Manual for
Vegetation Survey, Analysis and Mapping

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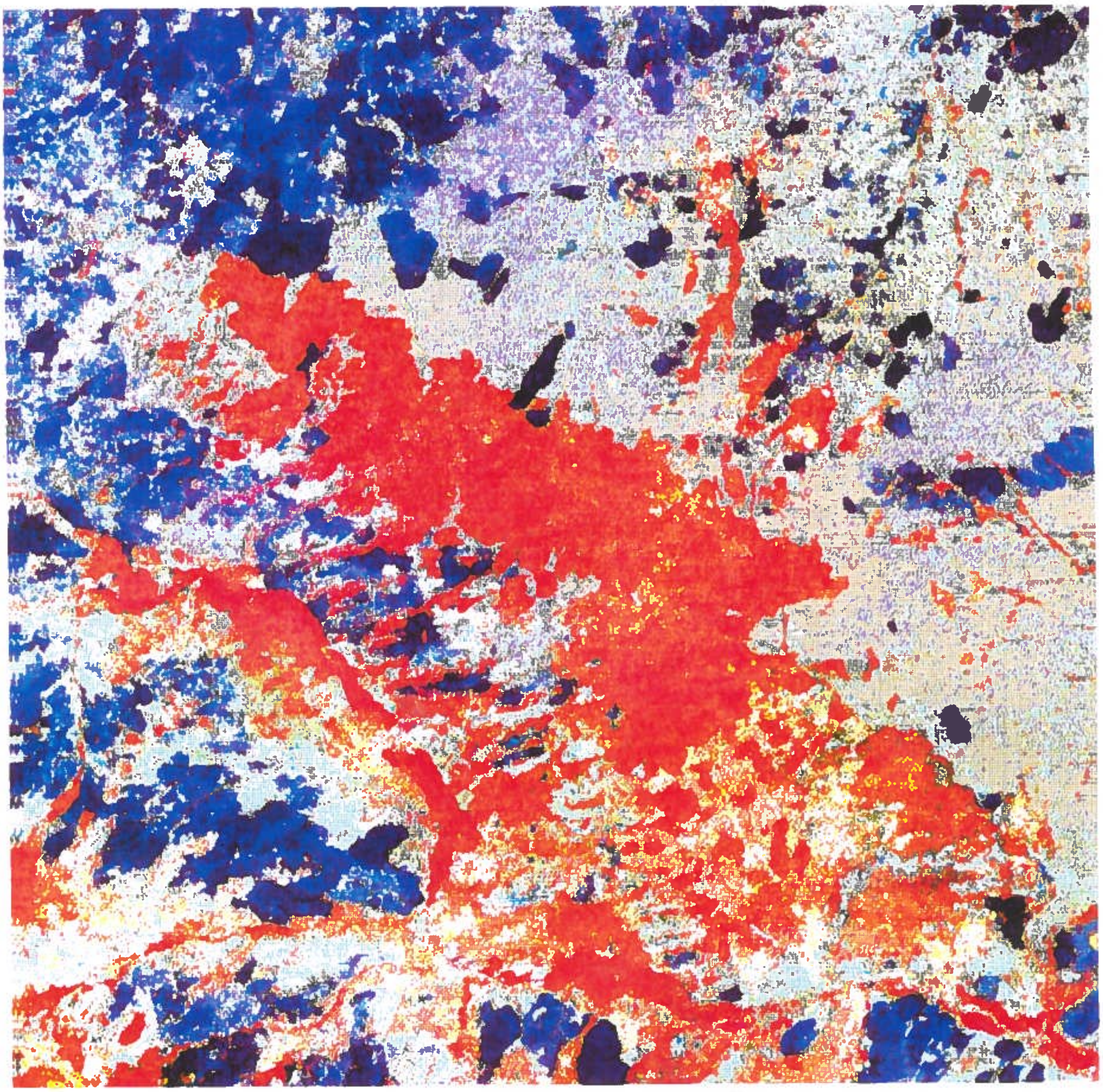

Forest Resource Management Project
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Front cover: Satellite image (TM 4-5-3) of Kogyae Strict Nature Reserve (for details see report on the vegetation of Kogyae Strict Nature Reserve).

"Given that techniques of vegetation science are increasingly supported by computers with the resulting danger of increased "digitalization of vegetation", it is necessary to look for a counterbalance which considers plant communities once again as living organisms without using emotional approaches only. The possibility of the "considering power of judgement", as summarized by GOETHE, is ... such a counterbalance." Vahl and Dettmar, 1988, p. 407.

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Three people who made particular contributions deserve special mention and thanks: my wife Dr. Anne-Katherine Brink supported me throughout the project and was an invaluable help with data inputting, typing, correction of my English and was a source of many fruitful discussions; Douglas Lucius gave me some indispensible insights into the workings of dBase IV; Dr. Jenny Wong was instrumental in setting up the IDRISI geographic analysis system.

List of contents

List of figures and tables

INTRODUCTION

The purpose of this manual is to describe the background to and the methods used in the botanical survey of the protected areas in the savanna region of Ghana. The same methods were applied to all the areas studied and reports on the vegetation of individual areas do not contain any further information on methodology.

Two additional sections will provide information on vegetation monitoring and on the graphic display of plant distribution data.

The database (dBase) data and programme files are given on a diskette in the appendix.

The literature quoted is included in a list which contains all the literature used in the botanical survey (appendix A).

AIMS

The terms of reference for the Botanical Survey are:

* To identify the major plant communities that occur in Ghana, and to identify quantitatively the extent to which they are represented in the existing protected area system.
* To identify plant species that are of special interest, and to plot their distributions and relative abundances in protected areas. These species will include those that are threatened, that have significance in local traditional medicine or that are of special interest for other reasons.
* To identify plant community parameters in protected areas, which may serve as indicators or inclusion in the monitoring programmes that will be prescribed in each protected area management plan.
* To identify special problems such as threatened communities and individual species that are at risk from factors such as uncontrolled burning, timber removal or other land use practices.

BACKGROUND

"Protected areas play a vital role in preserving the world's biodiversity, but their ability to preserve genetic material over the long-term will depend upon the extent to which sensitive and species-rich habitats are preserved." (Shrestha et al. 1990, p. 62).

Baseline data on species occurrence and distribution which are necessary for effective long-term management of protected areas include information on:

- **Flora**: particularly the abundance and distribution of species of special interest: rare and endangered species (status, distribution, ecology and habitat requirements), indicator species (plants which are most sensitive to environmental changes), fodder plants and useful plants.
- **Vegetation**: ie. the distribution and extent of plant communities (especially of those which are rare or threatened), allowing a vegetation map to be compiled.
- **Threatening factors,** such as grazing, fire and fuelwood collection, which may affect plant species, plant communities and their habitats, and on how to counteract such threats.

The methods used in this survey were chosen to achieve these objectives in a simple and rapid manner, suitable for West African savanna. Depending on the characteristics of the area studied

- **an initial qualitative description of the vegetation** or
- **a semi-quantitative classification of plant communities** was performed.

"... a plant community can be understood as a combination of plants that are dependent on their environment and influence one another and modify their own environment. They form, together with their common habitat and other associated organisms, an ecosystem (sensu Tansley 1935), which is also related to neighboring ecosystems and to the macroclimate of the region." (Mueller-Dombois and Ellenberg 1974, p. 27)

The semi-quantitative Zürich-Montpellier Method (Braun-Blanquet 1964) has been successfully applied to the classification of vegetation in various parts of Africa (cf. Werger 1977, Knapp 1979). The results are often comparable to those based on more time-consuming methods of data collection (Clark 1986). The method acts as a very flexible tool because its details and emphasis may be modified in the light of specific circumstances. For example, West African savanna is highly seasonal and the ground-layer is often completely burnt during the dry season. Although under these circumstances information on trees and shrubs only within relevés can be collected, using the Zürich-Montpellier Method a classification of vegetation based on this incomplete data can nevertheless be undertaken. In the analysis of the data emphasis can be placed either on dominant species and physiognomic criteria (Mueller-Dombois and Ellenberg 1974) or on floristic criteria. The former approach enables easy distinction of vegetation units throughout the year, whereas the latter approach also reveals plant species which are indicators of specific ecological factors (ie. those with ecological amplitudes reflecting small-scale differences in site conditions). This provides important information for the design of monitoring programmes.

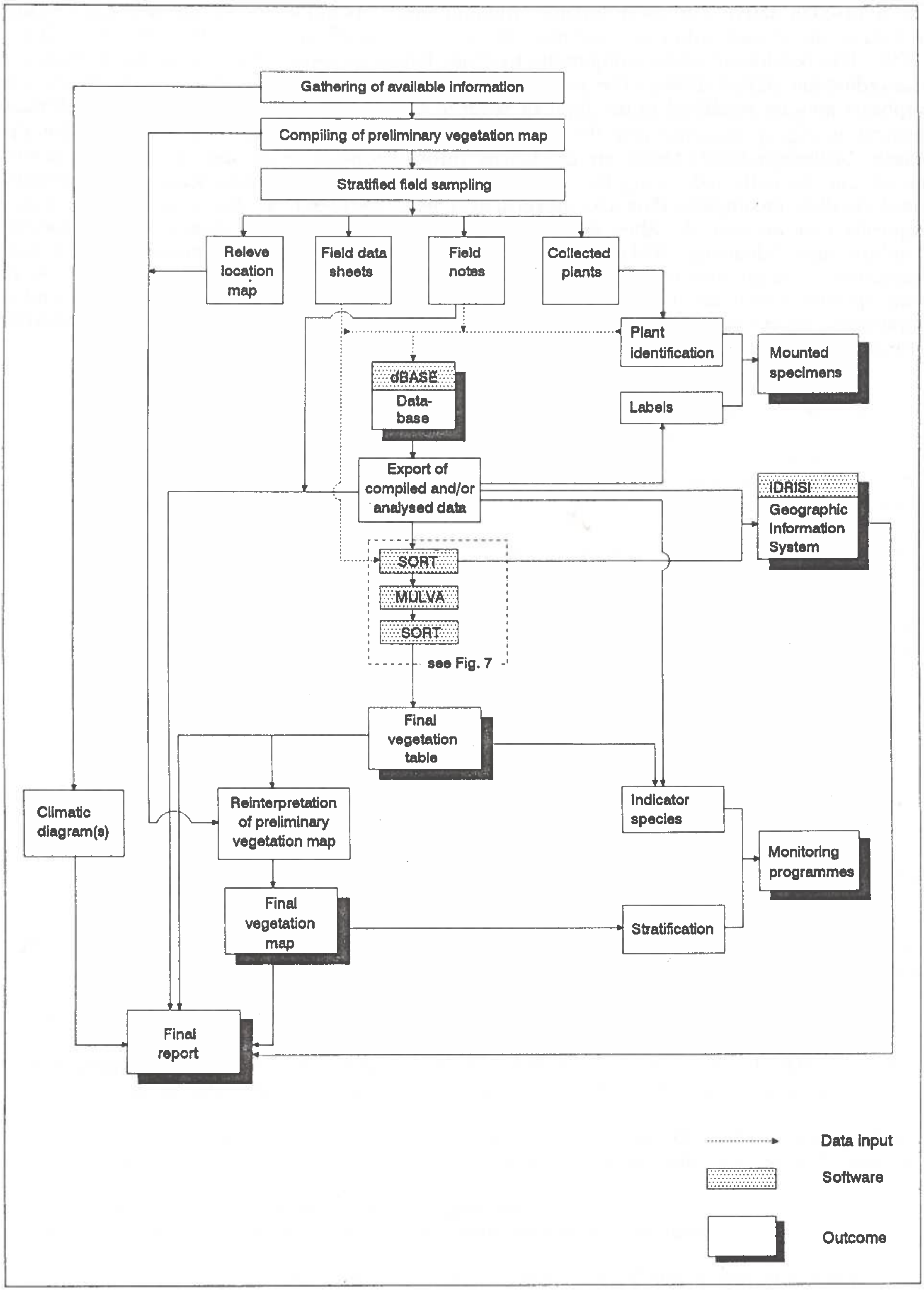

Fig. 1. Flow chart showing the individual steps involved in the botanical inventory.

