Effect of weeding on yield and panicles

Similar determinations were made in plots in other experimental fields. In Fig.5.10 paddy yields of many experimental fields are set to number of panicles, both calculated as the mean of two 9 m^2 plots and expressed as dry weight per m^2. This figure allows a number of important considerations. It is striking that the yields from the same field taken in the same season and differing only in weed treatment are so clustered. The effect of weeding on yield is limited to, about 40g paddy/m^2, in other words weeding was seen to improve yield to about 0.4 t/ha. The absence of weeds in the fields Poyo 1 and Poyo 2 explain part of their exceptional yields. However, more factors need to be considered, notably soil fertility. Apart from the two fields with hardly any weeds (Poyo 1 and 2) weeding does improve yield most of the time. In some fields, (Yai and Josephine) the yield gets concentrated in the same number of panicles regardless of weeding. Apparently during the vegetative phase the rice could tiller as well in unweeded plots, as it could in weeded plots. Hence the same number of panicles was formed in weeded and unweeded plots. In the weeded plots panicles were heavier, so here weeds rather played a role in the reproductive and in the ripening phase because in these stages the weight of the grains is determined.

Yields drop roughly to half the quantity in fields cultivated a second year. This has also been recorded from the rain forest zone of Sierra Leone for "traditional" and improved varieties (Perez & Mahapatra 1978). Though the number of panicles produced may be about equal the second year, their weight

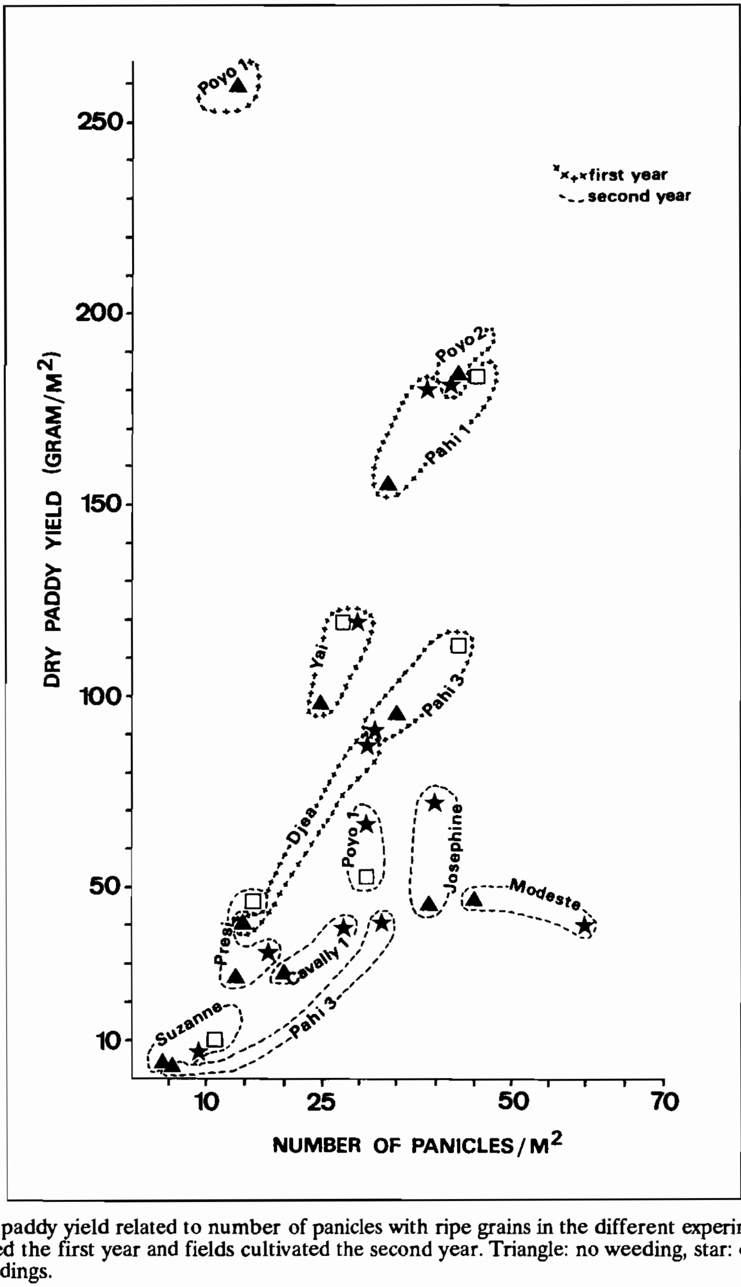


Fig. 5.10. Dry paddy yield related to number of panicles with ripe grains in the different experimental fields; fields cultivated the first year and fields cultivated the second year. Triangle: no weeding, star: one weeding, cube: two weedings.

is much lower. This makes the harvest of those fields still more unsatisfying. We see that the work needed to harvest the extra panicles is hardly rewarded by extra paddy. If the harvest is expected to be low, the time spent on extra weeding may very well get "lost" in harvesting the extra panicles. This makes the remuneration of the effort indeed little.

When general yield drop below about 400 kg per hectare, women take only the heaviest ears. In the experiment however, all panicles with ripe grains were harvested. The effect of weeding on yield is not more pronounced than it was the first year. Some fields (Presi, Poyo 1 second year, Josephine) respond to weeding by heavier panicles, other fields (Modeste, Cavally 1 and Pahi 3 second year) responds to removal of weeds by more, light panicles.

5.3.5.6 Decisions about weeding

These results suggest that more weeding usually does increase paddy yield but that the positive effect of weeding is restricted largely to the first year of cultivation. Considering the performance of the variety "Demandé" in the Pahi 1 experiment the first year (Fig.5.8), as compared to the range of rice yields in the Taï area by the same variety, the yield in the weeded plots are possibly close to the maximum this rice can produce. Leaf and stem production was already very similar in weeded and unweeded plots, both grew excessively tall (1.6 to 1.8 m). Because of the extra paddy produced in heavy panicles and the absence of weeds, most of the rice had lodged (dead leaves and leaves that are lodged were not included in Fig.5.8). In practice, the farmer is generally little prepared to do that extra weeding. From these observations and from those made in other fields we can conclude that decisions about hand weeding are made around 2 months after sowing. An estimated weed biomass far below 50 g/m^2, or a weed cover largely under 20 per cent is not sufficient an incentive to start weeding. If the field is more infested, around 50 g/m^2, or a weed cover of about 20 per cent, this may be a motive to start weeding, provided the rice is in good condition. Little or no weeding is done if the rice is diseased or ravaged by rodents or other animals, or if too many weeds are already established, the threshold being about 80 g/m^2.

5.3.6 Fertility aspects

In the previous paragraphs the role of nutrients have been mentioned in relation to total yield, number of panicles and competition with weeds. A study on fertility and rice was originally planned as an integrated and complementary part of this study on weeds. Pressed by circumstances, the soil scientist who was to do the job, could start his field work only after our rice and weed observation had ended. The following aims to compensate part of the lack.

The amount of nutrients added to the soil when the forest is burnt can be estimated by calculating the nutrients stocked up in the vegetation, or by analysing the soil before and after burning. Decline in fertility can further be monitored by analysing the soil regularly. The first was done by Jaffre (1985), Jaffre & De Namur (1983) and Fritsch (1982), the second in many of our experimental fields. For each plot a composite sample was formed from four cores taken with an auger. Surface litter was scraped aside before taking samples. Samples were air-dried, put through a 2-mm sieve and the fine earth was reserved for analysis. Samples were taken from the first 10 cm top soil for here the mineral fertility is concentrated (Fritsch 1982). These analytical data are summarized in Table 5.4. The general impression is that nutrient level of the soil is low and stays low, during cultivation and during fallowing. Fritsch (1982) found a good relationship between cation exchange

Table 5.4. Soil changes following cultivation in the Taï region. Analytical data of topsoil (1-10 cm) under secondary forest and in rice fields at the end of the cultivation period. Gravel content as percentage of whole soil, other analyses on fine earth only.

Name field	Cultivation and fallow years	Position on slope	Gravel %	Organic matter %	N %	C/N	P total %	Exchang. meq/100 gr.	pH-H2O	pH-KCl	Site history
Pahi 1 (normal burn)	1 yr of c.	mid-slope	2.5	3.5	1.58	12.92	0.27	9.46	7.1	6.3	Field in 19 year old fallow, at least 1 rotation before.
	2 yrs of c.	"	13.2	2.6	1.28	11.78	0.33	7.27	5.7	5.1	idem
	3 yrs of c.	"	15.5	3.0	1.92	9.07	0.42	7.57	6.4	5.4	idem
(mild burn)	1 yr of c.	"	12.9	3.2	1.48	12.45	0.15	7.14	5.4	4.5	idem
	2 yrs of c.	"	15.2	2.8	1.28	12.66	0.25	7.07	5.3	4.8	idem
	3 yrs of c.	"	22.5	2.8	1.62	11.01	0.42	6.81	5.1	4.5	idem
(normal burn)	1 yr of c.+2 yrs of f.	"	11.6	3.1	1.65	10.98	0.28	6.49	5.5	4.8	idem
	2 yrs of c.+1 yr of f.	"	3.4	3.9	1.93	11.63	0.54	8.45	6.1	5.4	idem
Pahi 2	6 yrs of f. (prior to clearing)	mid-slope	0.0	2.8	1.40	11.61	0.34	5.41	6.0	5.5	At least 2 rotations before.
	1 yr of c.	"	2.0	2.2	1.15	11.09	0.18	6.58	6.9	6.0	Field in 6 year old fallow, at least 2 rotations before.
	2 yrs of c.	"	0.7	2.4	1.45	9.41	0.30	6.12	6.4	5.5	idem
	1 yr of c.+2 yrs of f.	"	4.3	2.8	1.23	13.42	0.10	6.57	6.2	5.7	idem
	2 yrs of c.+1 yr of f.	"	7.3	2.3	0.89	14.98	0.09	5.79	6.2	5.6	idem
Pahi 3	21 yrs of f. (prior to clearing)	mid-slope	65.7	3.4	1.52	12.89	0.22	8.28	4.6	4.2	At least 1 rotation before.
	2 yrs of c.	"	67.6	3.6	1.50	13.89	0.11	9.15	6.8	6.2	Fields in 21 year old fallow, at least 1 rotation before.
	21 yrs of f. (prior to clearing)	lower sl.	1.2	2.1	1.18	10.15	0.15	6.14	4.2	4.0	idem
	2 yrs of c.	"	1.1	2.1	0.83	14.55	0.07	4.90	5.4	4.8	idem
Presi	2 yrs of c.	lower sl.	19.3	2.7	1.53	10.29	0.29	6.39	5.3	4.6	Field in primary forest.
Poyo 1	2 yrs of c.	valley b.	0.4	5.0	2.23	13.00	0.11	7.73	4.7	4.1	Field in primary forest.
Poyo 2	1 yr of c.	upper sl.	22.7	3.4	1.05	18.67	0.11	6.12	5.3	4.5	Field in primary forest, 1 year fallow, cultivation.
near Poyo 1	6 yrs of f.	lower sl.	0.3	1.5	0.65	13.05	0.16	4.26	5.0	4.3	Considered very bad soil, before primary forest.

Cavally 1	2 yrs of c.	alluvium	0.8	2.5	1.38	10.36	0.05	6.32	5.0	4.7	Field in X year old fallow, before, primary forest.
Suzanne	1 yr of c.	mid-slope	1.0	2.2	0.98	13.08	0.25	7.07	7.2	6.5	Field in 13 year old fallow, at least 1 rotation before.
	2 yrs of c.	"	4.4	2.2	1.20	10.50	0.30	5.75	6.2	5.6	idem
Yai	30 yrs of f. (prior to clearing)	upper sl.	8.5	3.2	1.43	12.90	0.22	8.01	4.2	3.8	Before primary forest.
near Yai	4 years old cocoa	mid-slope	15.9	3.3	1.43	13.38	0.21	9.16	6.4	6.0	Considered very good soil.
Joséphine	2 yrs of c.	mid-slope	5.4	2.1	0.88	13.95	0.20	5.22	6.6	5.7	Field in 16 year old fallow, at least 1 rotation before.
Modeste	2 yrs of c.	lower sl.	0.5	1.8	0.73	14.66	0.04	5.10	4.8	4.1	Field in primary forest.
Hélène	2 yrs of c.	lower sl.	10.7	1.6	0.70	13.34	0.06	5.12	5.8	5.3	Field in primary forest.
(Fritsch, 1982)	primary forest (1)	mid-slope	1.2	2.5	1.13	12.61	0.28	5.80	4.1	3.7	
	"	"	2.7	2.4	1.05	13.26	0.23	5.30	4.9	4.2	
	1 yr of c.	"	1.1	1.9	0.80	13.71	0.21	4.24	4.8	4.0	Field in primary forest.
	1 yr of f.	"	0.0	2.3	1.00	13.60	0.24	4.99	5.6	4.7	"
	2 yrs of f.	"	3.2	2.7	1.08	14.35	0.29	5.73	5.0	4.2	"
	4 yrs of f.	"	0.8	2.3	1.05	12.55	0.24	5.58	5.0	4.3	"
	7 yrs of f.	"	0.2	2.5	1.20	12.25	0.42	5.16	5.5	4.7	"
	15 yrs of f.	"	11.8	2.7	1.23	12.64	0.28	5.81	4.5	4.0	"

capacity and organic matter of the top soil. During cultivation a progressive, though slight, disappearance of organic matter can be perceived, and this induces a decrease in cation exchange capacity. As acidity increases, the availability of nutrients will most probably decline. The data on Phosphorus, considered the limited element in the Taï ecosystem and in agriculture (Fritsch 1982, Van Reuler & Janssen 1989) are difficult to comment on. A rise in total Phosphorus during the first years of fallow and cultivation is probably due to a strong faunal activity which incorporates partly burnt, or unburnt forest residues into the soil. The soil worked by earthworms is very significantly richer than the soil matrix (30-50 per cent more CEC, one unit pH higher, up to 100 per cent more Phosphorus content). Earthworms deposit a cover of 12.7 mm of this on the soil surface during the first two years that forest residues are available (166 ton/ha/year) (Fritsch 1982).

5.3.6.1 Differences between sites

The low pH of all fields prepared in primary forest is due to difficulties in burning the debris.

Fields lying on a lower part of the slope usually have lower organic matter content and low total Phosphorus. The soil middle and upper slope is generally somewhat better, despite the high gravel contents. The sandier lower slope soils have weaker structure than those more clayey up hill (Collinet 1984). Valley bottoms, provided the soil is not to sandy, are better than lower slopes. Alluvium can be clayey or sandy, but here soil conditions are particularly poor, in contrast with Guillaumet (1967, p.116) description of alluvial soils.

5.3.6.2 Soil and paddy yield

Although the study of the relation between soil fertility and measured paddy yield was not our main purpose, some general observations can be made. The following is necessarily limited to general impressions, based on yield determinations in permanent plots, on the chemical analysis of the soil there and on a general impression of crop performances in many fields observed in the period 1983-1989.

Maximum paddy yield was measured in field Poyo 1, a valley bottom with a clayey soil. During the first year of cultivation, plot yield averaged 2.6 t/ha, whereas outside the plots the yield was estimated at 1.8 t/ha. The main reason for this difference was the large quantity of unburnt wood lying about. The second year paddy yield dropped to an estimated 0.6 t/ha. Field Poyo 2, situated upper slope on the same toposequence, also had a good harvest, an average of 1.8 t/ha measured in the plots, and a general field harvest evaluated at 1.5 t/ha. Both fields carried very few weeds. The first had been cleared in primary forest and was moderately well burnt; the second had also been prepared in primary forest but two years earlier. Burning had been very insufficient and the harvest had been bad. The site was abandoned for one year and a half during which the great mass of wood had the opportunity to dry out thoroughly. During subsequent felling and burning almost all of the wood was consumed which gave a very clean seed bed for the rice. The subsoil carried mica flakes.

Another valley bottom (field Djéa), where a 16-year old forest had been cleared, produced almost 0.9 t/ha in the part where the field had been weeded, but only about 0.7 t/ha in the unweeded part. Soils of the field Pahi 1 and Yai were typical red gravelly soils. The general field paddy yield of the first crop was estimated about 1 t/ha for both. Field Pahi 3 had a rather steep slope, the sandier lower slope part of the field yielded more (1.0 t/ha) than those in gravelly, clayey soil up hill (0.7 t/ha). This is possibly due to water stress. All Pahi fields were very well burnt, the field Yai slightly less good. The average yield for these experimental fields during the first year of cultivation is somewhat above 1 t/ha. This seems to be above the performances of other rice crops observed in the same period in Taï, estimated between 0.70 and 0.95 t/ha. I do not think this is due to a better control of weeds in the experimental fields, for the rice fields not engaged in experiments were not better weeded than those outside the experimental plots. I am more inclined to think that the experimental fields were cleared, burnt and planted at the right moment. The great majority of fields is cleared, burnt and planted much later in the season, for the men's work in coffee and cocoa plantations competes with their task preparing the rice field. So a sub-optimal use is made of climatic conditions.

A second reason which could explain our better yields in experimental fields is the fact that all farmers engaged could dispose of rather much forested land. They had a more than average quantity of land from which they could choose the most promising combination of forest and soil. Many other farmers are more restricted in their choice and inevitably cultivate inferior soils or too young fallow vegetations.

The same cannot be said from those fields cropped for a second year for at that time, our experimental fields constituted the only fields in the region farmed for a consecutive year by Oubi and Guéré. All farmers interested in our experiments were encouraged to do so because their paddy yield the first year had been gratifying. Nowadays, as a result of more farmers trying to cultivate rice a second year, comparisons are possible.

The second year fields which were situated lower slope and issued from primary forest, had yields about 0.3 t/ha (field Presi) and 0.4 t/ha (field Modeste). Maximum yield came from field Josephine, situated middle slope (estimated at 0.6 t/ha) and prepared in 16 year old secondary forest. The Cavally fields yielded rather low, 0.8 and 0.7 t/ha the first year of cultivation (Fig.1.4, field 2, 3 and 4) and still less the second year (Fig.1.4, field 1), 0.3 t/ha.

Three fields carried so little rice, about 0.2 to 0,1 t/ha, that outside the plots the paddy was not even harvested, i.e. Pahi 1 and 3, and field Suzanna. The crop suffered from a combination of rodents and birds attacks while the rice itself was partially diseased (rust).

It is hardly possible to contribute any of these variation in yield to a difference in soil properties, and more precisely to different levels of chemical fertility. Abundance of ash can be obtained from any large forest on any soil. There where a fair quantity of ash has been deposited, rice grows extremely high (1.8 m). On places with no traces of ash, and during the second year of cultivation, the same variety does not grow higher than 1.2 m.

5.3.7 Yields completely lost to pests

Complete loss of all rice plants occurred as forest buffalos ate from the experimental field Helene, situated close to the Park.

The greater part of a paddy harvest was lost to birds who were seen "drinking" the milky rice grains directly from the stalks in field Suzanne. The farmer was not prepared to guard the field seriously, probably because she considered the harvest was not worth the trouble anyway.

Some experimental fields were seriously harmed by agoutis especially during the years (1984, 1985) the population expanded and the farmers were rather unprepared for it. Fencing newly cleared fields was not really considered an integral part of cultivation yet. If no enclosure was made the first year, it was certainly not worth the trouble to do it the second year. So, to avoid too much damage done to the experimental plots, labour was hired to fence each group of permanent quadrats separately at the onset of the trials, leaving the farmers free to enclose the field as they wished.

5.4 DISCUSSION AND CONCLUSION

5.4.1 Rice under stress

The typical response of the rice variety "Demandé" to different forms of stress has been summarized in Fig.5.11. "Demandé" can yield, under local management a near optimum paddy harvest of 200 g/m^2. This is possible if the field is thoroughly burnt, free of weeds and plants have a good water supply. Such a good rice performance has only been observed occasionally in first year fields. Under these rather rare growth conditions rice plants are subject to lodging.

It often happens that rice plants come under stress. Mild stress during the vegetative phase can be caused by low weed cover, or light water stress due to sowing early in the season or due to a gravelly topsoil, or by mutual competition. If, in the following growth phases, growth conditions are good, implying that the field had been weeded, or the rainy season is well advanced, the rice plant compensates by producing heavy panicles and yield may be equal or superior to unstressed plants. The same has been reported for upland rice growing under mild weed stress (less than 40 days of weed infestation) in central Côte d'Ivoire (Merlier 1978 fig.2). Compensation happens rather often under local practice during the first year of cultivation. If rice plants are subject to mild stress, notably weeds, during the reproductive and the ripening phase, the consequences are more serious. It does not effect the number of panicles but makes them lighter, so paddy yield is directly reduced and harvesting is more work for the same yield. This happens often during the first year of cultivation, especially in unweeded fields. Under heavy stress during the vegetative phase, most of the time due to weeds and occasionally due to water stress or agoutis pest, the rice produces many but only weak tillers. Even if growth conditions later in the season are good, the plant recovers just to produce many light panicles and a large proportion of infertile spikelets. Under these conditions only the heaviest panicles are taken in and total yield is very low. This happens currently in fields cultivated for a second year.

Heavy stress in the reproductive and ripening phase gives empty and light panicles of which only the heaviest are considered worth the trouble harvesting. It often occurs in second year fields which are weedfree at the beginning of the season while not much weeding is done afterwards. Yield loss can be near 100 per cent. Fig.5.12 summarizes the various reactions of rice "Demandé" on stress.

5.4.2 Comparing traditional with improved varieties

Most long-cycle rice varieties observed in the south-west Côte d'Ivoire resemble "Demandé", not only those cultivated by the Oubi and Guéré, but those of other rice farmers too, the Bété, the Yacouba, Krou, Bakwé and others. Those rice varieties have probably the

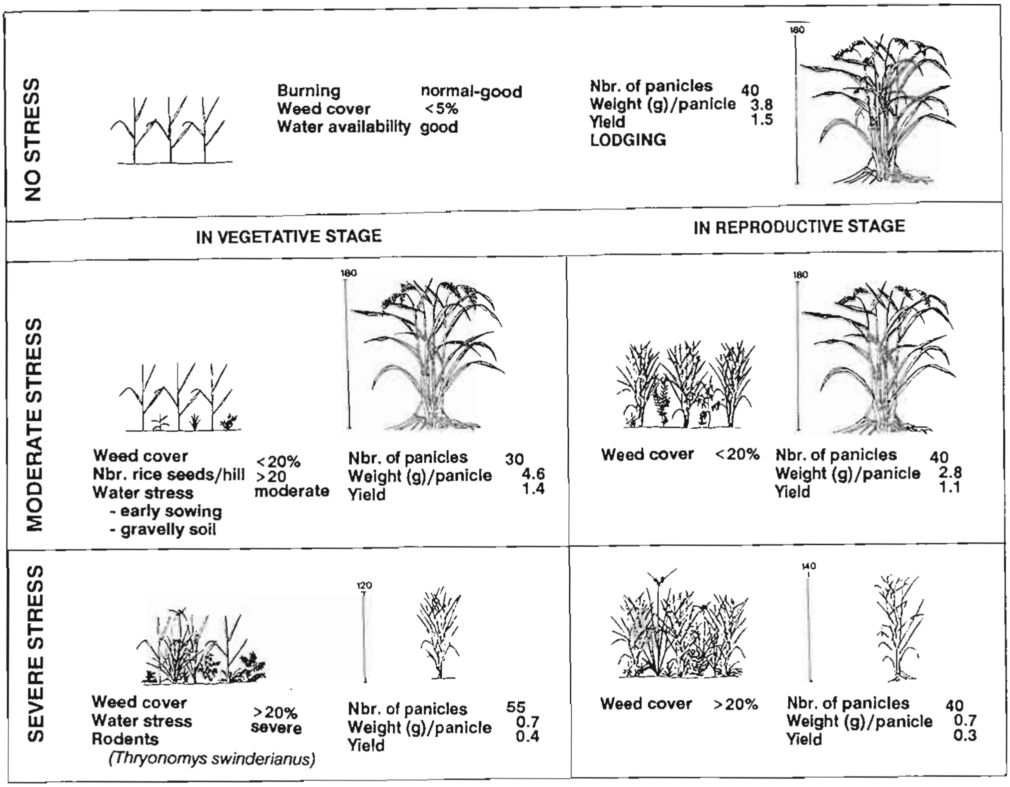


Fig. 5.11. The response of the rice variety "Demandé" to stress.

same capacity to overcame moderate stress in early growth by means of compensation.

Tall, so-called "traditional" varieties, as they are cultivated in many parts of West Africa, Latin America and the Far East, are of the so-called "panicle weight type". Increase in grain yield is usually a result of an increase in panicle weight. Improved varieties, which can be cultivated in the same area but under different management, are of the so-called "panicle number type". Increase in grain yield is a result of an increase in the number of panicles. One of the aims of their local selection might have been its capacity of compensation and hence a better use of resources. Another advantage of "compensation" is the tolerance to mixed cropping. Replace the weed population present during the vegetative phase with an early maturing crop like maize or a legume, and it will be evident that rice yield can remain satisfying thanks to the faculty of compensation of "traditional" varieties. Improved varieties, being of the "number of panicle type", suffer from an associated crop because yield depends directly on tillering.

The low yield potential of "Demandé" is a serious constraint to yield improvement, yet low yields go with some appreciated characteristics. Harvesting is productive because of the small number of panicles. A change to improved varieties, producing far more panicles, means more work.

Improving rice varieties starts by reducing the height growth of the tall traditional varieties and this greatly increases yield potential. A height of 1.00-1.20 m is often considered ideal (Jacquot 1978). This meets with resistance because farmers prefer harvesting standing up right and low stature rice forces them to bent down.

Hill planting and rather wide spacing is economic in sowing seed (15-25 kg/ha), while normal seeding rates range from 25-100 kg/ha.

Traditional rice varieties have many broad, drooping leaves which implies that lower leaves receive less light due to mutual shading. The heavy shade prevents photosensible weeds (notably the troublesome grass *Panicum laxum*) to germinate as was demonstrated in a seed bank study parallel with field observations (De Rouw & Van Oers 1988).

Improved varieties have semi-erect leaves, resulting in less mutual shading and a better light distribution which increases yield. Simultaneously, more light reaches the ground, triggering the germination of weeds.

Tall varieties are better competitors because they outgrow and shade weeds. Extra work needed to weed in the fields cultivated with improved varieties can be unavailable (Winch & Kivunja 1978).

If more modern varieties are to replace the locally selected ones in Taï, attention should be paid to the preservation of some precious properties: Long cycle rice gives more regular yields than medium and short maturing varieties and deep rooting and moderate tillering favours drought tolerance.

6 The competing growth of weeds and rice

To gain better understanding of the dynamics of the plants growing in a rice field, we will start by analysing general features of weed and rice populations, cover, height, life form and densities. How do weed populations change over time and how do they react to different forms of management?

6.1 METHODS

The plants appearing in a rice field are very divers according to floristics, regeneration, ecology and morphology, therefore this population is split up into the following categories :

Categories according to life form

- **trees**, all erect growing woody plants,
- **climbers**, either woody or sub-woody, including leaning and subscandent shrubs,
- for convenience called **broad-leaved herbs**, but comprising all herbaceous dicotyledons, prostate, creeping, erect or climbing and those monocotyledons with large leaves as far as they are not grasses or sedges (eg. *Marantaceae*),
- **grasses** and **sedges**, tufted, creeping or stoloniferous plants.

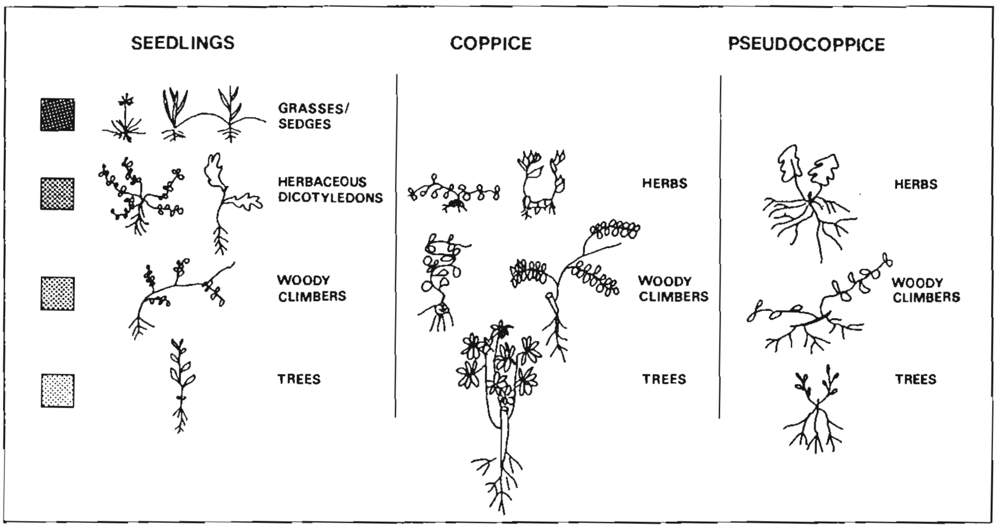


Fig. 6.1. Legend of Fig.6.2, 6.3, 6.4 and 6.5. Life forms of the weed population, herbaceous dicots, woody climbers and trees, and regeneration type, by seed, by coppice shoots, by "pseudo-coppice" shoots.

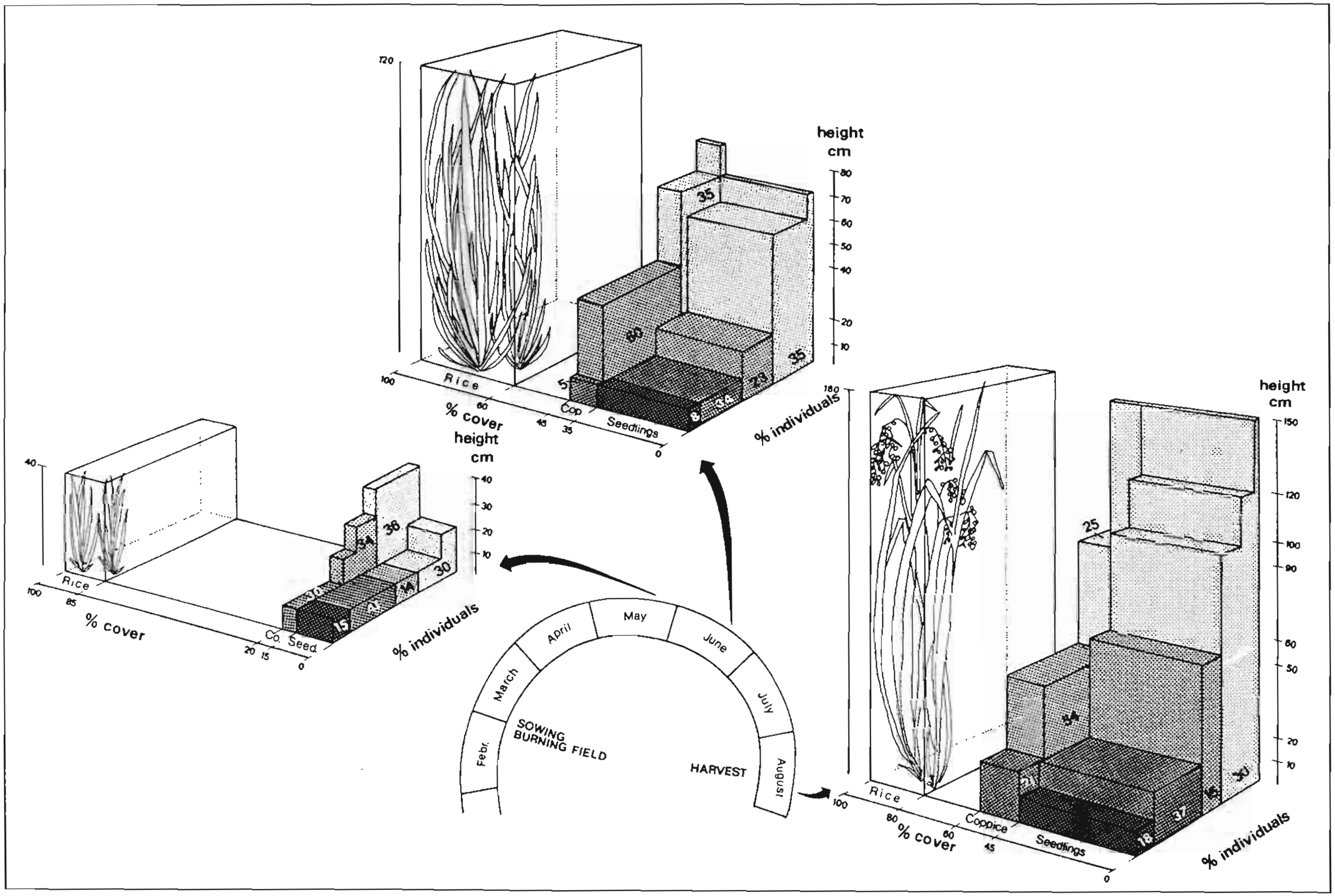


Fig.6.2. First year of cultivation, no weeding. Development of rice crop, and weeds during the cropping season (height growth and cover). Weeds population represented after the legend in Fig.6.1.

Categories according to means of regeneration,

- from **seed**, regeneration by germination of seeds from the seed bank or from later dispersed propagules,
- from **coppice**, regeneration arisen by sprouting of plants present prior to first cutting and burning,
- from **"pseudo-coppice"**, being a mixture of seed and coppice regeneration, regeneration by germination of seeds during the first cultivation year, followed by firm establishment which permits resistance to subsequent slashing and burning resulting in regeneration by sprouting during the second (and the third) cultivation year.

These categories, illustrated in Fig.6.1, are thus defined because plants within the same group tend to respond rather uniformly in terms of cover and height to the treatments tested in the trials. Recordings, although made per species (each plant being identified and measured separately), are generalized here to these categories in order to get a general impression of how weeds in rice fields act under different types of management.

6.2 RESULTS

A large part of the data from the permanent quadrats could be summarized in the diagrams Fig.6.2, 6.3, 6.4, 6.5. These diagrams are established from data from field Pahi 1 during the years 1983, 1984, 1985 joined with the data from field Pahi 3 (only plots on similar gravelly soil were taken) during the years 1985 and 1986. In the diagrams weed and rice development is shown at three periods during cultivation, two months, three months and about five months after planting. Cover by Rice, by Seedlings and by Coppice shoots is indicated in the x-direction. Total cover, represented in the diagram by the sum of contributions of Seed and Coppice, is hardly exaggerated compared to real cover for most plants are strongly heliophile and seek to catch the maximum of light. Densities are represented in the z-direction and are expressed per type of regeneration and per growth form. Height of plants is shown in the y-direction, also itemized per category.

6.2.1 First year of cultivation, no weeding

Rice

In Fig.6.2 rice plants are about 40 cm high, two months after sowing. One month later they have grown out to 1.2 m, covering 40 per cent of the land. We see that during the season, the height growth of the rice keeps in pace with those of the tallest weeds. Maximum height, around 1.7 m, and maximum cover, about 50 per cent, occurred in the last week of June and the first weeks of July. In fact, height of rice was already declining at harvest time. From July to August as the seeds ripen, the rice plants no longer expands but more and more dead leaves of decaying rice plants litter the ground (not represented in the diagrams).

Weeds, seedlings

Among the seedlings, trees go tallest although not at high as the rice. The fastest growing trees are *Trema guineensis*, *Ceiba pentandra* and *Alchornea cordifolia*, but, as soon as the rice starts to degenerate, the commonest tree, *Macaranga hurifolia*, catches up with these species. Seedlings of the tree species *Fagara macrophylla*, *Albizia adiantifolia* and *Ficus capensis*, lag behind throughout the cropping period. Trees

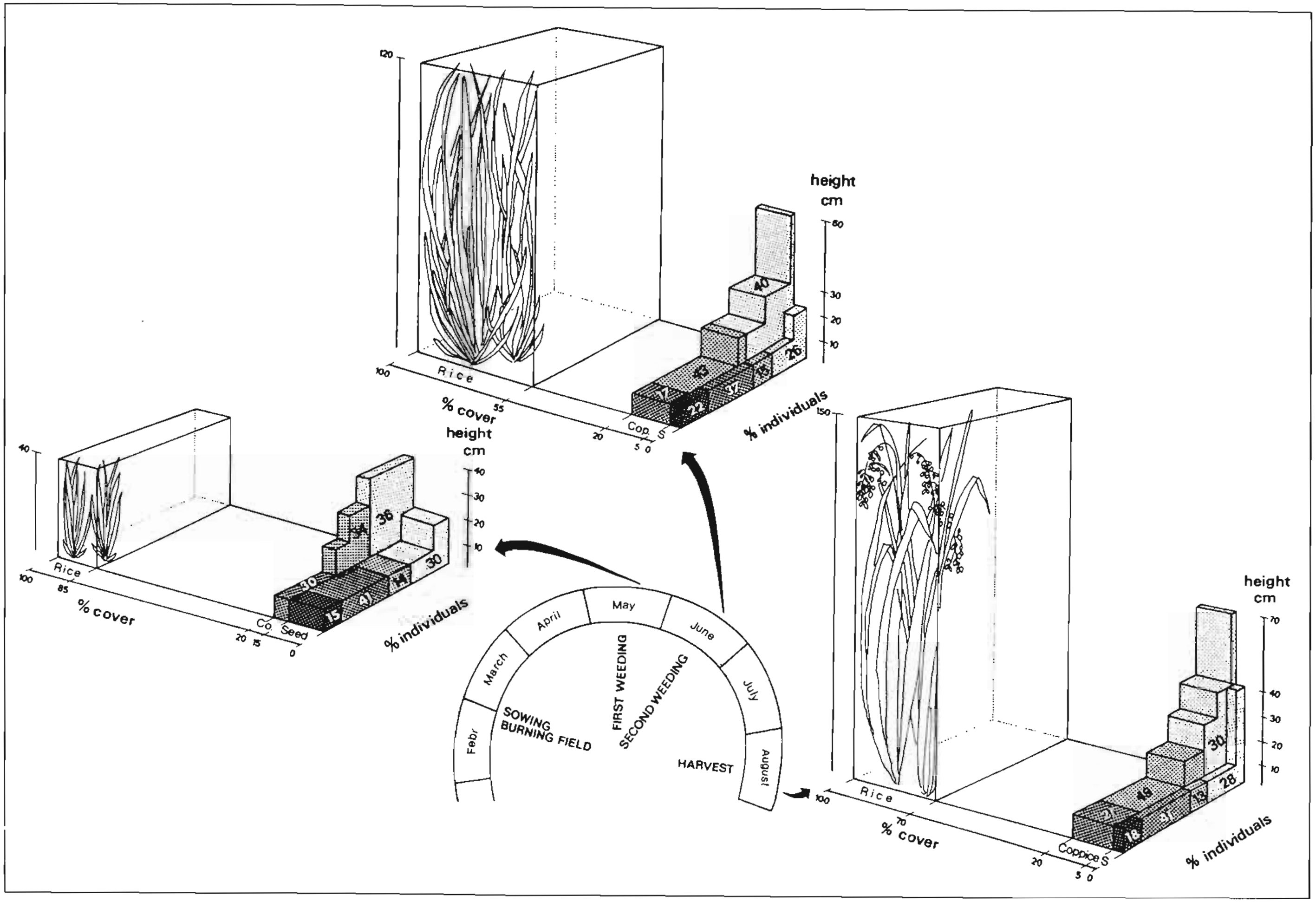


Fig.6.3. First year of cultivation, two weedings, two and three months after sowing. Development of rice crop, and weeds during the cropping season (height growth and cover). Weeds population represented after the legend in Fig.6.1.

account for 30 to 35 per cent of the seedling population. Almost all young trees are slender plants which grow upright. The stems of vines and many broad-leaved herbs grow several meters long, rather spreading horizontally than up-right (*Physalis angulata*, *Cissus* spp, *Cyathula prostrata*). Some plants however, do expand both horizontally and vertically (*Triumfetta rhomboidea*, *Solanum* spp). No grasses were recorded but between 10 and 20 per cent of all seedlings were sedges, mainly *Mariscus alternifolius*. In Table 6.1 absolute numbers of plants per m^2, are presented. We see that densities of seedlings decline from 71,2 plants per m^2 in May to 55.8 plants per m^2 in August. In Fig.6.2 we can observe that cover by seedlings increases steadily from 15 to 35 per cent during that period. Though some annual weed species have ended their life cycle in those few months, mutual competition should account for much of this decline.

During the season the relative contributions of trees, climbers, broad-leaved herbs and sedges stays much the same. It is very probable that they largely originate from the same seed source: the seed stock in the pre-existing secondary forest. The species composition of the seed bank is very comparable to the composition of this weed population (De Rouw & Van Oers 1988).

Weeds, coppice

Coppicing plants are represented by about one individual per m^2 (Table 6.1). Many different species are involved, essentially trees and lianas. Height growth during the cropping cycle is comparable to seedlings. Cover increases gradually mainly as a result of climbers (*Combretum* spp) which expand horizontally and vertically.

Table 6.1. Number of weeds and rice plants per m^2, first year of cultivation.

Treatment	**no weeding**			**one weeding 3 months after seeding**	**two weedings 2 and 3 months after seeding**
Months after sowing	2	3	5	5	5
Weeds per m2					
from seed	71.2	48.6	55.8	20.2	16.8
from coppice	1.0	1.1	1.3	1.4	1.4
Rice pieds per m2	6.9	6.9	6.9	7.0	6.9

6.2.3 First year of cultivation, two weedings

Rice

Fig.6.3 shows in a similar manner the rice, the seedlings and sprouting plants but now the plots have been weeded twice. Removal of weeds have influenced the development of the rice in two ways. Surface occupied by rice plants is somewhat higher. This means that the rice could tiller more freely during the months May and June. Again, maximum cover and maximum height occurred end of June, beginning of July. Secondly, rice grew less tall, obviously because competiting weeds grew less tall as well. This did not prevent some of the weak stems from lodging, no longer supported by tall weeds.

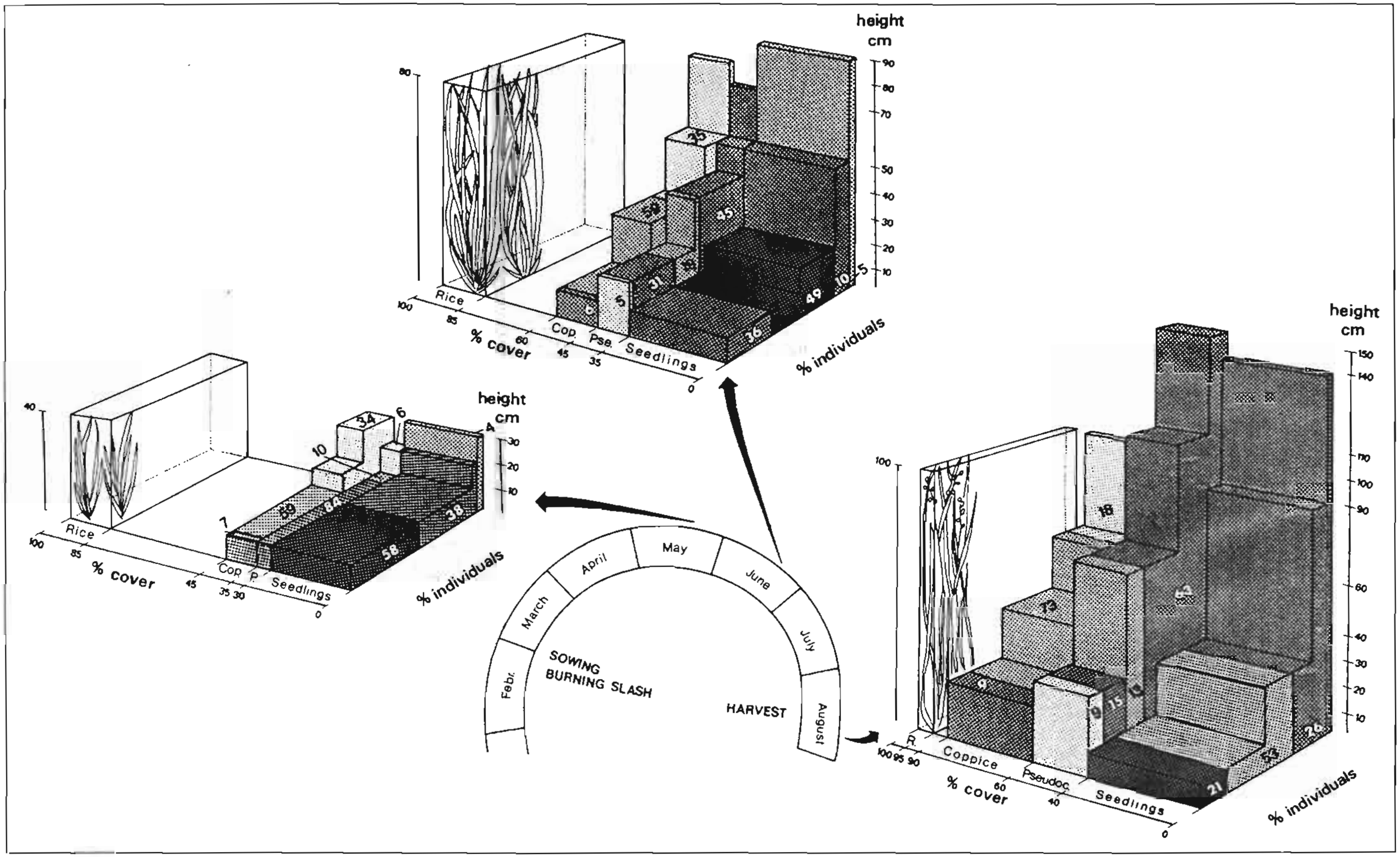


Fig.6.4. Second year of cultivation, no weeding. Development of rice crop, and weeds during the cropping season (height growth and cover). Weeds population represented after the legend in Fig.6.1.

Weeds, seedlings

The effect of weeding strongly affects the performance of seedlings. Table 6.1 demonstrates that in plots which were weeded once or twice, densities of weeds per m^2 are greatly reduced. Weeding does not change much in the proportion trees/climbers/broad-leaved herbs/sedges. About 30 per cent of new recruits after each weeding are trees. This is an indication that new germinations after each weeding continue to arise from the seed bank because the floristic composition of pre-existing seed bank and field population are still similar.

Weeds, coppice

Coppice shoots are not pulled out, as are seedlings, but are merely cut back. Weeding does hardly influence the number of coppicing plants and it does not affect the rate trees/lianas/herbs of the population (Table 6.1). Plants grow out vigourously after each slashing. Cover, but not height, by coppice shoots at the end of the growing season is similar in the no weeding plots, about 20 per cent.

6.2.4 Conclusions

The rice variety "Demandé" is quite a strong competitor. Even in unweeded plots, yields were very acceptable (1.3 t/ha). In weeded plots, yields were 1.5 t/ha. Because of the experimental setting these plot yields are higher than gross field yields. Fields have a variable quantity of unburnt wood lying about, and this has been removed from plots. Further, fields are interplanted with other crops, but our plots carried only rice. Finely, all paddy from the lodged stems was carefully harvested. Under normal conditions the paddy yield from lodged stems is largely lost.

A second exceptional thing is the effectiveness of weeding. Weeds arise from the seed bank at the onset of the cropping period. The population declines naturally mainly through mutual competition. If seedlings are pulled out, they are hardly replaced by new ones. Apparently, the seed bank has been largely exhausted and cover by other plants is such that germination is delayed.

6.2.5 Second year of cultivation, no weeding

Slashing and burning preceded the second year of rice cultivation. Experiments and observations were an exact rehearsal of those carried out the first year. Each permanent plot kept the same weeding treatment. Rice and weed development during the second cropping cycle is illustrated in Fig.6.4 and Fig.6.5. Table 6.2 provides densities of plants per m^2.

Rice

Considering the no weeding treatment (Fig.6.4), we observe that rice develops normally at first but after about 3 months growth rate slows down. The rice grows less tall and covers less surface as it did the first year of cultivation. The result is a poor stand.

Weeds, seedlings

Plants other than rice develop rapidly, covering 45 per cent of the ground surface already two months after planting the rice. At harvest time, 90 per cent of the ground is covered by weeds. Trees grown from seed the second year make up for less than 1 per cent of the total number of seedlings and they could not be represented in the diagram. The group of climbing shrubs and lianas comprises but 5 per cent of the seedling population, increasing to 20 per cent at the end of the season (*Bertiera* spp, *Mezoneuron benthanianum*, *Dioscorea* spp). Broad-

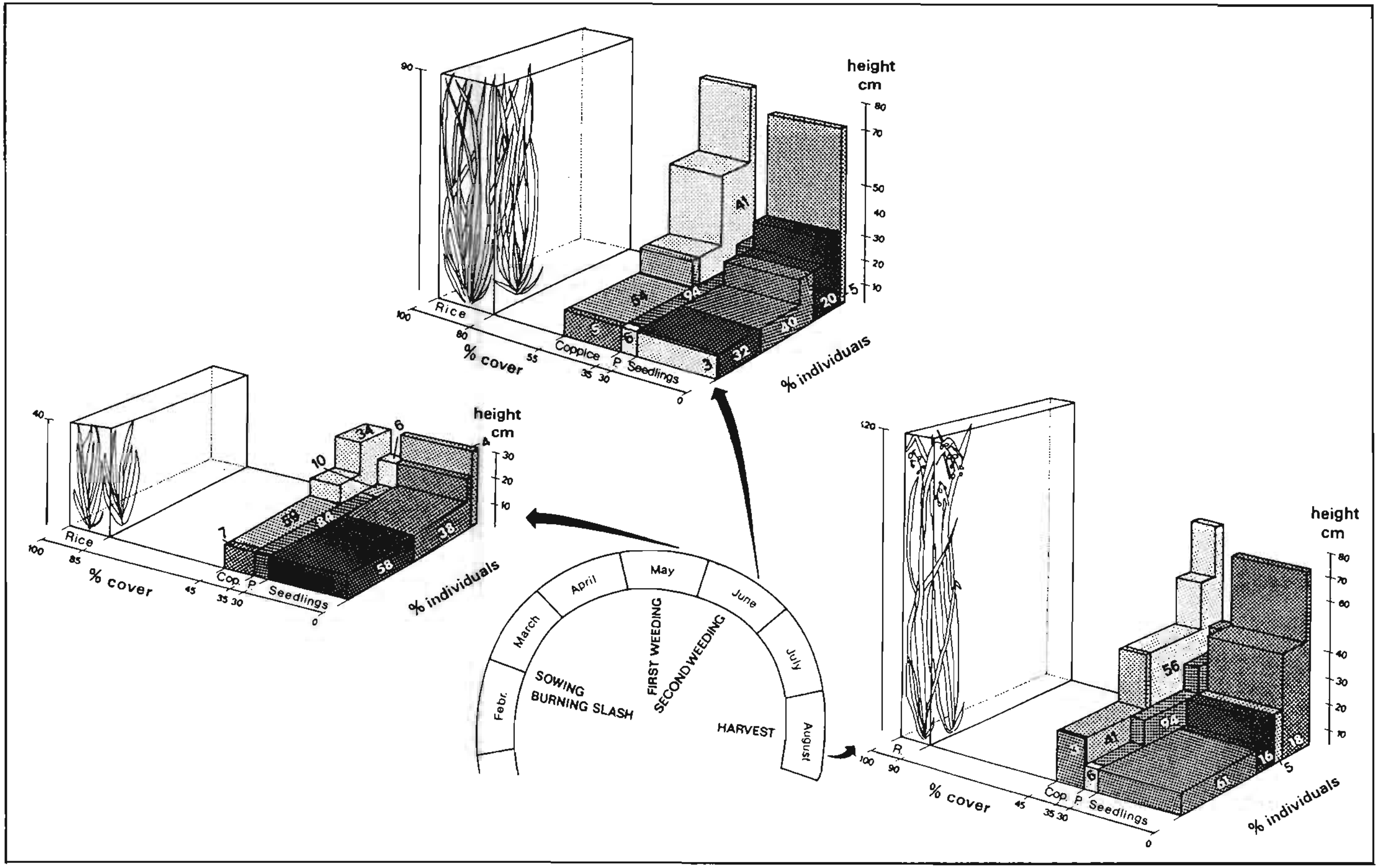


Fig.6.5. Second year of cultivation, two weedings, two and three months after sowing. Development of rice crop, and weeds during the cropping season (height growth and cover). Weeds population represented after the legend in Fig.6.1.

leaved herb which have come to flower in August grow tallest (*Erigeron floribundus*, *Pouzolzia guineensis*). The population of broad-leaved herbs is now largely dominated by well-known weed species, *Ageratum conyzoides*, *Erigeron floribundus*, *Mikania scandens*, *Microglossa pyrifolia* and *Crassocephalum crepidioides*, and, though still few in number, *Bidens pilosa*. All of these Composites, except for *Bidens pilosa*, have plumed wind dispersed seeds. In the period corresponding to the observations in the diagrams, *Eupatorium odoratum* was still rare in fields. Being a plumed Composite too, *Eupatorium odoratum* seedlings invades the field together with the other Composites. Grasses (*Panicum laxum*, *Paspalum scrobiculatum*) have invaded the plots, though sedges outnumber them. Sedges, mainly *Mariscus alternifolius* contributes to about half of the weed seedling population in June. Cover by seedlings is impressive two months after sowing but the rate of lateral expansion slows down during the rice season, mainly through competition with coppicing plants.

Table 6.2. Number of weeds and rice plants per m2, second year of cultivation.

Treatment	**no weeding**			**one weeding 3 months after seeding**	**two weedings 2 and 3 months after seeding**
Months after sowing	2	3	5	5	5
Weeds per m2					
from seed	124.7	122.4	116.5	97.3	38.0
from pseudo-coppice	3.9	8.7	4.4	4.6	10.7
from coppice	1.3	1.6	1.9	1.2	0.7
Rice pieds per m2	10.1	10.1	10.1	10.0	10.1

Weeds, pseudo-coppice

The group of plants regenerating by means of "pseudo-coppice" contains a fair amount of trees, mainly *Harungana madagascariensis* and *Phyllanthus discoideus* and lianas, *Bertiera bracteolata*. Height growth of these woody plants, however, stays behind that of herbaceous and sub-woody plants also regenerating by means of pseudo-coppice. They are essentially the *Solanum* species. Especially *Solanum torvum* and *Solanum verbascifolium* easily resist slashing and have outgrown the plants of other life forms. We see in Table 6.2 that the density of pseudo-coppicing plants is low, four to eight individuals per m2 but cover is impressive (Fig.6.4).

Weeds, coppice

Among the group of coppicing plants, trees remain well represented, but, in comparison with the previous year, lianas (*Griffonia simplicifolia*, *Clerodendrum* spp) have expanded on the expense of trees and herbs. Trees are tallest here and herbs smallest, in contrast with the group of pseudo-coppice where trees are smallest and sub-woody dicotyledons grow tallest. Coppice from stumps and roots of the pre-existing secondary forest represents 30 per cent of total cover at the end of the cultivation period.

6.2.6 Second year of cultivation, two weedings

Rice

In diagram Fig.6.5 we see that rice plants developed somewhat better in the repeatedly weeded plots. Average height at the end of the cycle is somewhat superior to the unweeded plots (1.2 m compared to 1 m), but overall crop condition is poor.

Weeds, seedlings

In June, a month after the first weeding round, non-rice plants cover the ground for about 55 per cent, this is more than they did before weeding. This is also demonstrated in Table 6.2, the first weeding round is not very effective. New plants appearing after weeding, belong to the same species, mainly the above mentioned Composites. It is the second weeding round which reduces weed densities more substantially (Table 6.2). Seedlings as a group, recovers best from repeated weeding, a steady 30 per cent of cover is maintained throughout the cropping season. Weeding does hardly influence the proportion grasses/sedges in the population, as compared to the no weeding treatment. Climbers are markedly reduced after two weeding rounds for the benefit of broad-leaved herbs, especially Composites. There are some trees (3 to 5 per cent of the population), mainly *Trema guineensis* and *Vismia guineensis*.

Weeds, pseudo-coppice

The plants belonging to the group of pseudo-coppice are not pulled out but are slashed as are normal coppice shoots. They suffer from the weeding, recover slowly but generally do not die. The *Solanum* species, notably *Solanum verbascifolium* having a powerful taproot, are most successful.

Weeds, coppice

Coppice withstands repeated slashing best. Trees remain present and outgrow plants of other groups. The tree component remains well represented and constitutes the groups of tallest growing plants, followed by the woody climbers.

6.2.7 Conclusions

During the second year of cropping the competetiveness of the rice is largely reduced. Yields in the weeded plots are about 0.3 t/ha and in the non-weeded plots next to nothing. The rice suffers from rust, too. In the previous chapter the role of nutrients has been discussed. It is evident that the weed population has become more aggressive. At least two weeding rounds are necessary and the first weeding round is to de done early. Despite the clean seed bed in March, infestation by weeds was impressive two months later.

Summarizing these results we can conclude that the first year of cultivation trees dominate and the general direction of growth is up-right. Weeding does not alter this. The second year of cultivation herbs have become dominant, notably Composites, and these plants tend to spread laterally rather than vertically. Weeding enforces the position of the Composites. The woody component in the vegetation is preserved in coppicing stumps and roots. Two cultivation cycles do not influence this much.

Considering the species composition of the weed flora the first year, most seedlings have developed from the seed bank. The weed flora which occupies the field during the second year of cultivation, is on the contrary, very different (De Rouw & Van Oers 1988). A plausible explanation is that the pre-existing seed bank is largely exhausted. Second-year plants are almost all wind-dispersed and are probably dispersed mainly after clearing of the forest. Profuse development during the second cropping year is favoured by the fact that the rice crops has lost all capacity to compete.

It is of great importance for the dynamic of weed populations to keep in mind that at the end of the first cropping cycle only few herbs produced ripe seeds because the weed population contained few annual plants. At the end of the second cropping cycle all Composites and all sedges and grasses produce seeds. They make up the majority of the weed population so the quantity of seeds produced is enormous. These plants will continue to re-seed the field almost continuously from that moment on, only checked by weeding or by installation of a canopy.