These steps have been grouped into sections for the purposes of the description which follows.

1. AERIAL PHOTOGRAPH AND SATELLITE IMAGE INTERPRETATION AND VEGETATION MAPPING

Black and white aerial photographs (scale 1: 40 000), taken between 1972 and 1974, were first interpreted in monoscopic and then in stereoscopic vision. Areas with the same features, ie. vegetation patterns, were identified according to grey values, texture differences and relief. These vegetation patterns were then transferred onto a base map using a mirror stereoscope.

Landsat TM (Thematic Mapper) images with a spatial resolution of 30 x 30 m were used for large areas, for which the interpretation of aerial photographs would be too time consuming, or for areas where more recent images were required. Combined false colour composites (FCC) of TM bands 4, 5 and 3 (of varying scales) were visually interpreted because computer-aided classification and mapping of small vegetation units is complicated and, as yet, insufficiently accurate (Löffler 1985, a comprehensive account on computer-aided vegetation classification and mapping is given in Mulder 1988). TM 4 5 3 FCC is a combination of 3 bands through different filters, band 4 (0.76-0.9 μm, records the near-infrared wavelength) through a red filter, band 5 (1.55-1.75 μm, records the mid-infrared wavelength) through a green filter and band 3 (0.63-0.69 μm, records the orange/red reflected light) through a blue filter, resulting in an image similar to a colour infrared picture. Healthy green vegetation appears red because of the high reflectivity of green vegetation in band 4 (projected through a red filter). The amount of reflection in the near-infrared wavelengths depends on the water content, thickness and structure (mainly mesophyll) of the leaves and the orientation of the leaves towards incoming light. The reflections from different plant species are distinct and also change with the seasons. The mid-infrared radiance provides information about the moisture content of the leaves and the soil. The radiance in band 3, the chlorophyll absorption band, helps with the discrimination of vegetation types/plant communities. A light table and transparencies were used to trace the boundaries of the mapping units, identified by differences in colour, onto a base map.

The legend of these base maps describes plant cover (vegetation structure and pattern) and terrain features (relief and drainage).

The mapping units were systematically investigated in the field by sampling plots (relevés). The location of the relevés was determined using a Magellan NAV 5000™ GPS (Global Positioning System) and then marked on the base map. After the vegetation classification was completed each unit distinguished on the aerial photographs/satellite images was correlated either with an individual plant community or with a small-scale mosaic of plant communities.

The final maps were compiled from re-interpretation of the aerial photographs/satellite images, integrating the results of the vegetation classification. These maps were transferred into their final scale by using Freelance Graphics Version 4.0 for small areas or a pantograph for larger maps.

2. STRATIFIED FIELD SAMPLING

The Zürich-Montpellier method (Braun-Blanquet 1964) of vegetation survey and analysis was used (Mueller-Dombois and Ellenberg 1974).

Areas of uniform vegetation and landform were chosen from aerial photographs/satellite images. Within these units **representative sampling plots** (relevés), ie. conspicuous, repeatedly occurring subdivisions of the vegetation, **with a homogeneous plant cover** were placed subjectively without preconceived bias, ie. the investigation was approached on the basis of a negative hypothesis *"...the investigator ... applies his mind to the fullest in the process of entitation; furthermore, ... he takes nothing for granted and ... he maintains a flexible program during the course of his investigation. Therefore, he is ready to accept a new working hypothesis as soon as further knowledge indicates a modification or change."* (Mueller-Dombois and Ellenberg 1974, p. 33).

Each sample stand has to fulfil the following criteria:

1 It should be large enough to contain all species belonging to the plant community, ie. bigger than the minimal sample area
2 The habitat should be uniform within the stand area, as far as this can be determined
3 The plant cover should be as homogeneous as possible.

2.1 Minimal Sample Area

The minimal sample area was determined using the nested plot technique (Mueller-Dombois and Ellenberg 1974). This involves first laying out an area of 1 x 1 m and recording all the species that occur within the area. The sample area is then increased successively by a factor of two (Fig. 2) and the new species are listed for each sample area. This process is continued until no further species are added to the list.

The minimal sample area is defined as the area where a 10% increase in area yields only a 5% increase in the number of species (see species/area curve, Fig. 3).

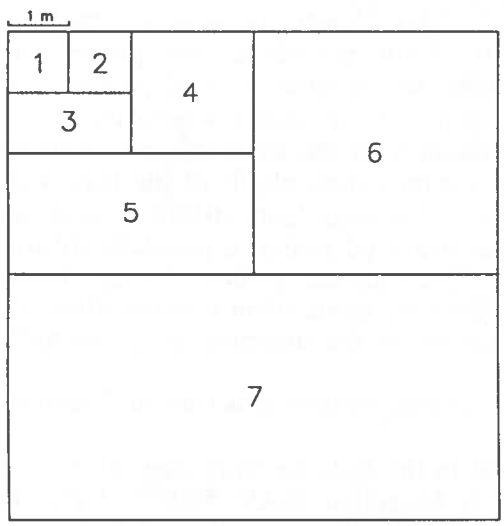

Fig. 2. A system of nested plots for establishing minimal sample area. The progressively sampled subplots are numbered in increasing order. The final plot size in this example is 64 m².

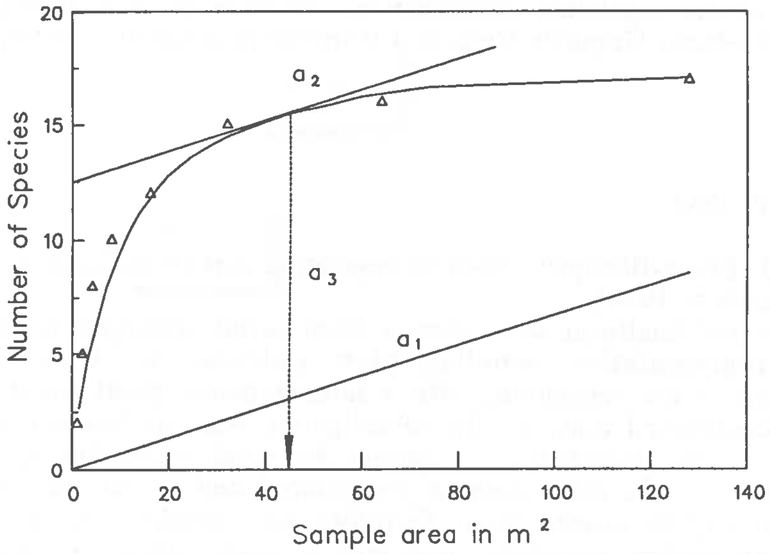

Fig. 3. Species/area curve for a dry evergreen forest (Shai Hills RR):

a_1=5% line (ie. line where a 10% increase in area yields a 5% increase in the number of species), drawn as a line joining the origin and the point at which x=100% of the sample area and y=50% of the total species number;
a_2=tangent parallel to 5% line;
a_3=protraction to minimal area.

Table 1. **Minimal sample areas established during the field work.**

Vegetation type		Minimal sample area (m^2) Field survey (1992/93)	other authors
Short grass savanna	grass layer	20	25[a]
	shrub layer	100	
	tree layer	50-100	
Guinea savanna	grass layer	25	24[b]
	shrub layer	100	
	tree layer	100-900	2 500[b]
Forest	dry evergreen	100	100[a]
	dry and moist semi-deciduous	50-100	
	riverine	100	

[a] Jeník and Hall 1976, [b] Hall and Jeník 1968

2.2 Sampling of relevés

The location of each relevé was mapped on the topographic field map either by using a compass and altimeter or a Global Positioning System (Magellan NAV 5000™). The data were later transferred onto a form (see appendix B) to ease the subsequent input in the database.

The site description was carried out according to the criteria listed in the field data sheet (see Fig. 6 at the end of this section). For details of the site-description see 'Guidelines for soil profile description' (FAO 1977). Broad texture classes, eg. sand, loam, silt or clay can be determined by feel in the field with reasonable accuracy as follows:

- *Sand*: the individual particles are very obvious to the eye, it is loose when dry and not sticky when wet.
- *Loam*: can be moulded easily when moist but sticks slightly to the fingers and some grittiness from the sand fraction is still obvious.
- *Silt*: the individual particles are not clearly felt when rubbed between the fingers but give a smooth and soapy feel.
- *Clay*: feels very sticky and smooth when moist and is hard when dry.

A simple clinometer made with a protractor, a thread and a weight (Fig. 4A) was used to measure slope steepness and to calculate tree heights (Fig. 4B) using the following formula: $h = h_1 + h_2$ where: $h_1 = d \times \tan\alpha$ [1]

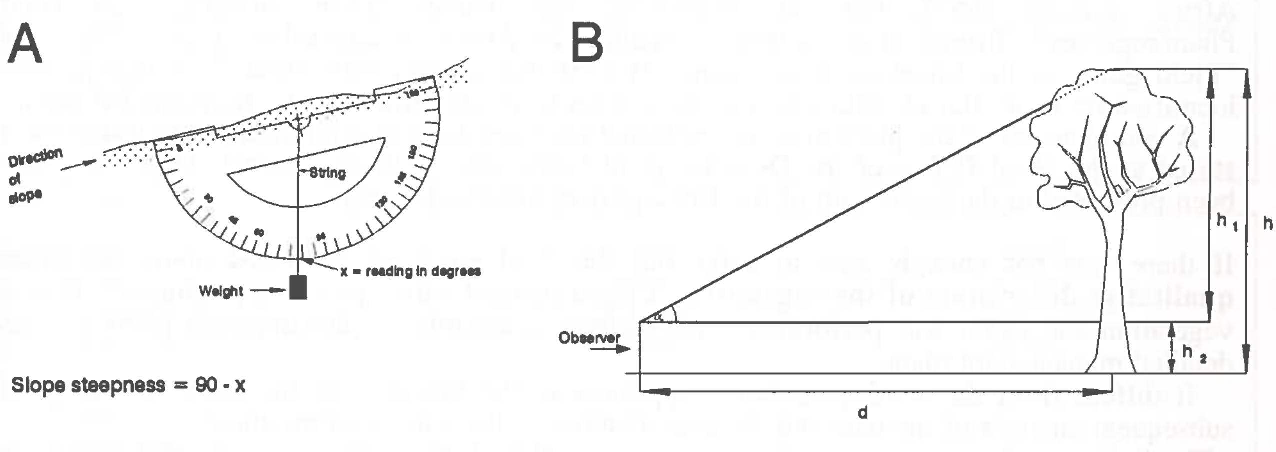

Fig. 4. **Use of the clinometer: A. For measuring slope steepness. B. For measuring tree height.**

[1] If the observer stands downhill from the base of the tree, the vertical distance between the base of the tree and the observer's feet must be estimated and subtracted from h_2. If the observer stands uphill from the tree, the vertical distance between the observer's eye and the base of the tree must be estimated and replaces h_2 in the calculation.