6.2.8 Third year of cultivation

An attempt was made to grow rice a third consecutive season. Cleaning the field by slashing and burning the regrowth meets with increasing difficulties. Up-right growing plants, when cut off, dry our and burn rather easily, but creeping herbs and especially grasses with long rooting stolons resist slashing, subsequent drying out and burning. Cleaning may leave the soil more or less bare but small bits of these plants litter the ground. Vegetative spread by layering and root sprouting occurs immediately. In fact, the Oubi technique of pulling out seedlings and slashing back coppice shoots has become wholly ineffective in this stage of weed infestation. Only working all of the soil with a hoe is a solution. This means digging up roots of certain pseudo-coppice plants (*Solanum verbascifolium*) and totally removing the grasses. This was not done very thoroughly in the experimental Pahi fields for it is so a tedious and labour-intensive task that no woman was willing to do it, not even for money, classifying these kind of vegetation as utterly "hopeless" where only one thing was to be done : wait until the forest recovers. In other experiments the field was completely cleared, indeed with hired labour (Burkinabé). During a third year of cultivation, individual plants could no longer be counted and this was one of the reasons why results are not represented in a similar diagram. Yet cover and height of the different groups could be estimated.

Rice

Rice plants do not have a chance. Rice never exceeded 80 cm of height and covered but a few per cent all through the crop cycle. Many plants did not complete their life cycle. Weeding did not change this.

Weeds, seedlings

Tree seedlings have disappeared. Seedlings are now of the same species as those already dominant: low herbs, mainly Composites, and grasses, mainly *Panicum laxum* and *Paspalum conjugatum*. At this time (1985) the sub-woody forb *Eupatorium odoratum* became frequent.

Weeds, pseudo-coppice

Eupatorium odoratum was the species regenerating by pseudo-coppicing which suppressed the plants of all other groups. Grasses and Composites grew 50 cm high, while forbs, like *Eupatorium odoratum*, when resprouting grew 1.5 m high in one month following weeding. Two weedings, without being in the least effective as to stimulate the rice, favoured the development of grasses, while no weeding helped the forbs, especially *Eupatorium odoratum*, to form closed thickets.

Weeds, coppice

Coppicing of forest plants still continued. Lianas and trees grew out up to 60 cm in two months after each cleaning of the plots, reaching 1.5 m at the end of the season. Cover by plants of this group is reduced to 5 per cent (weeding) and 10 per cent (no weeding).

6.2.9 Conclusions

Rice cultivation had become utterly impossible. A complete cover by weeds was established within two months after each cleaning. The structure of the vegetation was patchy. Open shrubland with a grassy ground layer dominates in plots which had been repeatedly cleaned. Shrubs, forming an almost closed thicket, dominated in the non-weeded plots. Here a grass stratum was absent or discontinuous. Only coppicing woody plants, remnants of the secondary forest cleared three years before, outgrew the shrubs.

6.2.10 Other fields, first year of cultivation

A comparison with four other rice fields, observed in a similar manner, permits to evaluate the representativeness of the Pahi fields. Location of those fields is shown in Fig.1.4. Two fields were in their first year of cultivation, Poyo 1 and Yai. Two were cultivated for the second consecutive year, Presi and Suzanne.

Field Poyo 1 was prepared in swamp primary forest. The field carried very few weeds throughout the cropping season, about 12 plants per m^2. Rice was already 50 cm high and covered 20 per cent of the soil two months after planting. Superior juvenile growth of the rice is probably caused by local excellent moisture conditions at the onset of season. At harvest time, 1.9 m high, rice stems suffer from lodging on places lacking tall weeds to support them. The weedy population consisted for 68 per cent of trees, for 25 per cent broad-leaved herbs and for a few per cent of sedges. Coppice was mainly the swamp tree *Mitragyna ciliata*. Both seedlings and coppice shoots occupied 10 per cent of cover two months after sowing, steadily extending to 20 per cent cover at the end of the cropping period but then weeds were only 1.2 m high. There were no grasses.

Field Yai, situated upper slope was prepared in a 30 year old forest. Two months after sowing the rice was almost 60 cm high but covered only 15 per cent for sowing of the rice had been done rather widely spaced. Early development of the rice, despite the very gravelly soil, should be attributed to the good partition of showers in the beginning of the rainy season in 1985. At the end of the cycle rice plants reached impressive dimensions of over 1.9 m high. On places not shored up by weeds, the stems were flattened. Weed densities (80 plants/m^2) and proportion of tree seedlings (45 per cent of total seedlings) were comparable to field Pahi 1 during the first year. There were but few sedges and no grasses. Two months after sowing cover by seedlings was 20 per cent increasing to 30 per cent at the end of the season. Some trees were 1.8 m high in August. Cover by coppice shoots stayed at a low level, 15 per cent at harvest time.

Comparison with the Pahi fields

Since weed seedlings arise largely from the pre-existing seed bank during the first year of cultivation, and primary forest soil is known to contain very few viable seeds as compared to other environments, it is not surprising that Poyo 1 contains very little weeds. A particularity of swamp forest is that few plants survive vegetatively the field preparation, so fields in swampy environments usually carry few coppicing plants. The weed densities in field Yai are very comparable to those of the Pahi fields, due to the secondary character of the forest cleared in both cases. In field Yai, trees hold a more important place. As a rule, the older the secondary forest felled, the more tree seedlings appear (proportionally) in the field the first year.

Fig.6.6 gives densities of weeds in no weeding plots. Densities may be rather high (Yai) or low (Poyo 1) but they do not increase during the season. By far most of the weeds germinate at the onset of the cropping period and for a variety of reasons, depletion of the seed stock, inhibition to germinate by shade, competition with the rice, no more recruits occur.

6.2.11 Other fields, second year of cultivation.

Field Presi, situated lower slope, had been prepared in primary forest the previous year. Unburnt wood had dried out and provided an excellent fuel supply to clear away all slashed vegetation at the onset of the second rice season. The thus cleared seed bed was rather weed free (Fig.6.6). Rice plants were 60 cm high and covered 15 per cent of the ground two months after planting. At the end of the season plants were 1.6 m high. Tall weeds prevented the occurrence of lodging. Weed densities were very low two months after planting, seedlings, pseudo-coppice and resprouting plants accounted for about 10 per cent cover each. Only plants regenerating as pseudo-coppice were able to grow as high as the rice. At the end of the season (no weeding plots) pseudo-coppice reached to 2 m high (the tree *Ficus capensis* and the forb *Eupatorium odoratum* (20 % cover). Seedlings, almost no trees, grew up to 1.2 m (>30 % cover), and coppice shoots up to 1.4 m high (10 % cover). Weeding had a clear beneficial effect on yield. On the plots which were weeded twice, seedling densities were reduced to about 30 plants per m^2 (20 per cent cover), pseudo-coppice to 3 plants per m^2 covered none the less 30 per cent (1.3 m high), and coppice covered but 10 per cent (0.6 m high) at the end of the cropping season.

Field Suzanne was situated middle slope and the same site had been cultivated three or four times earlier but always alternating with long fallow periods. The last fallow period had been 15 years. A careful slashing and burning (some use of the hoe) preceded the second cropping year. In the beginning the rice plants developed well but later growth stunted and did not exceeded 1 m at the end of the season. Weed densities were very low at the start of the season (about 20 plants per m^2, two months after planting) but already seedlings and pseudo-coppice covered 20 per cent 10 per cent respectively (up to 70 cm high), a further 10 per cent of ground surface is occupied by coppice shoots (50 cm high). At the end of the season with no weeding being done, cover by seedings was 30 per cent (general height 1 m), cover by pseudo-coppice was 15 per cent (1.2 m high) and by coppicing plants 10 per cent (1.5 m). Trees accounted for less than 2 per cent of the population, against 15 per cent of grasses and sedges. Weeding had no effect on the rice for general crop condition was bad. Two weeding rounds did not reduce weed densities but greatly stimulated germination of Composites and resprouting of pseudo-coppice (*Solanum verbascifolium*). Fig.6.6 shows an increase in weed densities during the cropping period.

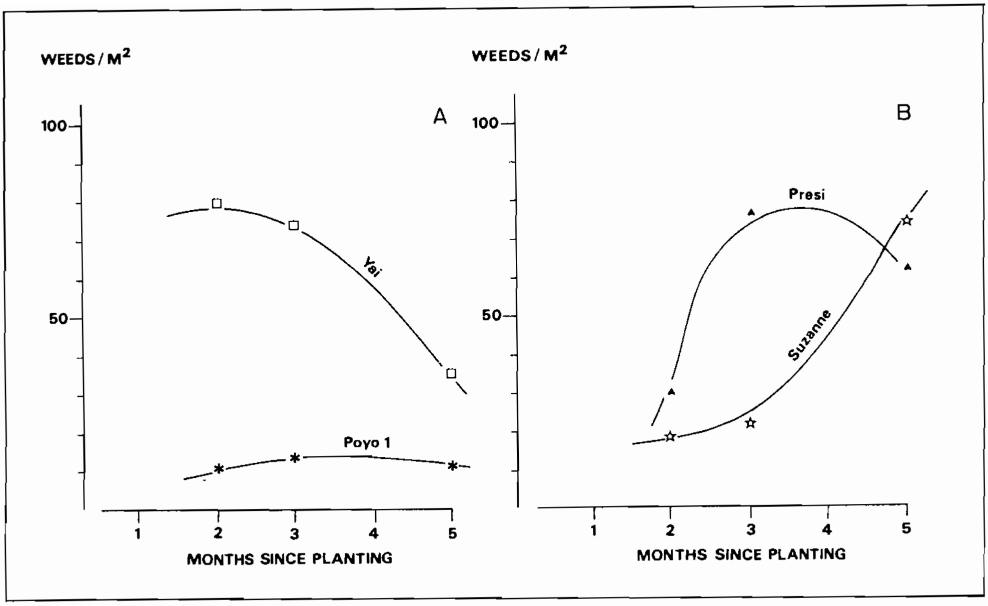


Fig. 6.6. Number of weeds/m2 during the cropping season, no weeding.
A. First year of cultivation, field Yai in old secondary forest, field Poyo 1 in primary forest.
B. Second year of cultivation, field Presi in primary forest, field Suzanne in secondary forest.

Comparison with the Pahi fields

Both fields were very clean at the onset of the second cultivation year, Presi by the burning of a considerable quantity of debris, Suzanne by hoeing the modest regrowth vegetation. The better performance of rice in Presi is probably due to the superior supply of nutrients. The Pahi fields were rather like Suzanne. Weed infestation on all three fields followed the same pattern. The seed bank had been enriched by seed bearing annual plants which have completed their life cycle during the first year of cultivation, rice plants are less vigourous and competes less good with weeds, and in the period since the opening up of the forest weed seeds from outside had reached the field, notably wind-dispersed Composites.

6.3 CONCLUSIONS

Weed populations in first year rice fields are very different from those in second year fields. The seedling population changes radically, the group of coppicing plants, far less so. In first year fields the pre-existing seed bank provides most of the germinations, in the second year this seed bank proves to be largely exhausted. Generally, the older the cleared forest had been, the greater the floristic variation in coppicing plants. Fields in primary forest are particularly rich, but swamp forest, on the contrary exceptionally poor. This could be due to the extreme change in micro-climate. Second year fields are invaded by herbaceous plants, belonging to species which are mostly wind-dispersed. The third year of cultivation is characterized by a predominance of vegetative regeneration of plants already installed. Stoloniferous grasses and pseudo-coppicing sub-woody shrubs tend to dominate weeds regenerating from seed.

If one wishes to control weed growth, one weeding round is sufficient the first year of cultivation, but, in a following season, two weeding rounds are necessary. The third year other clearing techniques (hoe) become indispensable to control weeds.

7 Aspects of fallow and weed populations

7.1 STRUCTURE OF THE FALLOW PRIOR TO CULTIVATION

7.1.1 Basal area and successional stages

Forest is converted into arable land. The quantity of wood is directly related with the amount of work involved to cut the forest. Observations on tree girths prior to felling permits to calculate basal areas and distribution of stem diameter of the secondary forest. Contribution per species can identify what part of the population is decaying. This too, has a strong relation with labour input. Finally, observations on basal area can help to "place" the secondary forest among the range of successional stages.

Table 7.1. Basal area of trees (m^2/ha) in two experimental fields prior to felling and after felling and burning.

	6 year-old secondary forest	**19 year-old secondary forest**
Total basal area prior to felling	17.2 *	14.0 *
Basal area of trees cut	13.4	12.2
Basal area of trees grown since last cultivation period	0.0	0.8
Basal area of trees grown over several cultivation periods	3.8	2.0

* excluded 10 adult oilpalms in each field.

In Table 7.1 basal areas per hectare are given for two experimental fields (Pahi 1, Pahi 2). About 80 % of total basal area was actually cut during field preparation. Most of the trees not cut had grown over several fallow periods. These relicts could have been either relicts of a primary forest (eg. *Ficus lyrata*, a straggling fig too troublesome to fell, and *Uapaca guineensis*, equally difficult to cut for the huge stilt roots), or long-lived secondary forest species left standing for a variety of reasons (*Nauclea diderrichii*, *Pycnanthus angolensis*, *Ricinodendron heudelotii*, *Triplochiton scleroxylon*). What is most remarkable in the table is the fact that a 19 year old secondary forest has a lower basal area than a 6 year old fallow.

7.1.2 Literature review

To understand this we should look at basal area figures of different successional stages, supplied by literature. Huttel (1977) gives basal area per hectare for primary forest near Taï, about 15 km from the experimental fields. They vary from 31.0 m^2/ha on the crest to 33.0 m^2/ha in the valley bottom, with a maximum at mid-slope (35.9 m^2/ha). Compared to other data (m^2/ha) from Wet Evergreen lowland forest this seems to be unsurprising: in Côte d'Ivoire 32.6

to 27.4 (Banco forest) and 33.3 to 28.7 (Yapo forest) (Huttel 1975a), in Ghana 25.5 (Hall & Swaine 1981), in Guiana 38.0 (Sarrailh *et al.*1990), in Venezuela 23.1 (Rollet 1974). Basal areas of different successional stages were studied by De Namur (1978b), on sites close to our experimental fields where shifting cultivation practices had been similar. He calculated for a 2 year old fallow a basal area/ha of 7.5 m^2, a 6 year old 17.0 m^2, a 13 year old 15.5 m^2, a 18 year old 24.0 m^2, and a 32 year old 21.0 m^2. Here we see the same discontinuity: basal areas decrease between 6 and 13 years and decrease a second time at 32 years of growth. Basal areas of secondary forest have been recorded elsewhere but observations on successive seral stages on one place where agricultural practices are uniform, are rare. They do not permit the detection of a discontinuity in basal area increase with age. Recordings (m^2/ha) are from Gabon 5 to 8 for a five year old secondary forest (Mitja & Hladik 1989), from Congo 8.2 for a seven year old forest, 15.3 for a fourteen year old forest and 29.6 for an eighty year old forest (Perreau 1983), from Surinam 9 for a three year old forest (Boerboom 1974), from Puerto Rico 35.7 for a thirty year old forest (Crow 1980), from Guiana 2.7 for a three year old forest and 13 for a four year old forest (Sarrailh *et al.*1990). These secondary forests had grown either after timber exploitation (clear-felling, bulldozer) or after a variable number of years of food cropping (with or without large trees surviving the cultivation period). The particular successional pattern occurring in Taï can thus hardly be observed elsewhere.

The tangled vegetation that follows each cultivation period rapidly acquires a forest-like appearance. The trees that form the fallow are, within a range of a few months, of the same age. Most of these pioneers have a limited, well defined life-span. In forest fallows in the Taï area two periods of strong decline of pioneer trees can be recognized. The first period occurs 7 to 9 years after the field has been abandoned and corresponds to a massive deterioration of a single pioneer tree, *Macaranga hurifolia*, a tree which had, until than, dominated the canopy. The decline is massive and rather suddenly and sets in after *Macaranga hurifolia* has reached its maximum height (13 m after 7 years of growth, Kahn 1978ab). A second period of decline sets in after 18-21 years of growth and this time trees of many species are affected, the most important being *Musanga cecropioides*, *Anthocleista nobilis* and *Harungana madagascariensis*. This decline in two waves seems to be rather particular for Taï because *Macaranga hurifolia* is here more dominant than elsewhere in forested Côte d'Ivoire (Alexandre 1978ab, De Namur 1978ab). Various aspects of this successional pattern, floristics, biomass, soil fertility, earthworms had been studied in Taï (Alexandre *et al.* 1978, Kahn 1982, Jaffré & De Namur 1983, Fritsch 1982). Fig.7.1 is an illustration.

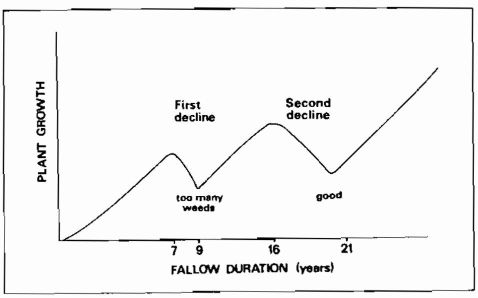


Fig. 7.1. How farmers appreciate the periodic decline of secondary forests stands. First period of decline, improper for cultivation because too many weed seeds remain viable in the soil. Second period of decline, appropriate for cultivation.

7.1.3 Basal area and distribution of girth classes

In Fig.7.2 and Fig.7.3 number of stems in successive girth classes is given. In Fig.7.2a, being a 19 year old fallow (field Pahi 1) of the community *Myrianthus libericus* & *Ptychopetalum anceps* (classification of vegetation in chapter 10), we see that the *Musanga cecropioides* trees in the sample constitute a decaying population. Many dead, not measured, *Musanga cecropioides* trees were encountered while the forest was being felled. It was mainly the decline of this tree which was responsible for the low basal area of the 19 year old forest. Some large trees, or smaller trees offering useful product, are left untouched during field preparation.

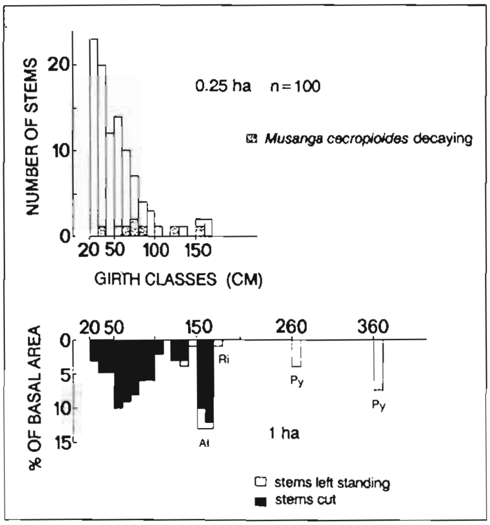


Fig. 7.2. Number of stems in successive 10 cm girth classes in a 19 year-old secondary forest (1 ha).
A. sample of 0.25 ha.
B. Contribution to basal area of felled trees and of trees left standing,
Py : *Pycnanthus angolensis*,
Al : *Albizia adianthifolia*,
Ri : *Ricinodendron heudelotii*;
10 adult oilpalms are not included.

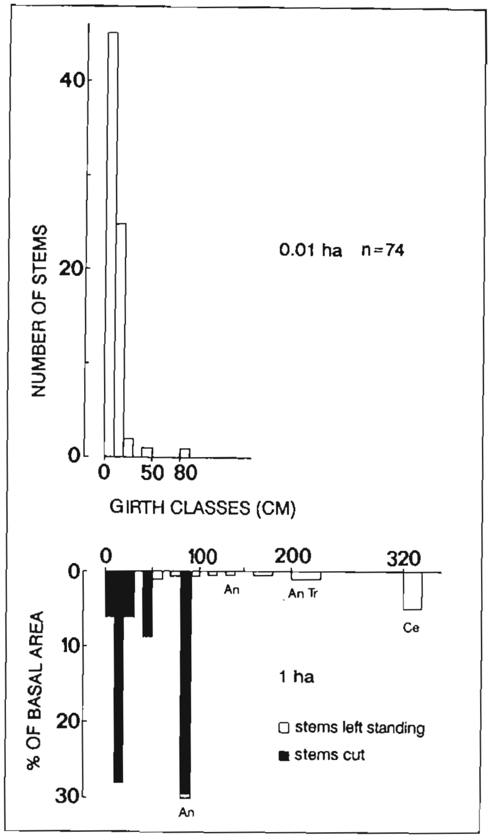


Fig. 7.3. Number of stems in successive 10 cm girth classes in a six year-old secondary forest (1 ha).
A. sample of 0.01 ha.
B. contribution to basal area of felled trees and of trees left standing,
Ce : *Ceiba pentandra*;
Tr : *Triplochiton scleroxylon*;
An : *Antiaris welwitschii*;
10 adult oilpalms are not included.

In the case of field Pahi 1 these were 10 adult oilpalms and 8 non-palm trees.

Four of them had survived an earlier cultivation period (*Pycnanthus angolensis*) and four became probably established during the last fallow period (*Albizia adianthifolia*, *Ricinidendron heudelotii*). Girth classes and contribution to total basal area is shown in Fig.7.2ab.

The girth classes distribution on Pahi 2, a 6 year old secondary forest of the community *Byrsocarpus coccineus* & *Rutidea parviflora* (classification of vegetation in chapter 10), was calculated from a smaller sample (100 m^2 instead of 0.25 ha), due to the very uniform development of *Macaranga hurifolia*, constituting 80 % of all trees in the sample. Field Pahi 2 counted an equal number of adult oilpalms which survived the present land clearing. Another 18 trees were left untouched belonging to different species (Fig 7.3b.) Relicts left standing on the field can contribute considerably to the basal area (Fig.7.2b, Fig.7.3b). In the study of an 8 year old fallow near Ibadan, Nigeria, an approximate overall basal area was 14-15 m^2 per hectare. The contribution of oilpalms was estimated a little less than 3 m^2 per hectare, while "relic stems", individuals which had developed over several cultivation periods, and "colonizing stems", individuals grown in the last fallow period, accounted for about equal numbers: between 5 and 6 m^2 per hectare each (Hall & Okali 1979). In our case basal area contribution of oilpalms was not included into the total count for most of them had not shed their leaf bases thus girth measurement was difficult.

7.1.4 Basal area and slope

The field Pahi 3, a 21 year old forest of the community *Myrianthus libericus* & *Ptychopetalum anceps*, was used to study another feature of girth class distribution and basal area. The field has a rather steep slope of about 10 % producing a prominent heterogeneity in soil within the field. Up hill we find a loamy soil (1-20 cm depth) and clayey soil (below 20 cm) with a very gravelly layer to a depth of 65 cm. Going down hill the soil becomes more sandy with less gravel. The fields Pahi 1 and Pahi 3 occupy the same toposequence and were, in 1964, part of one large rice field followed by undisturbed growth (Fig.1.3). Before felling, the field Pahi 3 was divided into 9 equal parts, 5 of them (A through E in Fig.7.3) were used for girth measurements and relevés. All decaying trees were marked and included into the count. Recently died trees as far as they were still identifiable[1] were noted. In Fig.7.4 stems are given in successive 10 cm girth classes for each of the 5 plots. Most pioneer trees had girths under 120 cm (*Macaranga barteri*, *M. hurifolia*, *Ficus capenis*, *Fagara macrophylla*, *Anthocleista nobilis*, *Caloncoba brevipes*) but some of them were capable of superior girth increment (*Ricinodendron heudelotii*, *Funtumia elastica*, *Bridelia grandis* and *Musanga cecropioides*). A number of large trees belonging to species which preferably develop in large gaps like fields, had grown so tall, girth between 200 cm and 300 cm, that perhaps their installation dates back from an earlier rice cultivation period, 40 years ago (*Nauclea diderrichii*, *Pycnanthus angolensis*).

The number of trees per plot varies greatly and so does the number of decaying trees per plot (Fig.7.4 and Table 7.2). There is a strong relation to slope. Going slope down, the number of trees per plot increases and, among them, the percentage decaying trees decreases. Even if the large trees at the edge of the field are left out, basal area is extremely

1 Women accustomed to collect firewood are very good at this.

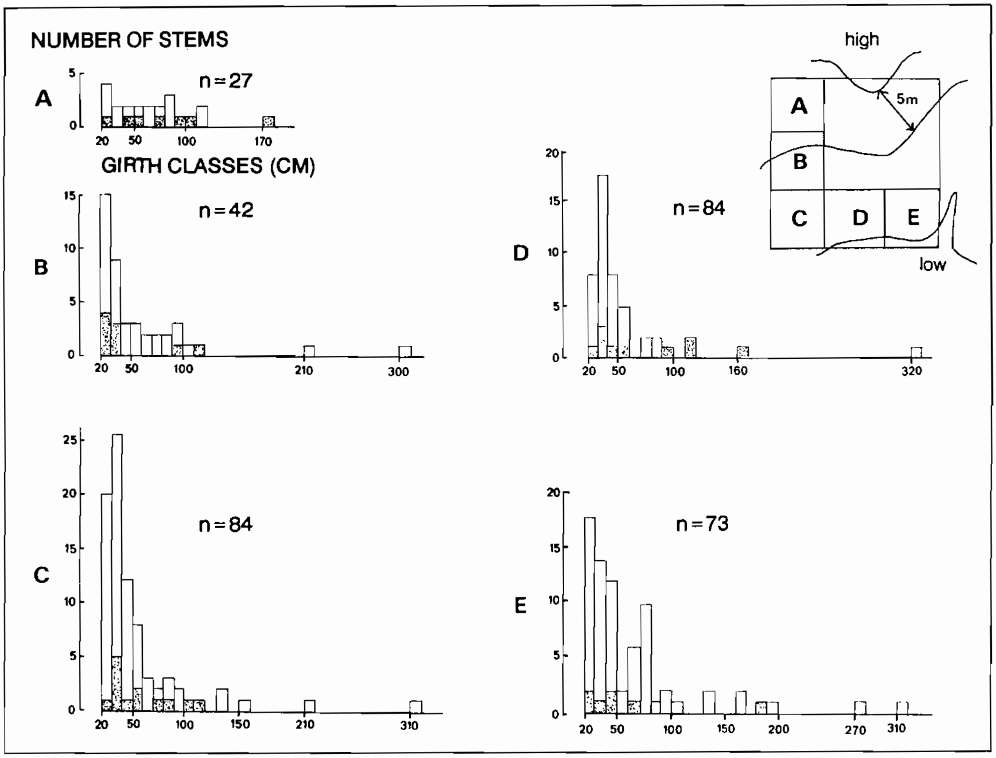


Fig. 7.4. Number of stems in successive 10 cm girth classes in a 21 year-old secondary forest.
A through E are 1/9 ha blocks along a slope.
Shaded area : decaying pioneer trees.

variable. In all plots some decaying and dead individuals of *Macaranga barteri* and *Musanga cecropioides* occurred, but dead and decaying trees of *Anthocleista nobilis* were more or less restricted to the lower slope plots. In plot D, the only surviving individual of *Harungana madagascariensis* was found, whereas dead trees of this species were found in large quantities in all plots. Among the still living trees of *Macaranga hurifolia* (maximum girth 160 cm) those occupying the lower slope were in better shape than the ones growing up hill. This means that the limited life-span of all those pioneers cited is not only genetically controlled but environment can be important too. Better moisture conditions may have prolonged the life of pioneers growing lower slope, but another aspect should be mentioned. Down hill, especially plot D and E the floristic composition of the forest is more varied. Trees of many different species constitute the canopy, and not only a few pioneer species. This can limit the danger of parasites responsible for a rapid and disastrous die-off of quasi monospecific populations (Kahn & De Namur 1978 for *Macaranga hurifolia*). It was observed that isolated pioneers in a mixed secondary forest environment could live much longer than those growing amidst other pioneers of the same species. The greater floristic variation down hill had probably been favoured by the bordering patch of primary forest, acting as seed source, though another thing has been probably of more importance. During the last land clearing 21 years ago, burning had beën insufficient there, bringing on the survival by resprouting (visible in the vegetation structure) The proximity of a primary forest may have favoured this process, because field edges, especially bordering High forest are difficult to dry out and to burn correctly.

Table 7.2. Number of trees with girth over 20 cm, number of trees decaying and basal area of a 21 year-old secondary forest in relation with gravel content of topsoil.

Plot * (33 x 33 m)	A	B	C	D	E
Gravel content (%) of top soil (0-20 cm)	68.4	63.0	1.2	0	0
Number of trees (> 20 cm gbh) in plot excl. oilpalms	27	42	84	48	73
Number of trees (> 20 cm gbh) decaying	6	9	13	10	7
Pioneers dying, species in order of importance **	*Mac.bart.* *Mus.cec.*	*Ant.nob.* *Mac.bar.* *Mus.cec.*	*Ant.nob.* *Mac.bar.* *Mus.cec.* *Mac.hur.*	*Mac.bar.* *Har.mad.* *Ant.nob.* *Mus.cec.*	*Mac.bar.* *Ant.nob.* *Mac.hur.* *Mus.cec.*
Number of adult oilpalms in plot	3	2	2	0	3
Total basal area (m2/ha)	10.1	17.8	26.9	25.3	42.1
Basal area of relicts *** (m2/ha)	0.0	6.9	7.5	7.1	21.3
Species		*Ani.rob.*	*Nau.did.* *Par.bic.*	*Fic.lyr.**	*Uap.gui.** *Pyc.ang.* indet

* See Fig.7.3.
** Mac.bar. = Macaranga barteri, Mus.cec. = Musanga cecropioides ,Ant.nob. = Anthocleita nobilis, Mac.hur. = Macaranga hurifolia, Har.mad = Harungana madagascariensis. *** trees not felled during field preparation,
Ani.rob. = Aningeria robusta, Nau.did. = Nauclea diderichii, Par.bic = Parkia bicolor
Fic.lyr. * = Ficus lyrata, field edge, Uap.gui.* = Uapaca guineensis, field edge
Pyc.ang. = Pycnanthus angolensis, indet = Rinorea sp.

From these data it is evident that the farmer can save considerable effort if he or she choses a secondary forest in a appropriate stage of decay. Another advantage is that the tree *Musanga cecropioides*, declining after 18-23 years of growth, dies off will standing. Dead trees, that can be recognized by a peeling bark, provide good fire wood at the time the field is to be burned. Other pioneer trees, notably *Harungana madagascariensis*, merely fall down and rot.

7.2 BURNING

Fire is used as a means for readying the land for planting. As a result the field is much changed, mainly in regards to soil properties, to the micro fauna and flora, and to weeds. Burning leads to an accumulation of potash, phosphates and other nutrients (fully discussed in chapter 2). Burning makes the soil less acid. As was demonstrated (chapter 6), the rice varieties in Taï do not produce

Table 7.3. pH H_20 of soil at different depths in four to five year-old cocoa plantations, established in forest of different ages.

Forest cleared	**Primary (n=30)**	**Secondary (n=9)**		
Age of fallow		3 - 6 years	8 - 15 years	over 30 years
pH H2O depth				
0 - 10 cm	4.7	6.0	7.2	5.4
40 cm	4.7	5.8	6.8	5.1

on normal acid forest soils[2]. This makes fire a prerequisite for any rice yield.

7.2.1 pH of the soil

The rise in pH is linked to the quantity of ashes deposed on the soil surface and this may be expected to be related to the age of the forest destroyed, though it may not be directly proportional to age. In a young secondary forest fuel consumption can easily be complete but the quantity of wood does not permit the formation of a large proportion of ash. More ash can be obtained if an older secondary forest is properly burnt. The difficulties to dry and burn a secondary forest increase as the forest matures. Eventually, primary forest proves to be so difficult to burn that the quantity of ash produced is disappointing. Next to the quantity of fuel available, the thoroughness with which the burning is carried out also determines the quantity of ashes added to the soil.

Soil samples were taken from 39 cocoa plantations, four and five years after felling and burning the pre-existing forest. We see (Table 7.3) that the soils under plantations established in primary forest are far more acid than those formerly covered by secondary growth. The data also demonstrate that a low level of acidity can be maintained over a number of years. The acidity increases but slowly with time (Table 7.4). This was also observed in Taï for cocoa and rice fields alike by Moreau (1983) and by Van Reuler & Janssen (1989) for rice fields. Fields lying uphill usually are less acid than those occupying lower positions on the slope (Table 7.5). This difference exists already in soils under primary forest (Fritsch 1980, Moreau 983). Though the number of samples presented may be small, the data in Tables 7.3, 7.4 & 7.5 express the general knowledge among Taï farmers, namely, that the beneficial effects of burning are easiest exploited if one prepares a field mid-slope, in a not too old secondary forest.

On places where an excessive quantity of biomass has been consumed, the soil surface is covered by charcoal. The coal has blackened the upper few centimetres of the soil. The topsoil is coloured red to a depth of about 5 centimetres. The pH H_2O on these spots (0 -5 cm) is always over 7.5 to a maximum of 8.4 (six months after burning). A well burnt field may have a few per cent of the surface occupied by those black spots.

7.2.2 pH and early succession

In an experiment conducted with R. Moreau (soil scientist ORSTOM) the relationship between pH of the top soil and early succession was studied. A small area (28 x 35 m) in field Pahi 1 was used, one year after burning and six months

2 In the field trials of H. van Reuler in Taï, rice yield continued to respond to a decrease of acidity to a pH-H_2O of 5.5 (pers. comm.).

Table 7.4. pH H_20 and pH KCl of soils (0-10 cm) under young fallows of different ages.

Years after burning	1 (n=18)	2 (n=19)	3 (n=20)	4 (n=25)	5 (n=4)
pH H2	6.1	5.8	5.0	5.4	4.7
pH KCl	5.4	5.0	4.5	4.4	3.8

after the harvest of the rice crop. The place had received no weeding of importance. The soil was sampled (0-5 cm, N=30) at regular intervals, in a grid pattern so as to make a map. From these samples pH-H_2O and pH-KCl was determined. In the same area common plant species were noted with maximum height growth of the vegetation. These data were mapped too. Three appreciations of vegetation development were distinguished:

Table 7.5. pH H_20 and pH KCl of soils (0-10 cm) in rice fields, one to two years after burning at different sites.

Land form	upland				alluvium
Position slope	upper (n=15)	middle (n=15)	lower (n=6)	valley bottom (n=3)	(n=2)
pH H2	6.2	6.0	5.7	5.4	5.6
pH KCl	5.5	5.3	4.8	4.7	5.3

1. **Well developed**, the pioneer trees, mainly *Macaranga hurifolia* constituted a closed canopy 3-4 metres above the ground, absence of grass and the weeds *Erigeron floribundus* and *Triumfetta rhomboidea*,
2. **Poorly developed**, the pioneer trees formed a broken canopy, 1-2 metres above the ground, presence of grass and *Erigeron floribundus*,
3. **Intermediately developed**, the pioneer trees, mainly *Trema guineensis* formed a broken canopy, 1-3 metres above the ground, absence of grass and *Erigeron floribundus* but presence of *Triumfetta rhomboidea*.

The soil-pH map and the vegetation map were superimposed and some clear patterns emerged. Fig.7.5 shows that regeneration was best where the soil is rather acid (pH-H_2O below 7.5), whereas poor regeneration is found where the soil is far less acid. A less acid soil means that large quantities of ash had been incorporated into the soil, so the fire had been intense on those places. The species composition of the "poorly developed" regrowth resembled to the field community *Ageratum conyzoides* & *Erigeron floribundus*, a community which covers commonly second year fields (classification of field vegetation in chapter 11). The vegetation called here good- or intermediately developed regrowth belongs to the community *Triplochiton scleroxylon* & *Oplismenus burmannii*, the usual community on first year fields. The species composition of the seed stock in forest soils prior to felling resembles that of the well developed and intermediately developed regrowth (De Rouw & Van Oers 1988). Where the fire has been intense most of the superficially buried seeds had been killed, and as a result weeds, mainly plumed Composites, can invade. The same thing happens when Composites colonize second year rice fields where a large part of the pre-existing seed stock has been eliminated during the first year of cultivation. So the present cover on poorly developed regrowth places has probably arose from seeds that were dispersed into the site recently, after the fire because the principal species are usually absent, or occur at very low densities in (old) secondary forest soil (De Rouw & Van Oers 1988).

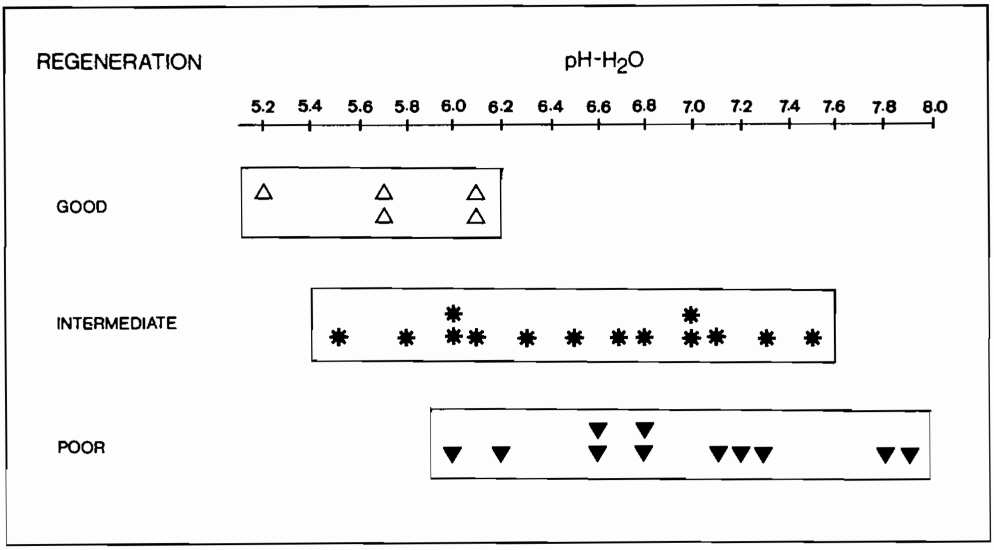


Fig. 7.5. Relation between pH-H_2O of topsoil (0-5 cm) one year after clearing a 19 year-old secondary forest and the quality of the regeneration.
GOOD : pioneer trees 3-4 metres high, closed canopy, *Macaranga hurifolia* dominant;
INTERMEDIATE : pioneer trees 2-3 metres high, no closed canopy, *Trema guineensis* dominant;
POOR : pioneer trees under 2 metres high, no closed canopy, broad-leaved herbs and some grasses.

Of course, these differences in regeneration will be rapidly obliterated by the vigourous growth of the trees present, the result being a continuous cover of trees everywhere. The present experiment suggests however, that the pre-existing seed bank might be profoundly altered by the intensity of the fire and that a destroyed seed bank favours the installation of herbaceous weeds which are far more troublesome than the seed bank weeds, being usually woody plants. In the following experiments this had been confirmed and quantified.

7.3 THE SEED BANK

Fire and the seed bank

In a forest soil the dormant seeds of mainly woody plants have accumulated through time. The all-importance of this seed bank has been recognized by many workers (Putz & Appanam 1987 in Malaya, Lawton & Putz 1988 in Costa Rica, Uhl *et al.* 1981 in Venezuela, Harcombe 1980, Borman & Likens 1979 in northern USA woodlands). Kahn & De Namur (1978) in Taï, observed no seedlings during six months in soil sterilized by burning. The population which eventually invaded those sites was similar to the one which swarmed into places where the top soil had been removed one year earlier. This indicates in another way that sites lacking a seed stock are invaded by species from the "seed rain" and that this takes some time.

The degree of destruction of seeds depends on the heat intensity generated by the fire. Samples taken from a forest soil (field Pahi 3) carried about 2000 viable seeds per m^2 soil. One day after burning this was reduced to about half that quantity (De Rouw & Van Oers 1988). An identical experiment in Costa Rica demonstrated the disappearance of 52 per cent of the seed stock which was initially valued at 8000 seeds per m^2 (Ewel *et al.* 1981). Brinkman & Vieira (1971) in Amazonia, observed that seeds buried to a depth of 5 cm could be killed by a fire. In addition insects and fungi attacked damaged seeds afterwards so that probably half of the seed stock was lost. Saxana & Ramakrishnan (1984) in India, found equally significant weed seed reduction after the burning of a 20 year old forest.

Felling and burning has still another effect on seeds in the soil. In the experiment (field Pahi 3) the germination of seeds that remained viable after burning was apparently stimulated. Emergence from post-burn soil samples started earlier, after 6 days instead of 23 days in the pre-burn soil samples. The rate of appearance was also accelerated, 90 per cent emerged in 60 days from the post-burn samples, against 90 per cent in 110 days in the pre-burn sample. Germination of seeds that survive may be promoted through some processes, because dormancy is overcome. Scarification of the hard testa protecting the seed (example *Macaranga hurifolia*, Kahn 1978a) may occur, so that imbibition becomes possible. Fire may play a role in destruction or removal of allelochemicals, some of which are known to prevent germination (Went, Juhren & Juhren 1952). In Taï, some of the common secondary forest trees and herbs are heat-stimulated and heat-resistant (De Rouw & Van Oers 1988). Saxana & Ramakrishnan (1984) recorded a similar reaction for some forbs and weed species in northern India.

7.3.2 Seed bank and light

It was found (field Pahi 3) that sunlight increased germination by 40 per cent compared to the number of seedlings germinating in the shadow of plants. Especially herbs responded by germinating if exposed to full sunlight. This is in accordance with the theory that germination of weeds and early successional species is often strongly inhibited by vegetation filtered light, in contrast with seeds from late successional plants, and those found in the climax forest, which seem to be less dependent on full sunlight for germination (Bazzaz 1979). The Taï secondary tree species showed an impressive capacity to germinate under shade (De Rouw & Van Oers 1988).

Opening of the canopy not only changes light conditions but also causes temperature and soil moisture to fluctuate over a wider range. This too may enhance germination of seeds, as was shown for *Cecropia* spp (Holthuijzen & Boerboom 1982) and for *Musanga cecropioides* (Aubreville 1947).

7.3.3 Seed emergence and weeding

After the initial burning, seedlings emerge almost simultaneously, this largely facilitates the task of weeding. Still, within the seedling population, different degrees of resistance to weeding could be observed. Present analysis is limited to very common species which act as weeds in every rice field during the first year of cultivation. These species constitute the majority of the seed stock in the soil of a secondary forest ready for renewed cultivation. Species behaviour fall into four broad classes (Fig.7.6):

1. The group of plant species (A), is among the first to appear after burning, but this group is completely eliminated during the first weeding. This group comprises of large and medium-sized trees seedlings and seedlings of crops grown in a previous cultivation period.
2. Secondly comes a group (B) whose seedlings emerge massively upon burning but new recruits become rarer as the seed bank is progressively exhausted during successive weeding rounds. Most pioneer trees belong to this group, but also some herbs.
3. A group of plants was distinguished (C) with a persisting seed bank from which seedlings emerge after each weeding thus making good for the losses. Except for *Trema guineensis*, all species mentioned are nevertheless largely eliminated in one season by three weeding rounds.
4. Plant species of the fourth group (D) are apparently delayed in germination which prevents the seed stock to be quickly exhausted. Viable seeds of *Musanga cecropioides* ranked first in frequency in post-burn soil samples (Pahi 3), but the species occupied only the 63th position in the actual rice field vegetation developed in the same period (Pahi 3). The behaviour of *Harungana madagascariensis* and *Vismia guineensis* is more easily explained. These species germinated immediately in the post-burn soil samples but only in full sunlight. Under field conditions shade is provided by the rice crop and weeds so the light needed to break dormancy may simply not be sufficient. Better germination conditions occur as a result of repeated weeding and a degeneration of the rice crop. All species of this group remain frequent during a second year of cultivation and under repeated weeding.

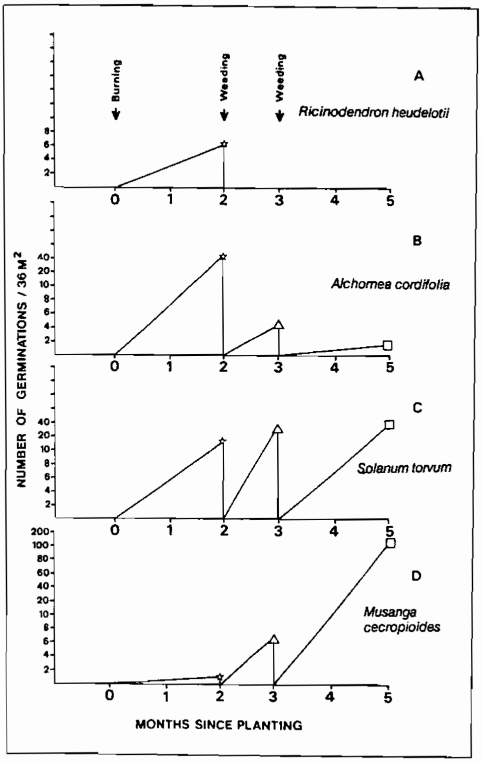


Fig. 7.6. Four strategies of weed emergence during the first year of cultivation (19 year-old fallow). **A** example: *Ricinodendron heudelotii*, other species with the same pattern, *Canarium schweinfurthii*, *Bussea occidentalis*, *Ceiba pentandra*;
B example: *Alchornea cordifolia*, other species with the same pattern, *Macaranga hurifolia*, *Triumfetta rhomboidea*, *Chassalia laxiflora*, *Albizia adianthifolia*, *Physalis angulata*, *Pouzolzia guineensis*;
C example: *Solanum torvum*, other species with the same pattern, *Trema guineensis*, *Rauvolfia vomitoria*, *Mariscus alternifolius*;
D example: *Musanga cecropioides*, other species with the same pattern, *Harungana madagascariensis*, *Vismia guineensis*.

Careful observation of weeds in first crop rice fields allows an impression of the intensity of weeding. Unweeded or hardly weeded fields carry representatives of group A, B and C. More weeding implies the disappearance of group A and the rarefaction of group B. The length of the last fallow period should also be kept in mind: rice fields prepared in young secondary forest (less than 7 years) tend to lack representatives of group A, while members of group B are present in lower densities. Irrespective of weeding, pioneers of group C and D are likely to dominate. Generally, during the second year of rice cultivation, independent of the length of the last fallow period, only representatives of group D and *Trema guineensis* continue to emerge. Furthermore we should keep in mind that traditional weeding involves the retention of a certain proportion of weeds, called "residual weeding" by Swamy & Ramakrishnan (1988). However, countings and observations shown in Fig.7.6 originate from clean weeded plots.

7.4 COPPICE GROWTH

7.4.1 Literature review

After felling a forest many stumps and roots produce coppice shoots. Detailed study of this way of regeneration has been neglected despite the importance attributed to coppice growth by many succession specialists. Three aspects of re-sprouting are usually discussed: burnt and unburnt sites are compared, the significance of coppice for regeneration of the forest is mentioned, and the exhaustion of sprouting reserves through cultivation is observed.

Some authors just mention the negative effect of fire, Maury (1979) in Guiana, Riswan (1979) in Kerenga forest in Kalimantan. Others authors estimate the number of stumps and roots per m^2 capable of surviving a single fire. About 6 plants per m^2 resprout three months after cutting and this is reduced to a tenth, four months after burning (Uhl *et al.* 1981, Venezuela). In the Moist Semi-deciduous forest of Nigeria, 44 per cent of species were coppicing on unburnt plots, against 26 per cent on burnt sites (Adedeji 1984). Though Stocker (1981), in a rain forest in Australia, took only plants over 1.3 m high into account, he found that 84 per cent of all species resprouted 23 months after burning. He observed the intensity of the fire to be quite variable.

In fields and young fallow vegetation, the primary forest species are merely present as sprouts (Uhl, Clark & Clark 1982, Riswan 1979). In freshly cleared fields almost all woody plants of the weed vegetation are derived from stumps and root stocks (Kellman 1980 Belize, Stromgaard 1986 Miombo woodland, Zambia). Rapid and efficient establishment of a bush fallow depends on there being ample coppice stumps and suckers left at the end of the period of cultivation (Kellman 1980, Clayton 1958 and Adedeji 1984 Nigeria, Ahn 1958 western Ghana, Snedaker & Gamble 1969 lowland Guatamala, Symington 1933 Malayan forest, Lambert & Arnason 1986 Belize, Kushwaha, Ramakrishnan & Tripathi 1981 and Swamy & Ramakrishnan 1988 northern India). Some studies compare regeneration by vegetative means with regeneration by seed (Mitja & Hladik 1989 Gabon, Larpin 1989 Guiana, Stocker 1981, Borman & Likens 1979 USA). All conclude that seedlings have highest growth rates.

Coppice shoots become less common as agriculture intensifies, thus they are almost lacking in permanent fields (Kellman 1980). Stocker (1981) observed that many trees coppiced immediately after felling but did not re-coppice after the fire. So certain rain forest trees may coppice after an initial burn, but subsequent fires and dry periods may eliminate most, if not all. Two cycles of cultivation and repeated weeding greatly diminish the number of coppicing plants in a field (Uhl 1987, Whitmore 1982 rain forest south-east Asia). Vine (1954), in south Nigeria reported that sometimes very short fallow periods are possible as long as stumps are preserved which check the invasion of grasses by coppicing freely. This was confirmed by Clayton (1958) for the savanna near Ibadan, Nigeria. Deliberate preservation of stumps was also mentioned by Aweto (1981a, south-western Nigeria) and by Zinke, Sabhasri & Kunstadter (1978) by the Lua' people in Thailand.

7.4.2 Experiments on coppice growth

These observations from literature go roughly for the disturbed areas of the Taï area, but they lack the precision required to answer the crucial questions:

- What is more damaging to the population of resprouting plants, burning, weeding or prolonged cultivation or any combination of these measures ?
- Which species are involved and how do they compete with the rice crop ?
- How do re-sprouting plants interfere with recovery of the forest?

Methods

Observations in the permanent quadrats were particularly elaborate in the field Pahi 1. Here, the same permanent quadrats were followed during three years of cultivation and two years of fallow. Next to the usual countings of re-sprouting plants per species, recordings included number of shoots per plant, growth rate and biomass. This permitted to determine, almost for each individual plant, the moment of exhausting and the competitive force of the shoots produced.

In the field Pahi 1 a series of permanent plots was laid out on places having received a normal initial burning, and on places having received but a mild initial burn. Slashing and burning preceding the second and third cultivation cycle and weeding during the cropping period was the same for all plots.

Results from field Pahi 1

Species richness

In the permanent quadrats (total of 12 plots of 9 m^2) those plants regenerating by sprouting from stumps and roots belonged to 153 different species, against 201 different species growing from seed. Only 45 plant species both coppiced and regenerated from seed.

Fig.7.7 shows the gradual disappearance of coppicing plant species from the field flora. Places where the initial burning had been slight are floristically richer than normally burnt sites, especially during the first year of cultivation. This difference is maintained throughout the three years of cultivation and the two years of fallow. Almost all species present on normally burnt places were also represented on sites where the fire had been mild. Concerning the normally burnt part of the field, the decline of number of resprouting species is sharp between the second and the third cultivation period. The proportion tree species to climbers does not change much over the years, but herbaceous species are less resistant to repeated cultivation. Resistance to repeated cutting and burning is largely a species attribute for all individuals of the same species tend to disappear from the field at about the same moment having received a similar treatment. It is of particular interest to know these species (common species have been listed in the Appendix 2). As we will see later re-sprouting plants play an important role in site recovery of overworked fields. These plants are often capable of strong lateral growth making them a serious competitor for heliophyl weeds and grasses. In Table 7.6 the most common coppicing species are arranged according to resistance to disturbance, ranging from delicate plants, hardly surviving one rice cycle, to more robust species which withstand repeated slashing, burning and severe competition with weeds. A distinction have been made between species only present as release from damaged forest plants and species, constituting a much smaller group, present both as coppicing plants and as seedlings. The first group disappears from the field with the exhaustion of the forest plant, while the latter has chances to remain present in the field vegetation. This faculty, to germinate or not in fields, seems to be also a species attribute (common species has been listed in the Appendix 2). Plants, still producing sprouts five years after the felling of the forest, have exceptional resistance to repeated disturbance. Many plants even seem to thrive in such an environment (*Baphia bancoensis*, *Millettia zechiana*). *Microdesmis puberula*, a very common shrub, appeared to suffer from the initial burning but endured the following slashing and burning. The *Clerodendrum* species are frequent inhabitants of cocoa and coffee plantation, where weeding can be more intense. The many lianas in this group expand mainly laterally from shoots and suckers close to the ground in an attempt to cover and shade low grasses and seedlings. Where dense thickets dominate the vegetation, those lianas climb into the forb canopy and thus compete for light, using the forb (example *Eupatorium odoratum*) as a support. The trees of this group usually have great difficulty piercing the forb canopy. Some of them like *Napoleana leonensis*, hardly grow out but seem to wait until forb and grass cover have weakened.

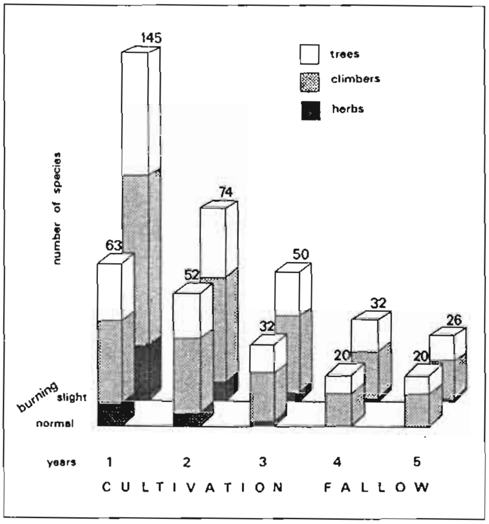


Fig.7.7. Number of species of the pre-existing secondary forest re-sprouting during subsequent years of cultivation (rice) and fallowing. Observations in permanent quadrats : 54 m2 where initial burning had been slight, 54 m2 where initial burning had been normal. Differentiation is made between trees, lianas and herbaceous plant species.

A fair amount of species survived three years of cultivation but disappeared once the field was left to itself. Apparently they withstood regular clearings but could not cope with grasses and forbs invading the field.

A great number of species resisted but poorly to slashing, burning and weeding for they disappeared after one or two cultivation cycles. Large *Marantaceae* herbs and the rattan *Ancistrophyllum secundifolium* grew out vigourously during the first cultivation year not to re-sprout the next season. Many primary forest species, mostly understorey plants and lianas, were present with one or two individuals in the permanent quadrats. They just produced coppice shoots once

Table 7.6. Number of years that plant species of the pre-existing secondary forest can resprout during subsequent years of cultivation and fallowing. (* species that survive only a mild initial burning).

	Present only as coppice	**Present as coppice and re-invades from seed**
Species resprout during 3 years of cultivation and 2 years of fallow	*Baphia bancoensis* * *Clerodendrum schweinfurthii* *Clerodendrum volubile* *Cnestis ferruginea* * *Euadenia trifoliolata* *Griffonia simplicifolia* *Hippocratea pallens* *Ipomoea mauritiana* *Leptoderris miegei* *Millettia zechiana* *Napoleona leonensis* *Pyrenacantha vogeliana* * *Salacia calumna*	*Dioscorea preussii* *Ficus capensis* *Geophila obvallata* *Mezoneuron benthanianum* * *Microdesmis puberula* *Mildbraedia paniculata*
Species resprout during 3 years of cultivation and 1 year of fallow, then die	* *Agelaea trifolia* *Canthium multiflorum* *Combretum grandiflorum* * *Loeseneriella africana*	
Species resprout during 3 years of cultivation, then die	* *Anchomanes difformis* * *Combretum dolichopetalum* *Combretum homalioides* *Combretum paniculatum* * *Combretum platypterum* *Monodora tenuifolia* *Pteris burtoni* *Rinorea longicuspis* *Salacia debilis* *Salacia erecta*	*Dioscorea praehensilis* *Phyllanthus discoideus* *Rauvolfia vomitoria*
Species resprout during 2 years of cultivation, then die	*Ancistrophyllum secundiflorum* *Bequeartia mucronata* *Bligia welwitschii* *Calpocalyx brevibracteatus* *Clerodendrum splendens* * *Combretum aphanostylis* *Combretum oblonga* *Erytrococca anomala* * *Myrianthus arboreus* *Neuropeltis acuminata* *Platysepalum hirsutum* *Secamone afzelii* *Sterculia tragacantha*	*Albizia adianthifolia* *Chlorophytum orchidastrum* *Costus deistelii* *Dioscorea burkilliana* *Megaphrynium macrostachyum*
Species resprout during 1 year of cultivation, then die	*Cephaëlis peduncularis* * *Chrysophyllum taïense* * *Distemonanthus benthamianus* * *Geophila afzelii* * *Lovoa trichilioides* *Mareya micrantha* * *Myrianthus libericus* * *Palisota hirsuta* * *Sarcophrynium brachystachus*	*Aframomum daniellii* *Aframomum sceptrum* * *Afrosersalisia afzelii* * *Albizia zygia* *Alchornea cordifolia* *Ampelocissus gracilipes* * *Dialium aubrevillei* * *Dioscorea bulbifera* * *Dioscorea liebrechtsiana* * *Dioscorea minutiflora* * *Dioscorea smilacifolia* *Fagara macrophylla* *Marantochloa congensis* * *Piptadeniastrum africanum* * *Trichilia heudelotii*

or twice after the first burning and then disappeared.

Plant densities

Not only species richness but also number of plants per m^2 is strongly affected by the intensity of the initial burning. Besides there is a response to weeding frequency. In Fig.7.8 and Fig.7.9 number of re-sprouting individuals per m^2 is set against time. Countings from normally burnt plots and slightly burnt plots are represented separately. No weeding is compared with two weedings per season. During the first and the second cultivation cycle differences in re-sprouting plant densities in the field are mainly a result of variations in fire intensities generated by the initial burning. Weeding strongly reduces coppicing plant densities on slightly burnt places, but has less effect on normally burnt sites. During the third cultivation period the different treatments, burning and weeding, all start to give the same result: plant densities stabilize at 1.0 to 1.4 individuals per m^2. This level is maintained during the following two years of fallow.

Uhl (1980), in Venezuela, gives densities for re-sprouting woody plants three months after cutting the forest: 6.37 individuals per m^2. Four months after burning the site the density was reduced to 0.63 plants per m^2. Repeated weeding (without burning), at least 5 times in two and a half years, was held responsible for the exhaustion of sprouting reserves, expressed in a steady decline of plant densities to about 0.11 individuals per m^2 (Uhl, Clark & Clark 1982). In the data provided by Uhl (1980) densities prior to burning are comparable to the Taï data for slightly burnt plots, but data from subsequent burnt and weeded plots are far below those found in Taï. The field had been prepared in forest bearing no sign of disturbance this in contrast to the secondary forest in Taï. Hence coppicing plants in San Carlos, Venezuela, were all primary forest species, while those plants in Taï were both primary and secondary species. This explains, however only part of the differences in density. The literature reports that fire and repeated weeding kills off most of the sprouting stems, stumps and roots. We conclude that many plants indeed die as a result of this but also, viewing a slight increase in re-sprouting plants per m^2 the fifth year among the weeded plots, that some plants are capable of site tenure and even expand.

Other features

The pace of shoot production is not the same for any stump or root. A large group of plants re-sprout promptly after each disturbance, and, if they fail to reappear, the plant has died (*Ancistrophyllum secundiflorum, Baphia bancoensis, Canthium multiflorum, Cnestis ferruginea, Combretum homalioides, Griffonia simplicifolia, Hippocratea pallens, Myrianthus arboreus, Rothmannia longipetala, Microdesmis puberula*). Another group comprises plants not found at each recording. They seem to take longer to recover, or do not re-sprout during the dry season, or in full sunlight. Before they succumb, appearances become less and less frequent (*Clerodendrum splendens, Clerodendrum bakeri, Dalbergia albiflora, Dioscorea bulbifera, Dioscorea preussii, Fagara macrophylla, Leptoderris miegei, Monodora tenuifolia, Secamone afzelii, Uvaria ovata, Vitex thyrsifolia*). An extreme example is the pygmy tree *Euadenia trifoliata*, known in Oubi as "Tu-ii-tahan", meaning "plante sorcière". It re-sprouts with one or two conspicuous spotted leaves, then disappears for years to reappear unexpectedly. the pace of re-sprouting seems to be a species attribute, though size of the plant and environmental factors may play a role.

Finally we can rate coppicing plants by their number of shoots produced simultaneously. This is not so much a characteristic of species but depends more on size of the plant and on the intensity the plant has suffered from the initial burning. Average number of shoots per individual plant at the end of the season was 4.25 (5.45 shoots/m^2) against 4.34 shoots per plant (25.1 shoots/m^2) on slightly burnt spots. Plants of the same species coppiced with a double amount of shoots on slightly burnt places. This accounts especially for the first cropping season, afterwards these differences damp off. The forest vegetation is generally cut off close to the ground. On normally burnt spots most sprouts grow from buried buds. On slightly burnt places, also buds situated above the ground can grow out. Large plants produced more shoots than smaller ones, independently of treatment. Sometimes number of shoots per individual can be a species characteristic. Some species produce always far more sprouts than average. Only few species coppice with more than 20 sprouts after each disturbance, they are, the lianas *Tetracera potatoria, Campylostemon sp, Griffonia simplicifolia, Hippocratea pallens, Secamone afzelii*, and the trees *Sterculia tragacantha, Calpocalyx brevibracteolata, Baphia bancoensis and Ficus capensis. Microdesmis puberula* re-sprouts most abundantly of all.

Results from other fields

Densities of re-sprouting plants per m^2 were also determined on 17 other fields. Only normally burnt spots were investigated. Average densities per field ranged from 0.58 plants/m^2 to 1.97 plants/m^2. The mean of all those fields was 1.28 (standard deviation 0.385).

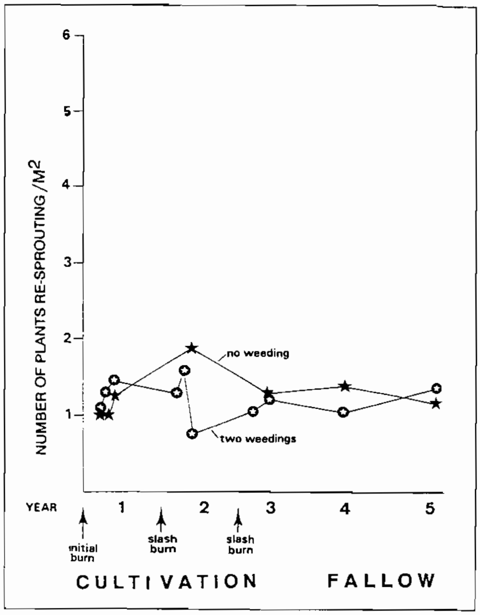


Fig.7.8. Number of plants of the pre-existing secondary forest re-sprouting during subsequent years of cultivation and fallowing. **Initial burning was normal.** No weeding and two weeding rounds during the cultivation periods.

Fields made in primary forest were not different from those made in secondary forest, nor did it matter whether the last fallow period had been long, over 16 years, or short, under 6 years. There was no relation between toposequence and density of coppicing plants, and number of plants the first year of cultivation did not significantly deviate from second year crop. There was just a weak relation between number of herbaceous plants and position on the slope: in valley bottom fields up to 40 per cent consisted of herbaceous plants (*Marantaceae* and *Zingiberaceae*) against some 20 per cent on fields up hill.

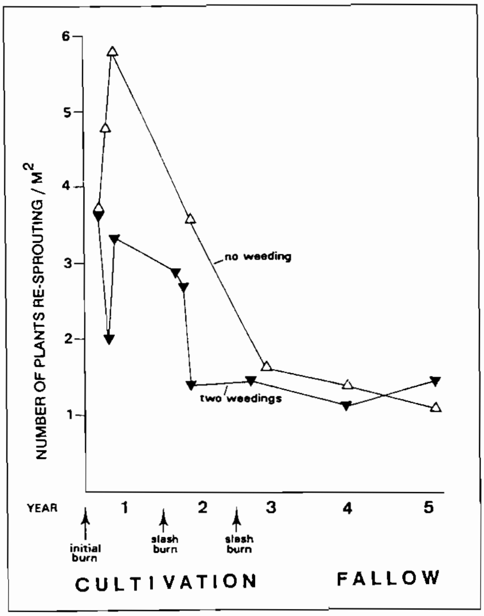


Fig.7.9.Number of plants of the pre-existing secondary forest re-sprouting during subsequent years of cultivation and fallowing. **Initial burning was slight.** No weeding and two weeding rounds during the cultivation periods.

7.5 CONCLUSIONS

Our observations on the life-span of common pioneers, being mostly genetically controlled, but also environmental, will help us to identify and judge successional stages.

Burning proves to be a key event in successional and shifting cultivation processes. The residual effect of burning remains noticeable in the vegetation even after many decades of undisturbed growth, structurally and floristically. In the case of excessive burning regeneration occurs by propagules from outside the burnt area. Plant species with very effective means of dissemination, weeds and ruderals, colonize the place. A normal burn allows part of the buried seed stock to survive as well as vegetative parts of forest plants capable of re-sprouting. The rapid development of plants already present "closes" the place for colonizers from outside (chapter 10 and 11). A mild fire favours the regeneration by coppice. Though not much seeds of the seed stock are destroyed, germination is averted by a variety of reasons, the most important one being shade rapidly produced by vigourous coppice shoots.

These observations on regeneration will help us to answer one of the main questions of this study: what cultural practices degrade the environment and how is this done?

8. Methodological aspects of the vegetation studies

The necessity to develop our own classification has been explained earlier (chapter 1). For general methods see Küchner & Zonneveld 1988, p.13-83. Some methodological aspects have to be described and explained in detail because there is still much diversity of opinion among vegetation scientists as to the methods to adopt in tropical rain forest vegetation studies.

8.1 SAMPLE PLOT SIZE AND THE ISSUE OF "MINIMAL AREA"

The sampling was executed by making "relevés". These are, in this case, descriptions of properties of a small area (6x6 metres and its near surroundings, about 100 to 200 square metres) where a full list of all plant species occurring at that spot are given with some indication of the abundance per species, as well as data on structure, and some additional data on the site such as soil -from auger description-, landform, relief, land use and several other ecological observable features.

To my knowledge no other vegetation scientist working in a rain forest environment used so small plot sizes (36 m^2) and identified so many different plant species in those plots (generally between 60 and 100). How can this be justified since the recommended size of a sample plot in tropical forested land is quite large (250-1000 m^2, Van Gils, Zonneveld & Van Wijngaarden 1982). The commonly practiced plot size is much larger too (150-1000 m^2 Guillaumet 1967, 500-1000 m^2 Hommel 1987, 1000 m^2 Zonneveld & Surasana 1988 and Federov 1966). These authors recorded all terrestrial plant species in a plot. Many other scientists, usually forest botanists, making relevés in rain forest, enumerate only woody plants above a certain girth size (625 m^2 Hall & Swaine 1981 p.14, 1250 m^2 Whitten 1982, 6400 m^2 Gartlan *et al.* 1986, 320 m^2 Swaine & Hall 1988, and many others). The question of plot size has an analytical and an empirical side.

8.1.1 Analytical argument

Ideally, the whole stand of a uniform vegetation should be sampled, but, this being impractical, an area of at least as large as a "minimum area" should be described. The "minimum area" is considered, for practical reasons, representative of the whole (Braun-Blanquet 1928). If the number of species is plotted against area, then the curve thus obtained rises quickly at first and then flattens out. The "minimum area" is often defined as the area which contains 80 per cent of the total number of species in the stand (which actually remains unknown), or the "minimum area" is indicated by the inflection of the curve (Braun-Blanquet 1928). If a sample area is not large enough, those species which would appear constant in the vegetation, cannot be found in sufficiently large numbers so no clear units can be obtained from these species lists. If the sample area is much larger, the number of additional species is few and these are probably unimportant because too dispersed.

Mangenot (1955) has compiled three species-area curves for the Yapo forest in

Côte d'Ivoire, taking all vascular plants into account. Two of the three curves do not clearly flatted out at 320 m^2 area, but 80 per cent of the total of 180 species recorded is present in about 100 m^2. In plots of 36 m^2 between 70 and 100 species are present. These are figures comparable to number of species in our relevés in primary forest in Taï. Hommel (1990) demonstrated (rain forest Indonesia) that by considering only part of the tree vegetation, e.g. trees of a certain girth, minimal area is automatically enlarged.

It has been observed by Poore (1955) that in practice the limits of a uniform stand are reached before a species-area curve can be determined successfully. A uniform sampling site is a prerequisite of all phyto-sociological theory. If no uniformity exists in a sample, the method fails because species composition cannot be related to a type of habitat. We should therefore conclude that the scientist first concern is homogeneous sample area, and only secondly he should get as much species as possible on the species list.

In the Taï region soil conditions including drainage patterns were found to vary greatly over short distances. For the greater part this variation is well organized in relation to land form and toposequence, though very complex (Fritsch 1980, summarized in Guillaumet, Couturier & Dosso 1984 p.42-45). The important change in species composition along a slope (only tree species over 11 cm gbh were considered) was demonstrated by Huttel (1977) and Vooren (1979) in a sample close to the Taï research station. Huttel (1977) compiled two species-area curves in primary forest. One of the curves comprised only trees with gbh over 40 cm (maximum 90 species in 2 ha), the second with trees with gbh between 11 and 40 cm (80 species in 0.4 ha). None of the curves showed an inflection.

Some of the soil variation, also changing over very short distances, cannot be found in geomorphological predictable positions, but, on the contrary, seems to be distributed erratically. This variation is related to lithology and hence depends directly on the wide variety of parent material provided by the basement complex.

8.1.2 Empirical argument

The problem with small plots in a rain forest is that most plants are seedlings and saplings of larger woody plants and these are usually difficult to identify. Our experience with the Taï flora started with fields and seed bank research, continued with secondary forest and ended with primary forest. In fields and in young fallow vegetation the majority of plants are young and here the necessary experience was gained in identifying juvenile plants. At the same time a group of ORSTOM botanists, also working in Taï, made special studies on seed dispersal and regeneration so large reference collections of seedlings became available, next to already existing flora's with special attention to seedling morphology (De La Mensbrugge 1966, De Koning 1983).

It was found that using the full species composition (except epiphyts) small plots could be floristically very rich, fields as well as secondary forest, as well as primary forest. The recommended plot sizes in High Forest are so large in order to cover a sufficient number of the highest trees. We found most of the large trees and lianas occurring dispersed as adults over a fairly large area (about 2000 m^2) to be present as seedlings and saplings in much smaller plots. Enlarging the sample plot would result in more time needed to search the area for new species, many of these species would be rather rare, so less well known and more effort would be needed to label, dry and identify them. A large plot would require repeated checks on soil conditions and auguring a gravelly soil can be very hard work. All this would slow down the accumulation of results considerably. To compensate the still very limited size of the sample plot many distinct relevés were made.

Many scientist have assumed that classification of a rain forest using all terrestrial plant species was rather impossible because of the many dispersed plants. This species richness proves to be rather an advantage, as was also demonstrated by Hommel (1987) who classified forest in Indonesia. The ecologist concern for complete species list of a community and an emphasis on "minimum area" is justified in temperate regions because sociological groups are small. In those relative species-poor environments sensitive indicator plants are often dispersed so they are easily "missed" in too small plots surfaces. In a tropical rain forest with high species diversity large sociological groups are formed whose members can occur very dispersed. However, even in small plots, always some members of a sociological group can be found (Hommel 1990). Of course to get to know the full group, many relevés are necessary. This makes sample size to some extent interchangeable with number of samples.

Uniformity of the vegetation was checked by eye with other consideration, evenness of slope, similarity of the drainage conditions and of the soil profile. Later, using statistical methods (tabular comparison) the homogeneity of samples could be checked, too.

8.2 COVER, DENSITY, STRUCTURE

A list of all species present in a relevé is of paramount importance, but next comes an estimate of the relative role each species plays in the economy of the stand. Percentage cover in the upper classes and abundances in the lower classes was the convenient measure of this (Table 8.1). Sampling was done with equal accuracy using the same field code everywhere, from primary forest to rice field vegetation. The field code proved to be a good system on small area. It is relatively easy to distinguish the degrees of abundance and the type of conclusions drawn allow for a rather broad margin of error in description. The field code can be converted directly into the matrix code and afterwards, if desired, suitable pseudospecies cutlevels can be chosen for further processing of the data (TWINSPAN, Hill 1979b).

In primary forest relevés, the cover of emergents and other high trees in the near surroundings of the plot were noted separately from those of smaller plants. Besides, adult trees and lianas were always recorded separately from their presence as seedlings and saplings. It is doubtful whether in our case an elaborate description of strata is worth the extra expenditure of time. All primary forest outside the Park and also part of the Bufferzone, has been logged, so some of the largest trees per hectare are likely to be missing. This influences forest structure but much less floristic composition. More important is the fact that primary forest near fields and settlements tend to lack systematically one class of pole sizes, universally used for construction material (Oldeman 1989). Though farmers have preference for wood of certain species, these species remain present in the relevé enumeration as coppice shoot or as seedling.

An estimate of the aggregation of one species was only noted whenever this was unusual.

In secondary forest, average height of the pioneer trees was always recorded.

The same accounts for rice fields where height of weeds, forbs and pioneer plants was noted. In fields and in secondary forest an index of vitality was given in two easily recognizable extremes - very good and very poor.

Presence of flowers was always recorded and, in the case of weeds, special attention was given to ripe fruits.

While processing the data from primary forest it was found that the different values for cover/abundance in the matrix did not influence the formation of clusters, so by classifying primary forest plain presence and absence was used. This indicates a fair amount of "robustness" of the data set, in the sense of Gaugh (1982 p.64). In the process of classifying secondary forest, cover data were far more important. It was essential, for example, in order to distinguish young stands where few pioneer species made up most of the canopy, from older secondary species where the canopy was build up by a large variety of tree species including an occasional tree of the previous dominant pioneer species. In the classification of field vegetation further emphasis was given to cover and abundance but also to vitality.

Table 8.1. Cover and density classes per species for vegetation analysis, field code and transformation to the matrix code (after Küchner & Zonneveld 1988 p.66).

Cover (%)	Number of individuals	Field code	Code in matrix
< 5 %	1 - 2	r	1
-	3 - 20	p	2
-	20 - 100	a	3
-	>100	m	3
5 - 15	1	1R	4
-	2 - 20	1P	4
-	> 20	1A	5
about 20	irrelevant	2	6
about 30	"	3	7
about 40	"	4	8
about 50	"	5	8
about 60	"	6	8
about 70	"	7	9
about 80	"	8	9
about 80 or higher	"	9	9

8.3 PROCESSING OF THE FLORISTIC DATA

Classification involves the grouping of similar entities together in clusters and it should both summarize and reveal the inner structure of data (Gaugh 1982 p.1-17). Samples, or relevés, with similar species composition are brought close together in clusters, as are species with similar sample distribution. One of the ways this can be done is by table arrangement. Such a table is an, often extensive, relevé- by-species matrix of occurrences. The person arranging the table seeks to order the sample-by-species matrix by placing samples and species into a disposition which reveals best the inner structure of the data (Braun-Blanquet 1928, Westhoff & Van der Maarel 1978). Values in the matrix are thereby concentrated in blocks and lines can be drawn in the matrix to mark off samples and species clusters (see also Küchner & Zonneveld 1988, p.84). So table arrangement expresses relationships among samples and species. The processing of the data is essentially a statistical, multivariate analysis of the matrix. It can be done by hand (Braun-Blanquet table method) or by computer followed by refinement by hand. A second, independent step consists of relating the thus achieved order to other kinds of date, including environmental and historical data. The assumption is that a number of species will respond to an environmental or other factor in a significant and possibly interpretable way.

Between 1978 and 1989 a great number of observations were made, about 600 relevés, comprising primary forest, secondary forest of different seral stages, rice fields, cocoa and coffee plantations, thickets, roadsides etc. Some stands were surveyed once, others were repeatedly sampled in order to follow their development over time.

The temptation is great to make one classification for all vegetation occurring in the Taï region. This seems still more appealing because efficient computer programmes exist nowadays which have a sufficient large capacity to "swallow" extensive sets of data.

In our case the clustering-ordination programme TWINSPAN, and the ordination programme DECORANA were used, both originating from Hill (1979a, 1979b) and further adapted by the department of Vegetation Science, Plant Ecology and Weed Science, Agricultural University Wageningen.

8.3.1 Particularities of the data set

In our first attempt to analyse the Taï vegetation the complete set of over 600 relevés was not fed into the machine, not only because the capacity of the micro-computers used was still insufficient, but rather for reasons of common sense. The floristic variation is induced by a combination of factors, environmental, historical and of course, mere chance. These factors vary on scale in time and in space and this makes an analysis effective for some factors but not for others. It was decided to set apart observations in agronomic field trials from relevés not in an experimental setting. The latter group (data set 1, Fig.8.1) has 249 relevés containing 960 identified species. From this set an ordination and a vegetation table were calculated. In Fig.8.2 we see the result of the ordination. Scores of the first axis (eigenvalue = 0.52682, residue = 0.000003) are set against scores of the third axis (eigenvalue = 0.25020, residue = 0.000054). The second axis (eigenvalue = 0.26690) was not used for it demonstrated a far to large residue (residue = 0.001536). The first axis corresponds largely to a gradient in disturbance. The third permits to differentiate between tree crop plantations and fallow vegetation. The vegetation table, not represented here, gave three clusters corresponding to primary forest, secondary forest and fields. All other features, soil, toposequence, geology, relief, land use pattern etc. were obscured. In order to reduce the importance of the factor Disturbance, we grouped together the relevés in vegetations with roughly the same rate of disturbance. We hope to force back some of the dominance of the Disturbance trend in order to create some more possibilities to analyze other variation. Hence data set 1 (Fig.8.1) was split up on data set 2, comprising primary forest, data set 3, comprising secondary forest, and data set 4 comprising fields.

8.3.2 Spatial and temporal trend

The more a forest matures, the more the vegetation develops towards a species-rich vegetation, being an optimum situation dictated by ecological factors like climate and soil. The more a

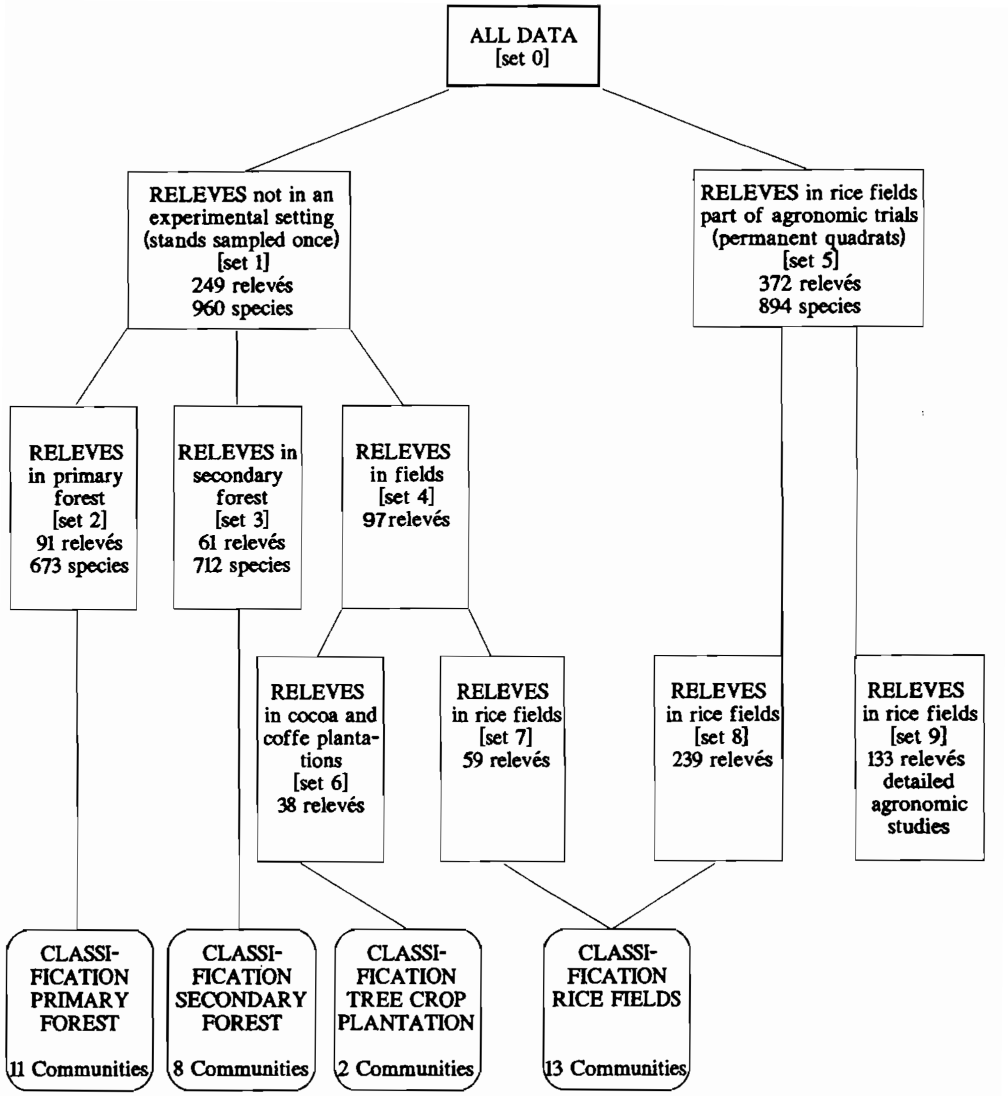


Fig. 8.1. Schematic representation of the structure of the vegetation data set and the spliting up of the set for appropriate analysis.

vegetation has been cut and burnt, the more it contains pioneer plants and weeds. The latter, besides being rather uniform throughout the study area, do not have much indicating value for site characteristics but chiefly indicate human activity. The sites most useful for our natural classification of spatial variation proved to be those carrying a forest as mature as possible (relevés of set 2).

In rice fields and in recently abandoned fields the vegetation is most dynamic. The main determinant is, again, frequency and severity of disturbances,

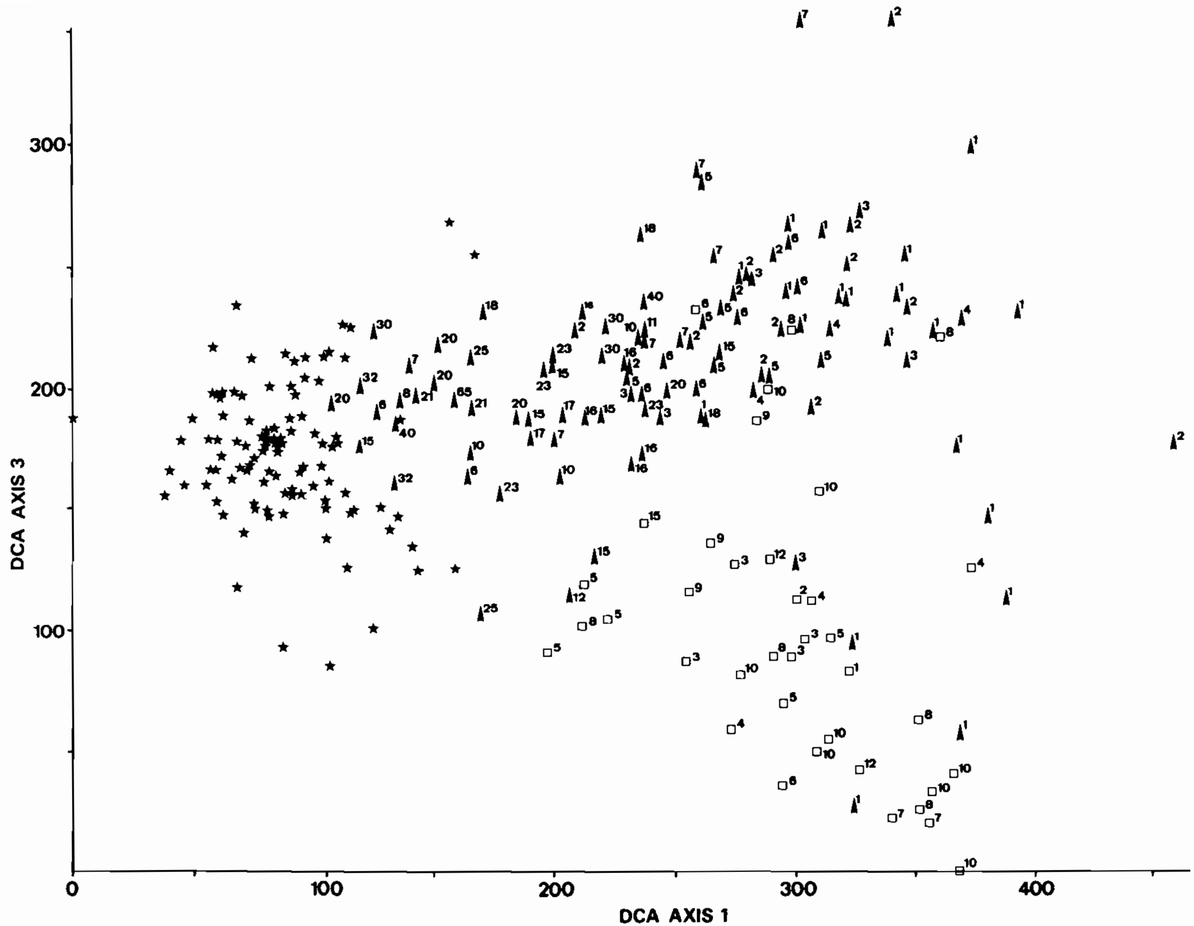


Fig. 8.2. Ordination of the relevés of data set 2 (Fig. 8.1), first and third axis scores. Star : primary forest, triangle : secondary forest with length of the fallow period indicated, cube : cocoa plantation with age indicated.

this time a strong and immediate relation is established between agricultural practices and field growth, although the soil proves to be important too. Vegetation in fields can best be studied by means of repeated observations in permanent quadrats (data set 5). These observations are supplemented by a wide range of data of similar observations at different sites, which are, in contrast with the previous method, surveyed only once (data set 7). Tree crop plantations were classified separately (data set 6), so data set 7 contains only rice fields. The data set 5 was "cleaned" from relevés of too detailed agronomical studies (data set 9), leaving data set 8.

For primary forest (set 2), for secondary forest (set 3) and for rice field vegetation (set 7+8) the initial arrangement of the vegetation table was acquired with the programme TWINSPAN. By successive refinement by hand, evaluating each species and sample, a better order of species and samples was established.

9 Plant associations in primary forest

9.1 EARLIER OBSERVATIONS AND CLASSIFICATIONS ON PRIMARY FOREST

9.1.1 Observations by Mangenot

Mangenot (1955) studied forest vegetations in Côte d'Ivoire and he was one of the first to classify them floristically with the help of species groups. He also detected to what extent climatic and edaphic factors could limit the occurrences of certain species groups. High forest in Côte d'Ivoire grows where water is sufficiently available. On sandy soils precipitation should not be less than 1300 mm a year, and on clayey soils not less than 1150 mm a year. If water availability increases, so does species richness. Around 1700 mm a year, the number of forest species increases considerably to constitute a "forest hygrophile". Mangenot further divided these humid forests according to regional soil properties: they were called either "psammo-hygrophile" for forest on rather sandy soil, or "pélo-hygrophile" for forest on more clayey soil. Although Mangenot did not have the opportunity to study the Taï forest as closely as the different forest near Abidjan, he classified it as a "pélo-hygrophile". An example of a "pélo-hygrophile" forest studied thoroughly by Mangenot is the Yapo forest, 50 km north of Abidjan. Within such a forest, soil properties may change over small distances. Local differences, especially in soil texture, are expressed by the presence of new species groups. On places with the most favourable soil moisture conditions the forest is enriched by a species group he called the "Exclusives".

An important conclusion of Mangenot was that all species of the sociological species groups he defined were usually present over the entire toposequence, except for the valley bottom. These species groups are sufficiently well represented in small plots of 100 m^2 to recognize them and to classify the site. Species richness is a good indicator for pedoclimatic conditions. In the Yapo forest, sites with more than 50 species per 100 m^2 have excellent growth conditions and we may find members of the species group the "Exclusives". Sites with approximately 45 species per 100 m^2 are drier or poorer than normal. Below 40 species per 100 m^2 the species constituting the sociological groups become lost.

9.1.2 Observations by the "Mission militaire".

In April 1960 a group of French and Ivorian scientists, among them botanists, a geomorphologist and a soil scientist, mainly ORSTOM, organized an expedition straight through the forest from Soubré to Taï. It was probably the second botanic scientific expedition of this type after Chevalier's (1906-1907), and the first in which scientists of different disciplines made their observations together. The French colonial army assisted the group, therefore the expedition remained known as the "Mission militaire" (Adjanohoun & Guillaumet 1960-1961, Riou 1960).

They found that, except for the area next to Soubré, which proved to be sandy with an appropriate "psammo-hygrophile" species composition, all forest lying more westward could not be placed in the same class, despite the soil often being sandy. The species composition resembled that of the "pélo-hygrophile" forest of Yapo. Above that, Mangenot's species group the "Exclusives" was unexpectedly common, also on rather sandy soils. The Mission was surprised to find so much variation in geology and so many remarkable examples of erosion and ravines. The erosion was partly attributed to the high density of elephants. They concluded that the rainfall distribution was probably very different from elsewhere in Côte d'Ivoire and that it had a pronounced influence on the vegetation. The Mission presumed that different forest communities existed on schists, on granite, on gneiss, on amphibolite and on alluvial soils.

9.1.3 Observations by Guillaumet (1967)

Guillaumet studied the forest in south-west Côte d'Ivoire from 1960 to 1979, writing a synthesis in 1967. He concurred with the classification of Mangenot and refined it for use in the Taï forest. What distinguishes the Taï forest from all other ivorian forest is the large number of endemic species. Because of this aspects he called it a forest "à faciès Sassandrien"[1]. He found that the primary forest becomes enriched by successive species groups as precipitation increases, considering a large area (about 200 km along a rainfall gradient) and a relative important variation in rainfall (1700 to 2400 mm per year). One of his conclusions was that not the group of "Exclusives" characterizes sites with optimum growth conditions, but mainly the group of endemic species, called "Sassandrien". He further stated that the discriminating value of the "Sassandrien species" is almost entirely lost on sites south of the 2200 mm isohyet. Finally he could not detect particular species groups for upland forest on schists, on granite, on gneiss on other rock types. The occurrence of a species group depends first of all on moisture conditions, though this can be related to lithology. Additional factors are: aeration of the soil, and base saturation together with pH.

9.1.4 The classification in "Le milieu naturel de la Côte d'Ivoire"

The vegetation of Côte d'Ivoire has been mapped by Guillaumet & Adjanohoun (1971), on a scale 1: 500.000. The method used can be described as a wilful adaptation of the theory of Braun-Blanquet, to handle complex tropical vegetation types. At the same time it united the points of view of many prominent botanist (Mangenot 1955, Aubreville 1957, Schnell 1952). Two of the primary forest communities they distinguished, occur in the study area: the community of *Eremospatha macrocarpa* & *Diospyros mannii* in the north, and the community of *Diospyros* spp & *Mapania* spp in the south. The boundary is purely based on moisture conditions, a combination of climate and soil properties (Table 9.1). The difference is merely defined as the community of *Eremospatha macrocarpa* & *Diospyros mannii* lacking a number of species present in the community of *Diospyros* spp & *Mapania* spp. The authors emphasize that a number of species proper to the community of *Diospyros* spp & *Mapania* spp can occupy sites with lower rainfall, notably along water courses and there where edaphic

1 The term "Sassandrien" comes from Mangenot (1955) who used it to indicate endemic species of "forêts hygrophiles" of western Côte d'Ivoire.

moisture compensates for rain (Avenard *et al.* 1971 p.168-176). The transition from one community into the other is usually gradual, but can be abrupt if clayey soils developed over schists alternate with the common coarser migmatite material. A structural difference is sometimes evident in the undergrowth, the community of *Diospyros* spp & *Mapania* spp being surprisingly rich in herbs.

9.2 PLANT ASSOCIATIONS IN PRIMARY FOREST

A multivariate analysis of the rain forest relevés (data set 2, Fig.8.1) resulted in 11 distinct communities. Units were recognized through the examination of numerous corresponding stands, first with the help of the clustering programme TWINSPAN, then followed by successive refinement by hand. A hierarchical classification had gathered units into groups, and groups into a dendogramme (Fig.9.1) which indicates some relationships among clusters. The first level of division sets apart the primary forest communities on uplands (Community group A) from those growing on other land forms (Community group B). Fig.9.2 gives the arrangement of sociological species groups over the different communities of the Community group A. Fig.9.3 presents the same for the communities of group B. In the Appendix 1 the species belonging to these different species groups are listed.

Table 9.1. Classification of upland primary forest in the study area by Guillaumet & Adjanohoun (1971) with ecological factors.

Forest type	Waterholding capacity of soil	Lithology	Annual rainfall (mm)	Number of consecutive months with water deficiency
Eremospatha macrocarpa	intermediate	variable	> 1700	2 - 5
& Diospyros mannii	good	schists, amphibolith	1500 - 1700	3 - 5
Diospyros spp &	good	schist	> 1700	2 - 4
Mapania spp	good	migmatites, granites	> 2000	2 - 3

9.2.1 Community group A

How are the different communities on upland correlated to other kinds of data? In Fig.9.4 a summarized version of the Land unit map is given (De Rouw, Vellema & Blokhuis 1990) showing the distribution of the eleven primary forest communities over the Land units in the study area. The Land units were defined by their composing land attributes, lithology, landform, soil, vegetation, land use. Boundaries between Land units coincides with these environmental complexes. In order to explain the ecological position of the upland forest communities within the total of the mapped landscape, let us compare the Land unit-vegetation map with the geological map (Fig.2.4) and the rainfall map (Fig.2.2). The ordination of primary forest had revealed that community A resembled closest to community B and, in diminishing order to, D, E, and F. In Fig.9.4 the same order of primary forest communities is found which corresponds with the north-south geographical line. This means that in the north a certain

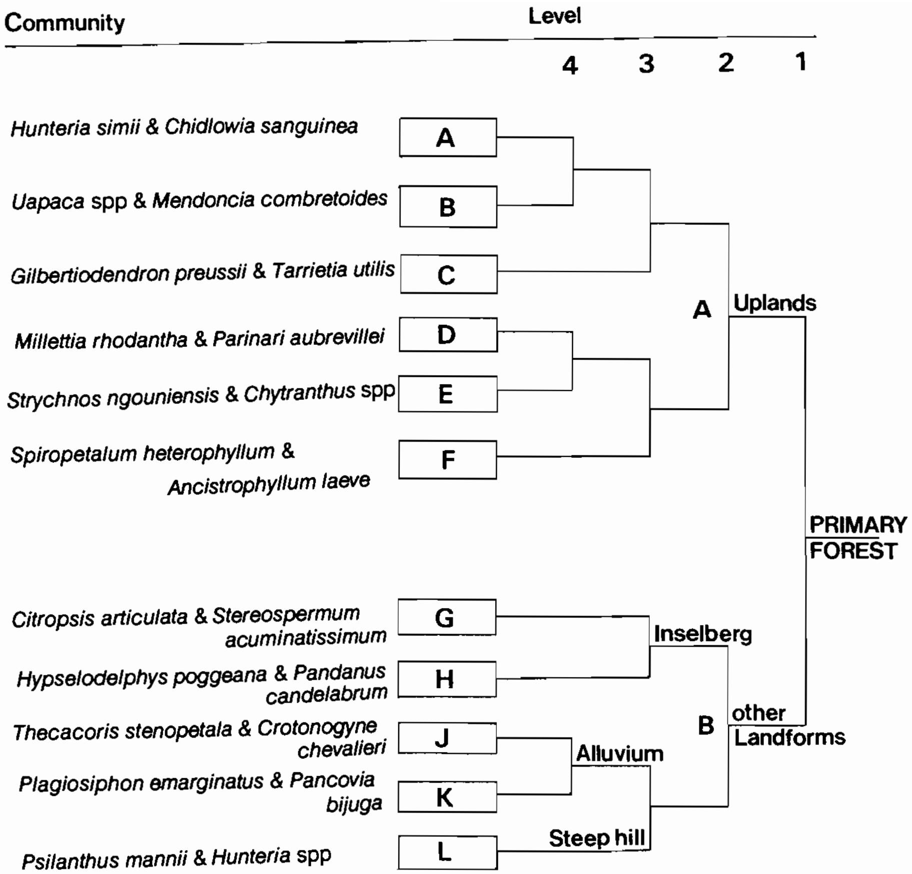


Fig. 9.1. Hierachical representation of primary forest relevés (data set 2, fig.8.1.) into eleven communities.
Community group A : upland communities.
Community group B : communities on other landforms.

type of forest occurs and while travelling to the south, the forest changes gradually in such a way that the forest furthest south resembles it least. A hypothesis most likely to account for this is the rainfall-distribution gradient. The major point is the increase of annual precipitation going to the south in addition to the probably ecologically more important decrease in number of days with water stress, also going to the south. Monteny (1987[2]) states that the difference between the relative "drier" north and the "wetter" south should be principally attributed to a difference in rainfall distribution and only secondly as a result of an absolute increase in annual rainfall.

2 In the south there are more days with relative small showers during which much of the rain infiltrates, compared to fewer days with large showers in the north during which part of the water is rapidly evacuated through streams and rivers (B. Monteny pers. comm.).

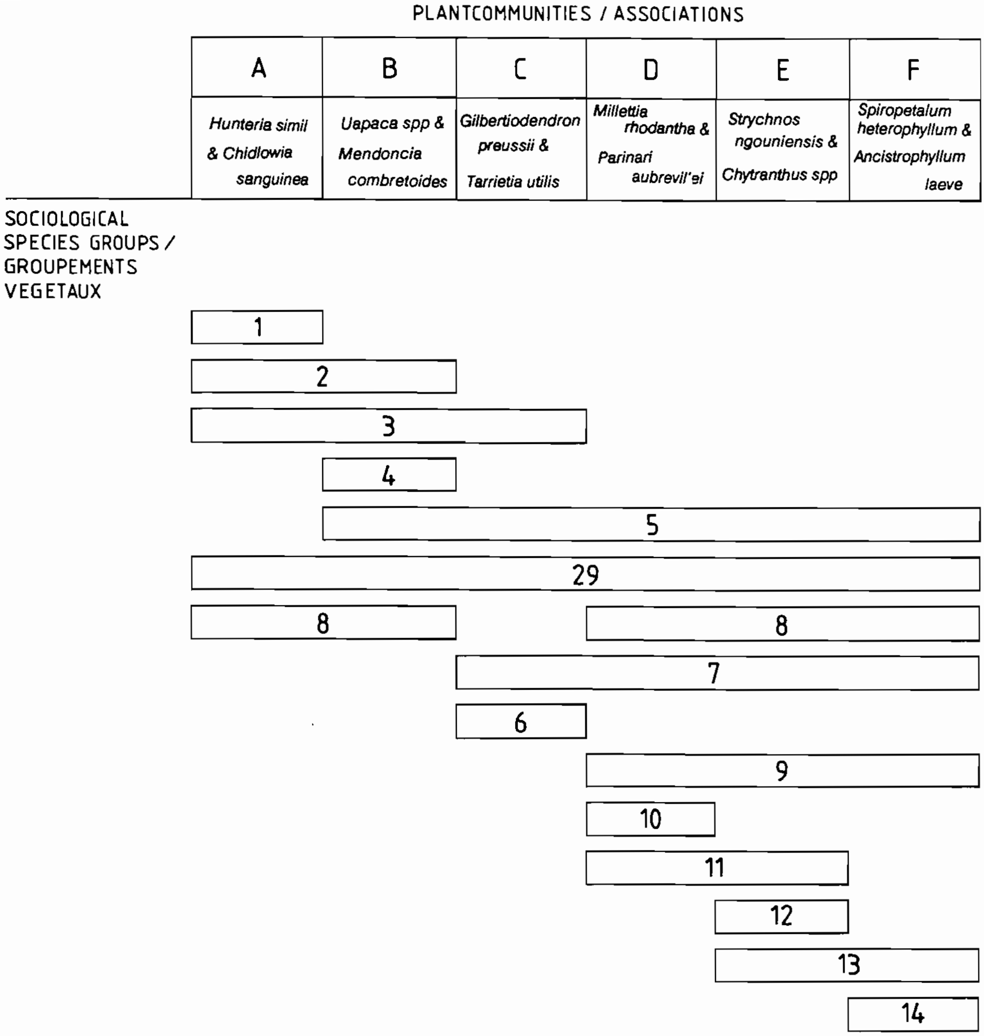


Fig. 9.2. Bar diagram representing the distribution of sociological groups over six primary forest communities on uplands (Community group A).

If we compare the Land unit-vegetation map with the Geological map (Fig.2.4) we see that both maps have large units in the north and smaller mapping units in the south. Besides, the morphology of the many Land units has an analogy with patterns in the geological map.

We may conclude that the vegetational gradient, being the gradual change in species composition and running from north to south, is related both to rainfall and to lithology. We will look for further evidence confirming this and we will try to separate both trends.

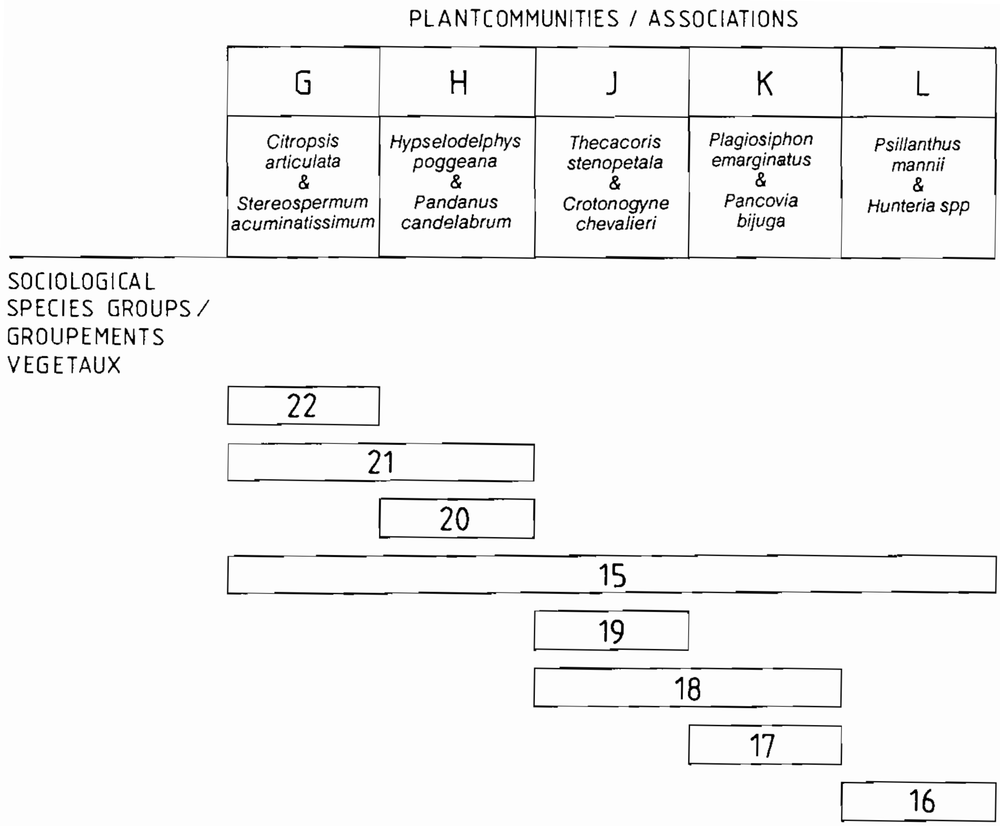


Fig. 9.3. Bar diagram representing the distribution of sociological groups over five primary forest communities on other landforms (Community group B).

9.2.2 Community group B

Vegetation on land form other than upland is further divided into forest near Inselbergs and rock outcrops, forest on Alluvium deposit and forest on a Steep sided hill (level 2 and 3, Fig.9.1). Finally forest growing on Cavally deposits could be distinguished from forest in deposits of smaller rivers. The differences between the forest types (G, H, J, K, L) are for the moments sufficiently explained by the great variation in land form and parent material (De Rouw, Vellema & Blokhuis 1990 for more details).

9.3 CLIMATIC GRADIENT

Our hypothesis is that floristic composition across the primary forest communities is related to, and probably controlled by, two environmental variables, rainfall and parent material. As they are supposed to determine broadly the limits of species distribution within the study area, a relation with planted crops is to be expected too.

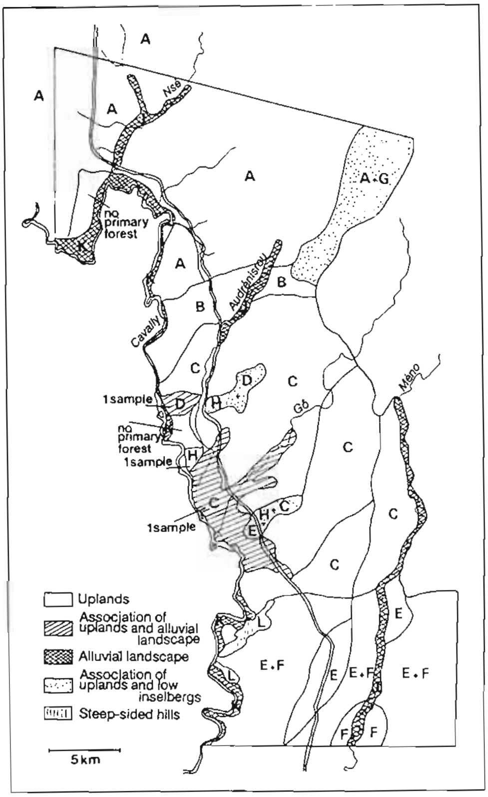


Fig. 9.4. Study area with primary forest communities in the different land units (A through L refer to communities in Fig.9.1).

Ordination of data set 2 suffered from a well known phenomenon that the multivariate analysis is dominated by so-called outliers, a few relevés with very different composition which obscure the other features of the data. In our case it were the relevés on Alluvial deposits, on a Steep sided hill, and one forest sample dominated by *Scaphopetalum amoenum*, which were omitted from further analysis. Their exceptional positions is sufficiently explained by the particular edaphic conditions on these sites. Reordination produced several clusters. Relevés taken in the northern part of the study area and those taken in the southern part appear at opposite ends of the first axis. Relevés taken in the centre of the study area appear roughly in between. We have seen that the geographic north-south line corresponds to a gradual increase in rain but also to a greater variation in parent material. After having considered soil and landscape data we resolve that the major trend is interpreted as the environmental moisture gradient, leaving undecided for the moment whether extra moisture comes from extra rain or is provided by the greater storage possibilities of the soil.

To see more clearly the influence of moisture on floristic composition we should "clean up" our sample of primary forest relevés by taking only those relevés of similar topographic positions. We had preference for relevés on the upper part of the toposequence since variations in soil are best expressed here. Further down slope these features tend to be less characteristic for a specific toposequence (De Rouw, Vellema & Blokhuis 1990). At the same time, by taking only relevés on crest, upper and middle slope, hydrological processes, especially drainage would be as uniform as possible. A reordination of relevés on well drained soils is shown in Fig.9.5 Here relevés are graphed according to their ordination scores on axis 1 and 2. The symbols indicate the geographic zone in which the vegetation has ben sampled (northern, transitional, southern), or the inselberg landscape (UB1, UB2, UB3). The community to which a relevé has been classified is indicated by a letter corresponding to Fig.9.1. If we should think that the clustering of stand belonging to the same community is rather poor here, we should keep in mind that community units were composed considering all relevés of data set 2, whereas the relevés represented in Fig.9.5 are only a sample of this. We should concentrate, on the contrary on the fact that the first axis corresponds again to the environmental moisture gradient. If the whole data set, and samples from that data set, demonstrate the same gross gradient, than this trend is particularly consistent and important (this is an expression of the "robustness" of a data set, Gaugh 1982 p.178).

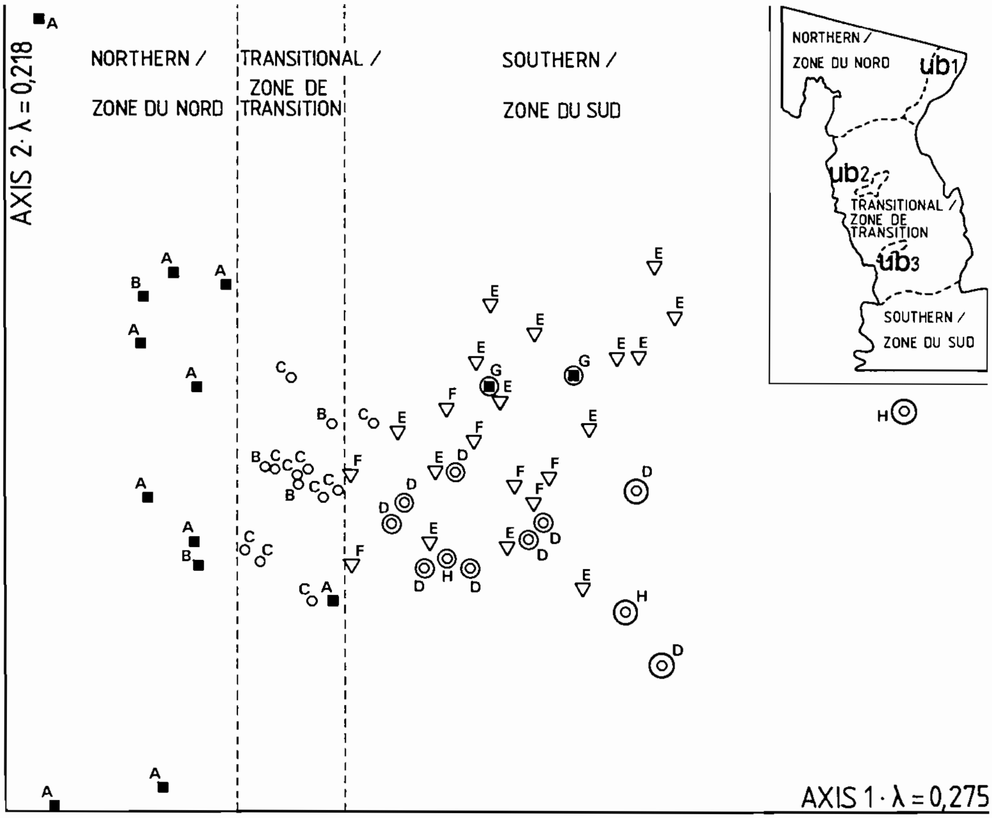


Fig. 9.5. Ordination of primary forest relevés on well drained soils, with community indicated (A through H refer to Fig.9.1).
cubes : relevés taken in the northern zone, circles : relevés taken in the transition zone, triangles : relevés taken in the southern zone, cube with circle : relevés taken in inselberg zone UB1, double circles : relevés taken in the inselberg zone UB2 and UB3.

9.4 SOIL-MOISTURE-CLIMATE RELATIONSHIPS

9.4.1 The soils of migmatite-gneissic origin

In theory it would be simple to study the influence of climate on forest composition separately from the effect of lithology on floristics. We would simply observe a number of relevés well distributed over the study area which are similar with respect to parent material and topographic position and thus would have comparable soil properties. The differences in species composition would then be largely contributed to variation in rainfall. Large units in the geological map are mapped as migmatitic and gneissic. The characteristics of soils developed from this material have been discussed in chapter 2 (more details in De Rouw, Vellema & Blokhuis, chapter 4). The selection of relevés which is formed in order to study rainfall influence is characterized by soils of this type, (derived from the weathering of migmatite-gneissic more or less granitic material), besides being homogeneous as regards topographic position. All soils in the selection have a very gravelly to gravelly topsoil, consisting mainly of ironstone. The thickness of the gravelly layer is more than 50 cm, but usually over 100 cm. All soils are well drained. Fig.9.6 shows the same ordination diagram as Fig.9.5 only all relevés of forest on soils

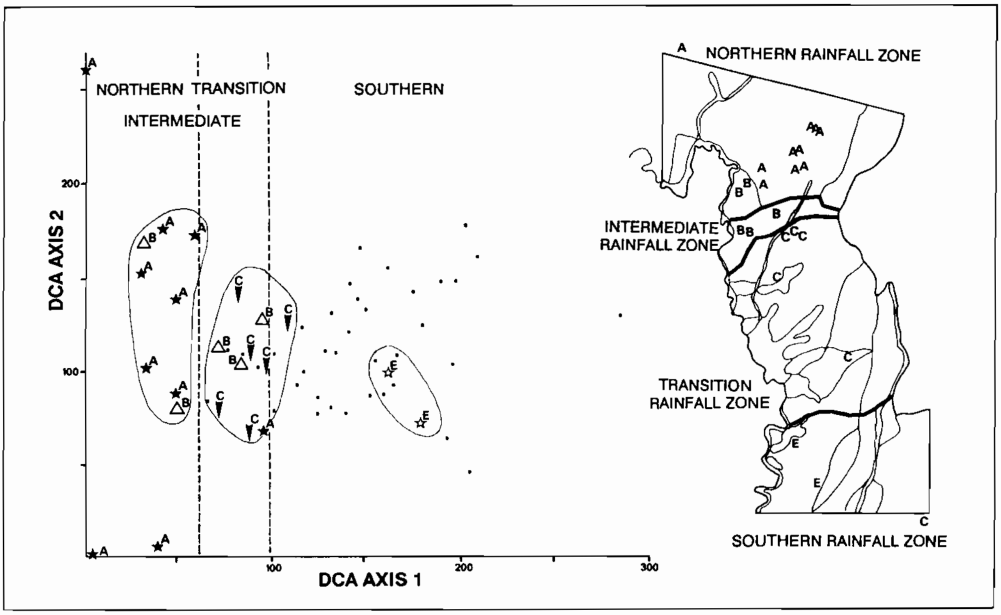


Fig. 9.6. Left : ordination of primary forest relevés on well drained soils. Symbols indicate the relevés on soils developed in migmatite parent material. Dots indicate the relevés on soils derived from other material. Letters refer to communities in Fig.9.1. Right : location of the relevés on soils derived from migmatite in the study area.

of this type have been highlighted. These relevés are indicated by a symbol and a letter indicating the community to which the vegetation has been classified. In the inserted map the geographic position of relevés is given. All relevés on soils of other parent material have been indicated by a dot. The partition of the "migmatite" samples over the first axis is a result of a simultaneous appearance or disappearance of many species. It indicates that many species have a relation with the environmental moisture gradient. Because the soils are very comparable, this gradual change in floristic composition reflects mainly climate. Upland forest having the lowest rainfall have lowest axis 1 values, upland forest with highest rainfall have highest axis 1 values. The zones in the map are therefore called rainfall zones. The results support the argument that even in such a wet environment as south-west Côte d'Ivoire a small increase in rainfall (about 200 mm a year) over a short distance (about 60 km) produces a gradual change in the species composition of the primary forest on well drained comparable soils.

In the Taï area this climatic moisture gradient is expressed in the vegetation in two ways. We will call them climatic indicators of the first and of the second type.

Table 9.2. Main climatic indicators of the first type and of the second type (see text) for four primary forest communities in the study area.

Community	Climatic indicator of the first type	Climatic indicator of the second type
Uapaca spp & Mendoncia combretoides	*Mendoncia combretoides* *Ctenitis protensa* *Drypetes pellegrini* *Leptoderris fasciculata* *Landolphia membranacea*	*Uapaca guineensis* *Uapaca heudelotii* *Cercestis afzelii* *Anthocleista nobilis* *Caloncoba brevipes* *Trichilia heudelotii* *Vitex micrantha* *Araliopsis tabouensis* *Baphia polygalacea* *Raphia sassandrensis*
Gilbertiodendron preussii & Tarrietia utilis	*Gilbertiodendron preussi* *Hypolytrum poecilolepis* *Nephthitis afzelii*	*Tarrietia utilis* *Uapaca esculenta* *Xylopia acutiflora* *Ancistrophyllum opacum* *Dracaena elliotii* *Sacoglottis gabonensis*
Strychnos ngouniensis & Chytranthus spp	*Strychnos ngouniensis* *Chytranthus mangenotii* *Uvariopsis guineensis* *Dracaena camerooniana*	*Chytranthus setosus* *Culcasia seretii* *Culcasia piperoides* *Raphidophora africana* *Trichoscypha chevalieri* *Lankestria brevior*
Spiropetalum heterophyllum Ancistrophyllum laeve	*Spiropetalum heterophyllum* *Ancistrophyllum laeve* *Monodore crispata*	*Desplatsia chrysochlamys* *Pteris burtonii* *Pseuderanthenum tunicatum* *Rhaphiostylis cordifolia* *Salacia lateritia* *Macaranga heterophylla*

- Climatic indicators of the first type. There is a successive floristic enrichment of the forest as moisture increases. These species do not seem to have a preference for position on the slope, they simply occur in the north and not in the south, or occur in the south and not in the north.
- Climatic indicators of the second type. A group of species confined to swampy places in the drier north expands to growing places on the slope and even on the crest in regions with more rainfall. They "climb" out of the valley bottom as soon as precipitation increases and thus, on better drained soils, they are able to use the moisture provided by the extra rain to replace the moisture provided by the swampy soil. This phenomenon is well known from much drier regions with a more pronounced climatic gradient where swamp plants occupy drier places as the climate becomes more humid. It is described by Walter (1964) in the law of relative site constancy. Now it is reported from a wet region also, and, even more

important, it has been detected over so small a range of rainfall. Table 9.2 presents a list of species which commonly act as climatic indicators of the first type, and as climatic indicators of the second type.