The sampling of each relevé requires the recording of all plant species and of their respective cover-abundances in different strata, the latter provides information on the structure of the community. Up to 4 different height strata were distinguished within the relevés:

T	Tree layer, any plant taller than 5 m
S1	First shrub layer, all plants between 0.5 - 2 m tall
S2	Second shrub layer, all plants between 2 - 5 m tall
H	Herb layer (not marked on the vegetation tables)

For each relevé and stratum a plant list was established and for each plant species cover-abundance was estimated according to the scale of Braun-Blanquet:

5	Any number of specimens, with cover more than 75% of the reference area
4	Any number, with cover 50-75%
3	Any number, with cover 25-50%
2	Any number, with cover 5-25%
1	Numerous, but less than 5% cover or scattered with cover up to 5%
+	Few, with small cover

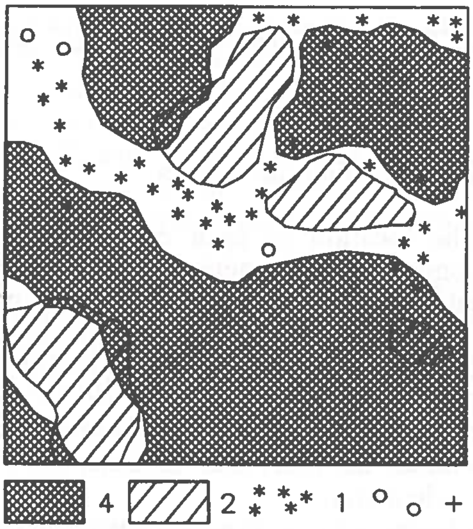

Fig. 5. Schematic presentation of cover-abundance values (4,2,1, and +) after the Braun-Blanquet scale (modified from Ellenberg 1956).

All plants collected were labelled in the fields and for each plant a general description, its life-form and habitat were recorded (see appendix B). The plants were later pressed and dried between newspapers; during the rainy season they were dried in a wooden drying box heated by a charcoal fire.

Identification was carried out at the herbarium of the University of Ghana, Legon. For most species the nomenclature of the "Flora of West Tropical Africa" (Hutchinson and Dalziel 1954-72) was followed. Poaceae (grasses) were identified according to "A manual of Ghana grasses" (Rose Innes 1977) and ferns according to "The ferns and fern-allies of West Tropical Africa" (Alston 1959). For the updates of plant names "Flore analytique du Togo: Phanérogames" (Brunel et al. 1984), "Legumes of Africa, a check-list" (Lock 1989) and "Field guide to the forest trees of Ghana" (Hawthorne 1990a) were used. The lichens were identified by Prof. Hertel (Munich) and the mosses were identified by Dr. Klemenz (Mainz).

A complete set of the plant material collected has been kept in a reference herbarium and is stored at the Head Office of the Department of Game and Wildlife (Accra). Duplicates have been presented to the herbarium of the University of Ghana (Legon).

If there was not enough time to carry out the field work as described above an **initial qualitative description of the vegetation**, a rapid method which provides preliminary data on vegetation and flora, was performed. This method is suitable for development plans and less detailed management plans.

It differs from the semi-quantitative approach in the intensity of the field sampling, the subsequent analysis of the data and the classification of the plant communities:

- The field sampling considers only the (2-5) **most abundant species** in each vegetation layer. Other data to be recorded are: the exact position (has to be marked on the basemap), landform, aspect, slope, drainage and apparent soil properties.
- The classification of plant communities is only **descriptive** and based on obvious differences in physiognomy and dominant species.

Fig. 6. Field data sheet

Relevé no:			Date:
Photo no: Vegetation description (general):			Observer(s):

SITE-description

LOCATION:

ALTITUDE: ________ m   EXPOSITION: N/NE/E/SE/S/SW/W/NW   SLOPE: ________ °

LANDFORM: MICRORELIEF:

physiographic position
- plateau
- summit
- escarpment
- concave slope
- convex slope (upper/middle/lower)
- valley bottom
- plain - depression

topography of surrounding country
- flat < 2 %
- undulating - 8 %
- rolling - 16 %
- hilly - 30 %
- steeply dissected > 30 %
- mountainous > 30 %

CLIMATE:

EROSION:

Type:	Rate:	Area affected:
water/wind	slight	< 25 %
sheet	moderate	25 - 50 %
rill	severe	50 - 75 %
gully		> 75 %

HYDROLOGY:

Flooding:	Frequency:	Duration:	Drainage:
none	rarely (/ yr)	days	very poorly
rain	periodically (months)	weeks	poorly
run-off	frequently (week)	months	imperfectly
river			moderately well
lake - sea			well
			excessively

SOIL: Parent material:

Surface stoniness:	Rock outcrops:	Others:
0 stone cover < 1%	0 < 2 %	salt
1 1 - 10 %	1 2 - 10 %	alkali
2 10 - 25 %	2 10 - 25 %	human influence
3 25 - 50 %	3 25 - 50 %	surface sealing
4 50 - 75 %	4 50 - 90 %	depth (shallow/medium/deep)
5 > 75 %	5 > 90 %	

Soil texture:

FIRE:

Land use

Wildlife:	Cultivation:	Livestock:
species	crops	animals
droppings *	field size *	herd size *
footprints *	others	others
numbers		
browsing *		
dom. species		
grazing *		
dom. species		

* - none or slight/low   ++ fairly intensive/high
+ moderate/medium   +++ heavy/very high

Layer (sample size)	Tree > 5 m (m²)	Shrub2 (2-5 m) (m²)	Shrub1 (0.5-2 m) (m²)	Herbs/grasses (m²)
Height (cm)				
Cover (%)				
Remarks				

Bare soil: % Rock outcrops/stones: % Litter: % Perennial grasses: %

Life-forms: Tree < 5 m, Shrub 0.5 - 5m, Herb, Grass, Climber, Liana, Parasite, Epiphyte

+ few	1: < 5% or many	2: 5 - 25%	3: 25 - 50%	4: 50 - 75%	5: > 75%

Layer	Cover	Species (life-form)	Layer	Cover	Species (life-form)

Input in Sort: .... (date)

3. DATA HANDLING (data-base)

A system of four interconnected data-bases has been created with the following aims:
- to enable easy handling of the large amount of data collected during the field work.
- to present information on the distribution and conservation value of plant species and
- to generate outputs for reports, files for export and further handling with other software, and labels for plant species for use in the herbarium.

A programme has been written in dBase IV, for menu-guided data input, editing, analysis, printing and export and backing-up of data (see appendix C).

The main menu contains the following options:

INPUT	EDIT	ANALYSIS	PRINT/EXPORT	SAVE	QUIT

3.1 Data input

The data input menu has the following options:

```
INPUT
In Plant list
In Identification list  ▸
In Releve/Collection list
In List of useful plants
```

On selection of the **first option** the following data-input screen will appear:

```
Plant name                                          CODES (Hawthorne 93)
Spec author                                         alphabet.
         ssp/var author                             numeric
         Family                                     Monocot./Fern {MF}
         Old name
         Life-form{TSCHGEPF}   Habitat{FRMGSAW}              Weed {W}
—Distribution—
Area Code
Guild      1a/b=pioneer 2=NPLD 3=shade-bearer 4=swamp 5=non forest 6=ot.
Forest type ordination score for axis 1     axis 2     (Hall & Swaine 81)
—Conservation value—
Distribution {A-E;1-3}   A=endemic B/C=limited distr. D=disjunct E=rare GH
Star rating  {Bk,bu,Gd,gn,R,S,P,X,x,z}                  IUCN category

Fodder
Site etc.
Indic. spec
Questions                      Use {X=input in extra database}

<PgDn> for next input   <Ctrl><End> save & exit   <Esc> exit without saving
```

Codes which are used for the input are given in curly brackets before the input field:
Life-form: Tree, Shrub, Climber, Herb, Grass, Epiphyte, Parasite, Fern.
Habitat: Forest, Riverine forest, Margin of forest/woodland/thicket, Grassland (=savanna), Swamp, Aquatic, Weed/ruderal.
Distribution class/source: A: endemic, **B:** Ghana & one other country, **C:** limited distribution in Africa, **D:** disjunct, **E:** rare in Ghana but otherwise widespread; Source: 1: Hall 1979, 2 FWTA & Brunel et al. 1984, 3: Lock 1989.

Star rating {Black, blue, Gold, green, Red, Scarlet, Pink, X} for details see Hawthorne 1993b.
IUCN category - for details see IUCN Red Data book - {Extinct, Endangered, Vulnerable, Rare, Intermediate, insufficiently Known, Out of danger, not threatened, ? no information; the new draft categories (Mace et al. 1992) are **EX**tinct, Extinct in the Wild, **CR**itical, **EN**dangered, **VU**lnerable, **SU**sceptible, Safe/Low Risk, Insufficiently Known, Not Endangered}.
Guild {1 pioneers (**1a** true pioneers, ie. always require gaps; **1b** cryptic pioneers, ie. tolerate shade in later life), 2 Non Pioneer Light Demander, 3 shade-bearer, 4 swamp, 5 non forest species, 6 others}.

On selection of the **second option** the following menu will appear:

```
1. Input new species in Identification list
2. Locate/edit this species in Plant list
3. Find this species in FROGGIE database
-------------------------------------------
   Exit
```

Choosing step 1 will bring up the following data-input screen:

```
PLANTS COLLECTED IN THE PROTECTED AREA SYSTEM
------------------------------------------------------------------------------
PLANT no.                  Releve Number              Area Code

Plant name
Family
------------------------------------------------------------------------------
Description


Life-form    -> Tree, Shrub, Climber, Herb, Grass, Epiphyte, Parasite, Fern
Habitat      -> Forest, Riverine forest, Margin of forest/woodland/thicket,
                Grassland/savanna, Swamp, Aquatic vegetation, Weed/ruderal
------------------------------------------------------------------------------
Determined by     -> KS (K. Schmitt), MA (M. Adu-Nsiah), DA (D. Abbiw)
Quality of        -> 1: ok, 2: cf. species, 3: cf. genus, 4: cf. family,
  Identification     5: sterile, 0: not identified
Mounted (GWD Herbarium: M)          Duplicate (Legon Herbarium: D)
==============================================================================
<PgDn> for next input <Ctrl><End> to save & exit <Esc> exit without saving
```

After data has been inputted and <Ctrl><End> entered the following popup menu will appear again:

```
1. Input new species in Identification list
2. Locate/edit this species in Plant list
3. Find this species in FROGGIE database
-------------------------------------------
   Exit
```

On selection of step 2 (must be preceded by step 1!!) the Plant list input screen will appear and show this species, if the newly identified species is already in the Plant list data-base. This allows for additional inputs such as 'Area Code' or the 'Habitat' to be made.
If the newly identified plant is not in the Plant list data-base the following instruction will appear on the screen:

```
          Plant not found!
         >>>Check spelling<<<

 Back to Identification list for spell-check
  Add this species to Plant list data-base
```

Select 'Back to Identification list for spell-check' if you are not certain about the spelling, otherwise select 'Add this species to Plant list data-base'.

On selection of step 3 (must be preceded by step 1 or 2!!) the screen will show: Name, Author, Family, Old Name, Alphabetical Code, Numeric Code, Axis 1, Axis 6, Star Rating and Guild for the respective plant species from the FROGGIE data-base and - if present in PG_LIST - also from the PG_LIST data-base. Additional inputs and corrections can be made later under the edit option.