Other sources of information sustain the existence of a climatic gradient in Taï. Guillaumet (1967), who is most explicit, found that the floristic composition of the primary forest in the whole of south-west Côte d'Ivoire depended first of all on moisture conditions. The zonal relation he observed between increasing rainfall and forest is much coarser: species composition changes markedly around the 1800 mm isohyet and again around the 2200 mm isohyet. I think, due to his method, his data set resists to a finer differentiation. He made very large relevés extending all over the toposequence so only climatic indicators of the first type (see above) could be detected. The position of his relevés is well documented and some of them were re-visited. Guillaumet species list, supplemented with soil data were incorporated in the data set 2. All relevés of Guillaumet (1967) were invariably classified with our "driest" **community A**, whether a relevés was made in a area with 1800 mm rainfall or in a region with 2100 mm rainfall. This is mainly due to his systematically under-sampling of the ground flora and the understorey tree layer. Precisely these groups of plants, small climbing herbs (*Araceae*), ferns and undergrowth (*Chytranthus* spp) proved to be sensitive indicators of moisture.

These results are chiefly responsible for the division of the Taï area into four rainfall zones, the northern, the intermediate, the transition and the southern rainfall zone (see inserted map in Fig.9.6). This division appears at a high level in the legend of the Land Unit map.

In the northern rainfall zone all upland primary forest belongs to **community A**. This community covers crest and slopes, only valley bottoms are different. It continues further to the North, at least up to the village Keibli, since all sites which were sampled beyond the northern limit of the area mapped, still belonged to this community.

In the intermediate rainfall zone upland primary forest belongs to the **community B**. This community can be distinguished from the former one by the presence of the sociological group 4 (Fig.9.2). With the help of the species listed in Appendix 1 and Table 9.2, we can detect whether a species of sociological group 4 acts as a climatic indicator of the first type or of the second type. The complete sociological group develops fully on crest and upper slope in the intermediate rainfall zone but not on the very comparable crests and upper slopes of the northern rainfall zone. The climatic indicators of the second type occurs in the northern rainfall zone, but species are confined to valley bottoms and the lowest part of the slope where they grow mixed with members of **community A**. So the change from community A to Community B is likely to be a climatically induced zonality. We have separated this community from the former one since phenomena like this usually have important ecological significance. Another point supporting the climatic explanation is the presence of community B on a few crests in the northern rainfall zone where other crests are covered by community A. Observation of the soil showed that the crest with community B had no gravel, while nearby crests with community A all correspond to the usual very gravelly topsoil. The gravel-free soil has a higher waterholding capacity, and could compensate for the lower rainfall in the north, thus permitting the development of a community that is normally found on gravelly crests further south, with higher rainfall. DRC (1967a) and Fritsch (1980) estimate that about one crest out of ten in the northern rainfall zone does not have gravel. The occurrence of gravel-free crests is attributed to parent material and distribution is considered rather erratic.

The **community C** is restricted to the transitional rainfall zone. The community is characterized by the sociological species group 6 (Fig.9.2, species in Appendix 1). Again, Table 9.2 indicates whether a species of this group is rather a climatic indicator of the first or of the second type. The climatic indicator group of the second type occupy valley bottoms and sometimes the lower part of the slope in areas where the remainder of the slope is covered by community A or B. Soils of migmatite origin do not change much over this interval, so again, most of the variation should be attributed to increasing rainfall.

Community E occurs in the southern rainfall zone where it occurs on a large variety of soils. Only three relevés were on sites with soils of clearly migmatite-gneissic origin. In the sociological species group 12 many climatic indicator plants are herbaceous climbers (*Araceae*). In regions further north they are restricted to wetter places, but here in the south, they grow on crests and upper slopes. The understorey tree *Chytranthus setosus*, possibly a climatic indicator of the first type, was recognized by Mangenot (1955) as an indicator of the wettest growing places in Côte d'Ivoire he knew.

9.4.2 Soils of granitic origin

It is interesting to check the influence of rainfall on a second sample of relevés with similar soils: those of granitic origin (see chapter 2). Granite is dominant in the southern rainfall zone, but granite inclusions occur elsewhere. The soils differ from those derived from migmatite in being much coarser-textured and the surface soil contains few ironstone gravel. They are well drained.

The relevés with thus corresponding soils are indicated with a symbol and a letter referring to their community in Fig.9.7. The geographic position of the relevés is marked in the inserted map. In the northern and intermediate rainfall zone no such forest was sampled. The relevés in the transition rainfall zone, classified as **community C**, belong to the some cluster as the C relevés in Fig.9.6. This means that the species of community C, among them those sensitive to moisture, appreciate gravelly, clayey soils (migmatite-gneissic origin) in the same way as they do more sandy soil without gravel (granitic origin).

The relevés classified as **community E** form two groups. The group with low axis 1 scores (indicated with 1) belongs to the same cluster which encloses the E-relevés in Fig.9.6. The forest relevés in group 1 were sampled in geomorphic units of complex geology. Soils of both migmatite-gneissic origin and soils derived from granitic inclusions alternate over short differences. In addition many transitions occurred (De Rouw, Vellema & Blokhuis 1990, chap 2). Some of the E-relevés in the migmatite sample (Fig.9.6) were taken near to the relevés on granite (Fig.9.7). The result is that all forest in those complex units tend to be largely the same, thus obscuring the influence of parent material. The second group classified as community E (indicated with 2) has high axis 2 values. These relevés were taken either in a landscape where granite was the dominant underlying rock, or in landscapes where the granitic intrusions were much larger. Comparing the group 1 with the group 2, we can say that granite influence is more "pure" in the latter. The chief difference between both groups is the number of species per

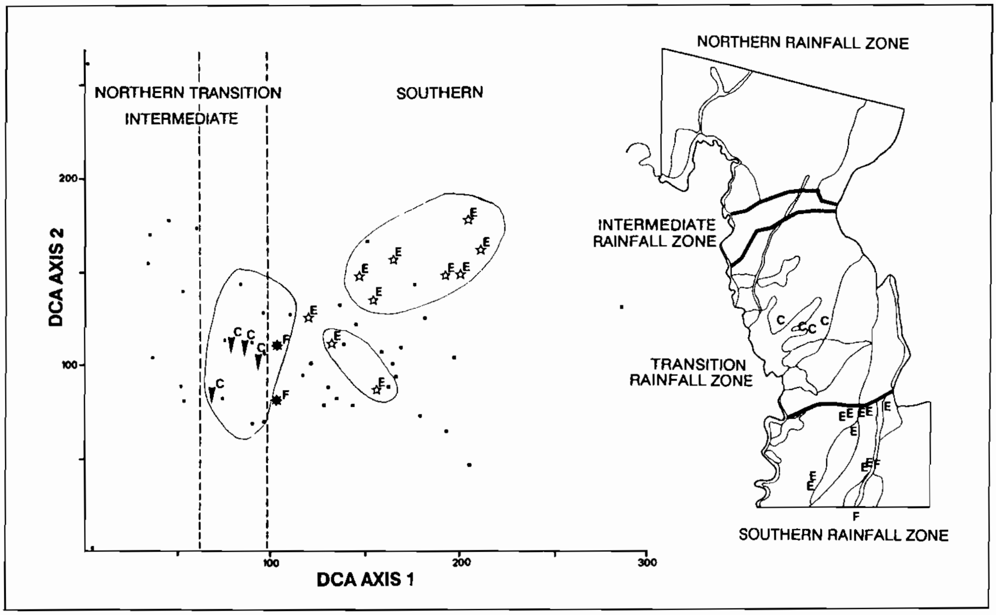


Fig. 9.7. Left : ordination of primary forest relevés on well drained soils. Symbols indicate the relevés on soils developed in granitic parent material. Dots indicate the relevés on soils derived from other material. Letters refer to communities in Fig.9.1. Right : location of the relevés on soils derived from granite in the study area.

relevé, being markedly lower (40-60) in the "purer" granitic group (2) than in the "complexe" granitic group (1) (60-90). Most species present in the first occur also in the second. The extra species in the "complex" granitic group belong to many different species often low dispersed which are confined to the southern rainfall zone. These species, occurring once or twice in the survey, could not be associated with any sociological group so they could not play a role in the classification. Hence relevés of both groups were classified as community E. They were, however, not left out while processing the data matrix and this makes that something of their specificity can be seen in the ordination. More relevés are needed to sort this out. Mangenot (1955), mainly from his study of the Yapo forest, observed the same thing: less species per area on sandy sites.

The two relevés classified as **community** F had sandy soils without gravel but it is doubtful whether this is a result of granitic weathering. In both cases the forest stood not far from the river Méno and some species in the list do indicate some alluvial influence. They were nevertheless classified as community F for the presence of some characteristic species of F.

From the granitic sample series a climatic gradient is obvious, too. In the transition and in the southern rainfall zone a gravelly, clayey soil "produces" about the same level of water availability as a gravel-free loam or sandy loam.

9.4.3 Soils derived from schist

In the study area schistose layers were most of times so small that typical schist-derived soils could not be identified, but

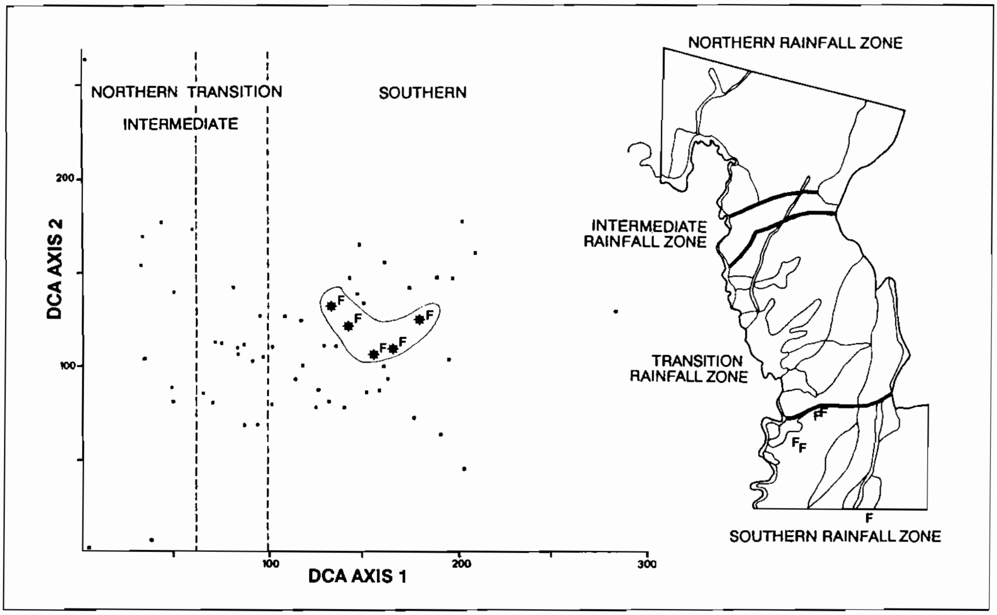


Fig. 9.8. Left : ordination of primary forest relevés on well drained soils. Symbols indicate the relevés on soils developed in schistic parent material. Dots indicate the relevés on soils derived from other material. Letters refer to communities in Fig.9.1. Right : location of the relevés on soils derived from schist in the study area.

in some cases, the intrusions were of sufficient extent to allow the development of a specific soil. Schist-derived soils have a clayey texture and contain less ironstone gravel and quartz (chapter 2). Soils are well drained. These soils are obviously better suited for water storage than most soils derived from migmatite, gneiss or granite. The relation of schist and moisture is obscured in the study area for all schist relevés were sampled in the zone with highest rainfall. These relevés are shown in Fig.9.8 indicated with a symbol and a letter. All were classified as community F. Two of the relevés lie in "schistes-quarzites" unit of the geological map (Fig.2.4); the others were sampled in the south, even south of the area mapped. Many species in these relevés are to be expected to be climatic indicators but the limited number of samples, the large number of species occurring only once or twice in the survey does not permit a more exact characterization of this community.

9.4.4 The soils in inselberg landscapes

The occurrence of inselbergs is restricted to a few areas, UB1, UB2, UB3. Fig.9.9 indicates the relevés sampled in inselberg landscapes. Relevés made in the neighbourhood of a rock outcrop (up to 20 m from the plot) have a very deviant species composition and were classified as **community G** (in unit UB1) or **community H** (unit UB2). It happens often that relevés were made apparently far from rock outcrops and the soil had the characteristics of a normal gravelly, clayey, migmatite derived soil. Still the forest composition was very different so it must be concluded that something in the parent material continued to be different. Changes in forest composition are abrupt in those

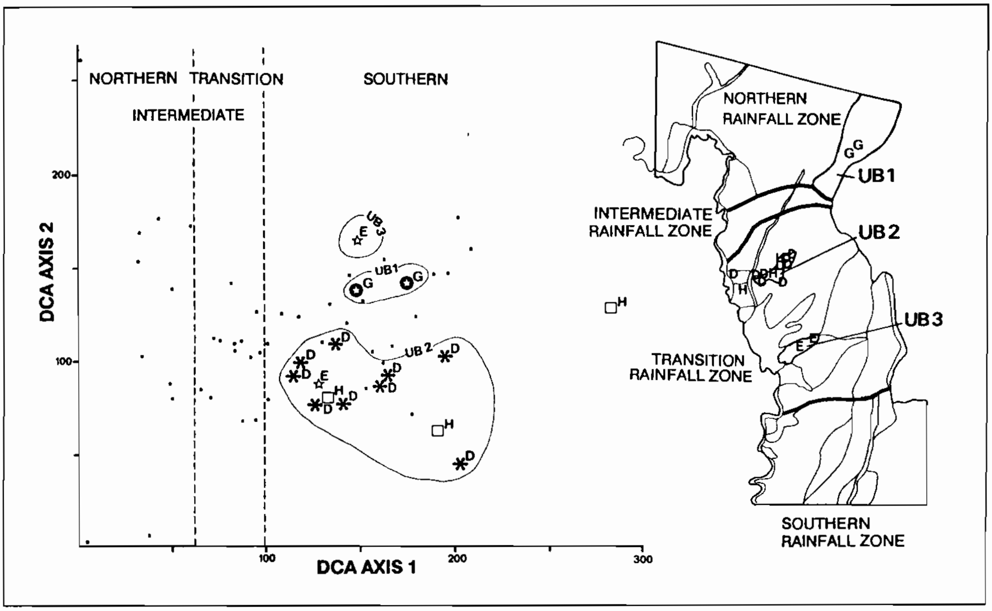


Fig. 9.9. Left : ordination of primary forest relevés on well drained soils. Symbols indicate the relevés taken in inselberg landscapes. Dots indicate the relevés on typical upland soils. Letters refer to communities in Fig.9.1. Right : location of the inselberg relevés in the study area.

areas and can be easily detected in the vegetation.

A striking thing in Fig.9.9 is the fact hat all relevés in inselberg landscapes have high axis 1 scores. This means that their species composition makes them resemble forest of the southern rainfall zone, in spite of their geographic location in the northern and in the transition rainfall zone. It seems that the landscapes with such an obvious deviant geology "produce" edaphic water which is capable of substituting to a certain extent, the lack of rainwater in these areas, thus permitting the vegetation to resemble those of wetter areas.

The relevés made in unit UB1, classified as G, are closely related floristically to the group 2 in Fig.9.7, called earlier the more "pure" granite group. In fact many places in UB1 appear to be of granitic origin. The relevés in inselberg unit UB2 constitute a distinct **community D**. The forest resembles community E. The inselberg unit 2 was large enough to be mapped, forming an "island" of community D in an land where the usual primary forest is community C. Some smaller "islands" exist disseminated in the study area but they are smaller and hard to detect for often all primary forest here has been cut. The forest in inselberg unit UB3 has been largely cut for agriculture too. Only one relevé in primary forest on a crest could be made, and this was classified as community E. The position of this relevé in the cluster of the "purely" granitic sites (group 2 in Fig.9.8) indicates a granitic origin comparable to unit UB1.

As we compare this classification with that of Guillaumet & Adjanohoun (1971) we fird that the latter is well in accordance with our observations. **Community F** is clearly a forest of the

Diospyros spp & *Mapania* spp type, but community E and D have some of its characteristic species too. However, the obvious ground flora, so characteristic for *Diospyros* spp & *Mapania* spp is absent. The communities A, B and C mostly lack them altogether, so they are rather of the forest type *Eremospatha macrocarpa* & *Diospyros mannii*.

9.5 CLASSIFICATION OF PRIMARY FOREST BY OUBI

Many people, mainly Oubi, were asked whether they distinguished different types of primary forest, where such forest could be found, and which aspects they were different. As often as possible we asked people to indicate in the field what they considered to be different forest types. We also asked them to classify the forest we sampled. We summarize our knowledge of their classification as follows.

9.5.1 Community group A

Zones with different upland vegetations are divided by lines perpendicularly on the main road. There are three zones, a northern, a central and a southern zone. The distinction between the northern and the central zone is sharp and lies a few kilometres north of the village Diéré-oula. The main difference between the two zones is the presence of the tree *Gilbertiodendron preussii* in the central zone and its absence in the northern area. Another difference is that rice cultivation is supposed to be easier in the central zone. The distinction between the central and the southern zone is less sharp. It lies somewhere in between the villages Nigré and Para. The change in forest type is defined by the appearance of unfamiliar plants in the southern zone. We are here outside the Oubi territory and Oubi do not have distinct names for those species.

After we have made our classification and drawn our map, we could check these observations. The Oubi separation between the northern and the central zone coincides with our separation of the northern (and the intermediate) and the transition rainfall zone. The Oubi distinction between the central and the southern zone fits approximately with our distinction between the transition and the southern rainfall zone. Thus the vertical lines in Fig.9.5 are consistent with the forest distinctions made by the local people.

The distinction between the two types of primary forest mapped (1:500,000) by Guillaumet & Adjanohoun (1971) is very similar to distinction the Oubi make: the forest type *Eremospatha macrocarpa* & *Diospyros mannii* continues down to the village Nigré whereas, south of this point, the forest type *Diospyros* spp & *Mapania* spp begins.

9.5.2 Community group B

Forest on alluvium and on uplands with inselberg crests is set apart the way as it is done in our classification. These forests are not only floristically, but also structurally very different from "normal" upland forest and are thus easily recognized.

A forest type which was too rare in our survey to be treated separately is called "Powi-kla" in Oubi. It is dominated by the shrub *Scaphopetalum amoenum* which forms a dense, almost monospecific understorey by means of vegetative layering, that bears resemblance to a cocoa plantation. Guillaumet (1967 p.80.) has stated that the community is related to schists, but we could not confirm this. Most of the known "Powi-kla" sites were in the Land unit Utm (De Rouw, Vellema & Blokhuis

1990), south of Troya and some kilometres east of Sakré and have been cleared for agriculture.

9.5.3 "Ferreclao"

Millettia rhodantha or "Ferreclao"in Oubi is considered an indicator plant for places favourable for agriculture, indeed, the very name "Ferreclao" stands for such a suitable site. Places where the primary forest has disappeared long ago for cultivation, are still indicated by this word although the presence of this primary forest species is reduced to occasional coppice shoots (eg.4 km north-east of Sakré, near the Sélédio rapids a large area occurs). In the northern and central part of the study area "Ferreclao" is often related to rock outcrops and low inselbergs, though it is absent from the Land unit UB1 (Fig.9.4), where the underlying rock is very probably (Fig.9.9) granitic. The sites where "Ferreclao" occurs are small, covering only a few hectares, sometimes less, but in the Land unit UB2 it grows over a large area. It is a characteristic species of the primary forest community there (community D). Occasionally "Ferreclao" is found on the borders of a river (arm of the Audrénisrou at former village Diéré-oula No.1, Fig.3.2). These areas are also small. In the southern part, the plant becomes widespread on a variety of soil, independent of rock outcrops. The limit of the Oubi territory corresponds with the region where the occurrence of "Ferreclao" often indicates an anomaly in the landscape. The relationship between "Ferreclao" sites, crop yield and soil properties needs further study, however, the vegetation analysis demonstrated that *Millettia rhodantha* is a plant species belonging to the southern rainfall zone. It will only penetrate into the transition and the northern rainfall zone if their is some compensation in the soil for the lack of rainwater. At least in the northern rainfall zone, the situation is likely to be complicated and obviously more than a question of moisture. A small inselberg area (about 10 ha) in the bufferzone east of the village Gouléako, had an undergrowth consisting largely of *Millettia rhodantha*. Soils were clayey, red and gravel-free, including crest and upper slope. The vegetation was classified as community D, whereas occasional gravel-free soils on upper slope and crests in the neighbourhood are covered with community B and do not have "Ferreclao".

In the northern rainfall zone occurrences of "Ferreclao" sites were probably too dispersed and too small to determine the location of settlements, but in the central part of the study area, this might well have been the case. The once large village Troya laid where the Inselberg unit UB2 touches the main road, the former village Tiéoulé-oula No.1 was situated amidst a large area (Sélédio) with *Millettia rhodantha*, the same accounts for the abandoned village Diéré-oula No.1, but here the area with *Millettia rhodantha* is much smaller.

9.6 CONCLUSION

The vegetation analysis has showed a strong relation between floristic composition of the primary forest, climate and soil. Soils are influenced by topography, but also very much by parent material. Rocks of different origin weather into soils of different chemical fertility and other soil properties. It came out that differences in lithology occurred on such a scale that it could not be mapped other than in an association or a complex. Still, small scale variations in lithology can be very important for crop production, as was demonstrated for cocoa (De Rouw, Vellema & Blokhuis

(1990). Because direct identification of parent material is a very difficult work in the Taï region, it is better to use vegetation as an indicator.

10 Plant associations in secondary forest

Secondary succession takes place wherever forest vegetation is damaged or destroyed. It shows a sequence of vegetation associations occurring in time. An important property ascribed to succession is that changes are progressive and directive which makes the process reasonably predictable. Succession is supposed to continue until the species combination suits best to the regional climate and soil conditions.

10.1 EARLIER STUDIES

Study of successional processes in humid western Africa, and the Taï region in particular, have assigned species and associations of species to places in a successional order. Successional theory has allowed to predict structural and floristic characteristics and to recognize successional stages. Pioneer work in Côte d'Ivoire was done by Aubreville (1947) and by Guillaumet (1967). The delimitation of the seral stages in the Taï area has been done in Alexandre *et al.* (1978) and summarized in Guillaumet, Couturier & Dosso (1984). Their aim was to investigate succession after disturbance caused by cultivation. In the Taï area this means the study of fallow vegetation involved in shifting cultivation cycles as it is practiced by the indigenous Oubi, Guéré and Kru farmers and described in chapter 4. Only once (Alexandre & Tehe 1981) forest recovery after logging was studied.

In Alexandre *et al.* (1978) four structurally and floristically defined stages are described, of which Fig.10.1 shows a schematic representation. The rice crop and the weeds constitute the first stage ("stade herbacé") covering the site for the first six months following disturbance. The second stage is called "stade sous-ligneux" and its characteristics are the sub-woody *Solanum* spp plants and the persistence in the field of some crops (cassava and banana). The final harvest of the food crops, together with the fruiting and dying off of the weedy plants, marks the end of the second stage, approximately two years after the initial disturbance. In the third stage ("stade arbustif pionnier") the tree *Macaranga hurifolia* plays a decisive role. The beginning is indicated by the moment the tree, with a few other pioneers, makes up most of the canopy layer. The end of the stage is marked by the breaking up of the even-aged *Macaranga hurifolia* stand, followed by degeneration as a result of senescence. The fourth stage, called "stade pré-climacique" is characterized by a canopy dominated by long-lived secondary forest trees which successively die off after 20, 30, 40 or a 100 years. At the same time, progressively, plant species of the primary forest are supposed to take their place, so gradually the forest change into which we call primary.

Kahn (1982) provided a general structural analysis of succession in south-west Côte d'Ivoire, supporting the four stages theory. Special attention was paid to the role of lianas and to some cases of blocked or obstructed succession, topics which are often neglected. In the study of Kahn (1982) soil, topographic position and cultivation history do not enter the discussion. Only once an allusion is made to climate.

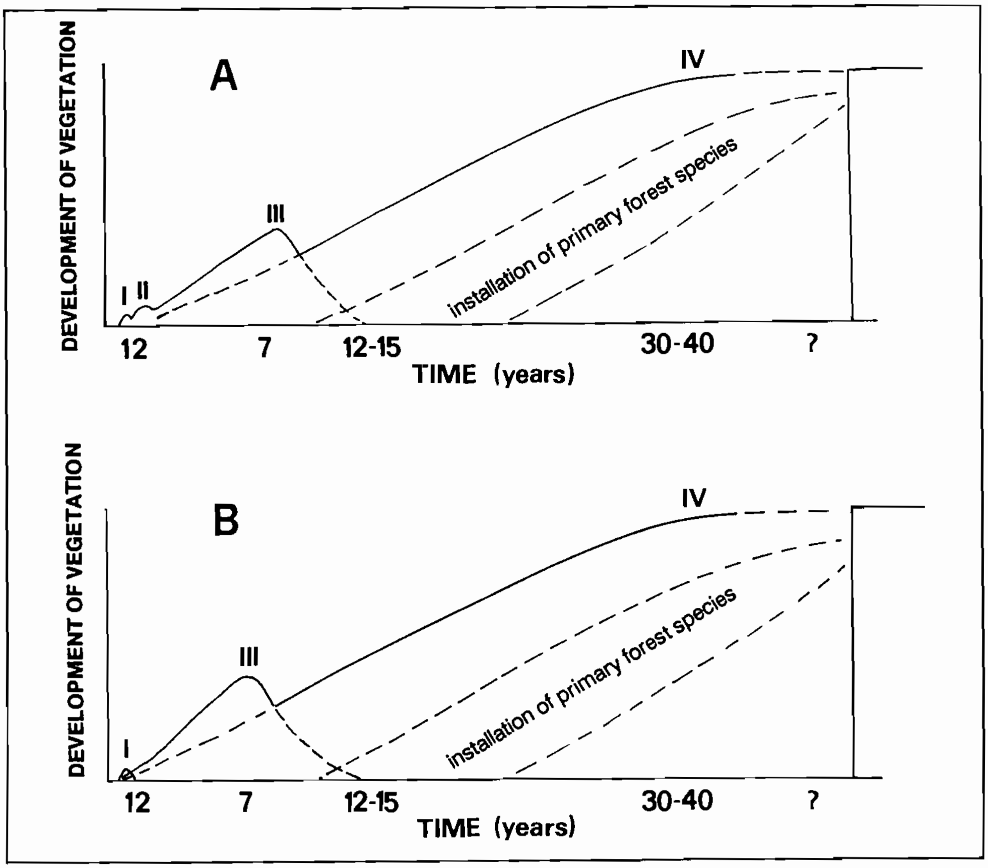


Fig. 10.1. Sequence of sucessional stages in the Taï region which are part of the Established shifting cultivation systems. A, after Alexandre *et al.* 1979, B, this study.
Stage I : "stade herbacé" Stage III : "stade arbustif-pionnier"
Stage II : "stade sous-ligneux" Stade IV : "Stade pré-climacique".

De Namur (1978a) who studied succession in Taï with emphasis on floristics found it rather difficult to generalize because of important edaphic variations between sites and differences in history. Both authors studied only few sites (14 and respectively 13).

In the multidisciplinary study of Fritsch, Jaffré and De Namur on succession in the Taï region, equal attention was paid to the soil (fertility) aspect and to the botanical side. They were, however, compelled to limit their attention to cases where disturbance caused by cultivation had been slightest (one rice crop in a field made in primary forest), and to sites with comparable soils and topographic position (Fritsch 1982, Jaffré & De Namur 1983, Jaffré 1985).

10.2 METHODS

In this study too, our attention is restricted to secondary forest implied in shifting cultivation by Oubi, Guéré and

Kru farmers whose practices are very similar. To complement and to discuss the findings of Fritsch, De Namur and Jaffré, we sampled not only secondary forest issued from a disturbed primary forest but also secondary forest on sites which had been cultivated repeatedly and had been left to regenerate after each cultivation period. Our large number of relevés supplemented by details on soil properties and history would perhaps clarify some of the floristic problems mentioned by De Namur (1978a). Though a structural analysis was not our chief objective, height and an impression of vigour was always recorded. Special attention was given to blocked successional stages. This would allow a comparison with the findings of Kahn (1982).

For reasons explained in Chapter 8 a special data set was divided off in order to study specific aspects of succession (data set 3, Fig.8.1). The selection is such that sample sites are spread out over the study area and ample information on soil and cropping history sustains the floristic data. All secondary forest is between 5 and approximately 65 years old, this means that the vegetation is either in the third stage ("stade arbustif-pionnier") or in the fourth stage ("stade pré-climacique"). By taking a sample-set with forest which is not too young (excluding the first two stages) we hope to gain a good insight into trends. This in contrast with the data set of De Namur (1978a) which contained representatives of all four stages. The ordination of De Namur (1978a) gave only weak clusters, mainly because the successional (time) gradient and edaphic factors (and possibly others too) were confused.

10.3 RESULTS

10.3.1 The secondary forest communities

Clustering of data (61 relevés, 712 species identified) gave 8 communities. The relative position of a community is given in Fig.10.2 as well as how groups of communities are arranged according to their affinities. After clustering, being, as usual, entirely defined by floristic composition, an environmental interpretation is added, where this was evident. The communities with their assembling species are represented in Table 10.1 (calculation by TWINSPAN followed by successive refinement by hand). Such a tabulation permits to see at a glance the range and type of floristic variation that may occur within a community and also in what characteristics it differs from those nearby allied to it. In the table only the prominent members of a sociological species group are represented. As was observed by Hommel (1990) sociological groups tend to be large in a rain forest environment. So, for practical reasons, the species not represented in the Table 10.1 which demonstrate nevertheless a preference for a sociological group, are listed in Appendix 2. Omitted are species which occurred only once in the data set 3 and those, only few, with no pronounced affinity for a sociological group.

The first, most important, division is made between young and old secondary forest. The separation is mainly produced by the occurrence of the sociological groups V (*Macaranga hurifolia*), II and IV (comprising other pioneers) whose members are commonly present in young secondary forest and, simultaneously, absent from old secondary forest. The communities 1, 2, 3 and 4 constitute the *Macaranga hurifolia* community group. Old secondary forest is further

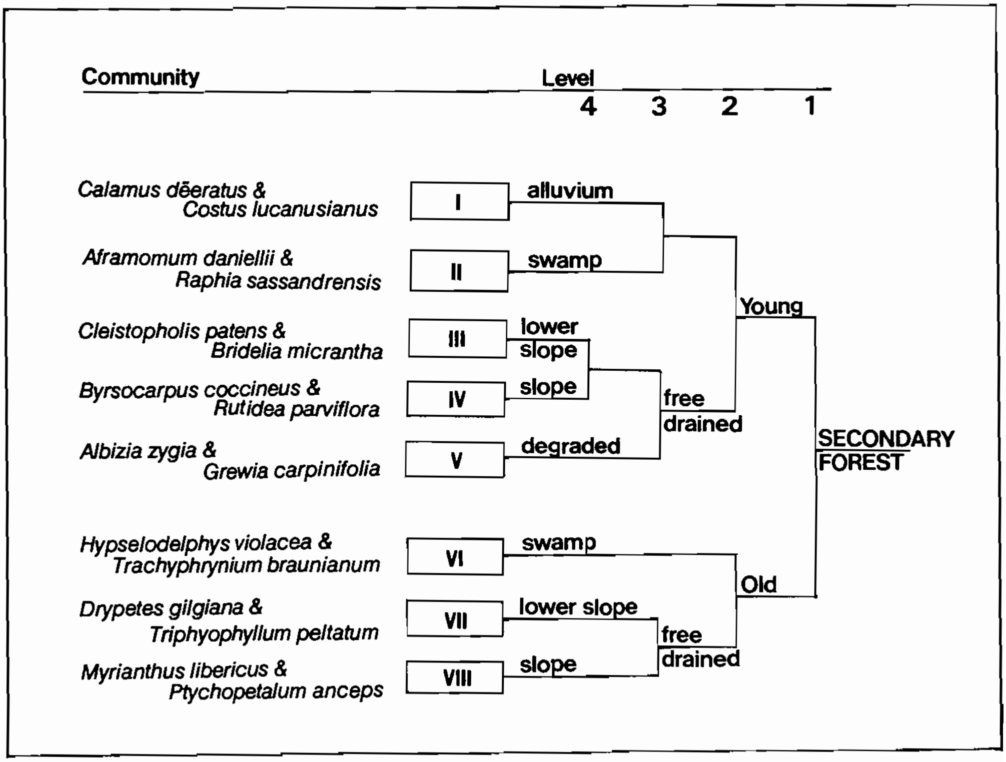


Fig. 10.2. Hierarchical representation of the division of secondary forest relevés (data set 3, Fig.8.1) into eight communities with environmental and historical interpretation.

characterized by the presence of the sociological groups XXII, XXIV, XXVI and XXVII, whose members are chiefly primary forest species invading the stand. The communities 5, 6, 7 and 8 form the *Pycnanthus angolensis* community group. This sequence in vegetation changes corresponds very well to the model provided by Alexandre *et al.* (1978): young secondary forest (*Macaranga hurifolia* community group) is vegetation in stage "arbustif-pionnier", and old secondary forest (*Pycnanthus angolensis* community group) is vegetation in the stage "pré-climacique", though the distinction is made not on the same grounds. A forest is called "pré-climacique" because the canopy is build up by long-lived pioneer trees. We classify a forest among the *Pycnanthus angolensis* community group because of the presence of a primary forest understorey, not because of tall long-lived pioneers.

We see that topographic position runs across the successional stages (Fig.10.2, Table 10.1), for both young and old secondary forest are subsequently divided between forest on poorly drained soils and forest on better drained sites. On the third and fourth level a further differentiation occurs, separating moderately well-drained soils (lower slope) from well drained soils (slope and crest). On a third level Alluvium is separated from swamp forest. Only young

Table 10.1. Vegetation table of secondary forest (code : matrix code, see Fig.8.2, 1 : 1, 2, 3, 4; 2 : 5, 6, 7; 3 : 8; 4 : 9).

		Young secondary forest																											Old secondary forest																																
						Macaranga hurifolia Community group																										Pycnanthus angolensis Community group																														
Community		com.I				com.II						com.III									com.IV								com.V									com.VI						com.VII									com.VIII									
		Alluv.				Valley-bot.						Lower slope									Slope & crest								Degraded									Valley-bot.						Lower-slope									Slope & crest									
Plot number			1	3	8	7	8	7	8	8	6	5	9	9	1	2	2	2			1	1	2	2	3	3			1	1	1	3	4	4		2	9	7	8	8	6	9	8	7	9	3	6	9	3	2	3		3	4	2	2	3	1	4	4		
		4	9	2	2	3	3	2	7	9	9	6	5	9	7	1	2	3	6	2	2	5	7	9	0	6	7	9	1	3	8	4	1	8	8	6	8	7	1	5	8	0	8	8	7	9	7	6	8	4	5	5	7	5	0	5	1	0	3	4	1	3
Plant species arranged in sociological groups																																																														
I	*Calamus deërratus*	3	1		2																																							1																		
	Costus lucanusianus	1			2																																																										
	Paullina pinnata	1		1																																																										
	Mussaenda afzelii			1	2												1																																													
	Ouratea myrioneura			1	1												1																						1																									
II	*Raphia hookeri*		2		2	1	1	1						1																																									1							
	Harungana madagascariensis		2	1				1	2						2		1				1												1											1																		
	Sabicea discolor	1						1							1		2																																			1										
	Cephaëlis peduncularis				1		1	1				1			1		1					1																																								
	Costus deistelii		1					1	1	1			1		1		1																			1				1														1								
	Clerodendrum schweinfurthii		1									1		1																																																
	Marantochloa leucantha									1	1	2		1	1					4				1				1									1																									
III	*Aframomum daniellii*							1		1	1	1					1																		1													2														
	Ceiba pentandra						1	1		1			1																									1																					1			
	Raphia sassandrensis	1							1		1											1													1								1											1								
IV	*Discoglypremna caloneura*			1									1	1			1																															1														
	Cleistopholis patens								1			1				1		1					1					1																																		
	Vismia guineensis							1			1		1		1	1	2				2								1								1																									
	Ricinodendron heudelotii									1							1	1																																												
	Parkia bicolor											1			1	1	1	1		1												1																											1		
	Chrysophyllum pruniforme						1								1	1	1		1																																	1										
	Macaranga barteri			1				1	1				1			1	2	1	1								1		1					1					2						1								1			1						1
	Bridelia micrantha														1	2			1		1																																		1							
	Sabicea calycina											2							1	1																	1			1																						
V	*Macaranga hurifolia*	3	2	1	1		1	3	2	2	1	1			2	1	2	1	1	1	1	1	1	1	1		2	2							1									1									1									

Table 10.1. cont.

		Young secondary forest																											Old secondary forest																																		
		com.I Alluv.				com.II Valley-bot.						com.III Lower slope									com.IV Slope & crest								com.V Degraded									com.VI Valley-bot.						com.VII Lower-slope									com.VIII Slope & crest									
VI	*Alchornea cordifolia*	2		1	2		2					4							1				1	1	1	1	1	2	1		1					1						2																				
	Ficus capensis	1			1			1		1						1	2	1			2		1	1			1		1	1		1															1															
	Trichilia heudelotii	1	1	1		1					1										1	2	1							1	1						1																		1							1
	Mezoncuron benthamianum	1						1	1			4		1	1		1				1				1		1	1			1		1	1																												
	Rauvolfia vomitoria	1	1					1		1	1			1	2	1	1	1			2	1	1	1	2	1	2	2	2	1	1	2	1	1	1							1			1					1				1								
VII	*Smilax kraussiana*					1		1			1					1	1				1					1			1																										1						1	
	Solanum verbascifolium							1		1							1				1		1		1		1																																			
	Leea guineensis					1			1	1	1	1		1	1					1		1			1			1					1	1		1							1					1									1		1			
	Funtumia elastica					1											1					1						1					1		1																				1							
	Panicum brevifolium						1	1									1		1								1				1		1			1																										
VIII	*Dioscoreophylum cumminsii*						1								1							1			1				1	1			1																													
	Cissus aralioides																2									1	1	1		1	1				1																											
	Tragia benthami																						1		1			1		1	1	1	1																													
	Deinbollia pinnata																1					1		1		1			1	2																																
	Erythrococca anomala	1		1										1							1	1	1					1		1			1	1	1	1																										
	Secamone afzelii																1				1			1	1	1	1			1	1	1	1			1	1																				1	1				
	Salacia camerunensis																							1							1				2																									1		
	Adenia gracilis										1									1	1						1		1				1														1															
IX	*Dioscorea bulbifera*																				1							1			1	1	1														1															
	Albizia zygia	1									1											1	1						1	1	1	1	1		1	1											1								1				1			
	Hymenostegia afzelii					1												1			1						1	1		1	1	1	2																			1							2				2
	Salacia debilis											1								4	1							1	1	1	1	1						1									1	2									1	1		1		
	Baissea zygodioides															1										1			1	1	1	1			1		1	1					1	1								1	1	1						1		
	Grewia carpinifolia																																	1	1	1																										
	Anthonotha macrophylla	1																					1											1	1	1				1										1												1
X	*Combretum paniculatum*	1	1																		1	2	1	1	1		2	1	1				1																									1				
	Millettia zechiana								1													1		1	1		1	2				1	1																													
	Uvaria afzelii						1															1	1		1	1					1																															
	Cola chlamydantha																					2		1				1																														1				
	Byrsocarpus coccineus			1															1	1		1	1	1	1	1	1	1	1																													1				1
	Rutidea parviflora																					1	1	1		1			1																								1								1	
	Acroceras zizanioides		1																		1		1	1			1		1																												1					

Table 10.1. cont.

		Young secondary forest				Old secondary forest			
		com.I Alluv.	com.II Valley-bot.	com.III Lower slope	com.IV Slope & crest	com.V Degraded	com.VI Valley-bot.	com.VII Lower-slope	com.VIII Slope & crest
XI	*Cephaëlis castaneo-pilosa*		1	1 1 1	1 1	1 1 1			1 1
	Costus afer	1	1	1 1 1	1 1 1 1 1	1 1			
	Desmodium adscendens		1	2 1 1	1 1 1	1 1 1			
	Antiaris welwitschii			1 1	1 1 1	1 1 1	1		1
	Aframomum sceptrum			1 1	1 1	1 1 1 1		1 1	1
	Sabicea ferruginea			1 1	1	1 1			
	Drypetes pellegrini		1	1 1		1 1			
	Canarium schweinfurthii			1 1	1	1			
	Uapaca heudelotii			2 1	2 1	1			
XII	*Piptadeniastrum africanum*	1	1 1 1	1 1	1 1 1 1	1 1 1 1 1 1 1	1 1	1	1 1 1
	Scleria barteri	1 1 1		1 1	1 1 1 1 1 1	1 1			1 1 1
	Tetracera potatoria	2 1	1	1 1 1 1 4	2 1 1 1 1 1	1 2 1 1 1	1		1 1 1 1
	Cnestis ferruginea		1 1 1 1	1 1 1 1	1 1 1 1 1	1 1 1	1	1	1 1 1 1
	Myrianthus arboreus	1	1	1 2 1	1 1 1	1 1 1 2 1	1 1	1	1 1 1
	Blighia welwitschii		1	1	1	1			1
	Elaeis guineensis	1 1	2 1 1	1 1	1 1 1 1 1	1	1	1	1 1 1 2 1
	Palisota hirsuta	1 1 1	1 1 1	1 1 1 1	1 1 1 1	1 1 1	1 1		1 1 2
	Neuropeltis velutina		1 1		1 1				2 1 1
XIII	*Dioscorea praehensilis*	1	1 1		1 1 1 1	1 1 1 1	1 1 1	1	
	Acacia pennata	1	1	1 1	1 1 1	1 1	1 1 1		1 1
	Cissus producta	1 1 1	1	4 1 2 4	1 1 1 1 1 1 1	1 1 1 1	1 1 1	1 1	1
	Dioscorea burkilliana	1 2	2 1 1	1 1	1 1 1 1 1	1 2 1 1 1 1 1	1 1 2	1	1 1 1
XIV	*Xylopia aethiopica*		1 1 1	1 1	1 1	1	1	1	1
	Griffonia simplicifolia	1	1 1 1	1 1 1 1 1 1	1 1 1 1 1 1 1 1	1 1 1 1 1 1 1	1 1 1	1 1 1 1 1 1	1 1 2 1 1 1
	Tiliacora dinklagei	1	1 1 1	1 1 1 1 4	1 1 1 1 1	1 1 1	1 1	1 1 1 1	1 1 1 1 1 1
	Thaumatococcus daniellii	1	1 1	1 1 1	1 1	1 1 1	1 1	1 1	1 1 1 1 1
	Cercestis afzelii	1	1 1 1	1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1 1	1 1 1 1 1 1 1 1
	Xylopia quintasii	1	2 1	1 1 1 1 1	1 1	1	1 1 1	1 1	1 1 1
	Dialium aubrevillei	1 1 1		1	1 1 1 1	2 1 1	1	1 1 1 1	1 1 1 1

Table 10.1. cont.

		Young secondary forest				Old secondary forest			
		com.I Alluv.	com.II Valley-bot.	com.III Lower slope	com.IV Slope & crest	com.V Degraded	com.VI Valley-bot.	com.VII Lower-slope	com.VIII Slope & crest
XV	*Baphia polygalacea*	1 1 2	1 1 1 1 1	1		1	1	1 1	1 1 1 1
	Bertiera bracteolata	1 1	1	1	1			1 1	1
	Fagara macrophylla		1 1	1 1 2 1 1		1		1 1 1 1 1	
	Musanga cecropioides	2	1 2	1 1 1	1		2 1	1	1
	Uapaca esculenta	1 1	2	1 1	1 1			1 1	1
XVI	*Hypselodelphys violacea DOM*	3	3 3				3 3 3		
	Trachyphrynium braunianum		2 2 2 2				2 2	1 2	
XVII	*Albizia adianthifolia*	1 1	1		1 1 1 1 1	1 1		2	1 1 1
	Cissus diffusiflora	1			1 1	2 1 1			1 1 1 1
	Clerodendrum volubile		1	1	1 1 1	1 1			1 1 1
	Sherbournia calycina		1	1 1	1 2 1 1	1 1 1		1	1 1 1 1
	Xylopia villosa			1	1	1 1			1 1
	Sabicea venosa	1			1	1 1		1	1
XVIII	*Canthium hispidum*	1		1	1 1 1			1	1 1
	Monodora tenuifolia				1 1 1				1 1 1
XIX	*Maesobotrya barteri*			1 1		1 1 1	1 1	1 1 1	1 1 1
	Neuropeltis acuminata		2	1 1	1 1	2 1 1 1 1	1 1 1 1	1 1 1 1 1 1 1	1 1 1 2
	Hunteria simii			1 1 1 1 4	1	1 1 1 1 1 1	1	1 1 1 1 3	1 1 1 1 2
XX	*Microdesmis puberula*		1	1 1 1 1	1 2 1 1 1 1	1 2 1 1 1	1 1 1	1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1
	Dichapetalum toxicarium		1	1 2	1 1	1 1 1 1	1 1 1 1	1 1 2	1 1
	Mildbraedia paniculata		1	1 1 1	1 1	1 1	1 1	2 1 1	1 1 1 1
	Strombosia glaucescens	1	1	1 1 1 1	1 1	1 2 1 1 1	1	1 1 1 1 2	1 1 2 1 1 1 1
	Streptogyna crinita			1 1 1	1	1 3 1		1 2 1	1 1
	Maranthocloa filipes		2	2 1 1 1 1	1 1 1 1	1 1 1 1 1	1 2 2	1 2 1 1 1 1	2 1 1 1 1 1 1 1
	Geophila obvallata		1	1 2 1 1 2	1 1 1 1 1 1 1	1 2 1 1 1 1 1 1	1 1 2	1 1 1	1 1 1 1 1 1 1
	Vitex micrantha		1	1 1 1	1 1	2 1 1 1	1	1 1	1 1
	Calycobolus africanus	1	1	1 1 1 4	1	1 1	1 1 1 2 2	1 1 1 1 1 1 1 3	2 1 1 1 2 1 2 2
	Chrysophyllum taiense			1 1	1 1	1		1 1 2	1 1 1 1 1

Table 10.1. cont.

		Young secondary forest				Old secondary forest			
		com.I Alluv.	com.II Valley-bot.	com.III Lower slope	com.IV Slope & crest	com.V Degraded	com.VI Valley-bot.	com.VII Lower-slope	com.VIII Slope & crest
XXI	*Geophila hirsuta*			2 1 1		1	1 2	1	1 1
	Massularia acuminata		1	1 1		1	1	1 1	1 1 1
	Diospyros chevalieri		1	1 1			1 1	1 1 1	1 1 1
	Napoleona leonensis		1	1 1 1	1 1	1 1	1 1 1	1 1 1 1 1 1 1 2	1 1 1 1 1 1
	Rhaphiostylis beninensis		1	1 1 1		1	1 1	1 1 1 1 2	1 1 1 1
	Manniophyton fulvum		2	4 1 1 1	1		2 1	1 1 1 1	2 1 2 2
	Diospyros soubreana			1 1 1 1 1	1 1 1	1	1 1 1 1 1	1 1 1 1 1 1	1 1 1 1
XXII	*Pycnanthus angolensis*		1 1	1 1	1 1 1	1	1 1 1	1 1 1 1	1 1 3 1 1
	Sarcophrynium brachystachys			1	1 1	1 1 1	1 2	1 1 1 1 1	1 1 1 1
	Rhigiocarya racemifera						1	1 1	1
	Neuropeltis prevosteoides			1	1 1	1	1 1 1 2	1 1	1 2 1
	Calycobolus africanus	1	1	1 1 1 4	1	1 1	1 1 1 2 2	1 1 1 1 1 1 1 3	2 1 1 1 2 1 2 2
	Cola heterophylla		1	1		1 1	1 1 2 2 2	1 1 1 1	1 1 1
	Popowia mangenotii	1				1	1 1	1	1 1
	Cola nitida		1				2	1	1
XXIII	*Craterispermum caudatum*			1		1 1			1 1 1
	Rothmannia whitfieldii					1 1		1	1 1 1
	Octoknema borealis			1		1		1	1 1
XXIV	*Drypetes gilgiana*							1 1 1	1
	Diospyros sanza-minika			1				1 1 1 1 1	1
	Triphyophyllum peltatum							1 1 1	1
XXV	*Diospyros canaliculata*			1 1 1 1 1		1	1	1 1 1	2 1
	Memecylon guineense			1 1	1			1	2 1
	Diospyros mannii			1 1 1		1		1 1 1 1 1 1	1 1 1 1
	Heinsia crinita			1 1	1			1 1	1
	Caloncoba brevipes			2 2	1	1		1 1 1	1 2
	Beilschmiedia mannii			1 1 1				1	
	Nauclea diderrichii			1 1				1	1
	Landolphia membranacea		1	1 1			1	1 1	1 1 1
	Cercestis sagittatus		1	1 1 1				1	1 1 1

Table 10.1. cont.

		Young secondary forest				Old secondary forest			
		com.I Alluv.	com.II Valley-bot.	com.III Lower slope	com.IV Slope & crest	com.V Degraded	com.VI Valley-bot.	com.VII Lower-slope	com.VIII Slope & crest
XXVI	*Decorsella paradoxa*			1	1			1 1 1	1 1
	Salacia lateritia							1 2 1 1	1 1 1 1
	Gilbertiodendron preussii							1 2	2 1
	Whitfieldia lateritia				1 1		2	1 1 1 1 1 1 1	2 1 1 1
	Soyauxia floribunda	1		1			1	1 1 1	1 1 1
	Culcasia scandens	1				1		1 1	1 1 1
	Araliopsis tabouensis			1				1 1 1 1	1 1
	Dorstenia smythei							1 1	1 1
	Thricoscypha beguei							1 1	1 1 1
	Kolobopetalum leonense					1		1 1	1 1
	Ctenitis protensa					1		2 1	1
	Cola caricaefolia		1		1			1 1	2 1
	Cuviera acutiflora					1		1	1 1
	Rinorea longicuspis		1			2 1		1 2 1 2	1 1 2 1 3
XXVII	*Enantia polycarpa*			1		1	1	1	1 1 1
	Coffea ebracteolata								1 1 1
	Myrianthus libericus		1		1				1 2 1 1 1
	Ptychopetalum anceps			1	1	1		1 1	1 2 1 1
	Aphanostylis mannii			1	1		1 1	2	1 1 1 1
	Drypetes chevalieri			1	1			1	1 1 1 1
	Culcasia glandulosa							3	1 1 1
	Culcasia longivaginata							1	1 1 1
	Strychnos cuminodora							1	1 1 1

Community I : Calamus deëratus & Costus lucanusianus, Community II: Aframomum daniellii & Raphia sassandrensis, Community III: Cleistopholis patens & Bridelia micrantha, Community IV: Byrsocarpus coccineus & Rutidea parviflora, Community V: Albizia zygia & Grewia carpinifolia, Community VI Hypselodelphys violacea & Trachyphrynium Community VIII: Myrianthus libericus & Ptychopetalum anceps.
Community VIII: Myrianthus libericus & Ptychopetalum anceps.

secondary forest on Alluvium could be found.

The community of *Albizia zygia & Grewia carpinifolia* holds an curious position. The vegetation table shows that these are forests from which pioneer species have gone (absence of sociological groups V, II, IV). Considering age and the definitely forest-like appearance of these stands, these secondary forests are old and, at least structurally, in the "stade pré-climacique". In the Fig.10.2 we see that this community, despite the absence of pioneers, still has more affinities, floristically, to young secondary forest ("stade arbustif-pionnier"). The reason is that many sociological groups, characteristic for old secondary forest are absent (XXII, XXIV, XXVI, XXVII). After inspection of the soil (auguring) and questioning of the owners, and considering the fact that these forests are species-poor, we concluded their degraded character.

10.3.2 Age

We expect young secondary forest to be young and old secondary forest to be old. However, successional stage is not always consistent with the period elapsed since abandon of the field. We should keep in mind that the seral stages "arbustif-pionnier" and "pré-climacique" result from floristic and structural observations, whereas the communities in Table 10.1 are defined by their floristic composition exclusively. We can thus observe that a forest can be, floristically, "ahead" of its stage, or, inversely that a vegetation develops slowly in respect to its age. Consequently, we can study the reason.

Young secondary forest with affinities to old forest

Occasionally, a community can develop a species composition resembling an old secondary forest within a few years of fallow. Examples in the Table 10.1 of young forest with hardly any pioneers, but, instead many primary forest species are, relevé 85 and 5, both seven years old, relevé 88 and 78 both six years old and relevé 96 being eight years old. Most other relevés of community *Drypetes gilgiana & Triphyophyllum peltatum*, community *Myrianthus libericus & Ptychopetalum anceps* and community *Hypselodelphys violacea & Trachyphrynium braunianum* are between 20 and 35 years old and one (relevé 10) of forty, and one (relevé 35) of approximately sixty-five years old. Two reasons explain such a rapid development.

1. **The field was prepared in primary forest and burning had been insufficient**. Many primary forest species have survived the land clearing vegetatively. Coppice shoots from stumps and root suckers rapidly covered the ground. With their shade the establishment of pioneers is hampered and some species may have been prevented from germination altogether by the acidity of the topsoil which lacks the alkaline ashes. (this matter is studied in detail in chapter 7[1]). This was the case in relevé 5 and 78.
2. **The field had an abundance of** *Marantaceae* especially the climbing members of this family (*Marantochloa* spp, *Hypselodelphys violacea*,

1 Alexandre (1989a p.62) reports the same thing. He mainly considered secondary forest grown up after no burning at all, but calls such a regeneration "slowed down" and not "advanced" because these stands are low and ill-structured and can remain so for a long time. He nevertheless admits that these plots resemble older forest floristically (pers. comm.)

Trachyphrynium braunianum). The *Marantaceae* were cut back during the cultivation period but at the end of the season were allowed to grow out. With large leaves and vigourous growth the ground was rapidly covered. This seems to be rather effective in preventing the spreading of early sucessional plant species. But shade is not so deep as to prevent the growth of primary forest species. The relevés 88, 85 and 96 are fallow vegetations which predominance of *Marantaceae*. The sites had been used for rice cultivation several times over.

So in both cases rapid shade is produced by the release of established individuals which are only damaged by the field preparation. They regenerate by sprouting from stumps and roots and prevent the normal pioneers to become dominant. The stage "arbustif-pionnier" had probably been very short, or had remained underdeveloped.

All exceptional and young secondary forest were sampled in valley bottoms or on lower slope positions. Forest on slopes and crest classified as community *Myrianthus libericus & Ptychopetalum anceps* was invariably old (between twenty and forty years old). Why is this so? We have seen that "being ahead of its age" depends on number and kind of coppicing plants present in a field at the moment the field is abandoned. *Marantaceae* plants are particularly frequent in wet places. It is likely that primary forest species survive more easily in the moist, lower topographic positions which are, in addition, more difficult to burn properly.

Relevé 5 was near the village Zaipobly in the north of the study area, relevé 78 in the Inselberg Landunit UB3, relevé 88 in the Landunit UA1 (Sélédio) and relevé 55 was near the village Sakré. Both 88 and 55 had floristic affinities with the Inselberg Landunit UB2. Relevé 85 was about 20 km north of the village Para. It is noteworthy that the youngest secondary forest on well drained soil (relevé 45), classified as community *Myrianthus libericus & Ptychopetalum anceps*, is a 17-year old "Ferreclao" site near the former village Dieré-oula No.1 (Fig.3.2).

Old secondary forest with affinities to young forest

We should look at the inverse situation too, secondary forest which is floristically much like young fallow vegetation in the "stade arbustif-pionnier" but is actually much older than 10 to 15 years. Again, exceptional cases are found in community of *Aframomum daniellii & Raphia sassandrensis* and community *Cleistopholis patens & Bridelia micrantha*, so in valley bottoms and in lower slope forest. They are relevé 73, forty years old, and the relevés 56 and 2 both eighteen years old. All relevés on slope and crest, community *Byrsocarpus coccineus & Rutidea parviflora* are young, between five and eleven years old. Non-exceptional relevés in valley bottom and lower slope are a little older, between six and sixteen years old. Secondary forest is classified as young *(Macaranga hurifolia* community group) because of pioneers with a short live-span are present. In chapter 7 we have seen that pioneers can live longer on wet places than on periodically drier sites.

Blocked succession, "Gbarou"

The relevés 73, 56 and 2 are blocked in their succession in the sense of Kahn (1982). Guillaumet (1967 p.102-105) and Alexandre *et al.* (1978) call these sites "Brousse à *Marantaceae*". In Oubi they are named "Gbarou" which means "horizontal forest". Succession has been blocked by the profuse development of *Marantaceae* and this gives a horizontal layering of the vegetation, 2 to 5 metres above the ground. Some large (up to 30 m) heliophil trees have grown above (*Ceiba pentandra*, *Pycnanthus angolensis*). Apparently *Marantaceae* species can both forward and block succession. The species group active in both cases is the sociological group XVI. These sites are classified as young secondary forest not because the few pioneer trees present, but because many heliophil liana and scrambling shrub species of the sociological groups II, IV and VI. These species continue to occupy the horizontal layer of the canopy (*Alchornea cordifolia*, *Mezoneuron benthamianum*, *Acacia pennata*, *Dioscorea* spp). All these species are absent from normal old secondary forest. Shade under the leafy layer of *Marantaceae* and lianas is so deep that primary forest species cannot invade. This prevents a "Gbarou" site from being classified as old secondary forest.