If the **third option** is selected the following data-input screen will appear:

```
RELEVE & COLLECTION LOCATIONS
---------------------------------------------------------------------
Releve/Collection Number  ░░░░                      Date ░░/░░/░░
---------------------------------------------------------------------
Area Code ░░░░   Location ░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░

                 Latitude  ░░░░░░░░ N
                 Longitude ░░░░░░░░ <Alt>248 => °
                 Altitude  ░░░ (m)
---------------------------------------------------------------------
Collected by ░░  KM/M/MJ/KJM  (K: K. Schmitt; M: M. Adu-Nsiah;
                               J: J. Amponsah)
=====================================================================
<PgDn> for next input <Ctrl><End> to save and return to main menu
                      <Esc> to exit without saving
```

If the **fourth option** is selected the following data-input screen will appear:

```
USEFUL PLANTS
--------------------------------------------------------------------------
Plant Name ░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░░  Source ░  1: Irvine
                                                        2: Abbiw
--------------------------------------------------------------------------
Food plant           ░  Condiments/Spices  ░  Beverages             ░
Fodder plant         ░  Bee plant          ░  Fats/Oils/Waxes       ░
Medicinal/Vet        ░  Poisons/Antidotes  ░  Tannin producing      ░
Gums/Resins/Waxes    ░  Dyes/Stains/Inks   ░  Cosmetics/Pomades     ░
Perfumery            ░  Mucilage plant     ░  Veg salts             ░
Fibres               ░  Decoration         ░  Fencing/Boundaries    ░
Hut & Yampoles/         Timber             ░
     Walls/Rafters   ░  Furniture          ░  Sacred plants         ░
Domestic use         ░  Firewood           ░
Manure               ░  Charcoal           ░
--------------------------------------------------------------------------
<PgDn> for next input  <Ctrl><End> to save and exit  <Esc> exit only
```

For a list of plants contained in this database see appendix D.

3.2 Data editing

The data editing menu has the following options:

```
EDIT
Plant list                    ►
Identification list           ►
Releve/Collection list        ►
-----------------------------
List of useful plants         ►
```

On selection of the **first option** the following popup menu will appear:

```
Sorted according to plant names  ►
Sorted according to families     ►
```

If 'sorted according plant names' has been selected, the following input-menu will be brought up on the screen:

```
Find plant name and edit/browse record(s)

Name: ▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒

Exit: delete input, press <return>
```

The plant name does not have to be typed in full. Input is completed by pressing return, this will bring up the following popup-menu:

```
List single species
List group of species  ►
-----------------------
Exit
```

On selection of the first option the Plant-list input-screen will appear. If the second option is chosen the following screen will be brought up (for an explanation of the fields see Table 2):

```
Select field(s) to be browsed (1-7), using arrow key and <return>

NAME                         Do you want to
OLD_NAME                     select another
AUTHOR                       field? (Y/N) ▒
SV_AUTHOR
FAMILY
L_F
HAB
CODE
F_M
WEED
USE
ANIM_FOOD
OTHERS
DIS
IND_SPEC
IUCN
STAR
GUILD
HS1
HS6
TSPCODE
MMCODE
QUESTIONS
```

Table 2. Explanation of fields in PG_LIST database.

Field Name	Width*	Explanation
NAME	45 c	Plant name
OLD_NAME	30 c	Old plant name/synonym if still widly used, written in brackets!
AUTHOR	45 c	Space between initial & name, but not if more than 1 initial
SV_AUTHOR	30 c	Name of author for subspecies or variety
FAMILY	30 c	Family name
L_F	1 c	Life-form: Tree, Shrub, Climber, Herb, Grass, Epiphyte, Parasite, Fern
HAB	2 c	Habitat: Forest, Riverine forest, Margin of forest/woodland/thicket, Grassland (=savanna), Swamp, Aquatic, Weed/ruderal
CODE	65 c	4-letter area codes (see p. 17), one blank between each code
F_M	1 c	Fern or Monocotyledon
WEED	1 c	Weed
USE	1 c	X for input in separate data-base
ANIM_FOOD	65 c	
OTHERS	65 c	Any additional information such as site requirements etc.
DIS	2 c	Distribution (letter) & source (number): A: endemic, B: Ghana & one other country, C: limited distribution in Africa, D: disjunct, E: rare in Ghana but otherwise widespread; 1: source=Hall 1979, 2: source=FWTA/Brunnel et al. 19884, 3: source=Lock 1989
IND_SPEC	32 c	
IUCN	1 c	IUCN categories: Extinct, Endangered, Vulnerable, Rare, Intermediate, insufficiently Known, Out of danger, not threatened, ? no information; or Extinct, Extinct in the Wild, Critical, Endangered, Vulnerable, Susceptible, Safe/Low Risk, Insufficiently Known, Not Endangered (see page 12); Source: WCMC 1993
STAR	2 c	Star rating: Black, Blue, Gold, Green, Red, Scarlet, Pink (see Hawthorne 1993b)
GUILD	2 n	1 pioneers (1a true pioneers, 1b cryptic pioneers), 2 Non Pioneer Light Demander, 3 shade-bearer, 4 swamp, 5 non forest species, 6 others
HS1	3 n	Ordination score for axis 1 (Hall & Swaine 1981)
HS6	3 n	Ordination score for axis 6 (Hall & Swaine 1981)
TSPCODE	4 n	Numeric code for species (Hawthorne 1993b)
MMCODE	10 c	Alphabetical code for species (Hawthorne 1993b)
QUESTIONS	20 c	

* c=character, n=numeric

If when editing the Plant list the option 'Sorted according to families' is chosen the same steps apply as just described, with the data-base sorted according to families.

On selection of the **second option** the following popup menu will appear:

```
List single species ▶
List all species
```

On selection of 'List single species' the following menu will appear:

```
1. Edit record in Identification list
2. Locate/edit this species in Plant list
3. Find this species in FROGGIE database

   Exit
```

Choosing step 1 will bring up the following input screen:

```
Select number of plant to be edited: ▒▒▒
```

The data-input screen shown on page 11 for the species selected will be brought up on the screen.

On selection of step 2 (must be preceded by step 1!!) the Plant list input screen will appear and show this species, if the edited species is already in the Plant list data-base. This allows for additional inputs to be made.

If the edited plant is not in the Plant list data-base the following instruction will appear on the screen:

```
              Plant not found!
             >>>Check spelling<<<

 Back to Identification list for spell-check
  Add this species to Plant list data-base
```

Select 'Back to Identification list for spell-check' if you are not certain about the spelling, otherwise select 'Add this species to Plant list data-base'.

On selection of step 3 (must be preceded by step 1 or 2!!) the screen will show: Name, Author, Family, Old Name, Alphabetical Code, Numeric Code, Axis 1, Axis 6, Star Rating and Guild for the respective plant species from the FROGGIE data-base and - if present in PG_LIST - also from the PG_LIST data-base. Additional inputs and corrections can be made later under the edit option.

On selection of 'List all species' all the records entered are displayed on the screen in numerical order. Use the arrow keys, tab-stops, PgUp, PgDn, Home and End keys to move around within the table. Press <Esc> to exit without saving or <Ctrl><End> to save and return to main menu.

On selection of the **third option** the following popup menu will appear:

```
List single releve    ►
List all releves
```

On selection of 'List single relevé' the following input screen will appear:

```
Select number of releve to be edited:
```

The data-input screen 'RELEVE & COLLECTION LOCATIONS' for the appropriate relevé will be brought up on the screen.

On selection of 'List all relevés' all the records entered are displayed on the screen in numerical order. Use the arrow keys, tab-stops, PgUp, PgDn, Home and End keys to move around within the table. Press <Esc> to exit without saving or <Ctrl><End> to save and return to main menu.

On selection of the **fourth option** the following popup menu will appear:

```
List single species   ►
List all species
```

If 'List single species' has been selected the following input-menu will be brought up on the screen:

```
Type name of plant to be edited
```

The plant name does not have to be typed in full. Input is completed by pressing return, this will bring up the data-input screen 'USEFUL PLANTS' for the selected species.

If 'List all species' has been selected the dBase 'browse' screen will display all species in alphabetical order together with their uses. The arrow keys, tab-stops, PgUp, PgDn, Home and End keys can be used to 'scroll' through the records. Press <Esc> to exit without saving or <Ctrl><End> to save and return to main menu.

3.3 Data analysis

The data analysis menu has the following options:

```
ANALYSIS
Records for a single area
   Count records                              ►
   List species of conservation value         ►
   List indicator species                     ►
-----------------------------------------------
Records for all areas
   List species of conservation value         ►
```

3.3.1 Analyse records for a single area

On selection of '**Count records**' you will be asked to enter the code for the area for which species and life-form numbers are to be counted.

```
Type area code
```

```
Area Code
---------
ANKA GBEL
ASIN KAKU
BIAN KALA
BIAG KOGY
BOFI MOLE
BOMF NINI
BUI  OWAB
DIGY SHAI
```

The codes are abbreviations of the names of the protected areas.

The next screen will give the following options:

```
Count total number of
species/life-forms
```

```
species
trees
shrubs
climbers
herbs
grasses
epiphytes
parasites
ferns
---------
Exit
```

Chose an option with the arrow key and select it by pressing <return>
The result will be displayed on the screen
Confirm continuation of counting by pressing <Y>
Otherwise abandon operation by pressing <N>

On selection of '**List species of conservation value**' you will be asked to enter the code for the area for which lists of species of conservation value are to be generated:

```
Type area code
```

After a few moments the following popup menu will appear:*

```
   Star species            ►
---------------------------
Distribution codes
   List on screen          ►
   Print records           ►
   Create txt file         ►
IUCN category
   List on screen          ►
   Print records           ►
   Create txt file         ►
---------------------------
Exit
```

* All print outs are formatted for Epson LQ printers and A4 paper!

After the option chosen has been executed select Exit to return to the data analysis menu.

On selection of 'Star species' the following popup menu will appear:*

```
Rare species
   List on screen
   Print records
   Create txt file
Species under pressure from exploitation
   List on screen
   Print records
   Create txt file
```

On selection of '**List indicator species**' you will be asked to enter the code (see page 17) for the area for which a list of indicator species is to be generated:

```
Type area code
```

After a few moments the following popup menu will appear:*

```
List on screen
Print records
Create txt file
---------------
Exit
```

After the option chosen has been executed select Exit to return to the data analysis menu.

The text files generated are saved in the subdirectory C:\GWD\DBS with the extension .txt:

Category	Name of txt file
Star species (rare)	STAR1.TXT
Species under exploitation pressure	STAR2.TXT
Distribution codes	DISTRIB.TXT
IUCN categories	IUCN.TXT
Indicator species	IND_SPEC.TXT

3.3.2 Analyse records for all areas

On selection of '**List species of conservation value**' the following popup menu will appear after a few moments:

```
Star species
   Rare species (Black, Gold, Blue star)          ►
   Black star species only                        ►
   Species under pressure from exploitation       ►
Distribution categories
   Endemic species                                ►
   Rare species with limited distribution         ►
   All categories (inc. IUCN)                     ►
---------------------------------------------------
Exit
```

On selection of any of the options the following popup menu will appear:*

```
List on screen
Print records
Create txt file
---------------
Exit
```

* All print outs are formatted for Epson LQ printers and A4 paper!

After the option chosen has been executed select Exit to return to the data analysis menu. The txt files generated are saved in the subdirectory C:\GWD\DBS with the extension .txt:

Category	Name of txt file
Rare species (Black, Gold, Blue star)	ALL1.TXT
Black star species only	ALL2.TXT
Species under exploitation pressure	ALL3.TXT
Endemic species	ALL_E.TXT
Rare species with limited distribution	ALL_I.TXT
All categories	ALL.TXT

3.4 Printing and export of data

The print/export menu has the following options:

```
PRINT/EXPORT

Print report              ►
Print label               ►

Create text file          ►
Create/export SORT.DBF    ►
```

First option: On selection of 'Print report' the following popup menu will appear:

```
Print plant list
    Family, Name, Author, Old Name, Life-Form, Habitat
    Name, Family
```

After confirming your choice by pressing <return> the following screen will appear:

```
For which reserve do you want to print a plant list        =>
```

Area Code	
ANKA	GBEL
ASIN	KAKU
BIAN	KALA
BIAG	KOGY
BOFI	MOLE
BOMF	NINI
BUI	OWAB
DIGY	SHAI

After entering the area code, the following screen will appear, which allows you to select the printer:

```
Select printer for print-out of plant list for: >>>> ....
```

.... = Code for selected area

```
Epson LQ printer
HP laser printer
```

After selection of printer you will be asked to confirm that the printer is on line.

Second option: On selection of option 'Print label' you will be asked to enter the first and the last number(s) of the label(s) to be printed and to select the printer:

```
Number of first label to be printed  ▒▒▒        Select printer

Number of last label to be printed   ▒▒▒        Epson LQ printer
                                                HP laser printer
```

Third option: On selection of 'Create text file' the following popup menu will appear:

```
Create a text file
    Family, Name, Author, Old Name, Life-Form, Habitat
    Name, Family
    List of collected and identified plants
```

Choosing options 1 or 2 will bring up the following input screen:

```
For which reserve do you want to create a text file ▒▒▒  =>  Area Code
                                                             ...
```

The resulting text file will be saved in the C:\GWD\DBS subdirectory under the name text1.txt for the option 'Family, Name, ...' and text2.txt for the option 'Name, Family'.

Choosing the third option will create a text file named det.txt, which will be saved in the same subdirectory.

Fourth option: On selection of 'Create export SORT.DBF' the following screen will appear:

```
For which reserve do you want to create a SORT.DBF ▒▒▒  =>  Area Code
                                                            ...
```

NB. The file Sort.dbf will be exported to the SORT\LEX subdirectory and overwrite the existing dbf file.

3.5 Back-up of data and quit programme

The save menu has the following options:

```
SAVE
Plant list
Identification list
Releve/Collection list
List of useful plants
```

Selection of any of the options will bring up a popup menu showing the types of files which can be backed-up on the A-drive:

Extension	File content
.dbf	database file
.mdx	multiple index file
.ndx	single index file

The quit menu has the following options:

QUIT
Quit dBase
Exit to dot prompt
Reindex all files

'Exit to dot prompt' leads to the command line in dBase. The programme expects a dBase command to be typed. If this option has been chosen by accident (or if the programme has crashed and the option 'Cancel' has been chosen) type 'do pag' and press <return> to go back to the programme menu.

'Reindex all files' will rebuild the index files (.mdx and .ndx). Performing this step is only necessary when a database does not seem to be sorted properly anymore.

Table 3. Explanation of fields in PPA, RE_LOC and USTG databases.

Field Name	Width*	Explanation
PPA database		
NO_G	4 n	Number of collected plant
CODE	4 c	4-letter area code (see p. 17)
RELE	3 n	Number of releve
HAB	1 c	Habitat: Forest, Riverine forest, Margin of forest/woodland/thicket, Grassland (=savanna), Swamp, Aquatic, Weed/ruderal
L_F	1 c	Life-form: Tree, Shrub, Climber, Herb, Grass, Epiphyte, Parasite, Fern
NAME	45 c	Plant name
FAMILY	5 c	Family code (the first five letters of the family name)
DET	2 c	Initials of person who determined plant: KS (K. Schmitt), MA (M. Adu-Nsiah), DA (D. Abbiw), WH (W. Hawthorne) and MC (M. Cheek)
I_Q	1 n	Quality of identification: 1=ok, 2=cf. species, 3=cf. genus, 4=cf. family, 5=sterile, 0=not identified
DES1	40 c	Description of plant (1st line)
DES2	40 c	Description of plant (2nd line)
M	1 c	M = mounted (GWD)
D	1 c	D = duplicate for the Herbarium at the University (Legon)
RE_LOC database		
RELE	3 n	Number of releve
DATE	8 d	Date (day/month/year)
CODE	4 c	4-letter area code (see p. 17)
LOC	35 c	Location of the releve
LAT	9 c	Latitude in degrees N (<Alt><248> = °)
LONG	9 c	Longitude in degrees (<Alt><248> = °)
ALT	3 n	Altitude in (m)
COLL	3 c	Releve established/plant collected by: KM/M/MJ/KJM (K: K. Schmitt, M: M. Adu-Nsiah, J: J. Amponsah)
USTG database		
NAME	30 c	Plant name
SOURCE	1 n	1: Irvine (1961), 2: Abbiw (1990)
FP	1 c	Food plant
CS	1 c	Condiments/Spices
BV	1 c	Beverages
FO	1 c	Fodder plant
BE	1 c	Bee plant
FOW	1 c	Fats/Oils/Waxes
MV	1 c	Medicinal/Vet
PA	1 c	Poisons/Antidotes
TP	1 c	Tannin producing
GRW	1 c	Gums/Resins/Waxes
DSI	1 c	Dyes/Stains/Inks
CP	1 c	Cosmetics/Pomades
PY	1 c	Perfumery
MP	1 c	Mucilage plant
VS	1 c	Veg salts
FI	1 c	Fibres
DE	1 c	Decoration
FB	1 c	Fencing/Boundaries
HW	1 c	Hut & Yampoles/Walls/Rafters
TI	1 c	Timber
FU	1 c	Furniture
DU	1 c	Domestic use
CC	1 c	Charcoal
FW	1 c	Firewood
MU	1 c	Manure
SP	1 c	Sacred plants

* c=character, n=numeric, d=data

4. VEGETATION CLASSIFICATION

Plant communities (recurring combinations of plant species) were classified by arranging species and relevés in an x-y table and sorting the table **to reveal correlations of presence or mutual exclusivity between species.**

In this study the following procedure (cf. van der Maarel 1982) was applied in order to generate a vegetation table:

1	Numerical analysis of the data using MULVA-4 V2.08 (Wildi and Orlóci 1990) see section 4.2
2	Subsequent rearrangement of the delineated clusters[4] using SORT 2.5 (Ackermann and Durka 1992) see section 4.3

Figure 7 shows the individual steps described in this chapter.

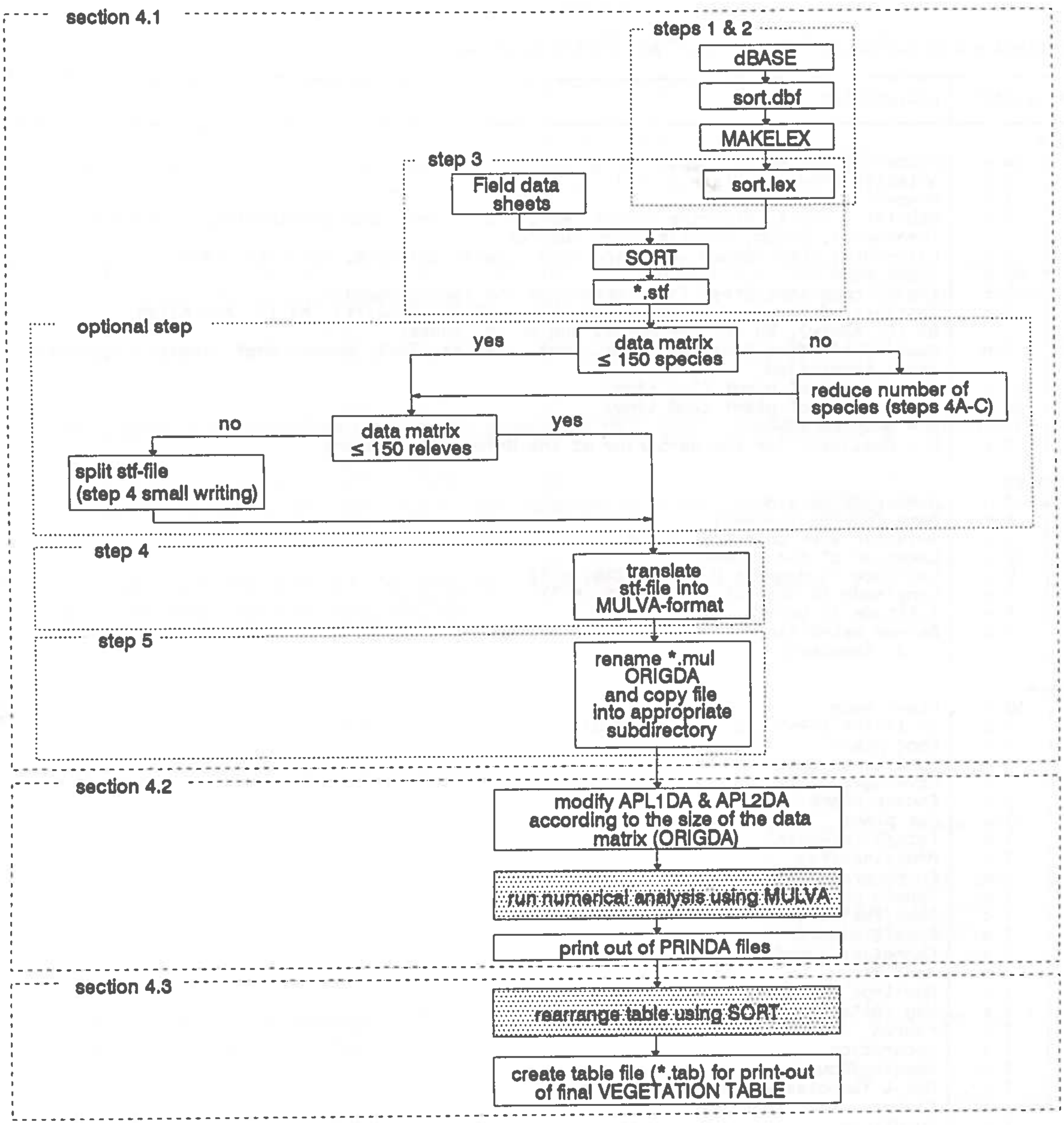

Fig. 7. Flow chart showing the steps involved in the vegetation classification.

[4] Wildi (1989) has recently produced a programme package, MULVA (revised version of Wildi and Orlóci 1983), which makes manual refinements of the vegetation tables unnecessary. It is, however, complicated to use and so for this study the simpler two step procedure was applied.

4.1 Data input

A combination of different softwares was used to ease the inputting process and to avoid spelling mistakes. For each area studied the following steps were undertaken:

1. Creation of a species list from a data-base file (SORT.DBF, see section 3.4)
2. Translation of this list (sort.dbf) into SORT.LEX using the programme MAKELEX
3. Input of data from field data-sheets using SORT 2.5 and SORT.LEX
4. Transformation of the data file created in SORT into the MULVA-4 format (using SORT)
5. Renaming this file ORIGDA and exporting it to the relevant MULVA subdirectory for analysis.

Step 1: see page 20 (section 3.4)

Step 2: Creation of a SORT.LEX file

The programme MAKELEX in the subdirectory C:\SORT\LEX is used to create a species list (Sort.lex) which is used for easy input of plant names into SORT.

Procedure:

1. Go to subdirectory SORT\LEX
2. Delete old version of sort.lex
3. Type **makelex** <return> NB. the programme is in German, so follow the following instructions carefully
4. The line on the screen reads "*Name der datenbank:*" type **sort.dbf** <return>
5. The next line reads "*Datenbank vom Verlag Goltze? J/N*" type **n**
6. The next line reads "*Name des neuen Sort-Lexikons:*" type **sort.lex** <return>
7. After the file sort.lex has been created successfully the line at the bottom of the screen reads "*Sort-Lexikon SORT.LEX fertig - Taste ...*" Press any key to return to the subdirectory.