Few "Gbarou" communities on the Taï area are still intact, most of them have been used for agriculture, especially for rice for these places are considered appropriate for cultivation. Relevé 73 was in Land unit UA2, close to the Cavally. The relevés 56 and 2 were both near the village Ponan in the north of the study area. The upland-alluvium Land unit UA2 has many former and damaged "Gbarou" sites, as does the Landunit Utm, especially east of the village Sakré and near the former village Troya. All these sites are in the central part of the study area. A blocked succession due to a dominance of *Marantaceae* seems to be restricted to flat depressions. "Ferreclao" is absent. We concluded that occurrence of "Gbarou" vegetation in Taïis determined by edaphic factors, in contrast with C. De Namur and D. Schwartz (pers.comm.) who conclude that in the Mayombe (Congo), blocked succession due to *Marantaceae* dominance is determined by historic factors alone. This type of vegetation can be found on any kind of soil (D. Schwartz pers.comm.).

Because "Gbarou" sites are actively looked for to cultivate, there are some former sites among the relevés in Table 10.1. This allows the investigation of some historic factors. Does a "Gbarou" develop after a primary forest has been cut, or does a new "Gbarou" develop each time a "Gbarou" is cut? In Table 10.1 relevé 4, 82 and 23 were formerly "Gbarou" forests. At the moment of sampling they were respectively seven, five and sixteen years old. This information was given by the men who had cut the forest at the time it was "Gbarou", from the vegetation itself it was far from obvious. In one case (relevé 82) the man assured that the now five year old fallow would be "Gbarou" in ten years time. It is our impression that a "Gbarou" develops immediately after a field in primary forest is abandoned. If a "Gbarou" vegetation is cut, then the return to a similar structured forest will take more time or it may not happen at all.

"Gbarou" types of forest are not sufficiently floristically different from other types of secondary forest as to constitute a separate community. However, "Gbarou" used for rice cultivation develop a proper weed community *Tragia tenuifolia* & *Cayratia gracilis* (chapter 11).

The role of sociological group XVI, comprising *Marantaceae* species, can be twofold. If the occurrence of *Hypselodelphys violacea* and *Trachyphrynium braunianum* is overwhelming, succession is blocked and a "Gbarou" (or "Brousse à *Marantaceae*") is formed. Pioneer trees, nor primary forest plants can develop normally. If the *Marantaceae* species are a less oppressive, then primary forest species are allowed to develop and invade, though heliophil pioneers have difficulties to dominate. The fallow vegetation develops rapidly, floristically, into an old secondary forest.

Degraded secondary forest

Concerning the community *Albizia zygia & Grewia carpinifolia* which has affinities both to young and to old secondary forest, these are vegetations between 16 and 30 years old. Looking at the sociological species group IX where characteristic species are listed, we get the impression that possibly this community can be split in two: The relevés 11, 13, 18, 34 and 41 have a species group, *Dioscorea bulbifera*, *Hymenostegia afzelii* and *Salacia debilis* which form a sub-group. The relevés 48, 8, 26 and 98 with the species *Grewia carpinifolia* and *Anthonotha macrophylla* form another sub-group. As was said earlier these forests are merely indicated as degraded. Although degradation can have here two distinct causes, one cannot say that one cause of degradation applies to one sub-group and the other cause of degradation to the other sub-group.

Overworked soils

The first cause of degradation which produces a secondary forest community *Albizia zygia & Grewia carpinifolia*, is extra disturbance. The place has been subject to many shifting cultivation cycles. The relevés 18, 34, 48, 90, 41 and 26 in Table 10.1, are all between sixteen and twenty years old. More time is needed than usual for primary forest species to invade. Because such worked-over sites are generally found close to relatively large villages where no or few primary forest is left, seed sources may be a problem. Farmers call these sites "fatigués" but consider them appropriate to re-newed cultivation if more time is granted for regeneration.

Naturally poor soils

A second cause of degradation by which the community *Albizia zygia & Grewia carpinifolia* develops is a poor soil. These sites are not called "fatigués" but esteemed improper to rice cultivation altogether. Relevés 11 and 8 were both thirty years old and relevé 13 was twenty three years old. All were previously covered by primary forest and an attempt was made to cultivate the site probably for the benefit of laying close to the village (all within 400 m). Relevé 11 (middle slope) and 8 (lower slope) showed soil characteristics (auguring) like texture, gravel content and colour which were quite conform to those described in the typical toposequences (Fritsch 1980, De Rouw, Vellema & Blokhuis 1990). So here soil inspection does not reveal any sign of inferiority. In the case of the lower slope site, relevé 8, rice had not grown higher than one metre and cassava roots remained very small. This 30 year old forest had a very open underwood with a continuous groundcover of the grass *Streptogyne crinita*. Many trees lacked vigour. It was pointed out to me that adult plants of *Smilax kraussiana* and of *Dioscorea* spp failed to form tubers. The extend of this piece of forest did not exceed half a hectare, all around the land was cultivated regularly with rice or under permanent crops (coffee). In a nearby coffee plantation (300 m) large tubers of *Dioscorea praehensilis* were harvested for consumption.

In relevé 13 (middle slop) the soil was different from usual. Between 40 and 85 cm a semi-hard plinthite layer occurred probably produced by a seasonal water-table at some depth. The forest was however impressive (*Triplochiton scleroxylon* of about 30 m high) and the understorey was well-structured. So to the untrained eye, it appeared as a good example of a forest in the stage "pré-climacique". On seeing the soil, the present three farmers expressed spontaneously their disapproval of the plinthite layer. Knowing that farmers usually introduce a matchet into the soil as a means of judging its quality, but never down to 40 cm through a gravelly top soil, I asked whether they could see by some other sign that the site was improper for rice cultivation. The farmers agreed that it was for the abundance of Sipo trees (*Entandrophragma utile*), two large ones (20 - 30 m), and two smaller ones (5 and 10 m). Because Sipo is rather an inhabitant of a drier forest type, north of the Taï region, the occurrence of the species here was presumingly an indicator of less favourable growing conditions. This made the site convenient for cassava, but less so for rice. This forest too, covered probably less than a hectare.

The first cause of degradation is obviously human-induced. Repeated rice-fallow-rice rotations had impaired regeneration. The second cause is probably due to a variation in parent material. As we have seen in Chapter 9 the underlying lithology (migmatite) can be highly variable over short distances. It is striking that an apparently infertile soil demonstrates all characteristics of a normal migmatite derived soil when sampled with an auger. Only chemical analysis or inspection of the vegetation reveals its inferiority. The variability of the parent material can result in a surprisingly good soil too, and it happens that inspection of the soil upon augering shows nothing abnormal[2]. In both cases it is the spontaneous vegetation which holds the key to the whole matter.

In my opinion, patches of old secondary forest in relatively intensely cultivated areas, remain so, in most cases, for re-cultivation is not considered worth the trouble. A scientist studying succession should be aware of this as he asks villagers to indicate him forest of different ages. For convenience sake, he has a great chance of being conducted to these degraded secondary growths. If we look at the species lists of the secondary forest between 29 and 61 years old, studied by Kahn (1982) in the south-west Côte d'Ivoire, omitting those in the Grabo area, we see that five out of six relevés show strong affinities with community *Albizia zygia & Grewia carpinifolia*. In the only relevé where *Albizia zygia* is absent, *Anthonotha macrophylla* (sociological group IX) is present. Most sites have an important ground layer of *Streptogyne crinita*, while *Salacia debilis* and *Baisea zygodioides* also occur. Kahn (1982) admits that some of the secondary forest he observed was left untouched because of a former bad harvest, but other motives were mentioned too, religious taboos and absent owners. Throughout the study area I found farmers little inclined to say their soil is bad. They generally prefer to say other things. In the Taï area old secondary forest of the community

2 Two examples in the study area. Riou (1960) sampled a soil closeby the former village Diéré-oula No.1 (Fig.3.2). The soil had a superior pH, was good provided with phosphorus and had a base saturation higher than usual. Because of these characteristics he suggested that the parent material of the soil derived from an ancient riverbed of the river Noulo (Oubi name for Audrénisrou). We re-visited the site and found "Ferreclao" to be abundant. H. van Reuler (pers. comm.) installed experimental plots where soil conditions (augering) gave the impression of homogeneity. During the experiments part of the field gave higher rice yields. This could only be explained after chemical analysis had revealed a less acid soil where yields were high. He concluded that the anomaly in the experimental field was induced by parent material (Van Reuler & Janssen pers. comm.). This experimental field was located at the intersection of the Buffer zone and the road leading to the I.E.T. MAB station. Although all natural vegetation had been cleared from the experimental field, nearby roadside vegetation carried "Ferreclao".

Albizia zygia & Grewia carpinifolia are either not cultivated or given to immigrants. Here too, the owner would not say he had given the land away because of the bad soil. Once, a farmer pressed on this matter (I said the soil was sandy and the regrowth poorly developed), objected that, on the contrary, the immigrants were happy with the forest she had given them because the trees were small and they, being a savanna people, were not used to felling big trees. An important part of the relevés of Table 10.1 was situated in the Buffer zone. Not seldom, farmers said it was a pity these sites were now part of the National Park protection zone for a good rice field could be made out of it (especially relevés 17 and 9).

10.3.3 Toposequence

In contrast with primary forest which changes due to increasing rainfall and to edaphic variation induced by lithology, secondary forest, at least those of similar age, vary only along the toposequence. So the secondary forest communities we distinguish occur in all rainfall zones. This is comparable with findings of Zonneveld & Surasana (1988) in Sumatra. There too, the climatic gradient was better expressed by the primary forest vegetation than by the secondary forest. In the study area secondary forest occurs where shifting cultivation is practiced, which means that it is restricted to areas occupied by Oubi, Guéré and Kru. The effect of toposequence on community was merely checked on young forest ("stade arbustive-pionnier") because these secondary forest are more common and can, usually, rather easily be reached. As was explained in the Land Unit Survey each observation on soil was accompanied with either a complete floristic inventory (which were used to build the classification system) or an incomplete quick relevé. After the classification was made, those many sites which had an incomplete species list, could be classified to one of the communities thanks to the identification of certain sociological species groups. We observed that the different positions the three communities of young upland secondary forest occupy on the slope are not identical in the north and in the south. The community *Byrsocarpus coccineus & Rutidea parviflora* which occupies crest, upper, and middle slope in the northern part of the study area, will occupy only crests in the southern part. Also, the community *Aframomum daniellii & Raphia sassandrensis* which develops in valley bottoms in the northern region, can occupy a greater part of the slope in the land more south. A schematic representation of this is shown in Fig.10.3. From these data, another relation with moisture became evident. Communities which cannot develop on gravelly soils in the north, do so in the southern part because extra rainwater makes up for the limited water storing possibilities in the soil. Relevé 99 classified as *Cleistopholis patens & Bridelia micrantha* was sampled upper slope near the village Para, whereas other relevés classified as *Cleistopholis patens & Bridelia micrantha* (56, 17, 21, 22, 23, 6, and 2) were sampled in the north, in forest situated lower slope. While travelling from north to south, the first crest we sampled (relevé 83) covered by the community *Aframomum daniellii & Raphia sassandrensis*, in the north confined to valley bottoms, was situated a few kilometres north of the village Nigré. The soil was clayey and contained no gravel. In the Table 10.1 the topographic position of communities in the north is given.

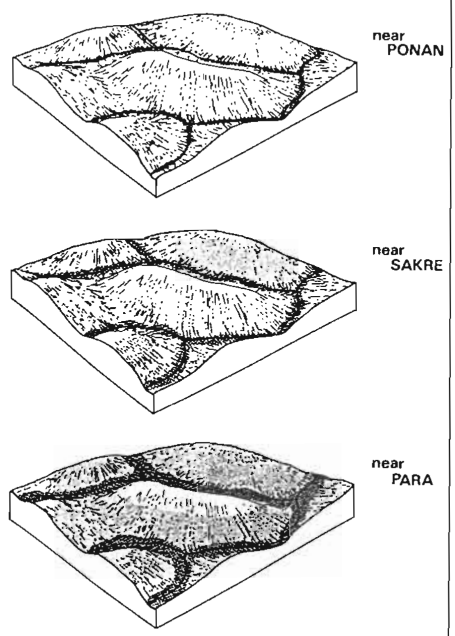


Fig.10.3. Schematic representation of three communities of young secondary forest occupying different positions on the slope, in the northern part of the study area, near Ponan, in the central part near Sakré, and in the southern part near Para.

10.4 VALIDITY OF THE CLASSIFICATION

Although the classification supplies much ecological important information, the force of the classification presented in Table 10.1 is limited. There are two main restrictions.

- The validity is restricted to the region where the tree *Macaranga hurifolia* is the commonest pioneer tree. This corresponds to the land where the primary forest has been classified as *Eremospatha macrocarpa & Diospyros mannii* or as *Diospyros* spp & *Mapania* spp (Guillaumet & Adjanohoun 1971, De Namur & Guillaumet 1978).
- The described successional units are only relevés in the Established shifting cultivation system (see chapter 4). The cultivation period should be limited to one crop, and fallow periods should be fairly long. Only under these conditions the seed stock of pioneer trees, especially *Macaranga hurifolia*, is preserved in sufficient numbers to allow such a succession as described here. If the seed stock gets exhausted, due to a prolonged cultivation and short fallow periods, succession may follow quite other paths, as we shall see in the next chapters.

The particularities of the pioneer stands of *Macaranga hurifolia* has been noticed by Kahn (1978a, 1978b, 1982): If a quasi-monospecific *Macaranga hurifolia* forest is cut, five or six years old, no seeds of *Macaranga hurifolia* will germinate in the field, although during the previous years of fallow huge quantities of seeds have been produced and stocked in the ground. If such a field is abandoned, the subsequent fallow will be far from normal. This we saw confirmed on well drained sites all over the study area where a young fallow dominated by *Macaranga hurifolia* was cleared, except in the flat, swampy Land units AU1 and AU2. Here, the primary forest has been cut long ago (aerial photographies of 1956) and now all of the land is covered by rice fields, recently abandoned rice fields and fallow vegetation mainly community *Aframomum daniellii & Raphia sassandrensis*. Rice is cultivated in short rotations and no fallow seems to be older than eight years. *Macaranga hurifolia* trees and seedlings however, were seen in all fallow vegetations, but densities remained inferior to those observed on better drained soils. A possible explanation to this, is that *Macaranga hurifolia* trees produce toxic substances (leached out of fallen leaves, or exudated by roots, or other) which inhibit seeds of the plant to germinate. In a very dense stand and on a relative dry soil these substances can remain active for a longer period than in soils where the density of trees is much lower and the ground often swampy. Here the toxic matter would not have the concentration needed to block germination and *Macaranga hurifolia* seeds can germinate.

10.5 CONCLUSIONS

The successional stages described structurally and floristically as "stade arbustif-pionnier" and "stade pré-climacique" (Alexandre *et al.* 1978) correspond to our community group *Macaranga hurifolia* and community group *Pycnanthus angolensis*, respectively. On well drained soils, the similarity is perfect, on imperfectly drained soils, the agreement is not always the case. This as partly because Alexandre *et al.* paid less attention to secondary forest in valley bottoms as compared to vegetation on well drained soils, and partly a result of the different way Alexandre *et al.* (1978) defined old secondary forest. The same authors emphasize the position of canopy trees. Where long-lived pioneer trees constitute the canopy, the forest is called pré-climacique. We considered the complete species list and a canopy tree or a non-canopy tree have the same importance. Old secondary forest is called old because primary forest species had invaded.

Our typology allowed a series of ecological interpretations, on coppice growth, on soil fertility and on moisture, which are not possible if part of the toposequence is neglected, or if mainly size of the dominant trees are considered.

The role of coppicing plants on well drained soils is often modest, whereas re-sprouting plants on wetter places, notably *Marantaceae*, can profoundly influence succession. A rapid cover by coppice shoots puts the heliophil pioneers in a disadvantage, but favours the installation of more sciaphil primary forest plants. If coppice growth is extremely vigourous, not even primary forest species can invade, and succession is blocked. Succession, in the sense of re-installation of primary forest species, can be blocked too, because the soil is extremely poor, either naturally, or because of over-exploitation. Finally, the climatic gradient is not so much expressed in particular secondary species which are present in the south and absent in the north (climatic indicators of the first type, chapter 9) but merely the communities relation to slope. This could be described as a secondary forest community, being in the north restricted to wet places, which "climbs out" of the valley bottoms in the south. The whole community rather act as a climatic indicators of the second type (chapter 9).

11 Plant associations in rice fields

11.1 METHODS

Sampling

The classification was established with data set 7, relevés in rice fields sampled once (59 samples), together with data set 8, relevés in rice fields in permanent quadrats (239 samples, see Fig.8.1). All relevés were made in the period 2 months after burning and 12 months after burning (=6 months after the rice harvest). All fields sampled were located in the northern part of the study area between the villages Zaipobli and Diéré-oula. The permanent quadrats were installed in the experimental fields whose location is shown in Fig.1.6. Permanent quadrats were sampled 2, 6, and 12 months after burning. Each experimental field carried weeded and unweeded plots. For more details on sampling methods in permanent quadrats see Chapter 1 and 5.

Processing of the floristic data

Treatment of the matrix was largely done by hand. TWINSPAN could only make few clear clusters and those where refined to a better arrangement of species and stands. As usual with a population of incomplete samples, mixtures, underdeveloped and degenerated stages could be recognized and re-arranged.

Vegetation units were always obtained by the junction of emunerations from different sites. So no community occurred on just one field, but units always were represented by sites sampled repeatedly and by sites sampled once.

The Minimum area exceded the relevé size (9 m^2), and a field had at least four plots which were sampled repeatedly during the season. Considering the weedy and pioneer tree flora, present by many seedlings/m^2, the difference might not be so large. The Minimum area is far too small for the far richer primary forest flora, present by larger re-sprouting plants. As this part of the Taï vegetation was studied in chapter 9 and 10, this is not a problem.

The classification presented here does not claim to be a permanent one, and no attempts were made to build something of a hierarchical system as is often done in the Braun-Blanquet school. There are two main reasons for this:

- The Taï field vegetations are highly dynamic. Not only agriculture itself is changing (adaptations to land shortage, new crops) and thus has an immediate effect on weeds, but also the weed flora itself is extremely dynamic. New species are currently introduced, and the arrival of all weeds common in rice fields elsewhere in the country, seems to be only a question of time.
- The scope of this study is to clarify relations between agriculture, weeds and fallow vegetation. It seeks to understand what is happening, the process itself, rather than to fix stages of the process.

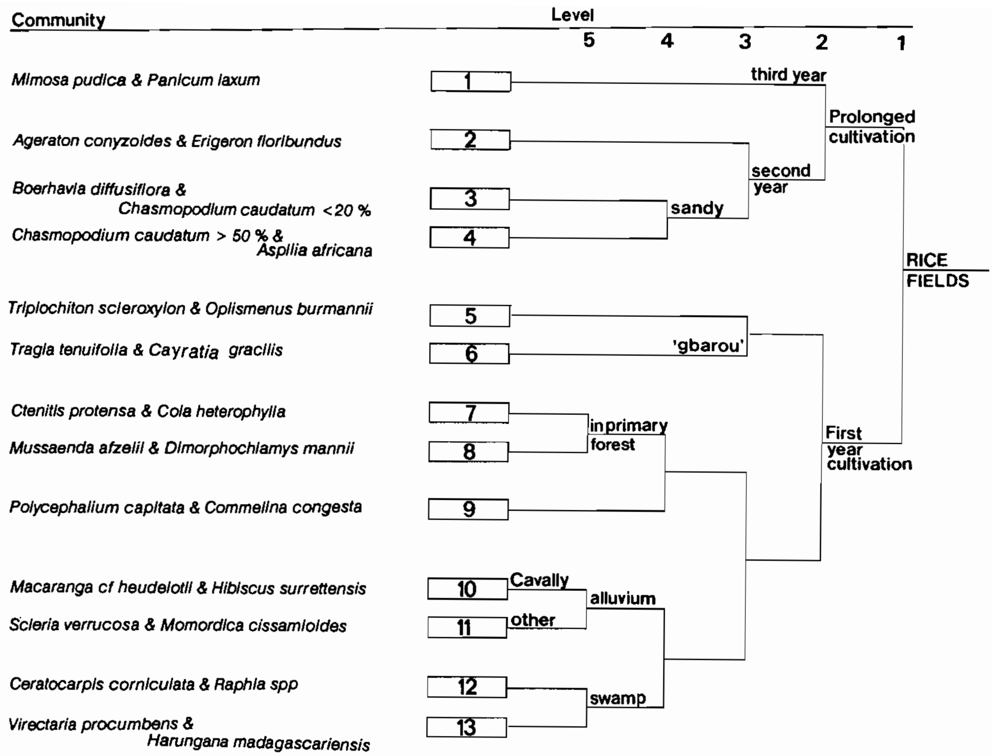


Fig. 11.1. Hierarchical representation of the division of rice field relevés (data set 7+8, Fig.8.1) into thirteen communities with environmental and historical interpretation.

11.2 RESULTS

11.2.1 Chief ecological determinants

The analysis of data set 7+8 gave 13 communities. The relative position of the communities is presented in a tree-like diagram (Fig.11.1) in a similar manner which was done earlier with primary forest (Fig.9.1) and secondary forest (Fig.10.2). An environmental interpretation of a division was added where this was evident. Three categories of factors strongly influence species composition in fields: two are historical (agricultural) factors, one is soil. We can assume that all three act upon all field vegetation, but work with different intensity.

1. Short term determinant

The field is cultivated :

- for the first year, following forest clearing,
- for a second year,
- for a third consecutive year.

2. Long term determinant

The field was made by clearing :

- a primary forest,
- a secondary forest which was previously primary,
- a secondary forest which has been re-cultivated and fallowed several times.

3. Edaphic determinant

The field was established :

- on the typical upland toposequence,
- on Cavally deposit,
- on deposits of other rivers,
- in a valley bottom.

The short term and the long term determinants are associated with the concept of disturbance. The plants in a field which is cultivated for the first year have grown after one recent severe disturbance, those growing in a field which is re-cultivated for a second or third consecutive year, have developed after two or three recent severe disturbances. The fact that severe disturbances occur at yearly intervals is essential. The difference between one, and more than one severe disturbances affect the vegetation more than any other factor (division on the first level, Fig.11.1). No matter the soil, no matter the previous site history, a second cultivation cycle largely effaces these differences which were visible in the field vegetation before, and the field flora is profoundly changed.

Fields that are cultivated for the first year have something of the cultural history of the site expressed in the floristic composition. These historical data can be translated into disturbance too, because it is the number of times the site has been cultivated that is predominant. We can distinguish fields made in primary forest from fields on sites where the forest vegetation has been disturbed once before, and these again from other fields where the forest vegetation has been disturbed twice or more before. It is essential that the period elapsed between successive disturbances is long, preferably over 15 years.

A general, overall result of all disturbance is that many long-lived primary forest species are replaced by few short-lived species.

The edaphic factor can be visible in a number of ways. Fields in swamps or on alluvium both have very particular vegetation even as the site becomes more disturbed. On the common upland soil type, soil conditions can play a much more subtle role in determining species composition. A very gravelly top soil can "enforce" the effects of disturbance which means that clearing has a much more harsh effect on vegetation and so disturbance takes a heavier toll. On the other hand, a clayey non-gravelly soil can "soften" the effect of disturbance on vegetation so more primary forest species can resist and survive than usual. This matter was not further studied, one reason was the sample unit being to small to study primary forest species in fields.

The final arrangement of species and stands is presented in Table 11.1. Communities and sociological groups are represented in an concise way by means of a bar diagram. The sociological species groups are expressed as bars in the X direction. The communities, or classification units, are shown in the Y direction. So at a glance one can see out of what species groups each community is composed. The shaded area indicates the communities where a sociological group should occur. The white enclosed area indicates the communities in which a sociological group may occur. Communities are characterized by their full species composition but not all species of sociological groups could be represented for practical reasons. Table 11.1 gives only the important members of a sociological group, other members are listed in Appendix 2

In Table 11.1 we can see that the communities 1, 2, 3 and 4 are very different from 5, 6, 7, 8, 9, 10, 11, 12 and 13. This divides the Table into fields cultivated for the first year, on the right side, and fields cultivated for two or three consecutive years, on the left side. In

Table 11.1. Vegetation table of weed vegetation in rice fields.

Length of cultivation period	Prolonged cultivation				First year cultivation								
Number of previous rotations	not important				2 or more		primary		1	not important			
Soil	typical		sandy		typical	gbarou	typical		typical	alluvium		valley bottom	
										Caval.	other		
extra disturbance	+dist			+dist				+dist					+dist
Community	com.1	com.2	com.3	com.4	com.5	com.6	com.7	com.8	com.9	com.10	com.11	com.12	com.13
Plant species arranged in sociological groups													
1 *Mimosa pudica* *Panicum laxum* >60%	■ 1												
2 *Spigelia anthelmia* *Paspalum scrobiculatum* *Bidens pilosa* *Synedrella nodiflora* *Millettia zechiana* *Ageratum conyzoides* <50% *Paspalum conjugatum*		■	■	■ 2									■ 2
3 *Ageratum conyzoides* >50 % *Borreria ocymoides* *Solanum anguivi* *Erigeron floribundus* >40%		■	■ 3										
4 *Dioscorea hirtiflora* *Boerhavia diffusa* *Chasmopodium caudatum* <20% *Euphorbia prostrata* *Centrosema plumieri* *Calopogonim mucunoides* *Oldenlandia lancifolia*			■	■ 4									
5 *Chasmopodium caudatum* >50% *Borreria latifolia* *Aspilia africana* *Borreria verticillata* *Euphorbia hirta*				■ 5									
6 *Eupatorium odoratum* >50%	□	■	■ 6	□							□		□
7 *Desmodium velutinum* *Mariscus alternifolius* *Physalis angulata* *Albizia zygia* *Triumfetta rhomboidea*	■	■	■	■	■ 7								
8 *Panicum laxum* <20% *Phyllanthus discoideus* *Pouzolzia guineensis* *Griffonia simplicifolia*	■	■	■	■	■ 8	□	□	□	□	□	□	□	□
9 *Solanum nigrum* *Momordica charantia* *Borreria intricans* *Cnestis ferruginea* *Desmadium adscendens* *Aneilema beniniense* *Bridelia grandis* *Ficus exasperata* *Hoslundia opposita* *Terminalia ivorensis*		■	■	■	■ 9	□	□	□	□	□	□	□	□

Table 11.1. cont.

Group	Species	Prolonged cultivation				First year cultivation								
		not important				2 or more		primary		1	not important			
		typical		sandy		typical	gbarou	typical		typical	alluvium		valley bottom	
											CavaL	other		
		+dist			+dist				+dist					+dist
		com.1	com.2	com.3	com.4	com.5	com.6	com.7	com.8	com.9	com.10	com.11	com.12	com.13
10	*Dissotis rotundifolia* *Oplismenus burmannii* *Panicum parvifolium* *Triplochiton scleroxylon* *Cissus vogelii* *Sterculia tragacantha* *Rutidea parviflora* *Streptogyne crinita*					10								
11	*Albizia adianthifolia* *Cyrtococcum chaetophoron* *Elytraria maritima* *Mezoneuron benthamianum* *Secamone afzelii* *Tragia benthami*		x	x	x	11				11				
12	*Microglossa pyrifolia* *Solanum torvum* *Cyathula prostrata* < 20% *Marantochloa leucantha* *Solanum verbascifolium* *Trema guineensis* *Vismia guineensis* *Aframomum sceptrum*		x	x	x	x	x	x	x	x	x	x	x	12
13	*Ficus capensis* *Eupatorium odoratum* < 20 % *Ampelocissus gracilipes* *Pyrenacantha vogeliana* *Rauvolfia vomitoria* *Parquetina nigrescens*	x	x	x	x	x	x	x	x	x	x	x	x	13
14	*Alchornea cordifolia* *Canarium scweinfurthii* *Ipomoea involucrata* *Scleria barteri* *Trichilia heudelotii* *Bertiera bracteolata* *Centotheca lappacea* *Clerodendrum schweinfurthii* *Acacia pennata*					x	14			x	14			
15	*Chlorophora excelsa* *Byrsocarpus coccineus* *Ceiba pentandra* *Costus afer* *Microdesmis puberula* *Harungana madagascariensis* < 20%					x	x	x	x	x	x	x	x	15
16	*Macaranga hurifolia* *Macaranga barteri* *Kolobopetalum chevalieri* *Adenia cissampeloides* *Anthocleista nobilis* *Ricinodendron heudelotii* *Dialium aubrevillei* *Fagara macrophylla* *Chassalia laxiflora* *Cissus diffusiflora*					x	x	x	x	x	x	x	16	
17	*Rhigiocarya racemifera* *Platysepalum hirsutum* *Vitex micrantha* *Anchomanes difformis* *Baissea zygodioides*					x	x	x	x	17				

Table 11.1. cont.

		Prolonged cultivation				First year cultivation								
		not important				2 or more		primary		1	not important			
		typical		sandy		typical	gbarou	typical		typical	alluvium		valley bottom	
											Caval.	other		
		+ dist			+ dist				+ dist					+ dist
		com.1	com.2	com.3	com.4	com.5	com.6	com.7	com.8	com.9	com.10	com.11	com.12	com.13
18	*Ampelocissus leonensis* *Musanga cecropioides* *Mussaenda tristigmatica* *Sabicea calycina* *Tetrorchidium didymostemon* *Tristemma coronatum* *Nauclea diderrichii* *Virectaria procumbens* <40% *Sabicea discolor*					□	□	■	■	■	■	■	■	■
19	*Adenia gracilis* *Allophylus africanus* *Bridelia micrantha* *Physedra eglandulosa* *Raphidiocystis caillei*					□	□	■	■	■	■	■		
20	*Morinda longiflora* *Mussaenda grandiflora* *Diospyros chevalieri*					□	□	■	■	■				
21	*Cleistopholis patens* *Acridocarpus longiflorus* *Chlamydocarya thomsoniana* *Discoglypremna caloneura*					□	□	■		■	□	□	□	
22	*Xylopia quintasii* *Kolobopetalum leonense* *Croton macrostachyus*					□	□	■			■			
23	*Chrysophyllum taiense* *Whitfieldia lateritia* *Mussaenda erythrophylla* *Solanum anomalum* *Crassocephalum crepidioides*					□	■		■			■	■	
24	*Acroceras zizanioides* *Commelina capitata* *Sabicea vogelii* *Smilax kraussiana* *Triumfetta cordifolia*					□	■			■		■		
25	*Cayratia gracilis* *Cordia platythyrsa* *Justitia tenella* *Tragia tenuifolia* *Chytranthus setosus*					■								
26	*Hunteria simii* *Marantocloa filipes* *Adenopus guineensis* *Diospyros soubreana* *Parinari excelsa* *Aframomum elliotii*					■	■	■	■		□	□		
27	*Geophila hirsuta* *Guoduella oblonga* *Torenia dinklagei* *Commelina congesta* *Polycepholium capitatum*						■	■	■		□	□		
28	*Drypetes afzelii* *Diospyros mannii* *Culcasia glandulosa*							■	■					
29	*Ctenitis protensa* *Cola heterophylla* *Diospyros sanza-minika*							■	□					

Table 11.1. cont.

		Prolonged cultivation				First year cultivation								
		not important				2 or more		primary		1	not important			
		typical		sandy		typical	gbarou	typical		typical	alluvium		valley bottom	
											Caval.	other		
		+ dist			+ dist				+ dist					+ dist
		com.1	com.2	com.3	com.4	com.5	com.6	com.7	com.8	com.9	com.10	com.11	com.12	com.13
30	*Mussaenda afzelii* *Dimorphochlamys mannii* *Diospyros vignei*							□	■					
31	*Bonamia thunbergiana* *Hibiscus surattensis* *Macaranga cf heudelotii*										■			
32	*Scleria verrucosa* *Momordica cissoides* *Oldenlandia affinis*										■	■		
33	*Cissus polyantha* *Adenostemma perrottettii* *Asplenium dreageanum* *Mitragyno ciliata*										□	□	■	■
34	*Halopegia azurea* *Cyclosorus striolata* *Ceratopteris cornuta* *Culcasia angolensis* *Eupatorium microstemon*												■	
35	*Virectaria procumbens* >40% *Cyathula prostrata* >50% *Harungana madagascariensis* >40%													■

fields cultivated for the first year, roughly the sociological species groups 7 to 34 can be found. In fields cropped a second year, only the sociological groups 2 to 13 occur. A third cultivation year reduces the number of sociological groups to four, 2, 7, 8 and 13. Species groups belonging to relatively undisturbed habitats contain more species, notably a variety of forest plants, whereas those species groups restricted to disturbed environments carry fewer species, being mainly pan-tropical weeds. So a dramatic loss of plant species is obvious as a field is cultivated a second year. The sociological species group which separates first year fields from second year fields is the group 16 in which *Macaranga hurifolia* is the most prominent member. The groups 15, 17, 18 and 19 are associated with this distinction.

Another loss of species groups can be seen if the site is subject to successive cycles of shifting cultivation. Fields established in primary forest have many species groups, (the groups 12 to 30). If the site is cleared again, after a fallow period of normal length, the sociological groups 28 to 30, comprising the more "delicate" primary forest species, do not reappear. Instead, the sociological groups 11 and 14 are present containing secondary forest species and some weeds. A large group of "less delicate" primary forest species (sociological groups 20, 26, 27) are still there. If the site is re-cleared for a third, or a fourth etc. cultivation period after a fallow period of normal duration, some of the "less delicate" primary forest species get lost too (sociological groups 26, 27) and they are replaced by the sociological groups 7, 8, 9 and 11. The latter contain weeds and secondary forest species.

In summary, if severe disturbances happen at short intervals, *(in casu* yearly) with the prolongation of the cultivation period, then a dramatic reduction in plant species is the result. This mass of lost plant species is almost the complete flora that normally makes up the young secondary forest (stage "arbustif-pionnier"). If severe disturbances happen at long intervals (the duration of a normal fallow period), then the accumulation of shifting cultivation rotations is followed by a gradual reduction of primary forest species, but the secondary forest (stage "arbustif-pionnier") is not altered.

11.3 THE PLANT COMMUNITIES IN RICE FIELDS

1. The community of *Mimosa pudica* & *Panicum laxum* cover >40%

Low, closed, grassy vegetation with sparse shrub cover.

The sociological species groups 1, 7, 8, 13 should occur, the sociological species groups 6 and 11 may occur.

Description

The dense grassy layer under 60 cm height consists of a mixture of two species, the stoloniferous grass *Panicum laxum*, and the pricky liana *Mimosa pudica*. Both plant species fruit continuously. The woody species (below 1-1.5 m) are chiefly relicts of a preceding community (*Desmodium velutinum, Albizia zygia, Phyllanthus discoideus, Rauvolfia vomitoria* and *Griffonia simplicifolia*). New recruits of these species are rarely found in the community.

The community is very poor in species, between 5-10 species per plot of 9 m^2.

Spatial variation

Rather constant vegetation type, more or less invaded by *Eupatorium odoratum* or more or less in competition with the woody plant species mentioned above.

Conditions for establishment

The community was deliberately created on some experimental plots where it appeared after three years of rice cropping, during the first year of subsequent fallowing. During cultivation the field had been clean-weeded three times a year and slashing and burning preceded each cropping cycle. During the second year of fallowing the community was invaded by *Eupatorium odoratum* and the still persisting trees grew out, but *Panicum laxum* and *Mimosa pudica* were still dominant.

The community occurs more "naturally" on places which has been used as "Parc à bois[1]" provided the site was sufficiently large and open. On one such place, 1.5 km west of the village Gouléako, the community showed some signs of succession after at least 10 years of *Panicum laxum* and *Mimosa pudica* cover.

The community is easily established too, if attempts are made to make an European style garden with a lawn. Sown or planted grass is readily driven out and as soon as *Mimosa pudica* invades it becomes very uncomfortable to walk without boots.

Successional position

Progressive

The community is the vegetation of extremely disturbed and impoverished environments, the ultimate stage of disturbance where groundcover is still complete. Succession is possible as the

1 Accumulation places of timber where heavy machinery has destroyed the topsoil.

trees mentioned above are able to grow out and shade the grass cover. As soon as these sites show some regenerative progression, the sub-woody forb *Eupatorium odoratum* invades. However, this process can be very slow because *Eupatorium odoratum* under these conditions develops slowly. If shade is produced, even light, both *Panicum laxum* and *Mimosa pudica* degenerate. It seems that all natural regeneration on these extremely disturbed sites passes through a stage of *Eupatorium odoratum* dominance (details De Rouw 1991).

Regressive

Unknown in 1989, possibly all woody elements of the vegetation get lost.

Distribution

Rather rare in 1989, small patches near villages and along timber extraction roads, on all kinds of soils but not in swampy areas.

Control

These sites seem to be utterly useless to cultivate. The only way to dispose of the vegetation cover is working the soil completely with a hoe and carrying the material away. Burning on the spot will never be complete and isolated tuffs and stolones of *Panicum laxum* will survive. Plant densities are surely over 1000 plants per m^2 but is in fact impossible to estimate because of the stoliniferous growth habit of the grass.

Synecological interpretation

Soil compaction, severe disturbance of the topsoil, an overworked site, a seedbank without woody species, all can contribute to the establishment of the community.

2. The community of *Ageratum conyzoides* **cover** >40% and *Erigeron floribundus* cover >30%

Open (weeded) to closed (unweeded) cover by broad-leaved herbs, mainly Composites with some upgrowing pioneer trees.

The sociological species groups 2, 3, 6, 7, 8, 9, 11, 12, 13 should occur, the sociological species groups 15 may occur.

Description

Two pantropical weeds *Ageratum conyzoides* and *Erigeron floribundus* form a layer under 60 cm, but the latter grows up to 1.80 as it flowers. Both species produce fruits continuously and seeds germinate on every place opened up. The well-known weed *Bidens pilosa* and *Eupatorium odoratum* are firmly installed. All four are Composites. The pioneer trees are of the hardier type, *Vismia guineensis*, *Rauvolfia vomitoria*, *Albizia* spp, *Hoslundia opposita, Phyllanthus discoideus*, *Harungana madagasariensis* and *Trema guineensis*. The community is rather poor in species , on samples of 9 m^2 between 15 and 30 species occur.

Spatial variation

A rather varied community. *Spigelia anthelmia*, a seasonal weed with a very short life cycle can completely dominate for one or two months. Many relicts of preceding forest communities may persists, mainly as coppicing plants. *Harangana madagascariensis* is an important pioneer on moist places. The grasses *Panicum laxum*, *Paspalum conjugatum* and *Paspalum scrobiculatum* can be present in variable densities.

Conditions for establishment

All fields made in secondary forest on free drained soils which are re-cultivated a second time develop this kind of weedy vegetation. Fields cultivated the first year where the interval between successive periods of cultivation has been short (less than 6 years) tend to develop the community too. The community is less developed on sandy topsoil.

Successional position

Progressive

Before the arrival of *Eupatorium odoratum* these sites regenerated back to a forest-like vegetation within a few years. The hardier pioneer trees mentioned above constitute the canopy. After the arrival of *Eupatorium odoratum* it became evident that the species has a partiality for this community. *Eupatorium odoratum* forms a solid thicket up to 3 m high as soon as weeding stops. During the first following years the vegetation does not seem to change. Depending on the number of woody plants capable of piercing the *Eupatorium odoratum* canopy, this period can be rather short (one or two years), or long (over three years). As soon as overhead shade is produced, by trees as *Albizia* spp and *Sterculia tragacantha*, but also by lianas climbing to the upper layer, (*Dioscorea* spp and *Adenia* spp), the *Eupatorium odoratum* stand degenerates (see also De Rouw 1991).

Regressive

If repeatedly and severely disturbed, not by mere weeding for this favours the Composites, but by slashing and burning, the community degenerates into community *Mimosa pudica & Panicum laxum* >40%.

Distribution

Among Oubi and Guéré this weedy community is not very common because two consecutive rice cycles are not the rule. It is, however, fairly common in the vicinity of the largest villages (Taï, Ponan, Sakré) where fallow periods have been shortened, and where it developed already in the first year of cultivation. Most fields cultivated with food by immigrants (not yam) have this vegetation due to more burning, weeding and prolonged cultivation.

Control

It is possible to control the community by repeated handweeding. Seedings can be pulled out, large plants of *Eupatorium odoratum* and coppice shoots are cut with a matchet. If stoloniferous grasses are forming a grassmat locally , only working the soil with a hoe followed by removal of the grass will help. Plant densities during the cropping period vary between 200 and 1000 plants per m^2.

Synecological interpretation

If the crop of pioneer trees gets exhausted as a result of repeated slashing, burning and weeding, the field lacks strong competitors for weeds. Simultaneously, as wind-dispersed plumed weed seeds are brought in, good conditions are created for the latter group to develop. The community develops on the typical upland toposequence, but less on water-logged soils.

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3. The community of ***Boerhavia diffusa & Chasmopodium caudatum*** **cover** <20%

Open (weeded) or close (unweeded) stand of low broad-leaved herbs and tall grass with sparse up-rising pioneer trees.

The sociological species groups 2, 3, 4, 6, 7, 8, 9, 11, 12, 13 should be present, the sociological species group 15 may be present.

Description

The group of Composites (*Ageratum conyzoides*, *Erigeron floribundus* and others) is enriched by other herbs, *Boerhavia diffusa* and the climber *Dioscorea hirtiflora*, making a low cover, under 1 m. The hairy grass *Chasmopodium caudatum* grows up to 2 m. If the grass is abundant, the low herbs cover less, if *Chasmopodium caudatum* is less dominant, herbs are more numerous. The position of pioneers is similar as in community *Ageratum conyzoides* >40% & *Erigeron floribundus* >30% and species richness is comparable.

Spatial variation

As in community *Ageratum conyzoides* >40% & *Erigeron floribundus* >30%.

Conditions for establishment

As in community *Ageratum conyzoides* >40% & *Erigeron floribundus* >30%, but the community has a preference for sandy topsoil.

Successional position

Progressive

Succession to a *Eupatorium odoratum* thicket occurs as soon as the land is no longer weeded. The period this thicket remains intact, depends, again, on the species richness of the stand, and mainly on the number of woody species present there before the *Eupatorium odoratum* canopy is completely closed. Only these plants can grow out and shade out the *Eupatorium odoratum* in a few years time. If woody species are absent and have to invade the closed *Eupatorium odoratum* thicket, the process takes much longer.

Regressive

Degeneration is possible if the field is slashed and burned again, extra weeding does not make the community change much. After severe disturbance the tall grass spreads and the community *Chasmopodium caudatum* >50% and *Aspilia africana* develop.

Distribution

As in community *Ageratum conyzoides* >40% & *Erigeron floribundus* >30%. Common on lower slope fields, these being often sandy. Also dispersed on more sandier patches on the slope.

Control

Chasmopodium caudatum regenerates abundantly from seed. Young plants, being more robust than the usual grasses, are difficult to distinguish from rice seedlings. This makes weeding tedious. The community can still be controlled by repeated hand weeding for the grass *Chasmopodium caudatum* is tussock-forming and the whole plant can be pulled out with one jerk. Local patches of stoloniferous grass have to be worked with a hoe. Large plants of *Eupatorium odoratum* and coppice shoots are controlled with a matchet. Plant densities during the cropping period vary between 300 and 1000 plants per m^2.

Synecological interpretation

Chasmopodium caudatum is the Oubi indicator plant for soils which are "fatigués". If one or two individuals start to appear in the field, this is a sign to leave it. From a distance the grass may look like *Imperata* sp but first this grass is (still) absent from the Taï region (1989), and secondly, *Chasmopodium caudatum* has a tuffed growth form and it regenerates by seed and not from small vegetative parts, as does *Imperata* sp. This makes the grass less troublesome.

4. Community of *Chasmopodium caudatum* cover > 50% & *Aspilia africana*

Closed vegetation with tall grass and some shrubs.

The sociological species groups 2, 4, 5, 7, 8, 9, 11, 12, 13 should occur, the sociological species groups 6 and 15 may occur.

Description

Chasmopodium caudatum grows up to 2.5 m high. The shade, being only moderate, allows a discontinuous ground layer of seedlings of species capable to survive temporarily light shade (Composites, mainly *Eupatorium odoratum* and some of the hardier pioneer trees). The tall grass alternates with shrubs (*Desmodium velutinum*, *Baphia bancoensis*) or small trees (*Hoslundia opposita*, *Albizia zygia*, *Phyllanthus discoideus*). The more or less climbing *Aspilia africana* mixes with the shrubs and trees.

Spatial variation

Probably not much, but mainly as a result of persistence of coppicing plants, elements of pre-existing communities.

Conditions for establishment

Prolonged cultivation, two or three years on a sandy topsoil.

Successional position

Progressive

Normally the community can not occupy a site for more than one year because the grass is an annual and dies off. Although many seedlings of *Chasmopodium caudatum* are found in the seedling layer beneath the adult grass, other seedlings, especially *Eupatorium odoratum*, are more aggressive. If not further disturbed, a *Eupatorium odoratum* thicket is formed. Woody plants will eventually drive out the *Eupatorium odoratum* after a relatively long period, usually more than two years are needed.

Regressive

If the community is disturbed by slashing and burning, it has difficulties re-establishing. The vegetation shows tendencies towards the low, grassy community *Mimosa pudica* & *Panicum laxum* >40%.

Distribution

Not widespread, only over-worked sites close to large villages, mainly lower slope.

Control

The shrubs, trees and the grass have to be cleared with a matchet for adult *Chasmopodium caudatum* irritates the skin. Patches of low stoloniferous grasses have to be worked with a hoe. Plant densities are over 1000 plants per m^2.

Synecological interpretation

These sites are improper for cultivation, even for cassava, nothing can be done but to await the restoration of vegetation and soil. The community was deliberately produced by the suppression of Composite herbs and pioneers through repeated weeding, slashing and burning. The tall grass had regenerated as a single generation. Observations on this type of vegetation were done in a period that *Eupatorium odoratum* was still at rather low numbers (up to 1987). With *Eupatorium odoratum* permanently expanding, it becomes clear that *Chasmopodium caudatum* and *Eupatorium odoratum* have a comparable ecological behaviour. Both invade severely disturbed areas, but have to leave as the site becomes too poor. Then the vegetation turns into a low grassland. If the grassland is allowed to rest, *Eupatorium odoratum* will eventually reappear and not *Chasmopodium caudatum*. So, in the long run, with increasing *Eupatorium odoratum* densities everywhere, stands dominated by *Chasmopodium caudatum* (this community) may be replaced by a *Eupatorium odoratum* thicket.

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5. Community of *Triplochiton scleroxylon* *& Oplismenus burmannii*

Open (seedling) or closed (sapling) stand of pioneer trees with some broad-leaved herbs.

The sociological species groups 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 should occur; the sociological species groups 18, 19, 10, 12, 22, 23, 24 may occur.

Description

In the even-aged pioneer stand the tree *Macaranga hurifolia* is most abundant. *Trema guineensis* and *Alchornea cordifolia* grow somewhat faster, *Musanga cecropioides*, *Albizia adianthifolia* and *Triplochiton scleroxylon* slightly slower than *Macaranga hurifolia*. By the time the tree canopy closes, about 6 months after the rice harvest, the non-climbing broad-leaved herbs have completed their life cycle (*Solanum* spp, *Triumfetta rhomboidea*, *Pouzolzia guineensis*) and only weeds of shady places persist for some time under the pioneer canopy (*Oplismenus burmannii*). The climbing heliophyl herbs are part of the canopy (*Dioscorea* spp, *Adenia* spp, *Rutidea parviflora*). A large number of forest species resprout having survived clearing and burning, so the community can be rich in species , 40 to 80 species in plots of 9 m^2.

Spatial variation

If the length of the last fallow period was rather long (about 20 years), members of the sociological groups 18, 19, 20, 21, 22, 23, and 24 occur disseminated over the field, as seedlings or as coppice shoots. If the last fallow period had been rather short (10-15 years) than the crop of pioneer tree tends to be almost exclusively composed of *Macaranga hurifolia* and *Trema guineensis*.

Conditions for establishment

The interval between successive cultivation periods should be long, cultivation should be limited to one crop, and there should have been at least two previous rice cycles on that site. The field should be burned only once. The community is established on all kinds of non-swampy soil during the first year of cultivation.

Successional position

Progressive

It is the typical first stage of succession of the Established shifting cultivation system. The smooth succession to a forest-like vegetation has been described above. As soon as the annual and biennial weeds have declined, the species composition is identical to that of a young secondary forest, community *Cleistopholis patens & Bridelia micrantha*, or community *Byrsocarpus coccineus & Rutidea parviflora*. *Eupatorium odoratum* will just have the time to produce one seed crop before being smothered by pioneer trees.

Regressive

If a field with this community is to be slashed and burned, the community *Ageratum conyzoides & Erigeron floribundus* develops on the normally textured soils, and community *Boerhavia diffusa & Chasmopodium caudatum* on the more humid and coarse textured soils. In both cases *Eupatorium odoratum* invades massively.

Distribution

Very common in rice fields of the Established shifting cultivation system. If we consider the conditions for establishment listed above, only Oubi and Guéré fields fall into that category because immigrants tend to burn twice or more, weed repeatedly, disturb the soil by making moulds, shorten fallow periods etc. In all those cases other weed communities are produced.

Control

The vegetation is easily controlled by one weeding round by pulling out the seedlings and by cutting back the coppice shoots. Many pioneer tree species have slow early growth and do not seem to compete with the rice to a degree as to justify clean-weeding, so many small plants are left. Plant densities during cultivation are between 50 and 90 per m^2.

Synecological interpretation

The sociological species groups of this community consist a large part of long-lived plants adapted to life in a young secondary forest. The short-lived plants disappear more or less simultaneously with the disappearance of the crops. In their description of post-cultural succession in Taï, Alexandre *et al.* (1978) and Kahn (1982) have distinguished two early stages (Fig.10.1) "stade herbacé" and "stade sous-ligneux". Our data set contains relevés on permanent quadrats where sampling occurred althrough the stage of "herbacées" and the stage "sous-ligneux". The resulting series of relevés do not permit to distinguish two stages. In Table 11.1 no floristic grounds can be found to subdivide this community (or another community) into two.

The occurrence of seedlings of the large tree *Triplochiton scleroxylon* is interesting. The tree is an inhabitant of a mature forest type in drier regions. In the classification of Ghana forests, Hall & Swaine (1981) the tree is abundant in the Moist evergreen, in the Moist semi-deciduous, and in the Dry semi-deciduous rainfall zone. It is less frequent in the Wet evergreen rainfall zone. In fact, as was shown in Hall & Daba (1979) and in Hall & Swaine (1981), it is not so much rainfall which guides the distribution of the tree, but merely soil. Ordination of a great many forest stand data in Ghana, distributed over all rainfall zones, (Hall & Swaine 1981 p.311) demonstrated that plot records with *Triplochiton scleroxylon* were very significantly correlated with relatively base-rich soils and a relatively high pH. In mature and primary forest the tree makes a distinction between poor, acid, ferrallitic soils and the less poor, less acid, ferrugineous soils. Because ferrugineous soils are common in drier forest types and less so in the Wet evergreen forest, many ecologists have thought the occurrence of *Triplochiton scleroxylon* was merely a question of climate. As clearing and burning a forest brings alkaline ashes and much organic matter to the soil which temporarily enriches the soil, *Triplochiton scleroxylon* prefers these sites to germinate. Very large *Triplochiton scleroxylon* trees are frequent near villages, where repeatedly cultivated fields are situated and they may serve as seed sources. Some Oubi farmers are aware that *Triplochiton scleroxylon*, in some rare cases, does occur in primary forest. In those places the soil is very good for cultivation.

Almost immediate cover by pioneer trees (*Macaranga hurifolia*) is possible thanks to the pioneers in the sociological groups 16, 15, 17 and 14. These groups occur in fields during the first year of cultivation and are absent in fields where cultivation continues. As has been shown in chapter 7, these pioneers arise from the seedbank, from seeds which have accumulated in the pre-existing secondary forest.

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6. Community of ***Tragia tenuifolia & Cayratia gracilis*****.**

Open (seedling) or closed (sapling) stand of pioneer trees with some broad-leaved herbs.

The sociological species groups 12, 13, 14, 15, 16, 17, 23, 24, 25, 26 should occur, and the sociological species groups 8, 9, 18, 19, 20, 21, and 22 may be present.

Description

The young crop of pioneer trees and heliophile herbs develops as described in the previous community. Broad-leaved herbs are less numerous but *Marantaceae* are frequent, both re-sprouting from tubers and roots and regenerating from seed. The community is characterized by the sociological group 25 which indicates a -possibly- edaphic induced variation. Species like *Cordia plathythyrsa* indicate humid growth conditions and *Chytranthus setosus* we have met as an understorey tree in primary forest in the southern rainfall zone and in the Inselberg landscape (Land unit UB3, community E). Species richness is intermediate, between 30 to 50 species in plots of 9 m^2.

Spatial variation

This occurs mainly according to the number of primary forest and late secondary forest species which survive land clearing and re-sprout subsequently.

Conditions for establishment

Similar as for the community *Triplochiton scleroxylon & Oplismenus burmanii* in addition to specific soil conditions associated with "Gbarou" sites (chapter 10).

Successional position

Progressive

If the field is left to rest, a young secondary forest will soon develop. The lower part of the field may give rise to the community *Cleistopholis patens & Bridelia micrantha*, or, all the field may become community *Byrsocarpus coccineus & Rutidea parviflora*. *Eupatorium odoratum* tends to be as quickly eliminated as in community *Triplochiton scleroxylon & Oplismenus burmanii*. Although most fields in this classification unit were once "Gbarou" forest, typical structure and floristic composition may take long to appear, if it shows up at all.

Regressive

If the vegetation is disturbed again, for example by a second cultivation period, the community *Ageratum conyzoides & Erigeron floribundus* develops and *Eupatorium odoratum* invades massively.

Distribution

Former "Gbarou" sites are rather rare in the northern and southern part of the study area, in the central area this vegetation type is more common.

Control

Seedlings can be easily pulled out and coppice shoots are cut back with a matchet. One weeding round is sufficient. Plant densities vary between 50 and 80 plants per m^2 during the cultivation period.

Synecological interpretation

Two previous "Gbarou" which were studied more closely were now cropped for the third time. Though the site had been cultivated as often as some of the fields classified as community *Triplochiton scleroxylon & Oplismenus burmannii*, these fields lacked the sociological groups 7, 8, 9, 11, being species groups containing many weed species. So, despite many returns to the site, these fields remained surprisingly weed free. Both "Gbarou" sites are located rather far from the village (30 - 35 minutes walk from Gouléako and Ponan respectively) and the forest around was partly primary, partly old secondary. Few recent fields occur, so few weed plants are available to contaminate the site with seed. A second reason is that the field vegetation contains *Marantaceae* plants which survive vegetatively and by rapidly re-sprouting, cover the ground, thus limiting the development of weeds.

Another particularity is the occurrence of the sociological group 26 containing many primary forest species. Places which were subjected to repeated cultivation usually do no longer have them. We think that it is not only the presence of the neighbouring primary forest with seed sources which is responsible for this, but also humid microclimate which is preserved in a field enclosed by forest and by the moist edaphic conditions responsible for the presence of plants like *Chytranthus setosus*.

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7. Community *Ctenitis protensa & Cola heterophylla*

Open (seedling) or closed (sapling) pioneer stand with many coppicing trees.

The sociological species groups 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 26, 27, 28 and 29 should occur, the sociological species groups 8, 9 and 30 may occur.

Description

The stand of pioneer trees is very varied, *Musanga cecropioides* is more frequent than in any other community, as are many long-lived secondary trees as *Canariun schweinfurthii*, *Ceiba pentandra*, *Nauclea diderrichii*. Density of *Macaranga hurifolia*, though still the commonest pioneer tree, is less than in other communities where a field is cultivated for the first year. Weeds are rare, almost all plants are woody. Many stumps of primary forest trees and lianas demonstrate a vigourous regeneration. If burning had been successful, the floor is remarkable clean. If burning had been only slight, not many seedlings appear either, but the ground is quickly covered by all kinds of coppice shoots and root suckers of primary forest plants. Despite the low density of plants per surface area, species richness is between 40 and 100 per plots of 9 m^2.

Spatial variation

This can be great and depends first on the intensity of the initial fire which may kill a variable number of stumps and roots, and secondly on the floristic composition of the forest cleared. Hence the variation in primary forest species can be great, the variation in secondary species is limited.

Conditions for establishment

The community develops during the first year of cultivation after having cleared a non-swampy primary forest.

Successional position

Progressive

If the field is left to itself, it will pass through the pioneer stage very quickly (community *Cleistopholis patens* & *Bridelia micrantha* or community *Byrso*carpus *coccineus* & *Rutidea parviflora*) and a floristic composition similar to an old secondary forest (community *Drypetis gilgiana* & *Triphyophyllum peltatum* or community *Myrianthus libericus* & *Ptychopetalum anceps*) will be obtained within a few years time. On one occasion this happened in two years time. Of course, the height of the regrowth was still small. Few seeds of *Eupatorium odoratum* are initially present and these plants have difficulty producing one seed crop in the developing forest regrowth.

Regressive

If such a community is slashed and burned, the number of pioneers declines markedly, but, as weeds remain poorly represented, these few pioneers mainly *Macaranga* spp and *Musanga cecropioides* can grow out and produce a forest cover within a few years (community *Mussaenda afzelii* & *Dimorphochlamys mannii*).

Distribution

Common because much primary forest is being cleared for cash crops (cocoa and coffee). Rice is always the first crop.

Control

Weeding is hardly necessary except cutting the re-sprouting stumps once in a while. Plant densities during the cultivation period are between 10 and 20 plants per m^2 if burning has been good, and between 20 and 50 plants per m^2 if burning has been slight.