Step 3: Input of field data in SORT (only certain important points are mentioned here):

1. Create a new table file (name = area code)
2. Create a "Header" (ie. matrix for input of site data for releves)
   Option: Data entry/Header -> New -> Choose *general (define '...user titles' or select 'Releve No', 'Column' and 'Species number'; the latter two should be generated only after completion of the data input).
3. Data entry

3.1 Input of site data

3.2 Species and abundance input

Use <F6> to switch between *Data Base* (= sort.lex) and *Table* (= species list in vegetation table). Different strata are marked by an extension directly after the plant name; it starts with ^ followed by the strata symbol (**S1**, **S2** or **T**). These extensions can only be added to the species from the *Data Base* (make sure during the inputting that a species of the same name and with the same extension is not in the *Table* !!!). New species (ie. those not in the *Data Base*) can be added to the *Table* only.

4. Save file, the extension will be **stf** (Standard Table Format)

Step 4: Creation of a MULVA file

1. Make a back-up copy of the final stf-file on a diskette.
2. Make sure that the stf-file contains fewer than 151 species and 151relevés (if not follow steps A to C below).
3. Translate the stf-file into MULVA format (extension **mul**) using the option Output -> MULVA-Format.

A. Sort the table in alphanumerical increasing order (using SORT option Table; mark all species and sort them using option <F2>). Create a file in 'Regensburger' format (extension **reg**) from the sorted stf-file (option Output -> Regensburger Format). Save the stf-file when you exit SORT, because this file will be used for rearranging the vegetation table after the numerical analysis (see section 4.3).

B. Reduce the number of species in the reg-file to 150 or less for further processing in MULVA. This is best done in WordPerfect (make sure that the resulting file is saved as an ASCII file: option save as DOS text) and give it a different name from the original stf-file (name = area code_tmp, extension = **reg**).

C. Create a new table file in SORT (name = area code_tmp). Load the Regensburger file with less than 151 species into the ...._tmp.stf file, option Read ASCII-file -> Regensburger format. Continue as described in number 3 above.

In case the original stf-file contains more than 150 relevés use the ...._tmp.stf file with ≤ 150 species and split it into two files (eg. all forest relevés in one and all grassland relevés in the other file) before translation into MULVA-Format. This is best done in SORT: use the stf-file with ≤ 150 species, delete the grassland relevés and save the resulting file under a different name (...._tp1); use the stf-file with ≤ 150 species, delete the the forest relevés and save the resulting file under a different name (...._tp2).

Step 5: Export and renaming of mul-file

For each vegetation table (ie. for each area) a separate subdirectory has to be opened under the M4 subdirectory because the standard input file for MULVA is always called ORIGDA

1. Copy mul-file into appropriate subdirectory and rename it **ORIGDA**.

4.2 Numerical analysis of the data using MULVA-4

The vegetation table is produced by a three-step analysis using the programme MULVA-4 version 2.08 (Wildi and Orlóci 1990):

1	Clustering of relevés
2	Clustering of species
3	Concentration analysis of groups

For the mathematical background to this programme see Orlóci (1978) and Wildi (1986).

The structure of the MULVA-4 programme is shown in Fig. 8. In order to simplify the use of this programme two applications programmes have been written which will run the different steps of the programme automatically. These applications are stored in files called APL1DA and APL2DA (see Tab. 4). They are executed by running programme **APPL** (see Fig. 8) and selecting options 1 - 2:

1. **Copy the files APL1DA and APL2DA into the subdirectory with the ORIGDA and edit them (using EDIT) according to the size of the data matrix:**

1.1 **APL1DA: Change lines 32 and 38. Line 32 = square root of number of relevés rounded to the nearest whole number; line 38 = 3 times the square root of the number of species rounded to the nearest whole number.**

1.2 **APL2DA: Change lines 18 and 57. Line 18 = square root of number of relevés rounded to the nearest whole number; line 57 = 3 times the square root of the number of species rounded to the nearest whole number.**

2. **Run numerical analysis using MULVA**

2.1 **Run first application (apl1da) by typing: M4 <return> 22 <return> 1 <return>. Get a printout of the resulting PRINDA-file!**

2.2 **Run second application (apl2da) by typing: M4 <return> 22 <return> 2 <return>. Get a printout of the resulting PRINDA-file!**

<table>
<tr><td colspan="3">1 Preparation of data, data simulation and file manipulation
CREO-11 SPAG-12 files-13 info-14</td></tr>
<tr><td colspan="3">2 Initializing the data system and description of the data
INIT-21 appl-22 macro on/off-23 print on/off-24</td></tr>
<tr><td rowspan="3">3
Data manipulation

EDGR-31
EDDA-32
EDCO-33</td><td>4 Resemblance structure
RESE-41 FSPA-42</td><td rowspan="3">7
Presentation of data

TABS-71
GRAP-72
ORDB-73</td></tr>
<tr><td>5 Primary analysis
RANK-51 CLTR-52 PCAB-53
MREG-54 ACOR-55</td></tr>
<tr><td>6 Secondary analysis
GRID-61 AOCL-62 DIAN-63
IDEN-64 REAL-65</td></tr>
</table>

Fig. 8. The structure of the MULVA-4 programme package:

Class 1 is used for the input of data for further analysis and was replaced in this project by SORT 2.5 (see above);
Class 2 creates files which contain intermediate results necessary for all subsequent steps;
Class 3 allows data manipulation;
Classes 4, 5 and 6 are the analytically important classes;
Class 7 performs the print-out and graphic presentation of the data.

The screen output of each programme-step is always written to a file called PRINDA. In the default mode, each subsequent programme-step will overwrite the PRINDA of the previous step[5], and the final PRINDA file will contain the vegetation table.

The contents of the two applications for the analysis of the data are shown in Table 4 and the individual steps are explained in a summarized form in Table 5. For more details see the programme manual (Wildi and Orlóci 1990) and the explanations in Orlóci (1978) and Wildi (1986).

Table 4. Contents of APL1DA and APL2DA files.

apl1da

INIT	RESE	INIT	RESE	CLTR	CLTR	AOCL	TABS
21	41	21	41	52	52	62	71
1	R1	2	S1	R1	S1	1	R8
1	1	2	5	3	3	R5	S8
	M	10	M	N	N	S5	1
1	n		n	*	**	0	
n	n	2	n	n	n	0	
n		n				Y	0
		n				N	n
						n	

apl2da

INIT	RESE	CLTR	INIT	RESE	PCAB	INIT	RESE	CLTR	AOCL	EDGR	TABS
21	41	52	21	41	53	21	41	52	62	31	71
1	R1	R1	2	R1	R1	2	S1	S1	1	R8	R20
1	7	2	1	8	3	2	4	2	R5	0	S20
	M	N		M	Y	10	M	N	S5	20	1
1	n	*	3	n	1		n	**	0	S8	
n	n	n	n	n	n	2	n	n	0	0	
n			n			n			0	20	0
						n			n	n	n

* square root of number of relevés rounded to the nearest whole number
** 3 times the square root of the number of species rounded to the nearest whole number

[5] If an analysis of the outputs of the different programmes applied in the analysis strategy is required, the programme **PRINT**, which creates files PRIN01 to PRIN20, should be turned on before running **APPL**.

Table 5. Strategies for the numerical analysis of the vegetation data.

Application 1 (APL1DA):

Objective	Step no.	Computer programme	Decisions	Method
Classification of the relevés	1	INIT (initialize)	scalar transformation vector transformation	square root normalize
	2	RESE (resemblance matrix)	resemblance measure for relevés	cross product of centred data
Classification of species	3	INIT (initialize)	scalar transformation vector transformation	log (x + 10) normalize
	4	RESE (resemblance matrix)	resemblance measure for species	Euclidean distance
Classification of the relevés	5	CLTR (cluster analysis)	clustering algorithm number of groups	minimum variance analysis according to objective (e.g. √n)
Classification of species	6	CLTR (cluster analysis)	clustering algorithm number of groups	minimum variance 2-5 times as many as there are relevé groups
Ordering dense blocks along the diagonal	7	AOCL (concentration analysis)	–	–
Printing of the entire vegetation table	8	TABS (printing of the vegetation table)	–	–

Application 2 (APL2DA):

Objective	Step no.	Computer programme	Decisions	Method
Classification of the relevés	1	INIT (initialize)	scalar transformation vector transformation	square root normalize
	2	RESE (resemblance matrix)	resemblance measure for relevés	similarity ratio (van der Maarel's cofficient)
	3	CLTR (cluster analysis)	clustering algorithm number of groups	complete linkage analysis according to objective (e.g. √n)
Ordination of species and relevés (correspondence analysis)	4	INIT (initialize)	scalar transformation vector transformation	square root presence-absence
	5	RESE (resemblance matrix)	resemblance measure, for columns	scalar product without centering (mandatory)
	6	PCAB (eigen analysis)	method	normal correspondence analysis
Classification of species	7	INIT (initialize)	scalar transformation vector transformation	log (x + 10) normalize
	8	RESE (resemblance matrix)	resemblance measure for species	Euclidean distance
	9	CLTR (cluster analysis)	clustering algorithm number of groups	complete linkage analysis 2-5 times as many as there are relevé groups
Ordering dense blocks along the diagonal	10	AOCL (concentration analysis)	–	–
Rearrange relevés and species within groups	11	EDGR (rearrange rows and columns)	order of groups order of relevés/ species within the groups	according to AOCL (step 10) according to 1st axis in correspondence analysis
Printing of the entire vegetation table	12	TABS (printing of the vegetation table)	ordering criteria	according to EDGR (step 11)

4.3 Subsequent rearrangement of the delineated clusters using SORT

The vegetation table is rearranged using SORT. The groups of species (differential species) that show similar distributions among the relevés (clusters) are moved to yield a systematically ordered table. This table groups the individual plant communities in a hierarchical system (from vegetation type to subcommunity) and reveals the site factors determining the distribution of the plant communities.
NB. Differential species distinguish different plant communities due to their **restricted** distribution within the relevés.

* The first step is to put all the representatives of one species recorded in different strata together, because MULVA treats them as different species.
* The next step is the rearrangement of the relevé and species groups. Those relevé groups which belong to the same vegetation type (eg. forest or grassland) should be grouped together and the species groups within this vegetation type should be arranged in a diagonal from top left to bottom right. It may occasionally be necessary to move some relevés and species to other groups in order to reveal clear correlations of presence and mutual exclusivity between species.
* Species groups which are found in more than one community should be moved in such a way that they clearly show their value as differential species:
  - species which differentiate vegetation types should be moved above the plant communities constituting the vegetation type,
  - species which differentiate groups of communities should be moved above the diagonal of the relevant communities,
  - species which have the same ecological amplitude but are found in communities of different vegetation types should be moved below the diagonal of all the plant communities they are found in,
  - species with a very wide ecological amplitude (ie. species which are found in most of the relevés) cannot be used to differentiate plant communities or groups of plant communities. They are considered to be companions and are placed at the bottom of the vegetation table.
* Rare species with no obvious differential value are placed below the companions, either within the vegetation table or in a separate list.

The plant communities are then named after the dominant species. The term 'community' is used instead of the term 'association' in the sense of Braun-Blanquet (1964) because no syntaxonomical studies/ranking could be performed within the short timespan of the project. The species groups are also named after the two dominant species.

The plant communities can be grouped together to form 'community groups' or divided into 'subcommunities'. Where appropriate a further subdivision into 'types' can be made.