Synecological interpretation

If a primary forest is cut, far away from settlements with High forest all around, or if a primary forest is cleared, close to a village which is the last remnant of primary forest in the area, this makes little difference for the field vegetation. Very few weeds spring up in the field, despite a neighbouring *Eupatorium odoratum* thicket or recently abandoned fields with fruiting wind-dispersed seeds. This weed seed rain is apparently not capable of infecting a primary forest seed bank and during the first rice crop, weed infestation stays at a very low level. This highlight the all-importance of the pre-existing seed bank. If the seed store in the soil was largely weed free, so will be the field during the first cropping season.

Many fields in the sample were located lower slope. Those situated near habitations often had a hardened plinthite layer in the subsoil, between 40 and 90 cm depth. The fields located far from settlements usually had not. Though the existence of an impermeable plinthite layer in the subsoils has been probably the reason for these forests still being primary despite their location close to villages, the vegetation Table 10.1 did not allow for a distinction between lower slopes with and lower slopes without plinthite, probably due to the small size of the plots and the species richness of this community. It remains unclear how farmers recognize hardened plinthite in the subsoil. We found two coppicing primary forest trees weakly associated with plinthite: *Diospyros vignei* and *Diospyros canaliculata*.

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8. Community of ***Mussaenda afzelli* & *Dimorphochlamys mannii*.**

Open (weeded) or closed (unweeded) vegetation of pioneer trees, broad-leaved herbs and coppicing tree stumps.

The sociological species groups 12, 13, 15, 16, 17, 18, 19, 20, 23, 26, 27, 28, 29 should occur; the sociological species groups 8, 9, 30 may occur.

Description

Pioneer trees like *Musanga cecropioides*, *Trema guineensis*, *Macaranga* spp, *Anthocleista nobilis*, and especially *Harungana madagascariensis* are common, though densities are rather low (generally all members of group C and D in Fig.7.5). The few weeds that occur are mainly wind-dispersed Composites, *Crassocephalum crepidioides* and *Eupatorium odoratum*. Many re-sprouting stumps and roots persist from the pre-existing primary forest, especially on mildly burned spots. Because of the highly variable latter group species richness remains relatively high, between 40 and 60 species per plot of 9 m^2.

Spatial variation

This can be considerable due to the intensity of the initial burning allowing a variable number of primary forest species to survive.

Conditions for establishment

A non-swampy primary forest is cultivated for a second year.

Successional position

Progressive

If left undisturbed, the pioneer trees, though not numerous, will allow a development towards a forest-like fallow. *Eupatorium odoratum* is the strongest competitor resisting this process. *Eupatorium odoratum* is first shaded out on spots where many primary forest trees re-sprout. The period needed to form a closed forest canopy depends on the number of stumps still able to produce powerful shoots and secondly on the number of pioneer trees.

Regressive

If the vegetation is disturbed further by slashing and burning the cover, then more Composites and new weed species invade. The pioneers of the sociological groups 16 and 18 are lost. The community *Ageratum conyzoides* & *Erigeron floribundus* develops.

Distribution

Rather common as it is much easier (because less work weeding), to cultivate a primary forest field for two years than a field cleared in secondary forest.

Control

The community can be rather easily controlled by pulling out the seedlings and cutting back the shoots and root suckers. Two weeding rounds are needed. Plant densities are 100 to 200 plants per m^2.

Synecological interpretation

Only a field in primary forest can remain rather weed free for two years and preserve some of the pioneers of the *Macaranga* spp group. It takes more than two years of rice cropping to infest the site up to densities which are difficult to control. One of the reasons for the survival of pioneers like *Macaranga* spp is that very little weeding is done, even the second year.

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9. Community of *Polycephalium capitatum & Commelina congesta.*

Open (seedling) to closed (sapling) stand of pioneer trees with some broad-leaved herbs and non-grass monocot herbs.

The sociological species groups 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 24, 26, 27 should occur; the sociological species groups 8 and 9 may occur.

Description

The community has great similarities with the community *Triplochiton scleroxylon & Oplismenus burmanii* but broad-leaved herbs are less frequent whereas long-lived secondary forest trees are more abundant (*Canarium schweinfurthii, Bridelia micrantha, Musanga cecropioides, Fagara macrophylla)* Seedlings of the *Commelinaceae* and *Zingiberaceae* family are abundant *(Costus* spp, *Aframomum* spp and especially *Aframomum elliotii*). Species richness ranges from 40 to 60 species per 9 m^2 plot.

Spatial variation

The community shows affinities with community *Triplochiton scleroxylon & Oplismenus burmanii*, but a range of primary forest species may be present too. Because the community occurs on a large variety of soils, something of the topographic position may be reflected in the species composition as well.

Conditions for establishment

Fields prepared in old secondary forest which were previously primary forest, during the first year of cultivation.

Successional position

Progressive

Succession to a forest-structured vegetation is usually very rapid, within 6 months after the rice harvest the community *Byrsocarpus coccineus & Rutidea parviflora* (or community *Cleistopholis patens & Bridelia micrantha*) develops. *Eupatorium odoratum* is eliminated in one or two years time.

Regressive

Degradation to community *Ageratum conyzoides & Erigeron floribundus* occurs if the field is subject to re-newed cultivation.

Distribution

Common where pressure on available forest is low. Not in swamps.

Control

Because of the presence of *Commelinaceae* and *Zingiberaceae* weeding may take some time, though one weeding round is sufficient. Plants are pulled out and weeding is often restricted to these patches. The spiny shoots of *Fagara macrophylla* trees have to be cut off repeatedly, otherwise harvesting will be difficult. Plant densities during the cultivation period may vary between 40 and 80 plants per m^2.

Synecological interpretation

The very rapid cover by pioneer trees is surely enforced by two factors: weeding is often limited to "dangerous" plants as the *Commelinaceae*, *Zingiberaceaea* and some spreading herbs leaving many pioneer trees free to grow. The second factor is, being a cleared secondary forest, the soil contains many tree seeds so that densities of pioneers tend to be higher than in unweeded fields made in primary forest.

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10. Community of *Macaranga cf heudelotii & Hibiscus surattensis*

Open (weeded) or closed (unweeded) pricky shrub with more or less scrambling pioneer trees, climbing Marantaceae and thorny palms.

The sociological species groups 12, 13, 14, 15, 16, 18, 19, 22, 31 and 32 should occur; the sociological species groups 8, 9, 21 and 3 may occur.

Description

Among the pioneers *Macaranga cf heudelotii* is prominent. It is a small statured tree with a semi-climbing growth and a tendency to form a dense impenetrable mass. *Combretum* spp, *Dioclea reflexa* and *Calamus deëratus* are common lianas growing through and above the *Macaranga* trees. This alternates with dense stands of the subwoody *Hibiscus surattensis* and locally non-climbing sedges, mainly *Scleria verrucosa*. *Ceiba pentandra* and *Nauclea diderrichii* are frequent and the original alluvial primary forest reappears by shoots of *Neosloetiopsis kamerunensis* and seedlings of *Plagiosiphon emarginatus*. The lianescent *Marantaceaea* re-sprouts from root suckers (*Hypselodelphys violacea*). The community is relatively species poor, 20 to 30 species in plots of 9 m^2 if the field was made in secondary forest, and 30 to 40 species per 9 m^2 if the field originated from primary forest.

Spatial variation

Unknown; only few fields were sampled and all were close to the village Gouléako.

Conditions for establishment

Primary or secondary forest on alluvium deposit of the Cavally during the first year of cultivation.

Successional position

Progressive

The pioneer *Macaranga cf heudelotii* grows quickly into a dense thicket, four to five metres high. The large lianas and *Hibiscus surattensis* grow up to the canopy and persist there for years. Once the sedges and the *Eupatorium odoratum* are suppressed, the stand contains all the species necessary to classify it as community *Calamus deëratus* & *Costus lucanusianus*. If the field vegetation contained many *Hypselodelphys violacea* and other climbing *Marantaceae*, the fallow vegetation may sometimes tends towards a "Gbarou" site.

Regressive

If cultivation continues a following year sedges will become very troublesome, *Eupatorium odoratum* can get firmly installed and other Composites too. The community *Ageratum conyzoides* & *Erigeron floribundus* develops.

Distribution

Not common, for only few alluvium soils are cultivated by Oubi and Guéré.

Control

Plant densities can be as high as 60 to 100 plants per m^2 if sedges are present, and lower 30 to 60 plants per m^2 on places without *Scleria* spp. Weeding the sedges has to be done early in the season and this is unpleasant for the edges of some species are razor-sharp. *Hibiscus surattensis* has to be removed too, for the adult plant highly irritates the skin during harvesting. The same accounts for the thorny palm *Calamus deëratus* which has to be cut back repeatedly.

Synecological interpretation

Primary forest on Cavally deposits stayed very long out of shifting cultivation cycles. There are several reasons explaining this. The wood of the dominant tree *Plagiosiphon emarginatus* is very hard. The field flora and the secondary forest vegetation comprise many irritating plants and this makes fieldwork and handling the secondary forest very uncomfortable. Thirdly, soil texture varies greatly, from very sandy to clayey. All fields sampled here were on clayey soils which softened only late in the rainy season (only then augering became possible). Once humid, the soil remained soft until far in the dry season. It became obvious from the Land unit survey, as many more alluvium soils were sampled all over the study area, that most deposits are very sandy. No shifting cultivation was observed on sand but the rare clearings made in the alluvial primary forest were the work of immigrants.

Though the primary forest community *Plagiosiphon emarginatus* & *Pancovia bijuga* is very constant throughout the study area, on sand as well as on clay, not much can be said with respect to the field vegetation and the secondary forest, as they only were observed on clay.

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11. Community of *Scleria verrucosa* & *Momordica cissamloides*

Land more or less covered by non-climbing sedges with pioneer trees and lianescent *Marantaceae*.

The sociological species groups 12, 13, 15, 16, 18, 19, 23, 24, and 32 should be present; the sociological species groups 6, 8, 9, 21, 26, 27, 30, 33 may occur.

Description

The sedges *Scleria verrucosa* and *Scleria racemosa* alternate with patches of pioneers, *Macaranga hurifolia* and *Alchornea cordifolia*, and a variety of climbing *Marantaceae* (*Hypselopelphys violacea* and *Marantacloa* spp) re-sprouting from tubers. *Tristemma coronatum* is the commonest dicot herb. *Ceiba pentandra and Ricinodendron heudelotii* germinate abundantly. The community is poor in species 20 to 40 species in plots of 9 m^2.

Spatial variation

Few fields were sampled but they differentiated mainly in degree of infestation of sedges and *Eupatorium odoratum* .

Conditions for establishment

In rather open habitats on riverbanks other than Cavally after a primary or secondary forest has been cut, during the first year of cultivation.

Successional position

Progressive

The pioneers and the *Marantaceae* will quickly suppress the sedges and the broad-leaved herbs. On wet places something like the community *Aframomum daniellii* & *Raphia sassandrensis* will develop, on better drained soils the community *Cleistopholis patens* & *Bridelia micrantha* will grow. Very poorly drained soils staying waterlogged for a long period during the rainy season, can loose a large part of the pioneer population (*Macaranga* spp, *Alchornea cordifolia*, *Musanga cecropioides*). Those plants are unable to survive such conditions for long. As soon as the soil dries out the open places are invaded by *Eupatorium odoratum*, grasses and sedges. *Eupatorium odoratum* may grow so vigourously that the soil is sufficiently drained in order to maintain a *Eupatorium odoratum* thicket. In general, regeneration on places which are periodically flooded is slower than on better drained soils.

Regressive

If the site is further disturbed and flooding remains incidental, ferns, low grasses (*Panicum laxum*) and *Eupatorium odoratum* appear. If the place becomes regularly flooded low *Marantaceae* (*Halopegia azurea*) and other plants of open, flooded habitats established themselves.

Distribution

Probably few such fields exist. Fields on deposits of two rivers were investigated, the Audrénisrou near the village Diéré-oula, and the river which crosses the main road near the village Poulé-oula.

Control

Weeding takes much time for plant densities are usually high (sedges), 100 to 300 plants per m^2.

Synecological interpretation

We would expect *Raphia* palms to grow here, as they do in valley bottoms. Some of the hazards of regeneration in swampy places is surely averted by the profuse growth of *Raphia* palms in wet places. It remains unclear why these palms do not grow on alluvium.

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12. Community of *Ceratopteris cornuta & Raphia spp*

Open vegetation of low broad-leaved herbs, and ferns with pioneers and *Raphia* palms.

The sociological species groups 12, 13, 15, 16, 18, 23, 33 and 34 should occur; the sociological species groups 8, 9, 21, 26, 27, and 29 may occur.

Description

Small weeds of wet places, *Tristemma coronatum*, *Virectaria procumbens*, mixed with low ferns, *Cyclosorus striolata*, *Asplenium dregeanum* form a sparse cover. Trees, especially *Ceiba pentandra*, *Ricinodendron heudelotii*, *Raphia* sp and *Musanga cecropioides* germinate readily. In no other field cultivated the first year so few coppicing plants occur, *Spondianthus preusii* and *Mitragyna ciliata* being almost the only ones. Species richness is low, between 20 and 40 species per 9 m^2 plot.

Spatial variation

Probably little. Few sites where studied.

Conditions for establishment

In primary or secondary swamp forest during the first year of cultivation.

Successional position

Progressive

If pioneer trees and especially large trees as *Ceiba pentandra* and *Ricinodendron heudelotii* get well installed, the regrowth will be more varied than mainly *Raphia* trees. The regeneration of *Mitragyna cilita* is very rapid, both from coppice and from seeds. If pioneers are less common, either because a primary forest had been cut and few seed is present in the seed bank, or because many seedlings have perished in a flood, the place gets invaded by grasses and *Eupatorium odoratum* as soon as it dries out. Succession tends to take more time than on well drained soils.

Regressive

Degeneration is easy, for cover is sparse the first year and so there is much opportunity of plants to invade. During a second year of cultivation the community *Virectaria procumbens & Harungana madagascariensis* develops.

Distribution

Common throughout the study area. Usually only clayey or loamy textured valley bottoms are used.

Control

If a primary forest has been well burnt, plant densities are extremely low, 10 - 20 plants per m^2 and no weeding is required. If a secondary forest is used, plant densities are higher, 40 - 60 plants per m^2 due to sedges. Especially *Scleria barteri* and *Scleria depressa* have to be removed early in the season. All plants can be easily pulled out.

Synecological interpretation

It is generally accepted, and confirmed by farmers, that the *Raphia* which dominate in valley bottoms in Taï originate from agricultural disturbance (De Rouw, Vellema & Blokhuis 1990). *Raphia*, which is part of the natural vegetation can spread and dominate for a very long period thanks to clearings. There are two *Raphia* species currently dominating valley bottoms, but they do not mix with each other. A valley bottom is either filled with *Raphia hookeri* or filled with *Raphia sassandrensis*, and very rarely with both. To distinguish the two species, especially as seedlings is difficult. I always relied on local residents for the plants are very well known. From *Raphia hookeri* palm wine can be made whereas *Raphia sassandrensis* supplies only thatch to cover roofs. Village people can tell in advance which one of the two *Raphias* occupies any swamp in the neighbourhood you plan to visit.

If a "wine" valley bottom is cultivated, the vegetation will return to a "wine" valley bottom, and a "thatch " valley bottom will remain so after cultivation. If a place is cultivated where both species occur, the "thatch "*Raphia* always enforces its position once the site is abandoned, so "thatch" wins over "wine". Of course the position of "wine" palms is further weakened for palms die after sap has been withdrawn. "Thatch" valley bottoms are larger and more frequent than "wine" valley bottoms. Only the "wine" *Raphia* can mix with the "Gbarou" vegetation. The ecological explanation of the distinction is still unknown.

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13. Community of *Virectaria procumbens* **cover** >40% & *Harungana madagascariensis* cover >40%.

Low cover by broad-leaved herbs and some up-rising pioneers.

The sociological species groups 2, 12, 13, 15, 18, 33, and 35 should occur; the sociological species groups 6, 8, and 9 may occur.

Description

The low, often closed cover is formed by *Cyathula prostrata*, *Virectaria procumbens*, *Ageratum conyzoides*, *Cissus* spp and other herbs. *Harungana madagascariensis*, cut off during repeated slashing of the vegetation, grows out and is the commonest pioneer tree. Non-climbing sedges (*Cyperus spacelatus*) and the grass *Panicum laxum*, together with *Eupatorium odoratum* are well represented too. Those places least flooded receive seedlings of *Chlorophora excelsa*, *Ceiba pentandra*, *Terminalia superba* and *Musanga cecropioides*. The community is poor in species, only 15 to 30 species in plots of 9 m^2.

Spatial variation

Unknown, only few sites were studied.

Conditions for establishment

In swamp forest during the second year of cultivation.

Successional position

Progressive

The development of a forest-like cover depends on the number of *Harungana madagascariensis* and other trees. *Eupatorium odoratum* forms close thickets where the ground is better drained. *Panicum laxum* re-invades any temporally dry open place. Succession is probably slow for few woody species are available and their position is weakened each time the soil is flooded.

Regressive

Though not often observed, this is very serious. Degradation is towards a vegetation deprived of trees, dominated by herbs of open, periodically or permanently flooded land. These communities are probably very steady. One of the first and very conspicuous members of this vegetation type is the giant *Araceae Cyrtosperma senegalense*. This plant had invaded a former primary forest after two years of cultivation and one year of fallow. In the period the field was prepared, intact primary forest surrounded the clearing. In the following years almost all forest around was cut for cultivation. During these years the water table in the field had risen progressively and pioneers and normal weeds had disappeared.

Distribution

Common in swampy fields where immigrants cultivate food crops.

Control

Plant densities can be very high, 200 to 800 plants per m^2 without considering the stoloniferous grasses. All grass needs to be removed with a hoe and carried away, for good burning under such wet conditions is not possible. This work has to be done before sowing the rice. Other weeds have to be pulled out by hand and at least two weeding rounds are necessary during rice growth. Rice cultivation becomes very difficult in grass-invaded habitats, still it is the only crop to grow in swampy land.

Synecological interpretation

The position of *Harungana madagascarienis* trees is surprizing. The plant regenerates by means of pseude-coppice. The tree has an advantage over other plants because it has been firmly established during the first year of cultivation. During the second year of cultivation it re-sprouts each time it is cut off.

Drainage is an important issue. Primary forest in swamps serves as a very efficient "pump". This was observed on several occasions. On 21 may 1986, the rainy season well advanced, the ground water table under primary forest was at 100 cm depth. At the same time, in a nearby field, 20 m from the forest edge and lying slightly higher, ground water was touched at 30 cm. During that year the swamp forest was only occasionally flooded, the rice field frequently, and for much longer periods. As trees were continuously removed both from the primary forest on the slopes and from the field, the ground water in the field became almost permanently at the soil surface. Trees could no longer germinate and plants of open flooded habitats arrived, making the return to forest still more difficult. This implies that the extend and other properties of valley bottoms still surrounded by primary forest depens on the degree this forest is left intact. People who plan an agricultural use of valley bottoms, like irrigated rice, should be conscious of the fact that size and flooding character of a valley bottom will change profoundly once forest on the slopes has disappeared.

11.4 SERAL STAGES

11.4.1 Methods

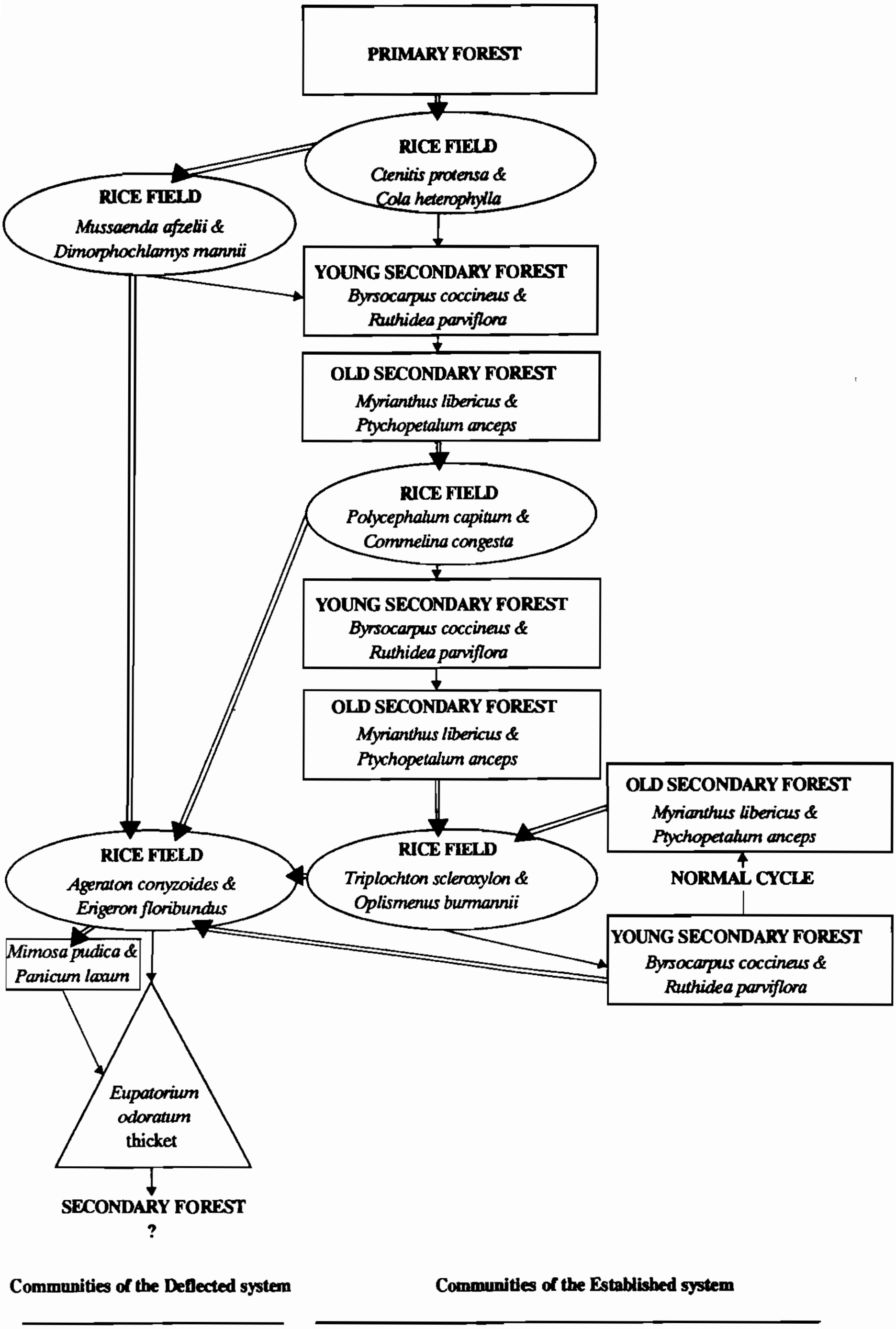
The distinct classification of primary forest (chapter 9), of secondary forest (chapter 10) and of field vegetations (this chapter) can lead to the composition of successional stages.

In many cases short term changes were observed directly, e.g. a secondary forest was sampled at the moment of clearing and the subsequent rice field was followed during several years. Long term changes were often observed on adjacent sites, e.g. a primary forest, a young regrowth and an old secondary forest were neighbouring vegetations on comparable soils. In order to provide a unified description it is necessary to assume homology between directly and indirectly observed sites. In the beginning we were forced to split the data set in three because this was the only way spatial variation and succession could be studied under a variety of soil, climate and historical conditions. Inevitably, many species occurred in two, or in three data set and the same species could belong to different sociological groups depending on the classification system. Far from being a disadvantage, these various configurations merely helped us to draw interesting ecological conclusions.

11.4.2 Communities of the Established system

In the Oubi and Guéré land a primary forest on free drained soil is likely to be either community *Hunteria simii & Chidlowia sanguinea* or community *Uapaca* spp *& Mendoncia combretoides* or community *Gilbertiodendron preussii & Tarrietia utilis*. This depends on the climatic zone. If the forest is felled and burnt the field community will be *Ctenitis protensa & Cola heterophylla*. The field is left to rest after the rice harvest and rapidly a *Macaranga* dominated secondary forest grows up, either community *Byrsocarpus coccineus & Rutidea parviflora*, or community *Cleistopholis patens & Bridelia micrantha*, depending on topography. Because the forest has been primary up to a very recent time, the succession to old secondary forest is quick. The community *Myrianthus libericus & Ptychopetalum anceps* or community *Drypetes gilgiana & Triphyophyllym peltatum* (depending on topography), are rapidly established. It has been observed more than once that these first rotation secondary forests were felled and recultivated with rice while still young, with apparently no danger for yield and subsequent development of the fallow vegetation. Anyway, whether a young or an older secondary forest is cut for a second shifting cultivation rotation, the resulting field community will be about the same: the community *Polycephalum capitatum & Commelina congesta*. Rice is cultivated in the conventional way and the subsequent fallow vegetation greatly resembles the young and old secondary forest communities mentioned above. If an old secondary forest is taken into renewed cultivation the field community *Triplochiton scleroxylon & Oplismenus burmannii* is formed. From now on, the third shifting cultivation rotation, rice-fallow-rice vegetations seems to be fairly stable. In Fig.11.2 this sequence is represented.

Fig. 11.2. Sequences of plant communities following rice cultivation in the Taï region, comprising the common communities on uplands belonging to the Established and the Deflected systems. Double lines and larges arrows : vegetation cleared for cultivation, single line and small arrows : recovery of the vegetation. >


PRIMARY FOREST
RICE FIELD
Ctenitis protensa &
Cola heterophylla
RICE FIELD
Mussaenda afzelii &
Dimorphochlamys mannii
YOUNG SECONDARY FOREST
Byrsocarpus coccineus &
Ruthidea parviflora
OLD SECONDARY FOREST
Myrianthus libericus &
Ptychopetalum anceps
RICE FIELD
Polycephalum capitum &
Commelina congesta
YOUNG SECONDARY FOREST
Byrsocarpus coccineus &
Ruthidea parviflora
OLD SECONDARY FOREST
Myrianthus libericus &
Ptychopetalum anceps
OLD SECONDARY FOREST
Myrianthus libericus &
Ptychopetalum anceps
RICE FIELD
Ageraton conyzoides &
Erigeron floribundus
RICE FIELD
Triplochton scleroxylon &
Oplismenus burmannii
NORMAL CYCLE
YOUNG SECONDARY FOREST
Byrsocarpus coccineus &
Ruthidea parviflora
Mimosa pudica &
Panicum laxum
Eupatorium
odoratum
thicket
SECONDARY FOREST
?
Communities of the Deflected system
Communities of the Established system

11.4.3 Communities of the Deflected system

Up to 1989, when last observations were made, the area with low land pressure, the village territory of the smaller settlements and those lands belonging to larger villages but lying far off, was covered by one of the communities of the Established System (Fig.11.2). The land close to the smaller settlements was engaged in the Normal Cycle (Fig.11.2) and the land remote from habitations, was more implied in stages between primary forest and Normal Cycle.

Near the larger settlements, Taï, Ponan, and Sakré, examples of the Deflected system could be found. A field vegetation dominated by Composites, community *Ageratum conyzoides & Erigeron floribundus* will be obtained by re-cultivation a second year the community *Triplochiton scleroxylon & Oplismenus burmannii*, or the community *Polycephalium capitatum & Commelina congesta*, or the community *Mussaenda afzelii & Dimorphochlamys mannii*, or the community *Tragia tenuifolia & Cayratia gracilis* or by clearing a young *Macaranga* forest of the Normal Cycle, the community *Byrsocarpus coccineus & Rutidea parviflora*, or community *Cleistopholis patens & Bridelia micrantha*. This Composites community if left to itself, does not regenerate back to a *Macaranga* forest but grows into an *Eupatorium odoratum* thicket. We mention again the highly dynamic situation in Taï. In 1983, when field work started, very few *Ageratum conyzoides & Erigeron floribundus* communities existed and *Eupatorium odoratum* was unknown. In 1989, when last observations were made, the successive stages following a stage of *Eupatorium odoratum* cover, could only be guessed.

11.5 DISCUSSION AND CONCLUSIONS

All previous workers in Taï only studied the communities of the Established System. The seral stages in Alexandre *et al.* (1978), Kahn (1982), Jaffré & De Namur (1983) were described and identified as changing pictures of dominant or predominant species. Communities were named after the largest common plants present. So the stage "sous-ligneux" is indicated by *Solanum* spp, the stage "arbustif-pionnier" by *Macaranga hurifolia*, and the stage "pré-climacique" by large, late secondary forest trees, for example *Fagara macrophylla, Canarium schweinfurthii, Triplochiton scleroxylon, Terminalia spp, Funtumia spp, Ceiba pentandra, Ricinodendron heudelotii* and *Chlorophora excelsa*. The successional stages here presented are defined and identified in a different way. We looked at the appearance and disappearance of species groups, which could be dominant or not, could be large plants or not. Hence the earliest stage of succession, a field vegetation, is characterized by a group of short-lived weedy species, ending their life cycles with the rice or shortly afterwards smothered by the pioneer trees. The next successional stage, the young secondary forest, is characterized by the absence of the weedy species and by the presence of many secondary forest species, mainly trees. The following successional stage, old secondary forest, can be recognized by the invasion and installation of a primary forest understorey. If we make a comparison between the succession stages of Alexandre *et al.* (1978) and ours, the seral stages are definitely the same. The stage "sous-ligneux" is community *Ctenitis protensa & Cola heterophylla* or *Polycephalium capitatum & Commelina congesta* or *Triplochiton scleroxylon & Oplismenus burmannii*. Stage "arbustif-pionnier" is community *Byrsocarpus coccineus* & *Rutidea parviflora* or *Cleistopholis patens* & *Bridelia micrantha*. The stage "pré-climacique" is community *Myrianthus libericus* & *Ptychopetalum anceps* or *Drypetes gilgiana* & *Triphyophyllym peltatum*.

If we look at the species composition of community *Triplochiton scleroxylon* & *Oplismenus burmannii* in Table 11.1 we see that the sociological groups 10, 11, 12, 13, 14, 15, 16, 17 contain all the typical species of the young secondary forest (Table 10.1) and also, that the late secondary species mentioned above, grow in fields during the first year of cultivation. We conclude that a field vegetation in the Established System already carries the complete secondary forest species composition of young and old secondary forest. If we consider the species composition of community *Ctenitis protensa* & *Cola heterophylla* and particularly those sociological species groups which characterize this field vegetation (20, 21, 22, 23, 24, 26, 27 and 28), we see that here already the species can be found of the primary forest understorey, the same species which characterize in our classification the old secondary forest communities *Myrianthus libericus* & *Ptychopetalum anceps* and *Drypetes gilgiana* & *Triphyophyllym peltatum*. So fields directly derived from primary forest have not only the complete secondary forest flora of young and old forest but also the primary forest flora common in old secondary forest.

It was observed already by Clements (1916) that regrowth often contained a large number of plants representing several successive stages and he suggested the possibility that seeds and fruits for the dominants of all stages, including the climax, might be present at the time of disturbance initiation. Because of a strong tradition among succession specialists of observing and classifying seral vegetation by looking preferably at dominant large trees and often ignoring all non-trees or all trees below a certain trunk diameter, few research was made on this matter since. Very few scientist study seedlings and coppicing plants in their relation to succession. The famous theoretical article of Egler (1954) still needs confirmation from field data. Egler elaborated on the concept of Initial Floristic Composition being all plants which have invaded the field at the time of abandonment. He considered it the most appropriate concept to describe succession. He refuted the theory of Relay Floristics (successive waves of plant populations which invade and decline Drurt & Nisbet 1973), as to be the only appropriate one. He mentioned that if the tree component was absent at the moment of abandon, the development of the vegetation progresses through to shrubland but an advance to forest does not occur in the normal manner because all tree species must come from actual invasion, and this is slow.

This seems very coherent with our findings in Taï. Initial Species Composition is the prevailing agent in succession. Vegetation succession (in the Established System) is rapid and dynamic **because** all plant species of successional species are present at the onset. Vegetation succession (in the Deflected System) is far less rapid and dynamic **because** plants of later successional stages are absent. Vegetation succession can get blocked although all plant species of successional species are present, because one group of plants regenerates faster than others (by means of coppicing) and suppresses the development of those species of late successional stages.

Egler (1954) defined the Initial Species Composition as all species present on the site at the moment a field is left to itself. This population can come from two sources, from seeds that were dispersed prior to disturbance and had remained viable in the soil, and from seeds that were dispersed into the disturbed area following destruction of the initial vegetation. We have demonstrated in De Rouw & Van Oers (1988) that all secondary species of the young and the old secondary forest were present as viable seeds the day after a 21 year old fallow was burnt and planting of the rice started. It is the seed bank under the Established system, at the onset of cultivation which assures the normal rapid succession. The Initial Species Composition for the various field communities described is not the same. The community *Ctenitis protensa* & *Cola heterophylla* contains the maximum of plant species belonging to late seral stages (and primary forest). As people return to cultivate the same site, the community *Polycephalium capitatum* & *Commelina congesta*, the community *Mussaenda afzelii* & *Dimorphochlamys mannii* and the community *Tragia tenuifolia* & *Carya gracilis* develop. The Initial Species Composition contains less and less numbers of species representing late seral stages (and primary forest). Instead, the number of representives of early successional stages increases. The community *Triplochiton scleroxylon* & *Oplismenus burmannii* characterizes sites which have been cultivated repeatedly while the length of the fallow period respected was just long enough to allow the seeds of all seral stages to be present in the soil at the onset of cultivation. If the length of the fallow period is no longer respected, the seeds of older seral stages are lost. The Initial Species Composition does no longer include all seral stages and the communities of the Deflected System are the result.

12 Regression and succession series

12.1 CLUSTERING OF RELEVES IN AGRONOMICAL TRIALS

We have seen through study of different aspects of weedy vegetations that prolonged cultivation brings about profound changes. In order to gain more insight into the evolution of weed populations, for example how vegetation recovers or fails to recover from past disturbances as a result of specific agricultural practices, we have to establish a relationship between field observations and the classification of field vegetation dealt with earlier. We will concentrate on the fields Pahi 1, 2 and 3, all are part of the same slope. The classification of fields (chapter 11) had been established from a balanced set of input data: a limited number of relevés per field and per cultivation period to avoid bias produced by an over-representation of data from one spot. Now we will class the remainder of our relevés of those three fields, according to this classification. This is not always easy for some relevés have a species composition situated in between two communities. Five communities were recognized in the total of 164 relevés taken from the Pahi fields in the period 1983 -1987.

- Community of *Triplochiton scleroxylon & Oplismenus burmannii*, (community 5)
- Community of *Ageratum conyzoides & Erigeron floribundus*, (community 2)
- Community of *Boerhavia diffusa & Chasmopodium caudatum*, (community 3)
- Community of *Mimosa pudica & Panicum laxum*, (community 1)
- Community of *Chasmopodium caudatum & Aspilia africana* (community 4).

These classifications based on floristics are consonant with some simple structural characteristics.

- A species-rich vegetation dominated by pioneer **trees** (community 5),
- a more or less species-rich vegetation dominated by **broad-leaved herbs** though trees and grasses are present community 2 and 3),
- a species-poor vegetation dominated by **grasses** and **thicket-forming** broad-leaved sub-woody **herbs** (community 1 and 4).

All the relevés on the Pahi fields were ordinated with DECORANA. Relevés, being weighed mean species scores were plotted for the first and the second axis. Each relevé received a symbol indicating the community to which it was classified. The configuration produced is related first of all to disturbance. The Community *Triplochiton scleroxylon & Oplismenus burmannii* (5) being mainly tree stands of relative undisturbed fields, have axis 1 scores over 170. Community *Ageratum conyzoides & Erigeron floribundus* (2) and Community *Boerhavia diffusa & Chasmopodium caudatum* (3) of moderately disturbed areas have axis 1 scores between 80 and 170. The Community *Chasmopodium caudatum & Aspilia africana* (4) and the Community *Mimosa pudica & Panicum laxum* (1) covering severely disturbed land, have axis 1 scores under 80. Thus the first DCA axis expresses the gradual changes in the field vegetation: the replacement of tree species by herbs and the replacement of broad-leaved herbs by grasses together with the developments of a species-rich vegetation into a species-poor stand.

Values of the second axis separate the Community *Boerhavia diffusa & Chasmopodium caudatum* from Community *Ageratum conyzoides & Erigeron floribundus* and Community *Chasmopodium caudatum & Aspilia africana* from Community *Mimosa pudica & Panicum laxum*. This coincides with site differences: most of the permanent quadrats in field Pahi 2 have a loamy sand topsoil and relevés are correlated with high axis 2 scores; most of the permanent quadrats in the fields Pahi 1 and 2 have finer texture in the topsoil and relevés scores on axis 2 are low. The chemical soil characteristic most related to the second axis is the CEC: the relevés with high axis 2 scores have relative low CEC values (6.22, standard deviation 0.550), relevés with lower axis 2 scores have somewhat higher CEC values (7.47, standard deviation 1.736). The difference is not statistically significant.

12.2 TWO CONJECTURES

If we take the DECORANA scores that one permanent quadrat obtains during consecutive years of observation, we can watch this permanent quadrat "travel" along the Disturbance gradient, to the left as long as cultivation continuous and back to the right as cultivation ceases. The **speed** at which a permanent plot "moves" along the Disturbance gradient is a measure for the impact a certain cultural practice had on the vegetation. The **distance** a permanent plot "moves" along the Disturbance gradient is supposed to be related to the severity of the impact and to the period needed for the vegetation to recover. The impact of the following practices was thus investigated:

- initial burning, normal or slight,
- weeding rounds, one, two or none,
- length of last fallow period, short (6 years) or long (19 years),
- length of the cultivation period, one, two or three consecutive rice seasons.

The data from field Pahi 1 and 2 are treated separately because of differences in soil texture.

12.3 RESULTS

12.3.1 Effect of burning

In Fig.12.1 the DCA axis 1 scores of four permanent quadrats situated in the field Pahi 1, are set out against time. Relevés are represented by the community to which they were classified. All plots have received two weeding rounds per cropping season. Two plots were laid in normally burnt places and changes in the floristic composition are indicated by a solid line. Two plots were set out on slightly burnt places, here floristic changes are represented by a broken line. We see that during the first cultivation period all axis 1 scores are comparably high, all plots carry the Community *Triplochiton scleroxylon & Oplismenus burmannii*, a vegetation dominated by pioneer trees. This is independent of initial burning intensity. Following the permanent plots along the successive years we see that plots connected by a broken line always have higher axis 1 scores. This means that the plots installed in 1983 on incompletely burnt spots do not degrade towards a species-poor grassy-thicket vegetation (Community *Mimosa pudica & Panicum laxum*) but maintains a broad-leaved herbaceous vegetation with some trees

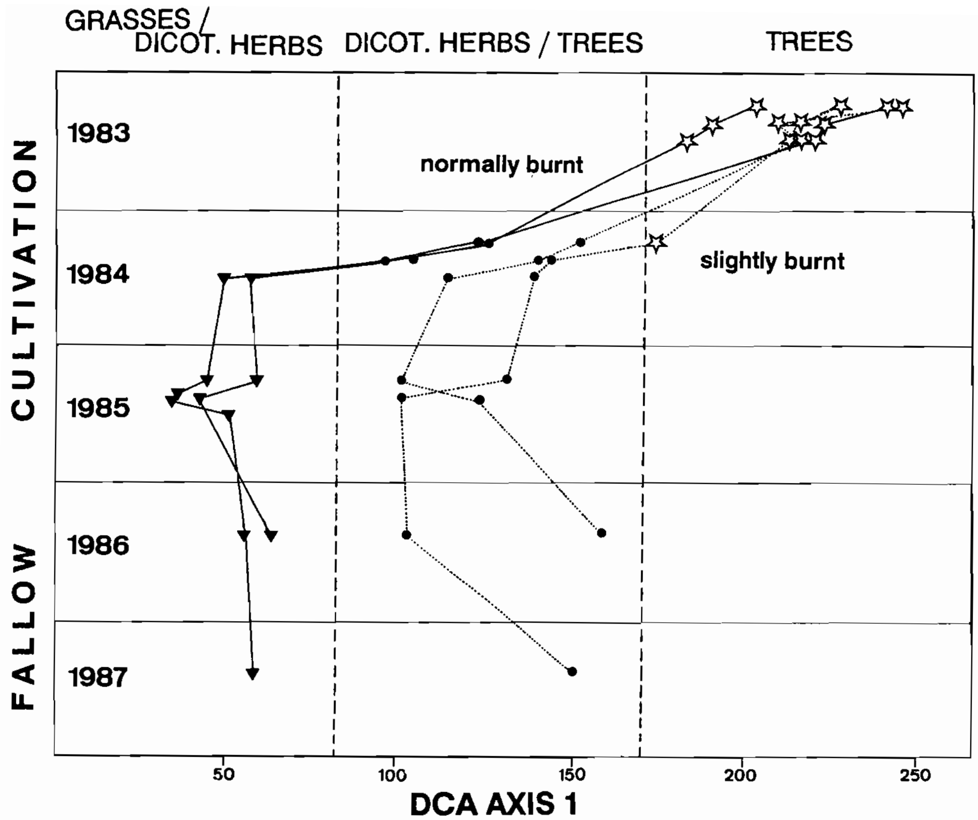


Fig. 12.1. Ordination scores of four permanent quadrats obtained during three years of rice cultivation and two years of subsequent fallowing. Two weeding per season. Two permanent quadrats were established where initial burning was normal (continuous line), and two permanent quadrats where initial burning was slight (stippled line).
Star : vegetation mainly pioneer trees, Community *Triplochiton scleroxylon & Oplismenus burmannii*, Dot : vegetation mainly broad-leaved herbs with some trees, Community *Ageratum conyzoides & Erigeron floribundus*, triangle : vegetation mainly grasses and broad-leaved herbs, Community *Mimosa pudica & Panicum laxum*.

(Community *Ageratum conyzoides & Erigeron floribundus*). The permanent plots set out on normally burnt places are carried through the stage of Community *Ageratum conyzoides & Erigeron floribundus* in the course of the second cultivation year and degenerate to the grass-forb stage (Community *Mimosa pudica & Panicum laxum*) that same year. Lowest axis 1 scores are achieved in the third year of successive cropping, indicating a very species-poor population.

In the subsequent two years of fallow DCA scores do not change from the level attained at the end of the second cropping year, meaning that in this period the field vegetation did not change.

The first year, while clearing the forest, a difference in burning intensity was created which strongly influenced the weed dynamics the following years. This difference lies in the number of stumps, roots and other elements of the original

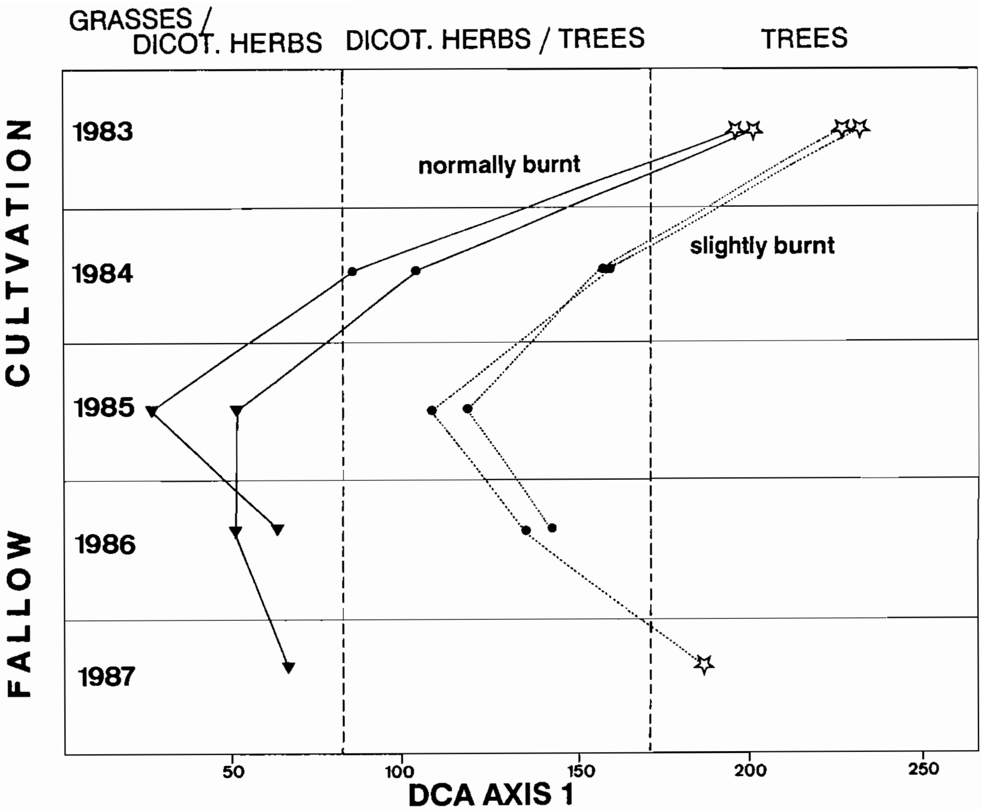


Fig. 12.2. As Fig.12.1, but no weeding.

forest which survive land preparation. There where the fire had been less intense, more forest plants were able to survive and resprout afterwards (chapter 7). The first year of cultivation, however, variations in burning are less apparent. Insufficient burning results in a prompt cover of the ground by coppice growth and the soil pH has remained low for very little ashes have penetrated the soil. In a previous study (De Rouw & Van Oers 1988) it was demonstrated that the majority of pioneer trees and lianas can germinate under this light shade and can grow in acid soil. So, the first year of cultivation, the crop of pioneer seedlings which arises from the seedbank is very uniform throughout the field. The second year most pioneer trees have been weeded out. The broad-leaved herbs, sedges and grasses, on the contrary, refuse to germinate in shade and some of them do not grow well in acid soil (De Rouw & Van Oers 1988). A differentiation takes place between normally burnt places with few coppice growth where broad-leaved herbs invade, and mildly burnt places with much coppice growth, where shade and other conditions prevents a massive installation of herbs. Although coppicing plants are weakened by each slashing and burning, the fires at the onset of the second and

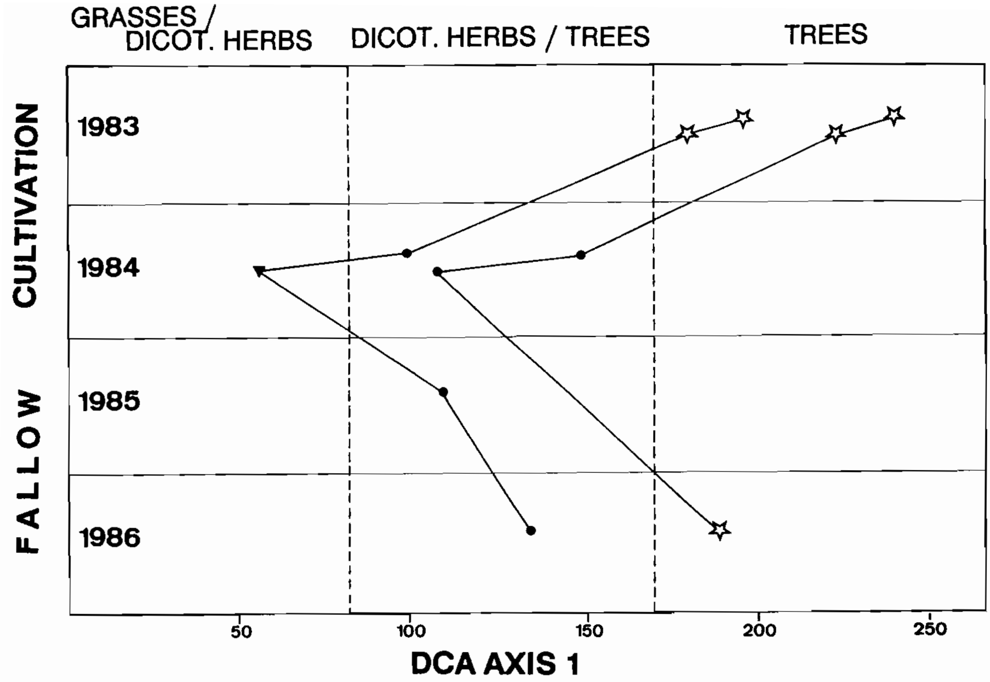


Fig. 12.3. Ordination scores of two permanent quadrats obtained during two years of rice cultivation and two years of subsequent fallowing. One weeding per season. Initial burning was normal.
Star : vegetation mainly pioneer trees, Community *Triplochiton scleroxylon & Oplismenus burmannii*, Dot : vegetation mainly broad-leaved herbs with some trees, Community *Ageratum conyzoides & Erigeron floribundus*.

third cropping period are insufficient to level off the initial difference.

12.3.2 Weeding frequency

A similar diagram was made from the plots which were not weeded during the cropping periods (Fig.12.2). Permanent plots subjected to two weedings a year have more recordings, for relevés were made prior to each weeding. In unweeded plots the vegetation was described only at the end of the cropping season. The patterns in floristics conform with those shown in Fig.12.1, meaning that weeding hardly influences the process of degeneration, nor of succession. Hence weeding frequency is not a factor determinant for a particular community. At most, absence of weeding delayed the degeneration to a grassy - thicket (Community *Mimosa pudica & Panicum laxum*) by several months and recover of the old-field vegetation on slightly burnt plots may be somewhat accelerated (Community *Triplochiton scleroxylon & Oplismenus burmannii* in 1987).

12.3.3 Length of the cultivation period

What happens if the field is cultivated for only two years and than left to rest ? Fig.12.3 shows the DCA axis 1 scores for two permanent plots which were followed for two years. Plots were weeded once during the cropping seasons and burning had been normal. One plot degenerated

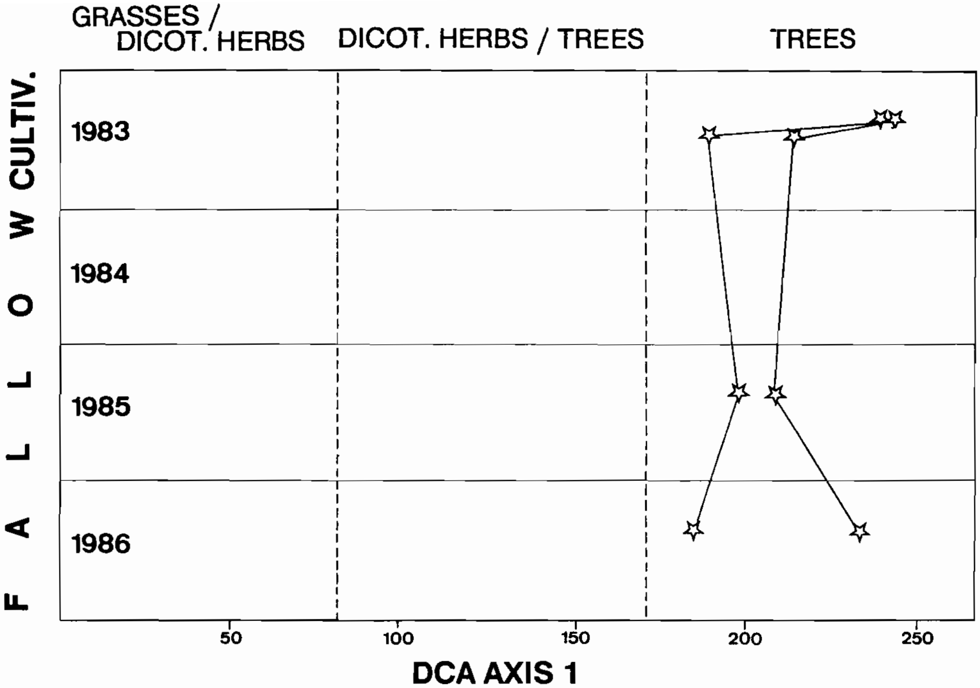


Fig. 12.4. As Fig.12.3 but there was only one cultivation season followed by three years of fallow. Star : vegetation mainly pioneer trees, Community *Triplochiton scleroxylon* & *Oplismenus burmannii*.

to a grassy-forb vegetation (Community *Mimosa pudica* & *Panicum laxum*) but the other did not. During the successive fallow years the first plot regenerated back to Community *Ageratum conyzoides* & *Erigeron floribundus* meaning that the dominance of grasses and forbs had been checked. More and more broad-leaved herbs and other plants were able to re-invade resulting in a fairly species-rich vegetation. Succession was even better on the second plot where the vegetation succeeded back to a tree-like vegetation (Community *Triplochiton scleroxylon* & *Oplismenus burmannii*). Comparing Fig.12.1 & Fig.12.2 with Fig.12.3 we see that succession is rather quick after two years of cultivation, but recover after three years of cultivation is very slow. It is the disturbance caused by the third consecutive cultivation year that keeps the field under a grass-forb cover during at least three or four years.

Another vegetation development is shown in Fig.12.4. The field is cultivated for one year. The crop was weeded once and burning was normal. We see that DCA axis 1 scores stay high throughout the experiment which means that the vegetation does hardly change during the cropping period and during the subsequent three years of fallow. Trees develop from the pre-existing seedbank and simply grow during the consecutive years. Broad-leaved Composites and grasses are either absent from the seedbank or fail to germinate under shade or, if they do germinate, are rapidly outcompeted by the trees. We see that it is the clearing of the land for the second cultivation year, while baring the soil,

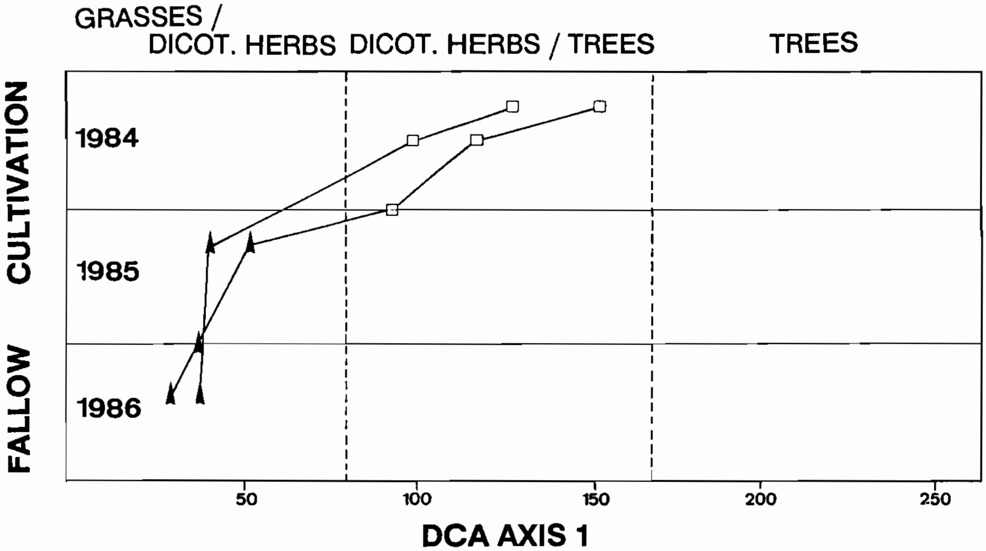


Fig. 12.5. Ordination scores of two permanent quadrats obtained during two years of rice cultivation and one year of subsequent fallowing. One weeding per season. Initial burning was normal.
Cube : vegetation mainly broad-leaved herbs with some trees, Community *Boerhavia diffusa & Chasmopodium caudatum*, pyramid : vegetation mainly grasses and broad-leaved herbs, Community *Chasmopodium caudatum & Aspilia africana*.

which enables these weeds to establish themselves massively.

12.3.4 Length of the last fallow period

On field Pahi 2 similar experiments were carried out but this field had a short last fallow period of 6 years against 19 years in the previous case. All plots were normally burnt and weeding levels were reduced to one weeding and no weeding. Two series of permanent plots were cultivated for two years, two others were cultivated for one year. All plots were studied during three years. Fig.12.5 demonstrates that already the first year of cultivation the field is dominated by broad-leaved herbs with some pioneer trees (Community *Boerhavia diffusa & Chasmopodium caudatum*). The situation quickly degenerates to a grass and forb cover during the second year of cropping (Community *Chasmopodium caudatum & Aspilia africana*). The vegetation does not change the following year.

If the plots are cultivated for only one season, the dominant vegetation stays mainly herbaceous for at least two or three years (Fig.12.6), Community *Boerhavia diffusa & Chasmopodium caudatum*). One permanent plot developed a tree canopy sufficiently dense to shade out most of the broad-leaved herbs (Community *Triplochiton scleroxylon & Oplismenus burmannii*, in 1986). In the other plot, number of herbs declined also but a thick layer of *Eupatorium odoratum* avoided the re-establishment of a pioneer cover. Comparing two versus one cultivation year, it is merely the slashing and burning proceeding the second cropping period which throws back the regeneration process. A fallow period of six years proves to be too short to eliminate most of the weed seeds from the seedbank. In addition to this, the pioneer tree

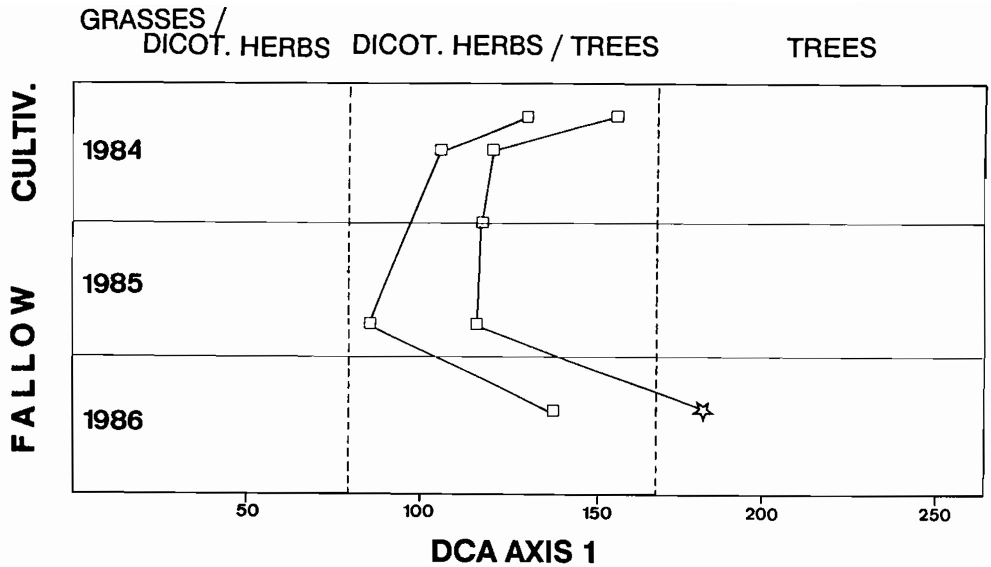


Fig. 12.6. As Fig.12.5 but there was only one cultivation season followed by two years of fallow.