The print out of the vegetation table can be done using SORT and an Epson LQ printer (Setting -> Hardcopy=Printer; Output -> Table), however creating a table file and using a laser printer is recommended:

1) Create a table file (extension .tab): Output -> Table
2) Use WordPerfect to print this table (the tab file is in ASCII format and has to be imported using <Ctrl> <F5> 12).

An example of a vegetation table resulting from numerical analysis (apl1da) and the subsequent rearrangement is shown in Tab. 6.
Relevé group 2 forms columns 1-7 in the final table
Relevé group 3 was split into two and forms columns 8-14 in the final table
Relevé group 5 forms columns 15-16 in the final table
Relevé group 4 and the first two relevés of group 6 form columns 17-20 in the final table
Relevé group 1 forms columns 21-31 in the final table
Relevé group 6 forms columns 32-35 in the final table

Table 6. Example of a numerical analysis and the subsequent rearrangement of a vegetation table. Example from Bomfobiri Wildlife Sanctury (Schmitt and Adu-Nsiah 1993a).

	RELEVE GROUP NO.		3	3	3	3	3	3	3	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	5	5	6	6	6	6	6	6	4	4
	RELEVE NO.		92	97	93	98	96	95	94	112	113	111	116	115	114	117	89	90	110	109	104	108	107	91	103	106	46	105	48	47	118	119	102	101	100	99	45	44
91	No. 815	1	2	1	2																																	
41	Ctenium newtonii	1	2	1	1	+																																
92	No. 818	1	+		2																																	
93	No. 819	1	+		+				1																													
94	No. 821	3			+		3	3																														
48	Detarium microcarpum T	3			1		2	2							+																							
95	No. 824	3					1	1	3																													
96	No. 826Combr S1	3					+																															
141	Terminalia avicennioides T	2							1																													
97	No. 826Combr S2	2				+			2																													
77	Maytenus senegalensis S1	2							+		+																											
98	No. 837	4				2																																
68	Lophira lanceolata S2	4	+			2					+		1																									
69	Lophira lanceolata T	4			2	2	2	2	1	+	+		1																									
65	Indigofera paniculata	4		1		1	+	1	+	+			+	+		1																						
45	Daniellia oliveri S1	4	2	1	+	2	1	1		1	+				+	+																						
139	Terminalia avicennioides S1	4		+				+																														
118	Polygala arenaria	4	1	+		+		+	+																													
150	Vitex doniana S2	6									+					+																						
106	No. 927	6									2																											
140	Terminalia avicennioides S2	6												+																								
6	Allophylus cobbe S1	6									+			+																								
142	Terminalia laxiflora T	6								2	2	1		1		1																						
40	Combretum fragrans T	6								1	1	2		+																								
46	Daniellia oliveri T	6	2				+	+	2	2	2	+	2	2	2	2																						
8	Andropogon tectorum	6						+	+	1	2	2	2	1																								
70	Loudetia simplex	7								+		+																										
62	Grewia villosa S1	7								+		+																										
47	Desmodium velutinum S1	7								+		+																										
115	Parkia biglobosa T	7								+		1																										
72	Malacantha alnifolia T	8													2																							
39	Combretum fragrans S1	8													+																							
105	No. 923	8								+				+	1																							
9	Annona senegalensis S1	8								+					+																							
10	Anogeissus leiocarpus T	8								+	+				+																							
107	No. 935	5											+	+		+																						
78	Maytenus senegalensis S2	5											+	+																								
138	Tephrosia elegans	5											+	+	+	+																						
103	No. 918	5										1	1	1	2	1																						
104	No. 922	5								+	+	+	+	+	+	2															+							
2	Aframomum spec.	5									+		1	1	1	+										1							+	1		+		
119	Pseudocedrela kotschyi S2	5								1			+			+																						
13	Aspilia africana	5		+									+		+	+						+		+														
129	Spermacoce ruelliae	5										+	+																									
144	Thalia welwitschii S1	23															1	1																		+		
26	Chromolaena odorata S1	23															3	2											+	1								
143	Thalia welwitschii	23															2	2	1	1	+	2	+	+	1			+						+		+		
25	Chromolaena odorata	23						+			+		+	+	+	+	5	4	2	3	4	4	4	4	4	2	3	2						+				
81	Momordica spec.	23															+	+	+		+				+	+		+				+						
61	Gongronema latifolium	23															+	+			+				+							+						
73	Mallotus oppositifolius	19																							+													
18	Baphia pubescens S2	19																							+													
12	Antiaris toxicaria T	19																							2													
14	Baphia nitida	19																							+	+												
113	Panicum maximum	21																			+																	
56	Ficus sur S2	21																			+																	
30	Clerodendrum buchholzii S2	21																			+																	
15	Baphia nitida S1	21																			+							+										
147	Trichilia prieureana T	20																								1	1	2										
136	Tapura fischeri S2	20																								+		+										
55	Ficus sur S1	20																								+												
33	Cola chlamydantha S1	20																								+												
127	Smilax kraussiana	20																				+				+												
132	Sterculia tragacantha S1	24																		+																		
128	Sorghum arundinaceum	24																	1	2																		
101	No. 898 S1	24																					1															
67	Lonchocarpus laxiflorus S1	24																	1				+															
29	Clerodendrum buchholzii S1	24																						+														

No.	Species	Group	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
134	Sterculia tragacantha T	22			+			
112	Panicum 824	22			1			
102	No. 906	22			+ 1			
135	Strombosia glaucescens T	17			2			
100	No. 890 T	17			2			
57	Ficus sur T	17			+			
35	Cola chlamydantha T	17			1			
23	Celtis zenkeri T	17			+			
53	Entandrophragma angolense T	17			+		+	
24	Centrosema plumieri	16				+ +		
5	Alchornea cordifolia	16				+ +		
114	Panicumc cf.maximum (529)	16				4 5		
116	Paullinia pinnata	16				+ +	+	
54	Euphorbia heterophylla	16				+ +	+	
79	Microdesmis puberula	18			+ +			
4	Albizia zygia T	18			2			
28	Clerodendrum buchholzii	18			+ +			
86	Newbouldia laevis S1	18			1 1		+	
1	Acacia pennata	18			+ +		+ +	
87	Newbouldia laevis T	18			+ 1			
20	Blighia sapida	18			+ +		+	
85	Newbouldia laevis	18			1		+ +	
36	Cola gigantea	18			+		+ +	
38	Cola gigantea T	18			2 2 2 2		2 2	
126	Sarcophrynium brachystachys	11					+ + +	
59	Funtumia elastica S1	11		+			1 + 1	
75	Marantochloa cuspidata	11			+		+ +	
37	Cola gigantea S2	11					1 +	
122	Pycnanthus angolensis T	11					2 2 2 1	
43	Culcasia scandens	11					+ + +	
3	Albizia zygia	11			+		+ + 1	
63	Griffonia simplicifolia	11			+ + + 2 +	+ +	+ + 1 1	
123	Raphia hookeri	13			+		+	
76	Mareya micrantha S2	13			1		+	
60	Funtumia elastica T	13			+		1	
42	Culcasia saxatilis	13			3		+	
51	Elaeis guineensis	13			+		+ +	
148	Trichilia tessmannii T	13					2	
66	Lannea welwitschii T	13					1	
22	Celtis zenkeri S2	13					+	
17	Baphia pubescens S1	13					+	
49	Diospyros abyssinica S1	13			+		+	
124	Raphia hookeri T	12					+ +	
82	Myrianthus arboreus S2	12					1 1	
7	Alstonia boonei T	12			1		1 3	
149	Triplochiton scleroxylon T	12			+ 1		2	
11	Antiaris toxicaria S1	12			+ +		+	
146	Trichilia prieureana S2	12					2	
120	Pseudospondias microcarpa T	12					1	
111	Oplismenus burmannii	12					1	
64	Hildegardia barteri S2	12					2	
50	Dracaena arborea	12			+		+	
133	Sterculia tragacantha S2	9					+	
99	No. 890 S2	9					1	
80	Microdesmis puberula S2	9					1	
71	Malacantha alnifolia S1	9					+	
32	Cola chlamydantha	9					1	
16	Baphia nitida S2	9					+	
121	Pterygota macrocarpa T	9			+		3	
117	Platisepalum hirsutum	9			+		+	
84	Nesogordonia papaverifera T	9			+		+	
131	Sterculia rhinopetala T	9			+		2 1	
137	Tapurea fischeri T	10					+	
83	Myrianthus arboreus T	10					+	
52	Elaeis guineensis S2	10					+	
34	Cola chlamydantha S2	10					+	
27	Chrysophyllum albidum T	10					+	
19	Baphia pubescens T	10					1	
145	Tragia akwapimensis	10			+		+	
21	Ceiba pentandra T	10			2		1	
110	No. 940	14					1 +	
109	No. 939	14					1 +	
125	Sansevieria liberica	14					+ +	
31	Clerodendrum capitatum S1	14					+ +	
108	No. 938	14					1 1	
130	Sporobolus pyramidalis	14					2	+ +
58	Fimbristylis ovata	14					+	
74	Mallotus oppositifolius S1	14			+		+	
89	No. 504	15						1 1
88	No. 503	15						1 1
44	Cyperaceae	15						1 1
90	No. 505	15						2 1

Column	1 1111 11 1112 222222 22233 3333
	1234567890 1234 56 7890 123456 78901 2345
Releve number	1111111 11 1 11 11111 111
	1111111999 9999 44 1144 890910 00000 0009
	2316547654 2738 87 8954 907109 34865 2109
Species number	1111111 11 11 1111 11 12 2322
	7575965722 9997 43 2200 755876 33993 5076
Altitude (m)	2222222 2222 33 2231 33 33 3211
	7627022 0315 32 8389 12 43 0964
	0000900 0000 00 0000 00 00 0000
Slope (degree)	1 43
	0005505000 5000 00 0000 000050 00000 0000
Rock outcrops/Stoniness *	0001100000 3232 00 2233 110000 00000 0000
Drainage *	M M MMMM PIII MM IIPP WMMIM M MMM MI W
Tree height (m)	1212211111 1 3 22231 3433
	0050055525 7 80 0 05055 5055
Tree cover (%)	4443243443 1 31 1 21146 6789
	0000000000 0 00 0 00500 0000
Herb cover (%)	1
	5656666876 3448 60 2454 996968 77864 1223
	0000000000 0000 00 5000 000000 00000 5000
Date (month/year)	0000000000 0000 00 0000 000000 00000 0000
	1111111111 1111 99 1199 111111 11111 1111
	9999999999 9999 99 9999 999999 99999 9999
	3333333333 3333 22 3322 333333 33333 3333
Daniellia oliveri - Lophira lanceolata species group (Savanna vegetation)	
Daniellia oliveri T	22+2222++2 2... .. ..
Daniellia oliveri S2	.......2.. +.+. .. ..
Daniellia oliveri S1	1+...++11. 21+2 .. ..
Daniellia oliveri	.+..+.+... ....
Lophira lanceolata T	++.1...221 ..22 .. ..
Lophira lanceolata S2	.+.1...... +..2 .. ..
Lophira lanceolata S1	...+.....+ +..+ .. ..
Indigofera paniculata	+..++.1+1+ .1.1 .. ..
Daniellia oliveri - Andropogon tectorum community	
Andropogon tectorum	12221...++ ....
Maytenus senegalensis S2	...++..... ....
Maytenus senegalensis S1	.+.......+ ....
Terminalia laxiflora subcommunity	
Terminalia laxiflora T	221.1.1... ....
Terminalia laxiflora S2	..+....... ....
Terminalia laxiflora S1	+......... ....
Combretum fragrans T	112.+..... ....
Combretum fragrans S2	+1+.1..... ....
Combretum fragrans S1	.....+.... ....
No. 918	..11121... ....
No. 922	++++++2... .... .. +... ....
Aframomum spec.	.+.111+... ....1. +1.+
Vitex doniana S2	.+....+... ....
Vitex doniana S1	..+....... ....
Allophylus cobbe S1	.+..+..... ....
Ipomoea argentaurata	+...+1.... ....
Annona senegalensis S2	.....+.... ....
Annona senegalensis S1	+....+.... ....
Anogeissus leiocarpus T	++...+.... ....
No. 935	...++.+... ....
Tephrosia elegans	...++++... ....
Pseudocedrela kotschyi S2	1..+..+... ....
Pseudocedrela kotschyi S1	1......... ....
Aspilia africana	...+.++... .+.. .. ..+.. ..+.. ....
Spermacoce ruelliae	..++...... ....
Parkia biglobosa T	+.1....... ....
Parkia biglobosa S1	1......... ....
Detarium microcarpum subcommunity	
Detarium microcarpum T	.....+.22. ..1. .. ..
Detarium microcarpum S2	....1. .. ..
Detarium microcarpum S1	.......+.. ..+. .. ..
No. 821	.......33. ..+. .. ..
No. 824	.......113 ....