Macaranga hurifolia is almost absent. It has been observed in previous work (Kahn & De Namur 1978) that *Macaranga hurifolia* germinates in large number if an old secondary forest is cleared, containing no longer *Macaranga hurifolia* trees. But a poor crop of *Macaranga hurifolia* seedlings develops if a young secondary forest is felled, in which *Macaranga hurifolia* trees are dominant. In the field Pahi 2 the vegetation felled consisted for over 90 per cent of *Macaranga hurifolia* trees.

12.4 CONCLUSION

After each disturbance, slashing and burning or weeding, the resprouting of established individuals is always quicker than the germination of new recruits. Therefore areas with many re-sprouting plants (mildly or unburnt sites) are rapidly covered by a light shade. These plants are excellent competitors and prevent the massive installation of grasses and forbs. Rice yield on poorly burnt areas is always low, even the first year of cultivation. So the factor which slows down or avoids the process of degradation, a mild initial fire, opposes to rice cultivation.

The length of the last fallow period has obviously a strong effect on the weed population. It takes three years of continuous cultivation to degrade an old forest fallow into a grass-thicket vegetation, while this stage is reached in two years if a young forest fallow is cleared. It is not so that the field vegetation issued from a young forest fallow is carried through the successive stages of degradation at a higher speed. Degradation takes place about equally rapid, independent of the length of the fallow period, but, in the case of a young forest having been cleared, the first stage of weed infestation which characterizes least disturbed land, is skipped.

Vegetation disturbance caused by weeding is of minor importance, it does not make field vegetation shift from one degeneration stage to the next. The factor which structures degradation processes is the slashing and burning of the regrowth prior to each cultivation cycle. This cultural practice "pushes" the field vegetation from one degeneration stage into the next.

13 General conclusions and extended summary

The Taï region is not only the last remnant of a one time vast primary forest, it has also preserved an extensive farming system adapted to and depending on a High Forest environment. From old literature and from the accounts of elderly people it becomes clear that in large stretches of west Africa where rice cultivating societies lived in a wet forest zone (Liberia, Sierra Leone, Guinea and other parts of Côte d'Ivoire) cultivation took place in a similar way. In those areas both primary forest and an archaic form of cultivation have largely disappeared. Extended areas of High Forest and this farming system seem to be related.

13.1 AN AFFLUENT SOCIETY

First the shifting cultivation system was studied functioning under little constraints. Later the productivity under pressure was determined.

In the so-called intact, or Established system, the farmers cooperating in the study retained freedom of choice in site selection, so only well-grown forest on soils of good or average quality were cleared for cropping endeavours. Besides, the different agricultural activities were performed in the season considered best suited for. Under these circumstances the more or less maximum productivity could be assessed for local crops under local management (chapter 5).

Despite the low natural fertility of the soils, this farming system is part of an affluent society. Rice is intended for local consumption and is not considered a marketable commodity. Consequently, extra yield is not rewarded by extra income, it merely increases prestige. So the extra work needed to give that extra yield is not considered worthwhile. As a result, **all objectives of the farmers are towards making food production as little tedious and laboriously as possible**. In addition, labour is spread out over as much time as allowed (chapter 4).

Crops are thus produced with surprisingly little work. Whenever possible, the farmer uses his or her knowledge of the environment and puts Nature to work. Forest fallows are cleared at a moment that many secondary trees decay and fall down by themselves. Large, hard-wooded trees are left standing so they can play an important role in post-cultural recovery of the site. Weeds seeds, accumulated in the soil during the cultivation period are left to decline to easily manageable levels. Only those weeds really harmful to the crop are removed (chapter 7).

In case of imminent danger of crop loss due to weeds, animal pests or other hazards, people are only barely prepared to do extra work in order to secure at least part of the harvest. Fields are readily given up when the expected yield drops too low. All of the ripe rice is seldom harvested, as it often implies many returns to a far off field after the main harvest period is over. Ripe ears which are too light are not cut off. Lodged rice plants are left where they are, to harvest the ripe paddy under the mass of leaves is too much trouble. Estimations by the farmers on sowing seeds and yields are approximate. Most of the cassava and bananas, planted as an insurance in case of need, simply become part of the forest fallow.

The relative affluence of the society is reflected in many other aspects of life. Land rights, though individualistic, do not include heritage. The nearby High Forest supplies a multitude of additional products. Fish and game are easily gained and are part of every day's meal.

If a man is asked how much food he (or his household) is going to produce, he answers - and this is a typical answer among rice farmers in Côte d'Ivoire - : that depends on the surface my wife can plant (or is willing to plant). This answer demonstrates two things.

Firstly, that it does not depend on him, although he is probably the one who clears the field and thus sets its boundaries. Apparently, if his wife wants a large field, he clears a surface accordingly, and *vice versa*.

Secondly, and this is very revealing, he says "planting" and not "weeding". This is quite in contrast with most rice (or other cereal) cultivators elsewhere in the world. One or two months are spent on sowing, which is long but not excessive. If weeding requires more than a month, she considers it already a burden, whereas few farming systems can be found that function with so little weeding.

13.1.1 Why weeds are few

Low weed infestation is the combined result of:

- **Few seeds in the seed bank prior to clearing.** The number of seeds in the forest soil before field preparation depends firstly on the length of the previous fallow period. Primary forest has lowest densities. Secondly, it depends on the quality of burning. The more intense the fire has been, the more seeds are destroyed. Thirdly, those annual weeds present in the field will not be allowed to produce more than one seed crop which ripens at the time the rice matures. This being prevented by a rapid development of the woody fallow vegetation which chokes the weeds after the harvest. Fourthly, all weeds germinate at the onset of the cropping period and the number of weeds declines naturally as a result of mutual competition and competition by the rice. Weeding is effective for weeds are not replaced by new ones.
- **The weeds present are mostly young trees** growing rather slowly in the beginning. Their slender vertical growth makes them not very dangerous and many of them are left untouched. The fraction of the more harmful, rapid growing annual herbs with a spreading growth form is small. The ratio woody plants/annual herbs is largely determined by, again, the length of the last fallow period, primary forest having lowest numbers of herbs.
- **Most varieties of rice used in the area are long cycle, tall, vigourous growing plants which outgrow and check weed growth.** The rice plant can do this weed-suppressing work if there are ample nutrients in the soil and the soil has lost most of its acidity. Nutrient availability and rise of pH depends on the quantity of ashes produced by burning. This is directly related to the quantity of fuel and so to the size of the forest which was cleared. In addition, natural fertility of soils, induced by parent material, is important.

13.1.2 The rice

Rice can be successfully cropped on a large variety of soils, with exception of some very poor sites where lack of natural fertility of the soil, again determined by parent material, prevents cultivation. Swampy land up to very gravelly upper slopes can give an average yield (0.8 -1.0 t/ha) provided a maximum of nutrients is liberated by the burning of forest.

It has been demonstrated in on-farm trials that weeds in the current practice of shifting cultivation compete for space with the rice crop in an early stage of development, and that this is not harmful. In a later stage of growth, weeds compete for nutrients. Rice growing in weedy places and rice growing under weed free conditions both attained impressive dimensions and a similar quantity of vegetative biomass was produced. There was, however a considerable difference in yield, the extra paddy in the weed free plots corresponded to the weed biomass in the weedy plots. **Weeds should be prevented to immobilize nutrients at a period the easy available nutrients provided by the burning start to lack.** Weeds can grow freely at a period the rice is still young. Through the number of panicles will be reduced due to weed competition for space, the rice has a capacity to compensate by making very heavy panicles. A limited number of heavy ears has the advantage that the work of harvesting is reduced. (chapter 5).

The primitive, locally selected rice varieties have a limited yield potential but they are resistant to poor standards of management, low natural fertility, flooding and waterstress hazards. In current practice of shifting cultivation they have an appreciable tolerance to weeds. So this is not only a cropping system with very few weeds, but also the rice planted is an unusual competitor.

The success of the rice crop and the absence of harmful weeds are both related to the maintenance of long fallow periods and short occupation periods. Both require forested land in good supply.

13.2 ADAPTATIONS OF THE SYSTEM, NO LAND SHORTAGE

Agriculture is often far less stable than we are inclined to think. Yet most rice varieties, now favourite throughout the study area, were spread within the last few decades. New varieties were usually introduced by exogeneous marriage. Contact with other ethnical groups in a more recent time, Baoulé, Dyula, Burkinabé have greatly developed the cultivation of staple crops making the people less dependent on rice. Though maize, cassava and bananas were well known crops being cultivated for a long period, all the varieties that are most appreciated now, have been brought in, mainly by immigrants, during the last ten, fifteen years. All these crops need more work and care than the old varieties, but this is currently done. A wider range of both staple crops and non-staple food is being cultivated since the arrival of immigrants. All these crops are market commodities. The local markets offer about five to ten times the volume of product as they did ten years ago, before the massive arrival of immigrants.

By comparison of aerial photographs of 1956 and SPOT imagery of 1988, it became clear how land use had changed over the last thirty years. Major changes resulted from the opening up of the land by timber extraction roads, the establishment of the National Park and the bufferzone, and by massive cocoa planting by immigrant farmers.

Guéré, Oubi and Kru presently occupy about the same area of land as in 1956. It is probable that emigration of the well educated part of the population to cities, has balanced much of the natural growth of this population. Most of the land used by the indigenous people is located on both sides of the main road. In 1956 shifting cultivation was practiced on the lower slopes and parts of the valley bottoms, but in recent times rice cultivation has moved uphill. This change is a result of two factors, both related to a growing popularity of tree crops. Firstly, tree crops do not thrive well on flooded land, and since a rice crop always precedes the tree crop, fields had to be found higher up the slope. Secondly, tree crops needed "fresh soils" which means that the vegetation cover should be primary forest, and that was, close to settlements, only available middle and upper slope. The result is that a certain amount of land passes yearly from usage in shifting cultivation into permanent agriculture (chapter 3).

Immigrants generally received remote-lying land. The majority of them follow the timber cutters in primary forest. They cut the forest and establish cocoa farms. Most cocoa plantations are less than 10 years old. Cocoa is still expanding (in 1990) although the health status of the plantations is often poor, the production per tree is low and the market prices are low. Most farmers tend to compensate for low cocoa yield by expending their plantation rather than by improving their management (chapter 4).

13.3 ADAPTATIONS OF THE SYSTEM UNDER LAND SHORTAGE

Under pressure of the limited availability of land around the largest settlements, farmers in shifting cultivation land are compelled to take less favourable sites into cultivation, meaning either, High Forest on inferior soils or too young forest fallow on normal soils. In addition, a farmer can prolong the cultivation period an extra year. This implies that the population continues the shifting cultivation practice on a lower level of productivity. In many cases all agricultural activities were delayed as a result of the men being occupied with the cocoa and coffee harvest and so they started too late cutting a new field. The period the biomass should have dried out, no longer coincided with the long dry season, so burning was the chief problem. The combustion achieved was less complete. A second inconvenience is, but this does not show up each year, that late planting of the long cycle rice pushes the period of maximum growth in the short dry season, whereas in normal practice, this period coincides with maximum rain. These possibilities, especially lengthening of the occupation period were tested on the rice fields of volunteer farmers.

13.3.1 Prolonged cultivation

There were some spectacular differences between the first and the second year of rice cultivation:

- The rice had lost all vigour. **At best, rice yield dropped to half of the previous yield**. Weed infestation, despite two weeding rounds was such that a competition for space prevented the rice to tiller normally. Lack of nutrients in the soil, being a combined result of the declining effect of the burned forest and of the direct immobilization of nutrients by weeds, gave small statured rice plants. Paddy yield was distributed over about the same number of ears, or more. Many panicles contained so few grains that it was hardly considered worthwhile to harvest them.
- **Number of viable weed seeds present at the onset of cultivation had doubled** or more than doubled. Instead of a natural decline during the cropping period, numbers increased after each weeding. Only the second weeding gave some weed reduction. Most plants were short cycled and produced generation after generation of seed (chapter 6).
- The floristic composition of the weed population had changed radically. **Woody species present the first year were**

replaced by herbs, mainly wind-dispersed Composites. They were initially absent from the seed bank but had invaded since. By their growth form and different ecology they are much more harmful than are pioneer seedlings (chapter 7).

13.3.2 Short fallow period

Results of rice performance and weed growth were about equally poor on fields where the fallow period had been short (6 years), as on fields cultivated a second year. Still **it is more profitable to cultivate after a short fallow rather than prolong the period of cropping**, because a forest fallow, even a short one has the advantage that it can be burnt, bringing at least some ash to the soil and eliminating some weed seeds, while the seed bank will contain some pioneer tree seeds. In this case, extra weeding can give extra yield.

13.3.3 Ecological consequences

A consequence of shortening of the fallow and of lengthening the cultivation period is that no normal secondary forest vegetation develops after the field is left to rest. Instead, a deflected fallow is formed in which the thicket forming Composite (*Eupatorium odoratum*) is prominent. The succession to a forest fallow takes longer and other species are involved. These stands accumulate less biomass so burning of a thicket gives none or far less of the beneficial effects of burning a normal secondary forest. In less degraded vegetation trees may be present, but other species, more hardy ones, take the place of the usual pioneers. In more degraded vegetation less trees and more grasses occur (chapter 11).

It became evident that in under current practice the rice thrived on the nutrients contained in the ash of the burned forest rather than on the nutrients of the mineral soil, and so **the nature of the soil was of relative little importance, as long as ample ash was produced from the burning of much biomass**. There were, however important differences in yield the first year of cultivation and this difference was attributed to some extent, to differences in soil. Under the pressure of land shortage, rice cultivation puts higher demands on soil and water, the intrinsic differences in soil fertility and waterholding capacity between soils are then beginning to show in the health condition of the crop. Differences among soils are also becoming more apparent as there is now a greater variety in crops as well as in cultivation methods. This trend is so recent that the farmers, notably the immigrants, have not yet gained the experience that is required for a proper choice of crop and a cultivation method for a specific soil.

14.4 HETEROGENITY OF THE LAND

The inventory of natural resources on a landscape scale contributes to a better understanding of soil-water-crop relationships (chapter 9). The inventory produced Land Units, which are units characterized by a specific combination of vegetation, soil, geology, land form and land use. The variation in Land Units increases in the study area from north to south. The few Land units in the north each cover a large area. In the south the average Land unit is much smaller. This does not mean that on a human observation scale the landscape is more uniform in the north, and more heterogeneous in the south. In the north, where most on-farm trials were carried out, very detailed mapping demonstrated a heterogeneity in parent material, vegetation and land form. This could not be mapped because patches were small and dispersed. In the south, part of the heterogeneity of landscape is expressed in larger patches so this could be mapped on the scale used. Besides the small-size, patchy character of the land heterogenity, it is very inconvenient that exceptional good or poor soils can hardly be detected in land form, drainage pattern etc, making them hard or impossible to detect on aerial photographies or even in the field where absence of rock exposures and inspecting the soil profile do not provide clues. The area with a different geology is so small and the landscape so old that all indications other than vegetation are effaced.

Patches of superior or inferior soils, even those smaller than half a hectare, can nevertheless be recognized by the natural vegetation. **The Oubi and the Guéré farmers have a fund of knowledge of the environment on which they rely in selecting sites for shifting cultivation**. In the north merely this has guided the choice of a farmer to prepare a field. In the south, where inclusions of superior soils are larger, this has not only determined cropping sites but also to a certain degree settlement patterns. This consistency with local ecological knowledge was a confirmation of our findings afterwards, for our inventory of the natural resources was conducted wholly independent of this. Extensive and systematic data collection using aerial photography and satellite images, soil description, chemical analysis, full species lists of the vegetation and notes on crops and performances of crops provided scientific and statistical evidence for the heterogeneity of the landscape. The heterogeneities of the land are very important for crop production as was demonstrated in the many field experiments. Heterogeneities over small distances obliged us to make the sample plots very small (36 m»). Our great number of relevés balanced the fact that plot size was far below minimal area.

Processing of the extended enumerations was done with computer programmes but needed successive refinement by hand in those cases, where not only a spatial gradient was present but also successional processes occurred (chapter 8).

13.5 PLANTS AS INDICATORS

In the rain forest vegetation, water is the chief factor determining species composition. It seems strange in a permanently wet environment that nevertheless moisture strongly influences species composition. Multivariate analysis of many relevés in primary forest demonstrated a gradual swift of large groups of species along the main gradient which is moisture (chapter 9).

In the study area moisture can be related to four different things:

- **To climate**. The gradual but small increase in rainfall from north to south is accompanied with a more even distribution of rain in the south. Both trends produce a slightly wetter climate in the south than in the north. Many species respond to this gradient by being absent in the north and present in the south or, more rarely, the inverse.
- **To soil-topographic position**. There is a change in species composition along the slope, the well-drained crest and upper slope being drier than the moderately to poorly drained lower slope and valley bottom. A combining effect of slope and climate was observed. A number of plant species "do not mind" if moisture comes from a lower position on the slope or from extra rainfall. These species occur in valley bottoms in the north where the climate is drier, and "climb" out of the

swamp to occupy higher positions on the slope in an area with more rainfall.

- **To soil-parent material.**The situation is more complex if there is a change in soil,related to lithology. Again, there are plant species which "do not mind" if the moisture is provided by the better water-holding capacity of the soil (clay content, lack of gravel) or by extra rainfall. This particularity allows us to recognize in the drier north those soils with better moisture conditions, simply because species from a wetter rainfall zone are present. The inverse is true as well, in the wetter south, those soils with poor water holding capacity do not have all of the species proper to the wet climate, but instead, some of the drier north occur.
- **To cropping history.** This is the most complicated and less apparent relation. It is probably closely related to the preservation of a rain forest micro-climate and other factors too. It could be demonstrated that fields made in primary forest, with much High forest around had moisture-indication plants occupying a large part of the slope. In fields which were made in secondary forest, especially if the site had been cultivated and fallowed many times over, the same species group occupied much lower topographic positions.

Next to a relation with moisture, the natural vegetation in primary forest also expresses other land forms than the usual uplands, notably alluvium and the occurrence of rock outcrops and inselbergs. In the landscapes with rocks and inselbergs nearby rocks (which may well remain invisible to casual inspection) induce the occurrence of species of a wetter environment, in addition to special species groups indicating the special nature of the rocks, this being largely granitic or mixed with richer material.

The secondary forest had a relation with moisture too. This was best demonstrated for young secondary forest because this vegetation type was most abundant. All secondary forest comunities occurred throughout the study area. However, the three young secondary forest communities occupied different positions on the slope. The secondary forest community of valley bottoms in the north could cover the greater part of the slope in the south and so extra rain in the south could compensate for the lack of edaphic water (chapter 10).

13.6 SUCCESSION

Compared to other shifting cultivation systems in rain forest, **the forest fallow vegetation in the Taï region is extremely quickly established**. The main reason is that the field is cultivated for the duration of one rice crop and weeding is often restricted to few harmful spreading annual weeds, leaving the mass of pioneer trees untouched. Those fields carry a complete set of secondary species, the dominants of early stages, and those of later stages. All these plants were largely present as seeds in the pre-existing forest soil. Many primary forest species are preserved as coppice shoots. If a field lacks the species of one of the successional stages, then succession advances up to the previous stage and tends to get blocked. An intact pre-existing seed bank comprising the species of all seral stages, is a conditio sine qua non for a successful secondary succession.

If a site is cultivated for the first time the field vegetation is varied and floristically the site passes quickly through the different stages of succession. Sites which have been subject to several shifting cultivation rotations carry less species rich field vegetations, notably less large tree seedlings of old successional stages and less primary forest understorey plants.

Abnormal, deflected or blocked successions are very easyly produced, as was demonstrated by long term surveys in permanent quadrats. Cutting a forest fallow too young, cropping the same field with rice for two years, these are practices which lead to a kind of intensification of the cropping regime that impairs regeneration for a long period. If a farmer has to chose between cropping plots for a longer period or use shorter fallows, the former is more damaging than the latter. Weeding, even repeated weeding during one season, disturbs far less than preparing the field for a second crop by slashing and burning (chapter 12). Deflected seral stages are produced because the seed crop of pioneers and late successional plant species is exhausted. Many wind-dispersed herbs invade and occupy the field. Tree seeds must come from outside and should be capable to invade closed thickets and grassy shrubland. In the shifting cultivation farming system weed invaded fields and **Deflected fallow vegetation are created where land is short, but in 1989 they were still not common.** In the farming system of immigrants, these communities accompany the usual crops. Repeated burning, clean weeding, working the soil with a hoe, and cultivating the soil for more than one season, contributes to the effect that immigrant fields never have the same type of weed population as shifting cultivation fields have. **Abandoned immigrant fields** do not have the usual secondary forest vegetation but **are covered at least for several years by thickets and shrub land scattered with some trees**.

13.7 INDICATORS AND AGRICULTURE

Plants react of course on the totality of environmental conditions. In this study the relative position of plant species have been determined along the different gradients. Thus we know of all common plant species their ecological preference with respect to rainfall, soil condition, and resistance to disturbance. In a given rainfall zone, on a given position on the slope, in a particular successional stage, there are plants we expect to grow there and there are plants we do not expect to grow there. Farmers obviously have the same outlook, although knowledge of the flora seems to vary enormously from person to person and is usually confined to plants with highly indicative value in the place where that person lives. So plants have their "normal" climatic position, their "normal" position on the slope and their "normal" position in successional stages. Any plant occurring outside its normal range of habitats is perceived as an anomaly. In the statistical analysis there were always a group of plant species acting together, never isolated plants. Most of the plant species with indicating value were inhabitants of the forest understorey, herbs, lianas, ferns and understorey trees.

Sites with plants indicating superior moisture conditions were actively looked for for rice cultivation. Sites with plants indicating inferior water conditions have been avoided if they were located far off, but were sometimes cultivated if close to settlements. Sites with the "normal" set of plants have been cultivated too. Most of the "anomalies" in vegetation originate from variation in parent material.

It should be stressed that the valuable species in this process are plants of relative undisturbed environments. In the current shifting cultivation practice, which produces the field and seral communities of the "Established" system, usually sufficient criteria remain to allow its classification. This is far from evident if the vegetation is disturbed so severely that it has been reduced to almost uniform levels and the communities of the "Deflected system" occur (chapter 11).

13.8 LOOKING AHEAD

There was, surprisingly, little similarity between the map of the natural resources (Land unit map) and the map indicating land use. This is partly obscured by the working scale. The shifting cultivators do distinguish different soil and forest quality and cultivate accordingly but this is on to detailed a scale to be mapped. Immigrants cultivate any soil given to them in largely the same way, because they are unfamiliar with the environment, inclusive the flora, and because they often have not much choice.

Generally under low population pressure, new crops and techniques are being introduced at a rather slow pace and adjustments to the environment come about more or less naturally, after a period of small scale trial and error. So the dynamic of the farming system is like a gradual evolution. In such a context farming systems have a chance of being more or less in accordance with ecological site characteristics. In the land cultivated by the Oubi there is one example of this. In the large flat swampy areas in the centre of the study area, rice is cropped in alternation with short fallow periods with apparent success because most of the rice is intended to be sold. Moisture is available during most of the year, and this allows for flexible planting and harvesting time. Still the same upland rice varieties are used, and cropping practices have undergone but little change. Excessive weed growth, notable *Eupatorium odoratum* dominance is avoided by a rapid cover of re-sprouting *Marantaceae* plants. The use of *Marantaceae*, as a weed break has become part of the evolved system. It is noteworthy that Oubi women who exploit the area, employ immigrant labour for weeding (the elimination of *Eupatorium odoratum* is essential). The shortening of the fallow period, apparently gave such a weed problem that the local people are unwilling to handle this. In the same manner other, similar moist land could be cultivated, demanding some more work but no large investments.

Agriculture as it is practiced by immigrants has characteristics of a transitional stage. It seems that poor management and failure to adjust the system to local resources brings about a more or less general collapse of the cocoa based cropping system. Only those cocoa plants on good soils with roots preferably reaching the saprolith can become potentially permanent systems.

In the future much of the remaining primary forest outside the protected area of the National Park will be cut. In the agricultural zone, it seems a far too optimistic view to consider those areas, now under primary forest or under old secondary forest, of the same quality as the land already under cultivation or under regular shifting cultivation. Our observations showed that **the better part of the soils available is already cultivated, because farmers can recognize them**. Food crop cultivation is bound to extent to those cocoa plantations afflicted with die-back. Here, Deflected succession and thicket covered areas will expand. Re-utilisation of this land needs careful study. Reforestation, with a variety of trees, never with just one species, seems to be a possibility. Trees should be selected among those secondary trees which demonstrate a tolerance to grassy shrubland and to *Euparotorium odoratum* thickets competition. In this study some of the candidates are listed (chapter 11, Appendix 2). There are trees particular apt for fire wood, other are legume trees and perhaps some can provide timber. Probably the soils would need to be inoculated with mycorrhyzae to ensure their successful establishment.

If shifting cultivation is allowed to function free of population pressure and other external constraint, does it, or does it not endanger the environment. Some authors even speak of a system in "equilibrium". As the concept "equilibrium" lacks definiteness, **we preferred to investigate whether the system in Taï is sustainable.** Cultivating once a field in former primary forest with primary forest all around just for one crop, seems to be very little damaging. After thirty or forty years it is really difficult to recognize the old field. But **the major issue is whether a forest can be used in such a way permanently without losses.** It was demonstrated that during three rotations on the same site each cultivation and (long) fallow period had brought the loss of primary forest species from the field vegetation and from the young fallow. The more a forest had been cut regularly, the longer it took for primary forest species to invade. The Taï region has not been inhabited by a fixed population for a long period and considering the abundance of land up to a very recent time, there a relatively few sites which have been really cropped during many rotations. Probably this is only the case on sites close to villages and on the best soils. Comparing the yields of paddy from fields which were recently under primary forest and from those under secondary forest for a long time, shows the yield of the first are higher. The whole system may be relatively in balance but continuing cultivation, e.g. rotation after rotation causes it to function on a declining level. If High forest is to disappear in the surroundings, the ecological influence may be far greater than one or two extra rotations.

In regions where rain forest disappears at an alarming rate, people anxious to preserve some of these precious resources usually condemn the farming system of shifting cultivation, and simultaneously, they praise permanent cultivation. In Taï the situation is quite the inverse. The proportion of land under shifting cultivation rotations has not increased during the last forty years. The reason for this is that the population practising shifting cultivation has been stable or, more probably, has decreased. The main reason behind this is the education of girls. Every educated woman seeks an employment outside agriculture and with every woman who leaves agriculture, one shifting cultivation household is lost. Because the number of Oubi and Guéré girls going to school in the Taï is well above the national average, this effect increases.

Permanent agriculture in the Taï region is permanent land use for as long as a cocoa tree grows. There are no examples of permanent food cropping. There are indications that the economic life of cocoa trees is not the usual 25 - 30 years, but about 10 years at most on good places. Strong indications exist that replanting cocoa or coffee is unprofitable because of weed infestation, general degradation of the soil, absence of mycorrizhae etc. So "permanent agriculture" is most often only temporarily profitable. The area of land under "permanent cultivation" is far more extensive than the land involved in shifting cultivation because immigrants who are the most important cocoa planters, greatly outnumber the indigenous population. Immigrants have commercial aims so children are rather ls encouraged to gain a life in agriculture, and are not so much pushed into education.

So for the cause of saving some primary forest in Taï, there is no need to try to "stabilize" the current practice of rice shifting cultivation, it is on the other hand very urgent to "stabilize" permanent agriculture.

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Appendices

The botanical nomenclature used follows Hutchinson & Dalziel (1955-1972, 2e ed.) in most cases. Authorities for nomenclature are given in Appendix 2. The nomenclature deviates occasionally from Hutchinson & Dalziel for the Families *Celastraceae* and *Araceae* and for the Genera *Tricoscypha* and *Chytranthus*. The monographs of Hallé (1962) and of Knecht (1983) has been used to identify plants of these families. Both authors have collected in the Taï forest. For the Genera *Tricoscypha* and *Chytranthus*, particularly developed in the Taï forest, determinations follow Aké Assi. Our collection of pressed voucher specimen has been verified with the collection of plants sampled in the Taï region deposited with the herbarium Centre Floristique, University of Abidjan. Afterwards, this collection has been deposited in the herbarium Vadense of the University of Wageningen.

Appendix 1

Species list per sociological species group for classification of primary forest (Fig.10.1 and Fig.10.2)

Sociological group : 1
Buforestia mannii, Calycobolus heudelotii, Cephaelis peduncularis, Cercestis sagittatus, Chidlowia sanguinea, Cola caricaefolia, Culcasia saxatilis, Hunteria simii, Lonchitis reducta, Memecylon cinnamoides, Monodora myristica, Ouratea reticulata, Ouratea subcordata, Ptychopetalum anceps, Rhinacanthus virens, Salacia calumna, Salacia leptoclada, Strychnos aculeata, Trichoscypha oba.

Sociological group : 2
Anthonotha fragans, Carpolobia lutea, Cissus aralioides, Culcasia scandens, Decorcella paradoxa, Drypetes chevalieri, Erythrophleum ivorense, Glyphaea brevis, Mareya micrantha, Parkia bicolor, Salacia miegei, Triclisia macrophylla.

Sociological group : 3
Amphimas pterocarpoides, Cephaelis yapoensis, Culcasia dinklagei, Culcasia longivaginata, Mapania baldwinii, Nauclea diderrichii, Newtonia duparquetina, Strychnos cuminodora, Trichoscypha arborea, Triphiophyllum peltatum.

Sociological group : 4
Anthocleista nobilis, Araliopsis tabouensis, Baphia polygalacea, Beilschmiedia mannii, Caloncoba brevipes, Cercestis afzelii, Chrysophyllum pruniforme, Combretum homalioides, Ctenitis protensa, Dacryodes klaineana, Drypetes pellegrini, Elaeis guineensis, Heinsia crinita, Kolobopetalum leonense, Landolphia membranacea, Leptoderris fasciculata, Mendoncia combretoides, Raphia sassandrensis, Rhigiocarya racemifera, Trichilia

heudelotii, Uapaca guineensis, Uapaca heudelotii, Vitex micrantha.

Sociological group : 5
Aphanostylis leptantha, Cuervea macrophylla, Diospyros sanza-minika, Eremospatha macrocarpa, Geophila afzelii, Pyrenacantha vogeliana, Sarcophrynium brachystachys, Spondianthus preusii, Thalia welwitschii.

Sociological group : 6
Ancistrophyllum opacum, Dracaena ellioti, Gilbertiodendron preussii, Hypolytrum poecilolepis, Nephthitis afzelii, Sacoglottis gabonensis, Tarrietia utilis, Uapaca esculenta, Ventilago africana, Xylopia acutiflora.

Sociological group : 7
Ctenitis variabilis, Dracaena humilis, Landolphia hirsuta, Ouratea schoenleiniana, Trichoscypha beguei.

Sociological group : 8
Agelaea trifolia, Antiaris welwitschii, Canthium hispidum, Griffonia simplicifolia, Guarea cedrata, Heisteria parvifolia, Jasminium pauciflorum, Palisota barteri, Piptadeniastrum africanum, Platysepalum hirsutum, Psychotria sciadephora, Pycnocoma macrophylla, Xylopia villosa.

Sociological group : 9
Ancistrophyllum secondiflorum, Asplenium africanum, Cola lateritia var.Maclaudi, Enantia polycarpa, Euadenia trifoliolata, Hugonia rufopilis, Linociera mildbreadii, Lomariopsis rossii, Lovoa trichilioides, Lychnodiscus reticulatus, Tricalysia macrophylla.

Sociological group : 10
Aningeria robusta, Cola heterophylla, Culcasia liberica, Geophila neurodictyon, Leptoderris miegei, Manotes expansa, Millettia rhodantha, Myrianthus libericus, Parinari aubrevillei, Polyceratocarpus parviflorus, Polyspatha paniculata.

Sociological group : 11
Calamus deeratus, Deinbollia pinnata, Drypetes ivorensis, Neuropeltis prevosteoides, Neuropeltis velutina, Oxyanthus formosus, Rinorea oblongifolia, Stanfieldiella imperforata, Sterculia oblonga.

Sociological group : 12
Anthonotha macrophylla, Baphia nitida, Chassalia corallifera, Chytranthus longiracemosus, Chytranthus mangenotii, Chytranthus setosus, Corynanthe pachyceras, Culcasia piperoides, Culcasia seretii, Dracaena camerooniana, Funtumia africana, Grewia mollis, Lankesteria brevior, Octoknema borealis, Popowia mangenotii, Rhaphidophora africana, Strychnos ngouniensis, Trichoscypha chevalieri, Uvariopsis guineensis.

Sociological group : 13
Eugenia calophylloides, Hugonia platysepala, Myrianthus arboreus, Piptostigma aubrevillei, Salacia erecta.

Sociological group : 14
Alchornea floribunda, Ancistrophyllum Laeve, Desplatsia chrysochlamys, Macaranga heterophylla, Monodora crispata, Oldfieldia africana, Pseuderanthenum tunicatum, Pteris burtoni, Rhaphiostylis cordifolia, Salacia lateritia, Spiropetalum heterophyllum.

Sociological group : 15
Cuviera acutiflora, Dorstenia smythei, Hymenostegia afzelii, Pachypodanthium staudtii, Rinorea ilicifolia.

Sociological group : 16
Dracaena ovata, Epinetrum scandens, Garcinia SP 1., Hunteria eburnea, Hunteria elliotii, Psilanthus mannii.

Sociological group : 17
Baphiastrum confusum, Alchornea cordifolia, Dialium aubrevillei, Garcinia kola, Lasiodiscus fasciculiflorus, Macaranga cf heudelotii, Nauclea xanthoxylon, Olax subscorpioidea, Pancovia bijuga, Parinari congensis.

Sociological group : 18
Coffea humilis, Daniellia thurifera, Dichapetalum pallidum, Millettia chrysophylla, Neosloetiopsis kamerunensis, Plagiosyphon emarginatus, Rhynchospora corymbosa, Salacia leonensis.

Sociological group : 19
Afrolicanea elaeospermum, Crotonogyne chevalieri, Mapania coriandrum, Pentaclethra macrophylla, Strychnos usambarensis, Thecacoris stenopetala.

Sociological group : 20
Hypselodelphis poggeana, Marantochloa congensis, Oncoba spinosa, Palisota hirsuta, Pandanus candelabrum, Pavetta staudtii, Scytopetalum tieghemii.

Sociological group : 21
Corymborkis corymbosa, Elaeophorbia grandifolia, Hibiscus surattensis, Mallotus oppositifolius, Mildbraedia paniculata, Oeceoclades maculata, Tragia vogelii.

Sociological group : 22
Bequaertia mucronata, Ceiba pentandra, Citropsis articulata, Nesogordonia papaverifera, Rothmannia whitfieldii, Stereospermum acuminatissimum, Triplochiton scleroxylon.

Sociological group : 29.
Calycobolus africanus, Chrysophyllum taiense, Diospyros chevalieri, Diospyros mannii, Diospyros soubreana, Garcinia gnetoides, Landolphia owariensis, Maesobotrya barteri, Marantochloa filipes, Napoleona leonensis, Neuropeltis acuminata, Piper guineense, Rhaphiostylis beninense, Rinorea longicuspis, Salacia debilis, Strombosia glaucescens, Tiliacora dinklagei, Xylopia quintasii.

Species frequently recorded in primary and secondary forest but showing a preference for primary forest.
Buchholzia coriacea, Canarium schweinfurtii, Cercestis stigmaticus, Cleistanthus polystachyus, Cola nitida, Combretum racemosum, Coula edulis, Craterispermum caudatum, Dichapetalum angolense, Dichapetalum toxicarium, Dicranolepsis persei, Diospyros canaliculata, Diospyros vignei, Dracaena smithii, Dracaena surculosa, Epinetrum cordifolium, Garcinia afzelii, Geophila hirsuta, Geophila obvallata, Gilbertiodendron ivorense, Gilbertiodendron limba, Halopegia azurea, Hypolytrum heteromorphum, Isonema smeathmannii, Ixora laxiflora, Klainedoxa gabonensis, Landolphia dulcis, Lomariopsis guineensis, Memecylon guineense, Memecylon lateriflorum, Memecylon membranifolia, Microdesmis puberula, Monodora tenuifolia, Neostenanthera gabonensis, Ochthocosmus africanus, Ouratea duparquetiana, Oxyanthus pallidus, Panda oleosa, Parinari excelsa, Combretodendron macrocarpon, Pleiocarpa mutica, Pollia condensata, Polyalthia oliveri, Psychotria subobliqua, Pycnanthus angolensis, Soyauxia floribunda, Strephonema pseudocola, Tetracera potatoria, Tricalysia reflexa.

Number of records of the species are too few to permit attachment to a sociological species group, but species show a preference for primary forest.
Acridocarpus smeathmannii, Allanblackia floribunda, Ancistrocladus abbreviatus, Angylocalyx oligophyllus, Anopyxis klaineana, Antidesma membranacea, Alsodeiopsis staudtii, Calycobolus parvifolius, Carapa procera, Cephaelis abouabouensis, Cephaelis mangenotii, Chlamydocarya macrocarpa, Cola chlamydantha, Cola digitata, Crudia klainea, Culcasia angolensis, Culcasia parviflora, Cynometra ananta, Deinbollia cuneifolia, Dialium dinklagei, Dichapetalum cymulosum, Drypetes aylmeri, Entandrophragma angolense, Entandrophragma candollei, Entandrophragma cylindricum, Eremospatha hookeri, Flagellaria guineensis, Garcinia smeathmannii, Gilbertiodendron splendidum, Guarea leonensis, Helictonema velutina, Heteropteris leona, Hexalobus crispiflorus, Icacina mannii, Iodes liberica, Irvingia gabonensis, Kantou guerensis, Khaya anthotheca, Kigelia africana, Lasiantus batangensis, Lophira alata, Mammea africana, Mapania linderi, Maschalocephalus dinklagei, Mendoncia iodiodes, Mitragyna ciliata, Myrianthus serratus, Omphacarpum ahia, Oxyanthus subpunctatus, Pachystela brevipes, Pauridiantha hirtella , Pellegrinodendron diphyllum, Penianthus zenkeri, Pentadesma butyracea, Placodiscus pseudostipulata, Renealnia maculata, Rinorea elliotii, Salacia nitida, Salacia uregaensis , Scaphopetalum amoemum, Sphenocentrum jollyanum, Symphonia globulifera,

Tabernaemontana crassa, Tarenna bipindensis,Thonningia sanguinea, Tieghemella heckelii, Treculia africana, Uapaca paludosa, Xylopia parviflora.

Species showing a preference for secondary forest.
Acacia pennata, Adenia lobata, Albizia adianthifolia, Anthocleista vogelii, Baissea zygodioides, Bertiera bracteolata, Bertiera racemosa, Bussea occidentalis, Byrsocarpus coccineus, Chlorophora exelsa, Cissus diffusiflora, Cissus polyantha, Cissus producta, Cleistopholis patens, Cnestis ferruginea, Cordia platythyrsa, Costus schlechteri, Diosocorea burkilliana, Dioscorea praehensilis, Dioscorea smilacifolia, Discoglypremna caloneura, Entada scelerata, Erythrococca anomala, Fagara macrophylla, Funtumia elastica, Guaduella oblonga, Harungana madagascariensis, Hypselodelphys violacea, Kolobopetalum chevalieri, Leea guineensis, Marantochloa leucantha, Macaranga barteri, Macaranga hurifolia, Megaphrynium distans, Millettia zechiana, Raphia hookeri, Ricinodendron heudelotii, Rutidea parviflora, Secamone afzelii, Scleria barteri, Sherbournia calycina, Stephania dinklagei, Tetracera alnifolia, Tetrorchidium didymostemon, Thaumatococcus daniellii, Trachyphrynium braunianum, Tragia benthami, Uncaria africana, Uvaria afzelii, Xylopia aethiopica.

Species showing a preference for coffee and cocao plantations.
Acridocarpus longifolius, Alstonia boonei, Clerodendrum schweinfurtii, Clerodendrum spendens, Clerodendrum umbellatum, Clerodendrum volubile, Massularia acuminata, Morinda longiflora

Appendix 2

List of plant species occuring in the relevés in the Taï region, with sociological groups of the secondary forest classification and of the rice field classification. Ecological preference for regeneration indicated.

Column 1
List of plant species occuring in the relevés
Column 2
Sociological group in secondary forest (Table 10.1), if no number, species observed only once or twice.
Column 3
Sociological groups in rice fields (Table 11.1), if no number, species observed only once or twice.
Column 4
Means of regeneration :
FS : regeneration in rice fields by seed,
FC : regeneration in rice fields by coppice,
FCS : regeneration in rice fields by coppice and by seed,
R : ruderal, not observed in fields or forest,
S : regeneration in secondary forest, not observed in fields,
P : regeneration in primary forest, not observed in secondary forest nor in fields,
PI : in primary forest on inselbergs,
L : planted.
Column 5
Collection No. deposit herbarium "Vandense", Wageningen.

Families and species	Sec.	Field	Regen.	Collection
Dicotyledons				
ACANTHACEAE				
Asystasia gangetica (L.) T.Anders.		26	FS	AR 343
Asystasia vogeliana Benth.			S	AR 190
Crossandra guineensis Nees			S	
Dicliptera alternans Lindau			S	
Elytraria marginata Vahl		4	FS	AR 136
Elytraria maritima J.K.Morton	IV	11	FS	AR 27
Justitia extensa T.Anders.			S	
Justitia glabra König ex Roxb.			S	
Justitia tenella (Nees) T.Anders.		25	FS	AR 89
Lankesteria brevior C.B.Cl.	V		S	AR 172
Lepidagathis alopecuroides (Vahl) R.Br. ex Griseb.			R	AR 88
Mendoncia combretoides (A.Chev.) Benoist	XXIV		P	AR 537

Mendoncia iodioides (S.Moore) Heine			P	
Nelsonia canescens (Lam.) Spreng.			FS	AR 342
Pandiaka heudelotii (Moq.) Benth.& Hook.f.			R	
Pandiaka involucrata (Moq.) Hook.f.			PI	AR 100
Phaulopsis falcisepala C.B.Cl.	VII	7	FS	AR 36
Pseuderanthemum tunicatum (Afzel.)Milne-Redh.	IV	35	FCS	AR 259
Rhinacanthus virens (Nees) Milne-Redh.	XVII		FC	AR 541
Thunbergia chrysops Hook.			FS	
Whitfieldia colorata C.B.Cl.			S	
Whitfieldia lateritia Hook.	XXVI	23	FC	AR 119

AMARANTACEAE

Alternanthera repens (L.)Link.			FS	
Alternanthera sessilis (L.) R.Dr.ex Roth			R	
Amaranthus viridis L.			R	
Amaranthus spinosus L.			R	
Celosia argentea L.			R	AR 339
Celosia laxa Schum.&Thon.		3	FS	AR 340
Cyathula achyranthoides (H.B.&K.) Moq.		12	FS	AR 144
Cyathula prostrata (L.)Blume		12;35	FS	AR 338

AMPELIDACEAE

Ampelocissus gracilipes Stapf	VII	13	FCS	AR 490
Ampelocissus leonensis (Hook.f.) Planch.	IV	18	FS	
Ampelocissus macrocirrha Gilg.& Brandt			FS	AR 466
Cissus aralioides (Welw.ex Bak.) Planch.	VIII	16	FS	
Cissus diffusiflora (Bak.) Planch.	XVII	16	FCS	AR 130
Cayratia gracilis (Guill.& Perr.) Süsseng.		25	FS	AR 265, 467
Cissus oreophila Gilg & Brandt			FS	
Cissus petiolata Hook.f.		16	FS	
Cissus polyantha Gilg. & Brandt		33	FS	
Cissus producta Afzel.	XIII	16	FCS	AR 337
Cissus vogelii Hook.f.		10	FS	AR 59
Cyphostemma adenopodum (Sprague) Descoin		12	FS	AR 58
Leea guineensis LG.Don	VII	16	FC	AR 336

ANACARDIACEAE

Lannea welwitschii (Hiern)Engl.	XXII		S	
Pseudospondias microcarpa (A.Rich.) Engl.			P	
Trichoscypha arborea (A.Chev.) A.Chev.		24	FC	AR 281, 335
Trichoscypha baldwinii Keay			P	AR 221
Trichoscypha beguei Aubr.& Pellegr.	XXVI		FC	AR 232
Trichoscypha cavalliensis Aubr.& Pellegr.			FC	AR 160
Trichoscypha chevalieri Aubr. & Pellegr.			FC	AR 176
Trichoscypha oba Aubr.& Pellegr.			P	AR 593

ANCISTROCLADACEAE

Ancistrocladus abbreviatus Airy Shaw			FC	AR 209
Ancistrocladus barteri Sc.Elliot			P	AR 268

ANNONACEAE

Anonidium floribundus Pellegr.			P	
Artabotrys insignis Engl.& Diels			P	AR 493
Artabotrys jollyanus Pierre ex Engl.& Diels			P	
Cleistopholis patens (Bent.) Engl.& Diels	IV	21	FS	
Dennettia tripetala Bak.f.			P	AR 334
Enantia polycarpa (DC.) Engl.& Diels	XXVII		FC	
Hexalobus crispiflorus A.Rich.		27	FCS	
Isolona campanulata Engl.& Diels	XIX		FC	AR 348

Isolona dewerei Engl.& Diels			P	AR 695
Monodora brevipes Benth.			FC	
Monodora crispata Engl.& Diels			P	AR 524
Monodora myristica (Gaertn.) Dunal	XX	16	FC	
Monodora tenuifolia Benth.	XVIII	11	FC	AR 743
Neostenanthera gabonensis (Engl.& Diels) Exell			P	AR 347
Pachypodanthium staudtii Engl.& Diels	XXVI		P	AR 546
Piptostigma aubrevillei Ghesq.ex Aubr.			P	AR 554
Piptostigma fugax A.Chev. ex Hutch.& Dalz.			P	
Polyalthia oliveri Engl.	XIV	10	FC	AR 556
Polyceratocarpus parviflorus (Bak.f.) Ghesq.			P	AR 346
Popowia congensis (Engl.& Diels) Engl.& Diels			P	AR 738
Popowia mangenotii Sillans	XXII		P	
Popowia whytei Stapf			P	AR 286
Uvaria afzelii Sc.Elliot	X	13	FC	AR 579
Uvaria baumannii Engl.& Diels			P	
Uvaria ovata (Dunal) A.DC.			FC	
Uvaria anonoides Bak.f.			P	AR 580
Uvariastrum insculptum (Engl.& Diels) Sprague	XVII		P	AR 581
Uvariastrum pierreanum Engl.	XVII		P	AR 582
Uvariodendron mirabile R.E.Fries	XXI		P	AR 583
Uvariopsis guineensis Keay			P	AR 540
Xylopia acutiflora (Dunal) A.Rich.	XXII		FS	AR 585
Xylopia aethiopica (Dunal) A.Rich.	XIV	16	FCS	
Xylopia parviflora (A.Rich.) Benth.	IX		P	
Xylopia quintasii Engl.& Diels	XIV	22	FC	
Xylopia staudtii Engl.& Diels			P	AR 586
Xylopia villosa Chipp	XVII		FC	AR 587

APOCYNACEAE

Alafia barteri Oliv.			P	AR 500
Alstonia boonei De Wild.	XXII		S	AR 502
Aphanostylis leptantha (K.Schum.) Pierre	XXIV	29	FC	
Aphanostylis mannii (Stapf) Pierre	XXVII	27	FC	
Baissea breviloba Stapf			FC	AR 670
Baissea leonensis Benth.			FC	
Baissea zygodioides (K.Schum.)Stapf	IX	17	FCS	AR 4
Callichilia subsessilis (Benth.) Stapf			P	
Clitandra cumulosa Benth.			S	
Dictyophleba leonensis (Stapf) Pichon			P	
Farquharia elliptica Stapf			P	AR 697
Funtumia africana (Benth.) Stapf	XIV	12	FS	AR 701
Funtumia elastica (Preuss) Stapf	VII	15	FCS	AR 536
Hunteria eburnea Pichon	XXV		S	AR 715
Hunteria elliottii (Stapf) Pichon			P	AR 716
Hunteria simii (Stapf) H.Huber	XIX	26	FC	AR 135
Isonema smeathmannii Roem.& Schult.			FC	
Landolphia dulcis (R.Br.ex Sabine) Pichon		21	FC	AR 687
Landolphia hirsuta (Hua) Pichon			P	AR 538
Landolphia membranacea (Stapf) Pichon	XXV		S	AR 688
Landolphia owariensis p.Beauv.	XXI	27	FC	AR 189, 269
Oncicotis pontyi Dubard			FC	AR 671
Pleiocarpa mutica Benth.			P	AR 750
Rauvolfia vomitoria Afzel.	VI	13	FCS	AR 754
Strophanthus barteri Franch.			P	
Strophanthus hispidus DC.			FC	
Strophanthus preussii Engl.& Pax			P	
Strophanthus sarmentosus (L.) O.Ktze.			P	

Tabernaemontana crassa Benth.			P	
Tabernaemontana glandulosa (Stapf) Pichon		14	FC	
ASCLEPIADACEAE				
Cryptolepis sanguinolenta (Lindl.) Schltr.	XVII	14	FS	
Parquetina nigrescens (Afzel.) Bullock	X	13	FCS	
Secamone afzelii (Schultes) K.Schum.	VIII	11	FC	
BALANOPHORACEAE				
Thonningia sanguinea Vahl			P	
BEGONIACEAE				
Begonia macrocarpa Warb.			P	AR 258
BIGNONIACEAE				
Kigelia africana (Lam.) Benth.	V	34	FC	AR 531
Newbouldia laevis (P.Beauv.) Seeman ex Bureau			FC	
Stereospermum acuminatissimum K.Schum.		4	FCS	
BOMBACACEAE				
Bombax brevicuspe Sprague			P	
Bombax buonopozense P.Beauv.			FC	
Ceiba pentandra (L.) Gaertn.	III	15	FS	
Hura crepitans L.			L	
BORAGINACEAE				
Cordia platythyrsa Bak.	XXII	25	FCS	
Ehretia trachyphylla C.H.Wright			FC	
Heliotropium indicum L.			R	AR 471
BURSERACEAE				
Canarium schweinfurthii Engl.	XI	14	FCS	
Dacryodes klaineana (Pierre) H.J.Lam	XXVI		P	
CAESALPINIACEAE				
Afzelia bella Harms			P	AR 498
Amphimas pterocarpoides Harms	XVIII		FC	AR 491
Anthonotha crassifolia (Baill.) J.Léonard			FS	
Anthonotha fragrans (Bak.) Exell & Hillcoat	XVII	21	FC	AR 504
Anthonotha macrophylla P.Beauv.	IX	17	FC	AR 510
Berlinia bracteosa Benth.			P	AR 674
Berlinia occidentalis Keay			P	
Berlinia tomentella Keay			S	
Bussea occidentalis Hutch.	XIV	16	FCS	AR 745
Caesalpinia bonduc (L.) Roxb.			P	
Cassia hirsuta L.			R	
Cassia mimusoïdes L.			R	
Cassia obtusifolia L.			R	
Cassia occidentalis L.			L	
Chidlowia sanguinea Hoyle	XXII	21	FC	AR 623
Crudia klainei Pierre ex De Wild.			P	
Cynometra ananta Hutch.& Dalz.			P	AR 709
Daniellia thurifera Pellegr.			P	
Detarium senegalense J.F.Gmel.			PI	AR 454
Dialium aubrevillei Pellegr.	XIV	16	FCS	AR 280
Dialium dinklagei Harms			P	AR 645
Distemonanthus benthamianus Baill.	XVII		FC	AR 535
Erythrophleum ivorense A.Chev.			P	AR 732
Gilbertiodendron ivorense (A.Chev.) J.Léonard			P	AR 231
Gilbertiodendron limba (Sc.Elliot) J.Léonard			P	AR 399

Gilbertiodendron preussii (Harms) J.Léonard	XXVI		FCS	
Gilbertiodendron splendidum (A.Chev.ex Hutch.& Dalz.) J.léonard			P	
Griffonia simplicifolia (Vahl ex DC.) Baill.	XIV	8	FC	
Guibourtia ehie (A.Chev.) J.Léonard		27	FS	
Hymenostegia afzelii (Oliv.) Harms	IX	19	FC	
Julbernardia seretii (De Wild.) Troupîn			FC	
Mezoneuron benthamianum Baill.	VI	11	FCS	
Pellegriniodendron diphyllum (Harms) J.Léonard			P	
Plagiosiphon emarginatus (Hutch.& Dalz.) J.Léonard			FC	
CAPPARIDACEAE				
Buchholzia coriacea Engl.			FC	AR 676
Cleome ciliata Schum.& Thon.			R	AR 478
Euadenia eminens Hook.f.		34	FC	
Euadenia trifoliolata (K.Schum.& Thon.) Oliv.			FC	
Gynandropsis gynandra (L.) Briq.			R	
Ritchiea fragariodora Gilg			P	AR 542
Ritchiea longipedicellata Gilg	XXVII		S	
CARICACEAE				
Carica papya L.		11	FS	
CELASTRACEAE				
Bequaertia mucronata (Exell) R.Wilczek	XXII		FC	AR 673
Cuervea macrophylla (Vahl) R. Wilczek ex N.Hallé	XXVII		FC	AR 639
Hippocratea africana (Willd.) Loes.ex Engl.			P	
Hippocratea myriantha Oliv.			P	
Hippocratea pallens Planch. ex Oliv.	XVII	10	FC	
Loeseneriella africana (Willd.) R.Wilczek ex N.Hallé			FC	
Loeseneriella iotricha (Loes.) N.Hallé	XI	10	FC	
Reissantia astericantha N.Hallé			P	
Salacia barterita N.Hallé			P	
Salacia calumna N.Hallé		24	FC	AR 597
Salacia camerunensis Loes.	VIII		FC	
Salacia cornifolia Hook.f.			FC	AR 598
Salacia debilis (Don) Walpers	IX	12	FC	AR 599
Salacia erecta (Don) Walpers	XVII	15	FC	AR 307
Salacia lateritia N.Hallé	XXVI		S	AR 112, 202
Salacia leonensis Hutch.& Moss.	XXVI		S	AR 224, 293
Salacia leptoclada Tul.	XXVII		S	AR 600
Salacia miegei N.Hallé	XXVI	17	FC	
Salacia nitida (Benth.) N.E.Brown			P	AR 602, 749
Salacia pallescens Oliv.			P	
Salacia pyriformis (Sabine) Steud.	XVII	18	FC	AR 604
Salacia senegalensis (Lam.) DC.			FC	AR 603
Salacia staudtiana Loes.			FC	
Salacia uregaensis R.Wilczek			P	AR 200
Salacia zenkeri Loes.	XXI		S	AR 605
Salacighia letestuana (Pellegr.) Blakelock			P	AR 601
Salacighia linderi (Loes.ex Harms) Blakelock			FC	
Simirestis dewildemaniana N.Hallé			P	AR 206
Tristemonthus nigrisilvae N.Hallé			P	AR 595
CHAILLETIACEAE				
Dichapetalum angolense Chodat.			FC	
Dichapetalum cymulosum (Oliv.) Engl.			P	
Dichapetalum crassifolium Cheb.			P	

Dichapetalum heudelotii (Planch.ex Oliv.) Baill.	XXVI		S	
Dichapetalum pallidum (Oliv.) Engl.	XXIV	16	FC	AR 127
Dichapetalum toxicarium (G.Don) Baill.	XX	21	FC	AR 649
Dichapetalum contractum			P	AR 646
Dichapetalum dictyospermum			P	AR 647
Dichapetalum parvifolium	I		S	AR 648
COMBRETACEAE				
Combretum aphanopetalum Engl.& Diels	XVII		FC	AR 539
Combretum bipindense Engl.& Diels			P	AR 630
Combretum comosum G.Don		28	FC	AR 631
Combretum dolichopetalum Engl.& Diels	XIV		FC	
Combretum fuscum Planch.ex Benth.			P	AR 667
Combretum homalioides Hutch.& Dalz.		11	FC	AR 633
Combretum grandiflorum G.Don	V	13	FC	AR 632
Combretum paniculatum Vent.	X	9	FC	
Combretum platypterum (Welw.) Hutch.& Dalz.			FC	
Combretum racemosum P.Beauv.			P	
Strephonema pseudocola A.Chev.			P	
Terminalia ivorensis A.Chev.		9	FS	
Terminalia superba Engl.& Diels	V	15	FS	
COMPOSITAE				
Acanthospermum hispidum DC.			R	
Adenostemma perrottetii DC.		33	FS	AR 275
Ageratum conyzoides L.		2;3	FS	AR 458
Aspilia africana (Pers.) C.D.Adams		5	FS	AR 149
Aspilia rudis Oliv.& Hiern			FS	AR 457
Bidens pilosa L.		2	FS	AR 76
Crassocephalum crepidioides (Benth.) S.Moore		23	FS	AR 456
Eclipta prostrata (L.) L.			R	AR 455
Eleutheranthera ruderalis (Sw.) Sch.			F	
Erigeron floribundus (H.B.&K.) Sch.Bip.		3;13	FS	AR 74
Eupatorium odoratum L.		6;13	FCS	AR 66
Eupatorium microstemon Cass.		34	FS	AR 387
Melanthera scandens (Schum.& Thon.) Roberty			FS	AR 64
Microglossa pyrifolia (Lam.) O.Ktze.		12	FS	AR 54, 388
Mikania cordata (Burm.f.) B.L.Robinson		15	FS	AR 148
Struchium sparganophora (L.) O.Ktze.			R	AR 389
Synedrella nodiflora Gaertn.		2	FS	AR 390
Vernonia cinerea (L.) Less.			FS	AR 78
Vernonia conferta Benth.	V		FS	
CONNARACEAE				
Agelaea obliqua (P.Beauv.) Baill.	XIV	27	FC	AR 744
Agelaea pseudobliqua Schellenb.	XIV		FC	
Agelea trifolia (Lam.) Gilg	XIV	15	FC	
Byrsocarpus coccineus Schum.& Thon.	X	15	FS	AR 677
Castanola paradoxa (Gilg) Schellenb.ex Hutch.& Dalz.	XXIV		FC	AR 620
Cnestis corniculata Lam.		24	FC	AR 302
Cnestis dinklagei Schellenb.			FC	
Cnestis ferruginea DC.	XII	9	FC	AR 344
Cnestis macrantha Baill.			FC	
Connarus africanus Lam.			P	AR 634
Manotes expansa Soland.ex Planch.	XXVII		S	AR 680
Manotes longiflora Bak.	IV		FC	
Santaloides afzelii (R.Br.ex Planch.) Schellenb.	XXIV		S	
Spiropetalum heterophyllum (Bak.) Gilg	XXI		S	AR 534

Spiropetalum reynoldsii (Stapf) Schellenb.			FC	AR 596
Spiropetalum triplinerve Stapf			P	AR 607
CONVOLVULACEAE				
Bonamia thunbergiana (Roem.& Schult.) F.N.Williams		31	FS	AR 274
Calycobolus africanus (G.DON) Heine	XX	26	FC	
Calycobolus heudelotii (Bak.ex Oliv.) Heine	XXII		FC	AR 196
Calycobolus parviflorus (Mangenot) Heine			P	AR 664
Ipomoea eriocarpa R.Br.			R	
Ipomoea involucrata P.Beav.	V	14	FS	AR 69
Ipomoea mauritiana Jacq.		8	FC	AR 314
Ipomoea triloba L.			R	AR 465
Neuropeltis acuminata Benth.	XIX	16	FC	AR 566
Neuropeltis prevosteoides Mangenot	XXII	16	FC	AR 567
Neuropeltis velutina Hallier f.	XII	18	FCS	
Stictocardia beraviensis (Vatke) Hallier			FC	
CRASSULACEAE				
Bryophyllum pinnatum (Lam.) Oken			S	
CUCURBITACEAE				
Adenopus breviflorus Benth.			FS	AR 255
Adenopus guineensis (G.Don) Exell		26	FS	AR 211
Coccinia barteri (Hook.f.) Keay		12	FS	
Dimorphochlamys mannii Hook.f.		30	FS	AR 142
Lagenaria siceraria (Molina) Standl.			FS	AR 310
Melothria capillacea (Schum.& Thon.) Cogn.			FS	AR 313
Momordica charantia L.		9	FS	AR 311
Momordica cissoides Planch.ex Benth.		32	FS	AR 164
Momordica foetida Schum.& Thon.		9	FS	AR 312
Physedra eglandulosa (Hook.fW.) Hutch.& Dalz.		19	FS	AR 270
Raphidiocystis caillei Hutch & Dalz.		19	FS	AR 153
DILLENIACEAE				
Tetracera affinis Hutch.			P	AR 308
Tetracera alnifolia Willd.	XV	15	FC	AR 309
Tetracera potatoria Afzel.ex G.Don	XII	7	FC	AR 590
DIONCOPHYLLACEAE				
Triphyophyllum peltatum (Hutch.& Dalz.) Airy Shaw	XXIV	22	FC	AR 588
EBENACEAE				
Diospyros canaliculata De Wild.	XXV		FC	AR 217
Diospyros chevalieri De Wild.	XXI	20	FC	AR 103, 373
Diospyros mannii Hiern	XXV	28	FC	AR 374
Diospyros sanza-minika A.Chev.	XXIV	29	FC	AR 375
Diospyros soubreana F.White	XXI	26	FC	AR 229, 376
Diospyros vignei F.White		30	FC	AR 162
Diospyros viridicans Hiern			P	
ERYTHROXYLACEAE				
Erythroxylum mannii Oliv.			S	
EUPHORBIACEAE				
Alchornea cordifolia (Schum.& Thon.) Muell.Arg.	VI	14	FCS	AR 372
Alchornea floribunda Muell.Arg.			P	AR 501
Antidesma membranaceum Muell.Arg.		34	FC	
Antidesma oblonga (Hutch.) Keay			P	AR 261
Bridelia atroviridis Muell.Arg.			P	AR 675
Bridelia grandis Pierre ex Hutch.	V	9	FS	

Bridelia micrantha (Hochst.) Baill.	IV	19	FS	
Claoxylon hexandrum Muell.Arg.	XIX		S	AR 371
Cleistanthus polystachyus Hook.f. ex Planch.			P	AR 666
Croton hirtus L'Hérit.			FS	AR 370
Croton macrostachyus Hochst.ex Del.		22	FS	
Crotonogyne chevalieri (Beille) Keay			P	AR 638
Discoglypremna caloneura (Pax) Prain	IV	21	FS	
Drypetes afzelii (Pax) Hutch.		28	FC	
Drypetes aubrevillei Léandri			FC	
Drypetes aylmeri Hutch.& Dalz.			P	
Drypetes chevalieri Beille	XXVII	27	FC	
Drypetes gilgiana (Pax) Pax & K.Hoffm.	XXIV		S	AR 188
Drypetes ivorensis Hutch.& Dalz.	XXVI		S	AR 654
Drypetes klainei Pierre ex Pax			P	
Drypetes pellegrini Léandri	XI	26	FC	
Elaeophorbia grandifolia (Haw.) Croizat			P	AR 655
Erythrococca anomala (Juss.ex Poir.) Previn	VIII	11	FC	AR 369
Euphorbia hirta L.			FS	AR 368
Euphorbia prostrata Ait.		4	FS	AR 67
Grossera vignei Hoyle			R	AR 367
Jatropha gossypiifolia L.		10	FS	
Macaranga barteri Muell.Arg.	IV		FS	
Macaranga beillei Prain			P	AR 678
Macaranga heterophylla (Muell.Arg.) Muell.Arg.	XXV	33	FC	AR 366
Macaranga heudelotii Baill.	I	31	FS	AR 179
Macaranga hurifolia Beille	V	16	FS	AR 178
Maesobotrya barteri (Baill.) Hutch.	XIX	16	FC	AR 518
Mallotus oppositifolius (Geisel.) Muell.Arg.			FC	AR 679
Manihot esculenta Crantz		10	FS	
Manniophyton fulvum Muell.Arg.	XXI	20	FC	AR 358
Mareya micrantha (Benth.) Muell.Arg.	XI	15	FC	AR 379
Martretia quadricornis Beille			P	AR 297
Microdesmis puberula Hook.f. ex Planch.	XX	15	FCS	
Mildbraedia paniculata Pax	XX	10	FCS	AR 380
Necepsia afzelii Prain			P	AR 565
Oldfieldia africana Benth.& Hook.f.	IV		S	AR 572
Phyllanthus amarus Schum.& Thon.		11	FS	AR 248
Phyllanthus discoideus (Baill.) Muell.Arg.	XVIII	8	FCS	
Phyllanthus muellerianus (O.Ktze.) Exell	IV	12	FCS	
Phyllanthus niruroides Muell.Arg.			R	AR 291
Phyllanthus riticulatus Poir.			FS	
Phyllanthus urinaria L.			R	AR 141
Pycnocoma macrophylla Benth.	XIV		S	AR 251, 378
Ricinodendron heudelotii (Baill.) Pierre ex Pax	IV	16	FS	
Sapium aubrevillei Léandri			P	AR 606
Spondianthus preussii Eng.		16	FC	
Tetrorchidium didymostemon (Baill.) Pax & K.Hoffm.	XV	18	FCS	AR 41, 377
Thecacoris stenopetala (Muell.Arg.) Muell.Arg.			P	AR 591
Tragia benthami Bak.	VIII	11	FS	AR 31
Tragia tenuifolia Benth.		25	FS	AR 277
Tragia vogelii Keay			FS	
Uapaca esculenta A.Chev. ex Aubr.& Léandri	XV		S	AR 530
Uapaca guineensis Muell.Arg.	XIV		S	AR 578
Uapaca heudelotii Baill.	XI	29	FC	
Uapaca paludosa Aubr.& Léandri			P	
FLACOURTIACEAE				
Caloncoba brevipes (Stapf) Gilg	XXV	21	FS	AR 138, 416

Oncoba spinosa Forsk.			P	AR 415, 514
Scottellia chevalieri Chipp			P	AR 527
GUTTIFEREAE				
Allanblackia floribunda Oliv.			P	
Garcinia afzelii Engl.			P	AR 702
Garcinia gnetoides Hutch.& Dalz.	XXVI		S	
Garcinia kola Heckel			P	AR 703
Garcinia mannii Oliv.			P	
Garcinia ovalifolia Oliv.			P	AR 704
Garcinia polyantha Oliv.			P	AR 705
Garcinia smeathmannii (Planch.& Triana) Oliv.			P	
Mammea africana Sabine			P	
Pentadesma butyracea Sabine			P	
Symphonia globulifera L.F.			FS	AR 614
HOPLESTIGMATACEAE				
Hoplestigma klaineanum Pierre			P	AR 529
HUMIRIACEAE				
Sacoglottis gabonensis (Baill.) Urb.	III		P	AR 520
HYPERICACEAE				
Harungana madagascariensis Lam.ex Poir.	II	15;35	FS	AR 40
Vismia guineensis (L.) Choisy	IV	12	FS	
ICACINACEAE				
Chlamydocarya macrocarpa (A.Chev.) Hutch.& Dalz.			S	AR 624
Chlamydocarya thomsoniana Baill.		21	FS	AR 237, 333
Desmostachys vogelii (Miers) Stapf			P	AR 642
Icacina mannii Oliv.	XVII	16	FC	
Iodes africana Welw.ex Oliv.			P	
Iodes liberica Stapf	XXI		FC	AR 205, 442
Leptaulis daphnoides Benth.			P	
Polycephalium capitatum (Baill.) Keay		27	FS	
Pyrenacantha mangenotiana Miège			FC	
Pyrenacantha vogeliana Baill.	XIV	13	FC	AR 8, 246
Rhaphiostylis beninensis (Hook.f.ex Planch.) Planch.ex Benth.	XXI	26	FC	
Rhaphiostylis cordifolia Hutch.& Dalz.		27	FC	AR 249
IRVINGIACEAE				
Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill.			P	
Klainedoxa gabonensis Pierre ex Engl.			FC	AR 686
IXONANTHACEAE				
Ochthocosmus africanus Hook.f.			P	
LABIATAE				
Achyrospermum oblongifolium Bak.			S	AR 494
Hoslundia opposita Vahl	XVII	9	FCS	
Hyptis lanceolata Poir.			R	
Hyptis suaveolens Poit.			R	AR 403
Leonotis nepetifolia (L.) Ait f.			R	AR 404
Ocimum basilicum L.			R	
Ocimum gratissimum L.			R	AR 405
Solenostemon monostachyus P.Beauv.			S	AR 83
LAURACEAE				
Beilschmiedia mannii (Meisn.) Benth.& Hook.f.	XXV	16	FC	AR 672

LECYTHIDACEAE				
Combretodendron macrocarpum (P.Beauv.) Keay	XVII		P	AR 629
Napoleona leonensis Hutch.& Dalz.	XXI	18	FC	AR 563
Napoleona parviflora Bak.f.			P	
Napoleona vogelii Hook.& Planch.			P	AR 564
LINACEAE				
Hugonia afzelii R.Br. ex Planch.	IV	27	FC	AR 400
Hugonia macrophylla Oliv.			P	AR 712
Hugonia planchonii Hook.f.	X	24	FC	AR 128
Hugonia platysepala Welw.ex Oliv.	XVI		S	AR 713
Hugonia rufopilis A.Chev. ex Hutch.& Dalz.	XX		S	AR 714
LOGANIACEAE				
Anthocleista nobilis G.Don	II	16	FS	
Anthocleista vogelii Planch.	II		S	
Spigelia anthelmia L.		2	FS	AR 71
Strychnos aculeata Solered.	XX	27	FC	
Strychnos barteri Solered.			P	
Strychnos campicola Gilg & Leeuwenberg			P	AR 396
Strychnos camptoneura Gilg & Busse			P	AR 611
Strychnos cumidora Leeuwenberg	XXVII		S	AR 726
Strychnos densiflora Baill.			P	
Strychnos dinklagei Gilg			P	AR 397
Strychnos floribunda Gilg			P	AR 733
Strychnos icaja Baill.			P	
Strychnos longicaudata Gilg			P	
Strychnos millepunctata Leeuwenberg			P	AR 398
Strychnos ngouniensis Pellegr.			P	AR 613
Strychnos splendens Gilg			P	
Strychnos usambarensis Gilg		20	FC	AR 734
MALPIGHIACEAE				
Acridocarpus chevalieri Spraque			P	AR 727
Acridocarpus longifolius (G.Don) Hook.f.	XXIV	21	FC	AR 395
Acridocarpus smeathmannii (DC.) Guill.& Perr.			P	
MALVACEAE				
Hibiscus asper Hook.f.			PI	AR 80
Hibiscus surattensis L.	I	31	FS	AR 181
Malvastrum coromandelianum (L.) Garcke			R	AR 412
Sida acuta Burm.f.			FS	AR 414
Sida corymbosa R.E. Fries			R	
Sida linifolia Juss.ex Cav.			R	AR 79, 93
Sida rhombifolia L.			FS	AR 413
Sida stipulata Cav.			R	AR 287
Sida urens L.			R	AR 94
Urena lobata L.		10	FS	AR 82
MEDUSANDRACEAE				
Soyauxia floribunda Hutch.	XXVI	21	FC	AR 608
MELASTOMACEAE				
Dinophora spenneroides Benth.			R	AR 345
Dissotis glauca Keay			PI	AR 650
Dissotis rotundifolia (Sm.) Triana		10	FS	
Memecylon barteri Hook.f.			P	
Memecylon cinnamomoides G.Don	XXVII		P	AR 682

Memecylon golaense Bak.f.			P	AR 748
Memecylon guineense Keay	XXV		FC	AR 729
Memecylon lateriflorum (G.Don) Brem.	XXII		FC	AR 683
Memecylon membranifolium Hook.f.			P	
Memecylon memecyloides (Benth.) Exell			P	AR 684
Tristemma hirtum P.Beauv.			R	AR 469
Tristemma incompletum R.Br.			FS	AR 468
Tristemma coronatum Benth.		18	FS	AR 38
MELIACEAE				
Carapa procera DC.			P	
Entandrophragma angolense (Welw.) C.DC.			P	
Entandrophragma candollei Harms			P	AR 657
Entandrophragma cylindricum (Sprague) Sprague	XVII		P	AR 658
Entandrophragma utile (Dawe & Sprague) Sprague			P	
Guarea cedrata (A.Chev.) Pellegr.			FC	AR 706
Guarea leonensis Hutch.& Dalz.			P	AR 707
Guarea thompsonii Sprague & Hutch.			P	AR 708
Khaya anthotheca (Welw.) C.DC.			P	
Lovoa trichilioides Harms			FC	AR 692, 693
Trichilia heudelotii Planch. ex Oliv.	VI	14	FCS	AR 522
Trichilia megalantha Harms	VI		P	
Trichilia prieureana A.Juss.			FC	
MENISPERMACEAE				
Chasmanthera dependens Hochst.			S	
Dioscoreophyllum cumminsii (Stapf) Diels	VIII	12	FCS	AR 417
Dioscoreophyllum volkensii Engl.		26	FS	AR 222
Epinetrum cordifolium Mangenot & Miège		4	FC	
Epinetrum scandens (Mangenot & Miège) Form.	VII	24	FC	AR 659
Kolobopetalum auriculatum Engl.			S	
Kolobopetalum chevalieri (Hutch.& Dalz.) Troupin	XIV	16	FCS	AR 26
Kolobopetalum leonense Hutch.& Dalz.	XXVI	22	FC	AR 419
Kolobopetalum ovatum Stapf			P	AR 108, 418
Penianthus zenkeri (Engl.) Diels			P	AR 193
Rhigiocarya peltata Miège			FC	AR 271
Rhigiocarya racemifera Miers.	XXII	17	FS	AR 159
Spenocentrum jollyanum Pierre			P	
Stephania dinklagei (Engl.) Diels	XVII		FS	AR 420
Syrrheonema fasciculatum Miers.			P	AR 746
Tiliacora dinklagei Engl.	XIV	18	FC	
Triclisia dictyophylla Diels	XVII		S	
Triclisia gilletii (De Wild.) Staner			FC	
Triclisia louisii Troupin			S	
Triclisia macrophylla Oliv.			P	AR 594
MIMOSACEAE				
Acacia ataxacantha DC.			S	
Acacia pennata (L.) Willd.	XIII	14	FC	
Albizia adianthifolia (Schum.) W.F.Wight	XVII	11	FCS	
Albizia malacophylla (A.Rich.) Walp.			FC	
Albizia zygia (DC.) J.F.Macbr.	IX	7	FCS	
Aubrevillea kerstingii (Harms) Pellegr.			P	
Aubrevillea platycarpa Pellegr.	XIV		P	
Calpocalyx aubrevillei Pellegr.		28	FC	AR 421
Calpocalyx brevibracteatus Harms	XXVI	25	FCS	AR 532
Entada scelerata A.Chev.		12	FC	
Mimosa pudica L.		1	FS	AR 422

Newtonia aubrevillei (Pellegr.) Keay			P	AR 568
Newtonia duparquetiana (Baill.) Keay	XXVI		P	AR 569
Parkia bicolor A.Chev.	IV	15	FS	
Pentaclethra macrophylla Benth.			P	
Piptadeniastrum africanum (Hook.f.) Brenan	XII	12	FCS	
Samanea dinklagei (Harms) Keay	XV		FC	
Xylia evansii Hutch.			S	
MORACEAE				
Antiaris welwitschii Engl.	XI	17	FCS	
Chlorophora excelsa (Welw.) Benth.		15	FS	
Dorstenia smythei Sprague	XXVI		S	AR 187
Ficus capensis Thunb.	VI	13	FCS	
Ficus djalonensis A.Chev.			FC	
Ficus exasperata Vahl		9	FS	
Ficus goliath A.Chev.			P	
Ficus kamerunensis Warb.ex Mildbr.& Burret			P	
Ficus lyrata Warb.			P	
Ficus mucoso Welw.ex Ficalho			S	
Ficus ottoniifolia (Miq.) Miq.			S	
Ficus ovata Vahl			P	
Ficus vallis-choudae Del.			FC	
Ficus vogeliana (Miq.) Miq.		27	FC	AR 516
Ficus vogelii (Miq.) Miq.		12	FC	AR 698
Musanga cecropioides R.Br.	XV	18	FCS	
Myrianthus artboreus P.Beauv.	XII	12	FC	
Myrianthus libericus Rendle	XXVII	12	FC	
Myrianthus serratus (Trécul.) Benth.& Hook.f.			S	
Neosloetiopsis kamerunensis Engl.		29	FC	
Treculia africana Decne.			P	AR 592
MYRISTICACEAE				
Pycnanthus angolensis (Welw.)Warb.	XXII	17	FS	
MYRTACEAE				
Eugenia calophylloides DC.			P	AR 661
Eugenia miegeana Aké Assi			P	
Eugenia whytei Sprague			P	AR 662
Syzygium rowlandii Sprague	VIII		S	
NYCTAGINACEAE				
Boerhavia diffusa L.		4	FS	
OCHNACEAE				
Lophira alata Banks ex Gaertn.			P	
Ochna membranacea Oliv.			P	AR 424
Ochna schweinfurthiana F.Hoffm.			P	AR 571
Ouratea affinis (Hook.f.) Engl.			P	AR 573
Ouratea duparquetiana (Baill.) Gilg			P	
Ouratea flava (Schum.)&Thon.) Hutch.& Dalz.			P	AR 574
Ouratea myrioneura Gilg	I		FC	AR 519
Ouratea reticulata (P.Beauv.) Engl.ex Diels	XV	24	FC	AR 575
Ouratea schoenleiniana (Klotzsch) Gilg	XXII	17	FC	AR 25, 107
Ouratea subcordata (Stapf) Engl.	XI		S	AR 122
Ouratea vogelii (Hook.f.) Engl.ex Gilg			FC	
OCKTONEMATACEAE				
Ocktonema borealis Hutch.& Dalz.	XXIII		S	

OENOTHERACEAE				
Jussiaea abyssinica (A.Rich.) Dandy & Brenan			PI	AR 95
OLACACEAE				
Coula edulis Baill.	XXI	16	FC	AR 668
Heisteria parvifolia Sm.		17	FC	AR 106
Ongokea gore (Hua) Pierre			P	
Ptychopetalum anceps Oliv.	XXVII	18	FC	AR 104, 355
Ptychopetalum petiolatum Oliv.	XXVII		FC	AR 105
Strombosia glaucescens Engl.	XX	18	FC	
OLEACEAE				
Jasminium pauciflorum Benth.	XVII		FC	AR 612
Linociera mildbreadii Gilg & Schnell.			P	AR 691
PANDACEAE				
Panda oleosa Pierre			P	AR 549
PAPILIONACEAE				
Abrus precatorius L.		7	FS	
Angylocalyx oligophyllus (Bak.) Bak.f.			P	
Baphia bancoensis Aubrév.	XIV	8	FC	
Baphia nitida Lodd.	XXI	16	FC	
Baphia polygalacea (Hook.f.) Bak.	XV	24	FC	
Baphiastrum confusum (Hutch.&Dalz.) Pellegr.			P	
Calopogonium mucunoides Desv.		4	FS	AR 240
Canavalia rosea (Sw.) DC.			S	
Centrosema pubescens Benth.	X	7	FS	AR 51
Centrosema plumieri (Turp.) Benth.		4	FS	AR 134
Clitoria ternatea L.			PI	AR 87
Crotalaria mucronata Desv.			L	AR 361
Dalbergia afzeliana G.Don			FC	
Dalbergia albiflora A.Chev.ex Hutch.& Dalz.	V		FC	
Dalbergia heudelotii Stapf	XVII	16	FC	
Dalbergia oblongifolia G.Don			FC	AR 533
Dalbergia saxatilis			FC	AR 360
Desmodium adscendens (Sw.) DC.	XI	9	FS	AR 6
Desmodium salicifolium (Poir.) DC.			FS	AR 3
Desmodium velutinum (Willd.) DC.		7	FS	AR 15, 359
Dioclea reflexa Hook.f.	V	14	FC	AR 180
Erythrina vogelii Hook.f.			S	
Leptoderris cyclocarpa Dunn	XVII		FC	
Leptoderris fasciculata (Benth.) Dunn		20	FC	AR 690
Leptoderris miegei Aké Assi & Mangenot	XIV	11	FC	AR 725
Leptoderris trifoliolata Hepper			FC	
Millettia chrysophylla Dunn	XXII	18	FC	
Millettia lane-poolei Dunk			S	
Millettia rhodantha Baill.	XIV		FC	AR 685
Millettia zechiana Harms	X	2	FC	AR 508
Mucuna flagellipes T.Vogel ex Hook.f.	XI		S	AR 278, 427
Ostryderris gabonica (Baill.) Dunn			FC	
Ostryderris leucobotrya Dunn	XVI		S	AR 506
Platysepalum hirsutum (Dunn) Hepper	XIX	17	FC	
Pueraria phaseoloides (Roxb.) Benth.		10	FS	
Tephrosia vogelii Hook.f.			L	AR 428
Vigna gracilis (Guill.& Perr.) Hook.f.			FS	AR 96
Zornia glochidiata Reichb.			R	AR 429

PASSIFLORACEAE				
Adenia cissampeliodes (Planch.ex BenthW.) Harms	V	16	FCS	AR 34, 430
Adenia dinklagei Hutch.& Dalz.		15	FS	
Adenia gracilis Harms	VII	19	FS	
Adenia lobata (Jacq.) Engl.	III	15	FS	AR 283
Adenia mannii (Mast) Engl.			S	
Adenia tenuispira (Stapf) Engl.			PI	AR 488
Androsiphonia adenostegia Stapf	XXVII		P	AR 503
Crossostemma laurifolium Planch.ex Benth.			S	AR 637
Passiflora foetida L.			R	AR 431
Smeathmannia pubescens Soland.ex R.Br.	XVII		P	AR 432
PEDALIACEAE				
Sesamum radiatum Schum.& Thon.			R	
PIPERACEAE				
Peperomia pellucida (L.) H.B.&K.			R	AR 433
Piper guineense Schum.& Thon.	XIV	18	FC	
Piper umbellatum L.	II	15	FS	AR 16
POLYGALACEAE				
Carpolobia lutea G.Don	XVIII		S	AR 263, 434
PORTULACEAE				
Portulaca oleracea L.			R	
Talinum triangulare (Jacq.) Willd.			L	AR 425
RANUNCULACEAE				
Clematis simensis Fres.			FC	
RHAMNACEAE				
Gouania longipetala Hemsl.		24	FCS	AR 61
Lasiodiscus fasciculiflorus Engl.		18	FC	AR 298
Maesopsis eminii Engl.	XIV	29	FC	
Ventilago africana Exell	XXII		FC	
RHIZOPHORACEAE				
Anopyxis klaineana (Pierre) Engl.	XVII		FC	AR 723
Cassipourea afzelii (Oliv.) Alston			P	AR 665
Cassipourea barteri (Hook.f.) N.E.Br.			P	AR 619
Cassipourea congensis R.Br.ex DC.			P	AR 751
ROSACEAE				
Acioa barteri (Hook.f.exOliv.) Engl.			P	AR 494
Afrolicania elaeosperma Mildbr.			P	AR 497
Parinari aubrevillei Pellegr.	XXVI		S	
Parinari congensis F.Didr.			P	
Parinari excelsa Sabine	IV	26	FS	
Parinari glabra Oliv.			P	AR 550
RUBIACEAE				
Aidia genipiflora (DC.) Dandy	XVII		S	AR 499
Atractogyne gabonii Pierre			P	AR 505
Aulacocalyx jasminiflora Hook.f.			P	
Bertiera bracteolata Hiern	XV	14	FCS	AR 7, 20
Bertiera breviflora Hiern	IV		S	AR 426
Bertiera racemosa (G.Don) K.Schum.	XVI	15	FS	AR 35
Borreria intricans Hepper		9	FS	AR 150
Borreria latifolia (Aubr.) K.Schum.		5	FS	

Borreria macrantha Hepper			FS	AR 18
Borreria ocymoides (Burm.f.) DC.		3	FS	AR 411
Borreria ramisparsa DC.			R	AR 410
Borreria scabra (Schum.éThon.) K.Schum.			FS	AR 45
Borreria verticillata (L.) G.F.W.Mey.		5	FS	AR 409
Canthium cornelia Cham.& Schlecht.			P	
Canthium hispidum Benth.	XVIII		S	
Canthium horizontale (Schum.&Thon.) Hiern			P	AR 616
Canthium multiflorum (Schum.&Thon.) Hiern			FC	AR 617
Canthium rubens Hiern	XXVI		FC	AR 509
Canthium setosum Hiern			P	AR 618
Cephaelis abouabouensis Schnell			FC	
Cephaelis castaneo-pilosa Aké Assi	XI		FC	AR 621
Cephaelis mangenotii Aké Assi	XI		FC	
Cephaelis peduncularis Salisb.	II	10	FC	AR 19, 75
Cephaelis schnellii Aké Assi			P	
Cephaelis yapoensis (Schnell) Schnell	XVII	18	FC	AR 92
Chassalia afzelii (Hiern) K.Schum.		27	FC	AR 325
Chassalia corallifera (A.Chev.ex De Wild.) Hepper	XVII	3	FC	AR 622
Chassalia kolly (Schum.) Hepper			P	AR 223
Chassalia laxiflora Benth.		16	FC	AR 324
Chassalia subherbacea (Hiern) Hepper		15	FC	AR 615
Coffea afzelii Hiern			P	
Coffea ebracteolata (Hiern) Brenan	XXVII		S	AR 227
Coffea humilis A.Chev.			P	AR 627
Coffea liberica Bull ex Hiern	XVII		S	AR 225
Coffea stenophylla G.Don			P	
Corynanthe pachyceras K.Schum.	XIV	12	FC	AR 636
Craterispermum caudatum Hutch.	XXIII	27	FC	AR 124
Cuviera acutiflora DC.	XXVI	21	FC	
Cuviera canescens			P	AR 640
Cuviera nigrescens (Sc.Elliot ex Oliv.) Wernham	XVIII	29	FC	
Diodia rubricosa Hiern		2	FS	AR 357
Diodia serrulata (P.Beauv.) G.Tayl.			R	AR 84
Euclinia longiflora Salisb.			P	AR 525
Gaertnera cooperi Hutch.& M.B.Moss			FC	
Gaertnera occidentalis Benth.			P	
Geophila afzelii Hiern	XIV	21	FC	AR 213
Geophila hirsuta Benth.	XXI	27	FC	AR 77
Geophila neurodictyon (K.Schum.) Hepper	XXII			
Geophila obvallata (Schum.) F.Didr.	XX	15	FCS	
Heinsia crinita (Afzel.) G.Tayl.	XXV	18	FC	AR 99, 174
Hutchinsonia barbata Robyns			FC	AR 717
Ixora aggregata Hutch.			P	AR 326
Ixora laxiflora Sm.			FC	AR 696
Ixora nimbana Schnell			P	
Lasianthus batangensis K.Schum.			P	
Leptactina densiflora Hook.f.	XXII		S	AR 689
Massularia acuminata (G.Don) Bullock ex Hoyle	XXI	17	FC	AR 446
Mitracarpus scaber Zucc.			R	AR 449
Mitracarpus villosum Cham.& Schlecht.			R	AR 450
Mitragyna ciliata Aubr.& Pellegr.		33	FCS	
Morinda longiflora G.Don		20	FC	AR 451
Mussaenda afzelii G.Don	I	30	FS	AR 126, 448
Mussaenda chippii Wernham		18	FS	AR 175
Mussaenda elegans Schum.& Thon.		18	FS	AR 257
Mussaenda erythrophylla Schum.& Thon.		23	FS	AR 139
Mussaenda grandiflora Benth.		20	FS	AR 167

Mussaenda isertiana DC.			FS	AR 288
Mussaenda nivea A.Chev.ex Hutch.& Dalz.			FS	AR 50
Mussaenda tristigmatica Cummins		18	FS	AR 447
Nauclea latifolia Sm.			L	
Nauclea diderrichii (De Wild.& Th.Dur.) Merril	XXV	18	FS	AR 452
Nauclea xanthoxylon (A.Chev.) Aubr.			P	
Oldenlandia affinis (Roem.& Schult.) DC.		32	FS	AR 319
Oldenlandia corymbosa L.			FS	AR 320
Oldenlandia lancifolia (Schum.) DC.		4	FS	AR 146
Oxyanthus formosus Hook.f.ex Planch.	XVII		S	AR 576
Oxyanthus pallidus Hiern	VIII		FC	AR 577
Oxyanthus subpunctatus (Hiern) Keay			P	
Pauridiantha afzelii (Hiern) Bremek.	XIX		S	AR 551
Pauridiantha hirtella (Benth.) Bremek.			P	AR 515
Pauridiantha stipulosa (Hutch.& Dalz.) Hepper			P	AR 552
Pavetta corymbosa (DC.) F.N.Williams	XVII		FC	AR 109
Pavetta mollissima Hutch.& Dalz.			P	AR 511
Pavetta nitida (Schum.& Thon.) Hutch.& Dalz.			FC	AR 737
Pavetta owariensis P.Beauv.	V		S	AR 720
Pavetta staudtii Hutch.& Dalz.			P	AR 553
Psilanthus mannii Hook.f.			P	AR 318
Psychotria brachyantha Hiern	XXII		FC	AR 292, 317
Psychotria bidentata (Thunb.ex Roem.& Schul.) Hiern			P	AR 316
Psychotria chalconeura (K.Schum.) Petit			P	AR 526
Psychotria elongato-sepala (Hiern) Petit	V		S	AR 559
Psychotria gabonica Hiern	XI		FC	AR 719
Psychotria hallei Aké Assi			FC	AR 560
Psychotria limba Sc.Elliot			P	AR 123
Psychotria sciadelphora Hiern	XIV		FC	AR 238, 315
Psychotria subobliqua Hiern			P	AR 561
Rothmannia hispida (K.Schum.) Fagerlind			P	AR 356
Rothmannia longiflora Salisb.	XXII	29	FC	AR 173
Rothmannia megalostigma (Wernham) Keay			FC	
Rothmannia whitfieldii (Lindl.) Dandy	XXIII	21	FC	AR 98
Rutidea olentricha Hiern			P	AR 543
Rutidea parviflora DC.	X	10	FCS	AR 22, 73
Rutidea smythii Hiern		21	FC	
Rytigynia canthiodes (Benth.) Robyns			P	AR 731
Sabicea brevipes Wernham			FS	AR 56
Sabicea calycina Benth.	IV	18	FS	AR 97, 267
Sabicea cordata Hutch.& Dalz.		11	FS	AR 57
Sabicea discolor Stapf	II	20	FS	AR 129
Sabicea ferruginea (G.Don) Benth.	XI		S	AR 472
Sabicea pilosa Hiern			FS	
Sabicea rosea A.C.Hoyle			FS	AR 62
Sabicea venosa Benth.	XVII	12	FS	
Sabicea vogelii Bent.	X	24	FS	AR 42
Sherbournia bignoniiflora (Welw.) Hua			P	AR 722
Sherbournia calycina (G.Don) Hua	XVII	11	FC	AR 473
Tarenna bipindensis (K.Schum.) Bremek.			P	
Tarenna conferta (Benth.) Hiern			P	AR 724
Tarenna vignei Hutch.& Dalz.			P	AR 219
Tricalysia macrophylla K.Schum.	XXI		FC	AR 216
Tricalysia pallens Hiern			P	AR 721
Tricalysia reflexa Hutch.			P	
Tricalysia reticulata (Benth.) Hiern			P	
Trichostachys aurea Hiern	XXVII		S	AR 110
Uncaria africana G.Don			FC	AR 475

Uncaria talbotii Wernham			R	AR 474
Vangueriopsis discolor (Benth.) Robyns			S	
Virectaria procumbens (Sm.)Bremek.		18;35	FS	AR 86
RUTACEAE				
Aelopsis chevalieri Swingle			P	
Araliopsis tabouensis Aubr.& Pellegr.	XXVI	16	FS	
Citropsis articulata (Willd.ex Spreng) Swingle & Kellerman			P	AR 512
Fagara macrophylla Engl.	XV	16	FCS	
SAMYDACEAE				
Casearia barteri Mast			P	
Homalium letestui Pellegr.			P	
Homalium molle Stapf	XXII		S	AR 711
SAPINDACEAE				
Allophylus africanus P.Beauv.	XIX	19	FS	AR 741
Aphania senegalensis (Juss.ex Poir.) Radlk.			P	
Aporrhiza urophylla Gilg	IX		S	AR 483
Blighia sapida Konig			FC	
Blighia unijugata Bak.			FC	
Blighia welwitschii (Hiern) Radlk.	XII	4	FC	AR 53, 484
Cardiospermum grandiflorum Swartz			FS	AR 152
Cardiospermum halicacabum L.			FS	AR 485
Chytranthus angustifolius Exell			P	AR 185
Chytranthus atroviolaceus Bak.f.ex Hutch.& Dalz.			FC	AR 52
Chytranthus bracteosus Radlk.			P	AR 234
Chytranthus longiracemosus Gilg ex Radlk.			FC	AR 228
Chytranthus mangenotii N.Hallé & Aké Assi			P	AR 626
Chytranthus setosus Radlk.		25	FC	AR 284
Chytranthus talbotii (Bak.f.) Keay			P	AR 730
Deinbollia cuneiflolia Bak.			P	AR752
Deinbollia pinnata (Poir.) Schum.& Thon.	VIII	12	FC	AR 641
Eriocoelum pungens Radlk.ex Engl.			P	AR 736
Lychnodiscus reticulatus Radlk.			P	AR 694
Majidea fosteri (Sprague) Radlk.			P	
Pancovia bijuga De Wild.			FC	AR 547
Pancovia turbinata Radlk.			P	AR 548
Paullinia pinnata L.	I		S	AR 453
Placodiscus leptostachys Radlk.			FC	
Placodiscus pseudostipularis Radlk.			P	
Placodiscus riparius Keay			S	
Placodiscus splendidus Keay			P	AR 544
SAPOTACEAE				
Afrosersalisia afzelii (Engl.) A.Chev.	XVII	14	FCS	
Aningeria altissima (A.Chev.) Aubr. & Pellegr.			FC	AR 753
Aningeria robusta (A.Chev.) Aubr.& Pellegr.			P	AR 492
Chrysophyllum pruniforme Pierre ex Engl.	IV	14	FC	
Chrysophyllum taïense Aubr.& Pellegr.	XX	23	FC	
Chrysophyllum welwitchii Engl.			P	
Endotricha taïensis Aubr. & Pellegr.			P	AR 656
Ituridendron bequaertii De Willd.			P	
Kantou guereensis Aubr.& Pellegr.			P	
Manilkara multinervis (Bak.) Dubard			P	
Omphalocarpum ahia A.Chev.			P	AR 528
Pachystela brevipes (Bak.) Baill. ex Engl.			P	AR 545
Synsepalum dulcifolium (Schum.& Thon.) Daniell			P	

Tieghemella heckelii Pierre ex A.Chev.			P	
SCROPHULARIACEAE				
Lindernia diffusa (L.) Wettst.			R	
Scoparia dulcis L.			R	AR 482
Torenia dinklagei Engl.		27	FS	
Torenia thouarsii (Cham.& Schlecht.) O.Ktze.			FS	AR 65
SCYTOPETALACEAE				
Scytopetalum tieghemii (A.Chev.) Hutch.& Dalz.	XVII		FC	AR 607
SIMARUBACEAE				
Gymnostemon zaizou Aubrév.& Pellegr.			P	
SOLANACEAE				
Capsicum frutescens L.		12	FS	AR 68
Physalis angulata L.		7	FS	AR 154
Physalis pubescens L.			FS	
Schwenckia americana L.			R	AR 481
Solanum aculeatissimum Jacq.		12	FS	AR 479
Solanum aethiopicum L.			FS	AR 480
Solanum anguivi		3	FS	AR 166, 486
Solanum anomalum Thonning.		23	FS	AR 49
Solanum nigrum L.		9	FS	AR 477
Solanum torvum Sw.		12	FS	AR 476
Solanum verbascifolium L.	VII	12	FCS	AR 72
STERCULIACEAE				
Cola attiensis Aubrév.& Pellegr.			P	
Cola caricaefolia (G.Don) K.Schum.	XXVI	16	FC	
Cola chlamydantha K.Schum.	X		S	AR 441
Cola digitata Mast.			P	AR 507
Cola heterophylla (P.Beauv.) Schott & Engl.	XXII	29	FC	AR 215, 230
Cola lateritia K.Schum. var. maclaudi (A.Chev.) Brenan	XXI		S	
Cola nitida (Vent.) Schott & Engl.	XXII		S	AR 628
Hildegardia barteri (Mast.) Kosterm.			PI	AR 710
Nesogordonia papaverifera (A.Chev.) Capuron	VI		S	AR 740
Octolobus angustatus Hutch.			P	
Pterygota beguaertii De Wild.			P	
Scaphopetalum amoenum A.Chev.			P	AR 523
Sterculia oblonga Mast.	XIV		S	AR 610
Sterculia tragacantha Lindl.	XVIII	10	FCS	
Tarrietia utilis (Sprague) Sprague	XXIV	16	FC	
Triplochiton scleroxylon K.Schum.	IX	10	FS	
THYMELEACEAE				
Dicranolepis persei Cummins	XIV		FC	AR 327
TILIACEAE				
Clappertonia minor (Baill.) Becherer			R	
Desplatsia chrysochlamys (Mildbr.& Burret) Mildbr.& Burret	XIV		FC	AR 643
Desplatsia dewevrei (De Wild.& Th.Dur.) Burret			P	AR 644
Duboscia viridiflora (K.Schum.) Mildbr.			P	AR 330
Glyphaea brevis (Spreng.) Monachino	IX	17	FC	AR 192, 329
Grewia barombiensis K.Schum.	XV		S	AR 328
Grewia barteri Burret			S	
Grewia carpinifolia Juss.	IX		S	
Grewia coriacea Mast.			S	

Grewia malacocarpa Mast.			P	
Grewia mollis Juss.			P	
Grewia pubescens P.Beauv.	XXII		S	AR 521
Triumfetta cordifolia A.Rich.		24	FS	AR 101
Triumfetta rhomboidea Jacq.		7	FS	
ULMACEAE				
Celts mildbraedii Engl.			FS	
Trema guineensis (Schum.& Thon.) Ficalho		12	FS	
UMBELLIFEREA				
Centella asiatica (L.) Urb.			R	
URTICACEAE				
Fleurya aestuans (L.) Gaud.ex Miq.		18	FS	AR 322
Pouzolzia guineensis Benth.		8	FS	AR 17
Urera cuneata Rendle			S	AR 321
Urera obovata Benth.			S	AR 747
Urera repens (Wedd.) Rendle			S	
Urera robusta A.Chev.			S	AR 169
VERBENACEAE				
Clerodendrum capitatum (Willd.) Schum.& Thon.	XXIV	16	FC	AR 739
Clerodendrum schweinfurtii var. bakeri Gürke	II	14	FC	
Clerodendrum sinuatum Hook.			FC	
Clerodendrum splendens G.Don	XXII	12	FC	AR 444
Clerodendrum umbellatum Poir.			S	
Clerodendrum volubile P.Beauv.	XVII	9	FC	AR 445
Premna hispida Benth.			P	AR 558
Stachytarpheta cayennensis (L.C.Rich.) Schau.			R	
Vitex doniana Sweet			FC	
Vitex grandifolia Gürke	XIV		FC	AR 728
Vitex micrantha Gürke	XX	17	FCS	
Vitex oxycuspis Bak.			P	AR 584
Vitex rivularis Gürke	XXV		S	
Vitex thyrsiflora Bak.			FC	
VIOLACEAE				
Decorsella paradoxa A.Chev.	XXVI	27	FC	AR 182, 235
Hybanthus enneaspermus (L.) F.v.Muell.		7	FC	AR 11
Rinorea brachypetala (Turcz.) O.Ktze.			P	AR 323
Rinorea breviracemosa Chipp	V		S	AR 214
Rinorea elliotii Engl.			FC	
Rinorea ilicifolia (Welw.ex Oliv.) O.Ktze.	VIII	15	FC	AR 125
Rinorea kibbiensis Chipp			P	AR 735
Rinorea longicuspis Engl.	XXVI	21	FC	AR 102
Rinorea oblanceolata Chipp			FC	
Rinorea oblongifolia (C.H.Wright) Marquand ex Chipp	XI	27	FC	
Rinorea subintegrifolia (P.Beauv.) O.Ktze.			P	
Stachytarpheta cayennensis (L.C.Rich.) Schau.			R	AR 443

Monocotyledons

AGAVACEAE				
Dracaena arborea (Willd.) Link			P	AR 651
Dracaena camerooniana Bak.	XVII		FC	AR 191, 294
Dracaena elliotii Bak.			P	AR 341
Dracaena humilis Bak.			P	AR 652
Dracaena ovata Ker-Gawl.	XVII	30	FC	AR 653
Dracaena surculosa Lindl.	XX	21	FC	AR 120, 252
AMARYLLIDACEAE				
Haemanthus cinnabarinus Decne.				AR 555
Haemanthus multiflorus Martyn		10	FC	
ARACEAE				
Amorphophallus johnsonii N.E.Br.			S	
Anchomanes difformis (Bl.) Engl.	XVII	17	FC	
Cercestis afzelii Schott	XIV	16	FC	AR 117
Cercestis sagittatis Engl.	XXV	21	FC	AR 244
Cercestis stigmaticus N.E.Br.	XXII	28	FC	
Culcasia angolensis Welw.& Schott	XVII	34	FC	AR 143
Culcasia dinklagei Aké Assi			P	AR 151
Culcasia glandulosa Hepper	XXVII	28	FC	AR 199
Culcasia liberica N.E.Br.	XXVI		S	AR 349
Culcasia longivaginata Engl.	XXVII	28	FC	AR 350
Culcasia parviflora N.E.Br.		16	FC	AR 156
Culcasia piperoides A.Chev.			P	AR 121
Culcasia saxatilis A.Chev.	XVII	27	FC	AR 362
Culcasia scandens P.Beauv.	XXVI	28	FC	AR 161
Culcasia seretii De Wild.			P	AR 111, 207
Culcasia striolata Engl.			P	AR 351
Culcasia tepoensis A.Chev.ex Knecht			FC	
Cyrtosperma senegalense (Schott) Engl.			FS	
Nephthytis afzelii Schott	XXIV		S	AR 208
Raphidophora africana N.E.Br.	XV	34	FC	AR 147
CANNACEAE				
Canna indica L.			R	
COMMELINACEAE				
Aneilema aequinoctiale (P.Beauv.) Kunth.			FS	AR 186
Aneilema beniniensis (P.Beauv.) Kunth.		9	FS	AR 28
Buforrestia mannii C.B.Cl.	XXII	27	FS	AR 157
Commelina aspera Benth.			PI	AR 91
Commelina benghalensis L.			R	
Commelina capitata Benth.		24	FS	AR 177
Commelina congesta C.B.Cl.		27	FS	AR 303
Commelina diffusa Burm.f.			FS	AR 304
Commelina macrosperma J.K.Morton			P	AR 260
Commelina thomasii Hutch.		34	FS	
Floscopa africana C.B.Cl.			S	AR 699
Palisota barteri Hook.		17	FS	AR 273
Palisota bracteosa C.B.Cl.		25	FC	AR 137
Palisota hirsuta K.Schum.	XII	16	FCS	AR 305
Pollia condensata C.B.Cl.	XVII		S	AR 118
Polyspatha paniculata Benth.	XXVI	27	FS	
Stanfieldiella imperforata (C.B.Cl.)Brenan	XIV	24	FS	AR 306
CYPERACEAE				

Bulbostylis andougensis C.B.Cl.			FS	AR 44
Bulbostylis pilosa (Willd.) Cherm.			FS	AR285
Cyperus distans L.f.		4	FS	AR 130
Cyperus fertilis Boeck.			S	AR 669
Cyperus renschii Boeck.			FS	AR 241
Cyperus sphacelatus Rottb.		16	FS	AR 391
Fimbristylis dichotoma (L.) Vahl			FS	AR 408
Fimbristylis ferruginea (L.) Vahl			FS	AR 81
Kyllinga erecta Schumach.			R	AR 242
Kyllinga squamulata Thonn.ex Vahl			R	AR 407
Hypolytrum africanum Nees ex Steud.			P	
Hypolytrum heteromorphum Nelmes			P	AR 718
Hypolytrum poecicolepis Nelmes			P	AR 296, 557
Mapania baldwinii Nelmes	XXIV		S	AR 198, 233
Mapania coriandrum Nelmes			P	AR 681
Mapania linderi Hutch.& Dalz.			P	AR 218
Mapania mangenotiana G.Lourougnon		28	FS	AR 210
Mariscus alternifolius Vahl		7	FS	AR 406
Mariscus flabelliformis Kunth.		10	FS	AR 245
Mariscus longibracteatus Cherm.			FS	AR 264
Rhynchospora corymbosa (L.) Britton			P	AR 295
Scleria barteri Boeck.	XII	14	FS	AR 392
Scleria depressa (C.B.Cl.) Nelmes			FS	AR 393
Scleria naumanniana Boeck.		14	FS	AR 383
Scleria verrucosa Willd.		32	FS	AR 170
DIOSCOREACEAE				
Dioscorea bulbifera L.	IX	10	FCS	AR 39
Dioscorea burkilliana J.Miège	XIII	15	FCS	AR 132
Dioscorea hirtiflora Benth.		4	FS	AR 85
Dioscorea lecardii			FCS	AR 289
Dioscorea liebrechtsiana De Wild.	XXII	21	FCS	
Dioscorea minutiflora Engl.	XV	15	FCS	AR 247
Dioscorea praehensilis Benth.	XIII	15	FCS	AR 12, 23
Dioscorea preussii Pax		10	FCS	AR 24
Dioscorea smilacifolia De Wild.	XIV	15	FCS	AR 63
FLAGELLARIACEAE				
Flagellaria guineensis Schum.			S	AR 700
GRAMINAE				
Acroceras zizanioides (Kunth.) Dandy	X	24	FS	AR 382
Axonopus compressus (Sw.) P.Beauv.		3	FS	AR 55
Brachiaria lata (Schumach.) C.E.Hubbard			R	
Centotheca lappacea (L.) Desv.	XIV	14	FS	AR 363
Chasmopodium caudatum (Hack.) Stapf		4;5	FS	AR 332
Chloris pilosa Schumach.			R	AR 365
Chloris pycnothrix Trin.			R	AR 364
Chrysopogon aciculatus (Retz.) Trin.			R	AR 464
Commelinidium gabunense (Hack.) Stapf			R	AR 463
Cynodon dactylon (L.) Pers.			R	AR 462
Cyrtococcum chaetophoron (Roem.& Schult.) Dandy	VIII	11	FS	AR 70
Dactyloctenium aegyptium (L.) P.Beauv.			R	AR 250
Eleusine indica (L.) Gaertn.			FS	AR 460
Eragrostis ciliaris (L.) R.Br.			R	AR 461
Eragrostis tenella (L.) P.Beauv.ex Roem.&Schult.			R	
Guaduella oblonga Hutch.	XIV	27	FS	AR 113
Leptaspis cochleata Twaites			S	AR 459
Olyra latifolia L.	XI	16	FC	AR 384

Oplismenus burmannii (Retz.) P.Beauv.		10	FS	AR 114
Oplismenus hirtellus (L.) P.Beauv.			S	AR 32
Panicum brevifolium L.	VII	12	FS	AR 385
Panicum laxum Sw.		1;8	FS	AR 386
Panicum parvifolium Lam.		10	FS	AR 290
Paspalum conjugatum Berg.		2	FS	AR 43
Paspalum scrobiculatum L.		2	FS	
Perotis indica (L.) O.Ktze.			R	
Setaria barbata (Lam.) Kunth			R	
Setaria chevalieri Stapf.			R	
Sporobolus pyramidalis P.Beauv.			R	
Streptogyna crinita P.Beauv.	XX	10	FCS	AR 381
LILIACEAE				
Chlorophytum alismifolium Bak.			FCS	AR 625
Chlorophytum orchidastrum Lindl.	VIII	17	FCS	AR 401
MARANTACEAE				
Ataenidia conferta (Benth.) Milne-Red.		27	FS	
Halopegia azurea K.Schum.		34	FC	
Hypselodelphys poggeana (K.Schum.) Milne-Red.			P	AR 353
Hypselopelphys violacea (Ridley) Milne-Red.	XVI	15	FC	AR 48, 354
Marantochloa congensis (K.Schum.) J.Léonard & Mullend.	XXI	16	FCS	
Marantochloa cuspidata (Roscoe) Milne-Red.			FS	AR 470
Marantochloa filipes (Benth.) Hutch.	XX	26	FC	AR 21, 352
Marantochloa leucantha (K.Schum.) Milne-Red.	II	12	FCS	AR 47, 394
Megaphrynium distans Hepper			FCS	
Megaphrynium macrostachyum (Benth.) Milne-Red.	XIV	15	FCS	AR 13
Sarcophrynium brachystachys (Benth.) K.Schum.	XXII	16	FCS	AR 10
Sarcophrynium prionogonium (K.Schum.) K.Schum.	XXVI	16	FS	AR 29
Thalia welwitschii Ridl.	XVII		S	
Thaumatococcus danielli (Benn) Benth.	XIV	24	FCS	AR 115
Trachyphrynium braunianum (K.Schum.) Bak.	XVI		S	
ORCHIDACEAE				
Angraecum birrimense Rolfe			P	
Corymborkis corymbosa Thou.	XVII		FC	AR 635
Oeceoclades maculata (Lindley) Lindley			P	AR 570
Nervilia petraea (Afzel.ex Pers.) Summerh.		10	FS	
PALMAE				
Ancistrophyllum laeve (Mann & Wendl.) Drude			P	AR 299, 300
Ancistrophyllum opacum (Mann & Wendl.) Drude	XXIV	33	FC	AR 301
Ancistrophyllum secundiflorum Wendl.	XIV	16	FC	AR 487
Calamus deërratus Mann & Wendl.	I	31	FC	AR 663
Elaeis guineensis Jacq.	XII	14	FS	
Eremospatha hookeri (Mann & Wendl.) Wendl.			P	AR 660
Eremospatha macrocarpa (Mann & Wendl.) Wendl.	XXV		S	AR 116
Raphia hookeri Mann & Wendl.	II	15	FS	
Raphia sassandrensis A.Chev.	III	16	FS	AR 158
PANDANACEAE				
Pandanus candelabrum P.Beauv.			FC	AR 517
RAPATACEAE				
Maschalocephalus dinklagei Gilg & K.Schum.			P	
SMILACACEAE				
Smilax kraussiana Meisn.	VII	24	FCS	AR 204

ZINGIBERACEAE				
Aframomum citratum (Pereira) K.Schum.			P	AR 253
Aframomum cuspidatum K.Schum.			FS	
Aframomum daniellii (Hook. f.) K.Schum.	III	18	FCS	AR 183
Aframomum elliotii (Bak.) K.Schum.		26	FCS	AR 155
Aframomum latifolium (Afzel.) K.Schum.			FS	AR 282
Aframomum longiscapum (Hook.f.) K.Schum.			P	AR 254, 489
Aframomum melegueta K.Schum.			R	
Aframomum sceptrum (Oliv.& Hanb.) K.Schum.	XI	12	FCS	AR 5
Aframomum simiarum A.Chev.		34	FC	AR 272
Aframomum subsericeum (Oliv.& Hanb.) K.Schum.		27	FC	AR 331
Aframomum sulcatum (Oliv.& Hanb.) K.Schum.			P	AR 168
Costus afer Ker-Gawl.	XI	15	FS	AR 2
Costus deistelii K.Schum.	II	12	FCS	AR 239
Costus dubius (Afzel.) K.Schum.	XIII	17	FS	AR 243
Costus engleranus K.Schum.			FCS	AR 33
Costus lucanusianus J.Braun & K.Schum.	I	24	FS	AR 236
Costus schlechteri Winckler		10	FCS	AR 9
Renealmia maculata Stapf			P	

Ferns

ADIANTACEAE				
Adiantum confine	I		S	AR 496
Adiantum incisum Forsk.			S	
Adiantum vogelii Mett.ex Keys			P	AR 262
Ceratopteris cornuta (P.Beauv.) Lepr.		34	FS	AR 266
Pteris atrovirens Willd.	X		FS	AR 37
Pteris burtoni Bak.	XXII	15	FC	AR 203
Pteris preussii Hieron.			S	
Pteris similis Kühn			S	AR 562
ASPIDIACEAE				
Ctenitis pilosissima (J.Sm.) Alst.			P	AR 513
Ctenitis protensa (Afzel. ex Sw.) Ching	XXVI	29	FC	AR 184
Ctenitis variabilis (HK.) Tard.		10	FCS	AR 1
Ctenitis vogelii (Hook.) Ching		18	FS	
Lastreopsis efulensis (Bak.) Tard.		15	FC	AR 133
Lastreopsis vogelii (Hk.) Tindale			P	
ASPLENIACEAE				
Asplenium africanum Desv.			S	AR 439
Asplenium buettneri Hier		16	FS	AR 140
Asplenium diplazisorum Hier			P	AR 195
Asplenium dregeanum Kunze		33	FS	AR 131
Asplenium variabile Hook.			S	
DAVALLIACEAE				
Arthropteris monocarpa (Cordem) C.Chr.			FS	AR 145
Arthropteris obliterata Chr.			P	AR 194
Arthropteris palisoti (Desv.) Alston			S	AR 212
Davallia chaerophylloides (Poir.) Steud.			FS	AR 279
Nephrolepis acutiflora (Desv.) Christ			S	
Nephrolepis bisserrata (Sw.) Schott	V	16	FS	AR 437
Nephrolepis undulata (Afzel.ex Sw.) J.Sm.		18	FC	
DENNSTAEDTIACEAE				
Anisosorus occidentalis (Bak.) C.Chr.			PI	AR 440
Histiopteris incisa (Thbg.) f.Sm.			S	AR 226

Lonchitis reducta C.Chr.	XVII	17	FS	
Pteridium aquilinum (L.) KÜhn			R	AR 436
LOMARIOPSIDACEAE				
Bolbitis auriculata (Lam.) Alston		20	FC	AR 163
Bolbitis gaboonensis (Hk.) Aston			P	
Lomariopsis guineensis (Underwood) Alston			P	AR 256
Lomariopsis palustris (Hook.) Mett.ex Kühn			P	AR 197
Lomariopsis rossii Holltum			P	AR 201, 220
THELYPTERIDACEAE				
Cyclosorus afer (Christ) Ching	I		S	
Cyclosorus dentatus (Forsk) Ching			FS	AR 276
Cyclosorus oppositifolius (Hook.) Tard.		15	FC	AR 165
Cyclosorus striatus (Schum.) Copp.			S	AR 171
Cyclosorus striolata		34	FS	
Lygodium smithianum Presl.			R	AR 438
Tectaria angelicifolia (Schum.) Copp.			FS	AR 589
LYCOPODIACEAE				
Lycopodium cernuum L.			R	
SELAGINELLACEAE				
Selaginella myosurus (Sw.) Alston			R	AR 435

Curriculum vitae

The author was born in 1955 in Leiden, The Netherlands. In 1973 she started her studies in Tropical Crop science at the University of Wageningen, followed by a practical period in 1979 in Côte d'Ivoire. She obtained her degree in 1982 with a specialization in Vegetation science and in Theoretical Production Ecology.

From 1984 to 1987 she was employed as a researcher by the Agricultural University of Wageningen in Côte d'Ivoire. The field work in the south-west of Côte d'Ivoire had begun two years earlier. From 1987 to 1989 she carried out a vegetation-agronomical survey in the south-west Côte d'Ivoire, funded by Tropenbos. The present thesis is based on the results of all previous work in Côte d'Ivoire.

After returning to Europe she was a guest at the Muséum National de l'Histoire Naturelle in Brunoy, France. At present she is employed as an agronomist by ORSTOM, Institut Français de Recherche Scientifique pour le Développement en Coopération.

 

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