Polygala arenaria species group	
Polygala arenaria	........++ 1+.+ .. ..
No. 819	.........1 +.+. .. ..
Terminalia avicennioides T	.........1 ....
Terminalia avicennioides S2	....+..... ....
Terminalia avicennioides S1	........+. .+.. .. ..
No. 826Combr T	.........+ ....
No. 826Combr S2	.........2 ...+ .. ..
No. 826Combr S1	.......+.. ....
Daniellia oliveri - Ctenium newtonii species group (Savanna on shallow soil)	
Ctenium newtonii	.... 211+ .. ..
No. 815	.... 212. .. ..
No. 818	.... +.2. .. ..
Panicum maximum species group	
Panicumc cf.maximum (529)	.... 45 ....
Alchornea cordifolia	.... ++ ....
Centrosema plumieri	.... ++ ....
Euphorbia heterophylla	.... ++ +... ....
Paullinia pinnata	.... ++ ....+.
No. 533 S1	.... ++ ....
No. 538	.... ++ ....
No. 541	.... ++ ....
Boval vegetation (undifferentiated)	
Cyanotis arachnoidea	.... +... .. 11.. ....
No. 940 (Poaceae)	.... 1+.. ....
Sansevieria liberica	.... ++.. ....
Clerodendrum capitatum S1	.... ++.. ....
Fimbristylis ovata	....+.. ....
Sporobolus pyramidalis	.... .2++ ....
No. 503 (Poaceae)	....11 ....
No. 504	....11 ....
No. 505	....21 ....
Cyperaceae	....11 ....
Chromolaena odorata species group (Shrubland and disturbed forest)	
Chromolaena odorata	.+.++++.+. .... 544423 44422 .+..
Chromolaena odorata S1	.... +1 .... 32.... ....
Chromolaena odorata S2	....+ ....
Thalia welwitschii S1	.... 11.... ....+
Thalia welwitschii	.... 22++11 1+2.+ .+.+
Momordica spec.	....+.. ++..+. ++.++ ....
Gongronema latifolium	....+.. ++.... ++... ....
Lonchocarpus laxiflorus S1	....+.1. ....
Lonchocarpus laxiflorus	....+... ....
Lecaniodiscus cupanioides	....1... ....
Sorghum arundinaceum	....12 ....
Antiaris toxicaria - Triplochiton scleroxylon species group (forest)	
Milicia excelsa was found occasionally, but not included in any releve	
Antiaris toxicaria T	.... 2.... ....
Antiaris toxicaria S2	....+... ....
Antiaris toxicaria S1	....+ ...+. ...+
Antiaris toxicaria	.... +. 1
Triplochiton scleroxylon T	.... +..1. ...2
Triplochiton scleroxylon S2	.... +...
Triplochiton scleroxylon S1	....+
Cola gigantea T	.... .222. 22..
Cola gigantea S2	.... .1.+
Cola gigantea	.... ++..
Griffonia simplicifolia S1	.... +2.+
Griffonia simplicifolia	.... ++ ....+. +..++ ++11
Ficus sur species group (Forest)	
Ficus sur T	....+ ....
Ficus sur S2	....+... ....
Ficus sur S1	....+. ....
Tapurea fischeri T	....+..
Tapura fischeri S2	....++ ....
Tapura fischeri S1	....+. ....
Baphia nitida S2	.... +...
Baphia nitida S1	....+..+ ....
Baphia nitida	.... +..+. ....
Smilax kraussiana	....++. ....

Pycnanthus angolensis species group (Riverine forest)	
Pycnanthus angolensis T	 2221
Sarcophrynium brachystachyum	.... ++++
Culcasia scandens	.... +++.
Piper guineense	....+.
Palisota bracteosa	....+.
Cercestis afzelii	....+.
Rothmannia whitfieldii S2	....+..
Rothmannia whitfieldii	.... +...
Discoglypremna caloneura S1	.... +...
Myrianthus arboreus T	....+..
Myrianthus arboreus S2	11
Myrianthus arboreus	....+..
Raphia hookeri T	....++
Raphia hookeri	....+.
Elaeis guineensis S2	....+..
Elaeis guineensis	....++
Funtumia elastica T	....1.
Funtumia elastica S2	.... +.+.
Funtumia elastica S1	.+........ .... 1+.1
Funtumia elastica	.... +...
Albizia zygia S2	.... +...
Albizia zygia	.... ++1.
Forest companions (Riverine forest and disturbed forest)	
Trichilia prieureana T	....12 ....
Trichilia prieureana S2	2
Newbouldia laevis T	....+... ....
Newbouldia laevis S1	.... +... ....1 ....
Newbouldia laevis	.... ++..
Cola chlamydantha T	....1 ....
Cola chlamydantha S2	....+..
Cola chlamydantha S1	....+. ....
Cola chlamydantha	.... 1...
Celtis zenkeri T	....+ ....
Celtis zenkeri S2	....+.
Celtis zenkeri S1	....+
Celtis zenkeri	....+.
Baphia pubescens T	.... .1..
Baphia pubescens S2	.... +.... ....
Baphia pubescens S1	....+.
Baphia pubescens	....+..
Entandrophragma angolense T	....+ .+..
Microdesmis puberula S2	.... 1...
Microdesmis puberula	.... +.... ....
Diospyros abyssinica S1	....+ ..+.
Alstonia boonei T	....1. ..13
Dracaena arborea	....+ ...+
Pterygota macrocarpa T	....+. 3...
Sterculia rhinopetala T	....+ 21..
Marantochloa cuspidata	....+. .+.+
Companions (Forest and derived thickets)	
Acacia pennata	.... ++.. ...... +.... ....
Blighia sapida	....+... .+..
Blighia sapida S1	....+
Blighia sapida S2	....+..
Ceiba pentandra T	.... .2.... ..... .1..
Mallotus oppositifolius	.... +.... ....
Mallotus oppositifolius S1	....+.. ....+ ....
Panicum spec.	.... +..2.. ....

* Rock outcrops/Surface stoniness: 0: <1%, 1: 1-10%, 2: 10-25%, 3: 25-50%, 4: 50-75%, 5: 75-100%
Drainage: P = poor, I = imperfect, M = moderately well, W = well

Other species:
Acacia gourmaensis^S1 (116:+); Acacia gourmaensis^S2 (116:+); Albizia adianthifolia^S1 (106:+); Albizia coriaria^S1 (111:+); Alstonia boonei^S2 (106:+); Aneilema umbrosum (99:+); Baphia pubescens (101:+); Borassus aethiopum^S1 (111:+); Bridelia ferruginea^S1 (117:+); Chrysophyllum albidum^S2 (102:+); Clerodendrum buchholzii S2 (104:+); Clerodendrum buchholzii S1 (91:+); Clerodendrum buchholzii (106:+, 108:+); Clerodendrum sinuatum (107:+); Clerodendrum splendens (110:+); Clerodendrum splendens^S1 (110:+); Commelina spec. (101:+); Costus afer (91:+); Culcasia saxatilis (99:+, 105:3); Cussonia arborea^S2 (117:+); Deschampsia spec. (45:+); Desmodium spec. (44:+); Desmodium velutinum (111:+); Detarium microcarpum^S1 (93:+, 96:+); Diospyros mespiliformis (99:1); Dornig Owabi^S1 (48:+); Dracaena surculosa (118:+); Eribroma oblonga^S1 (91:+); Hibiscus scotellii (45:+); Hildegardia barteri^S2 (99:2); Hyperetelia dissoluta (47:+);

Imperata cylindrica (119:+); Kyllinga spec. (44:+); Lantana camara (117:+); Loudetia simplex (112:+, 111:+); Malacantha alnifolia^S1 (102:+); Malacantha alnifolia^T (114:2); Mareya micrantha S2 (99:+, 105:1); Millettia barteri^S2 (47:+); Monechma ciliatum (111:+); Morus mesozygia^T (102:+); Nesogordonia papaverifera (102:+); No. 506 (44:+); No. 507 (44:+, 45:+); No. 508 (45:+); No. 510 (44:1); No. 535 (48:+); No. 536Combr^S1 (47:+); No. 538 (47:+, 48:+); No. 813 (103:+, 89:+); No. 814 (91:+); No. 820 (92:+); No. 823 (97:+, 93:+); No. 825 (94:+); No. 825^S1 (94:+); No. 828 (95:+); No. 829 (95:+); No. 837 (98:2); No. 871 (99:+); No. 875 (100:+); No. 878 (100:+); No. 879 (100:+, 101:+); No. 880 (100:+); No. 881 (100:+); No. 882^S1 (100:+); No. 882^S2 (100:+); No. 884 (101:+); No. 886^S2 (101:+); No. 889^S2 (102:+); No. 890^S2 (102:1); No. 890^T (105:2); No. 891 (104:+); No. 892 (105:+); No. 893^S2 (105:+); No. 893^T (105:+); No. 906 (109:+, 108:1); No. 916 (115:+); No. 919 (113:+, 111:+); No. 920 (112:+, 111:+); No. 925 (112:+); No. 927 (113:2); No. 930 (114:+, 115:+); No. 931 (114:+); No. 932 (114:+); No. 936 (115:+); No. 937^S1 (115:+); No. 941 (118:+); Olyra latifolia (105:+); Oplismenus burmannii (99:1); Palisota hirsuta (106:+); Panicum maximum (104:+); Panicum spec. (89:+, 91:2); Panicum spec. (89:+, 91:2); Parkia biglobosa^S1 (112:1); Pericopsis laxiflora^S2 (94:+); Platisepalum hirsutum (105:+, 102:+); Poaceae spec. (48:+); Portulaca grandiflora (45:+); Pseudospondias microcarpa^T (99:1); Rauvolfia vomitoria^S1 (106:+); Salacia leptoclada (99:+); Sterculia tragacantha (101:+); Sterculia tragacantha^S1 (109:+); Sterculia tragacantha^S2 (102:+); Sterculia tragacantha^T (108:+); Strombosia glaucescens^T (105:2); Talinum triangulare (118:+); Teramnus labialis (97:+); Tetrapleura tetraptera^T (101:+); Thonningia sanguinea (99:+); Trichilia tessmannii^T (100:2).

5. METEOROLOGICAL DATA

Climatic diagrams according to Walter and Lieth (1960-67) should be produced for all areas investigated. They clearly show the annual distribution of rainfall and the length of arid and humid periods (Fig. 9).

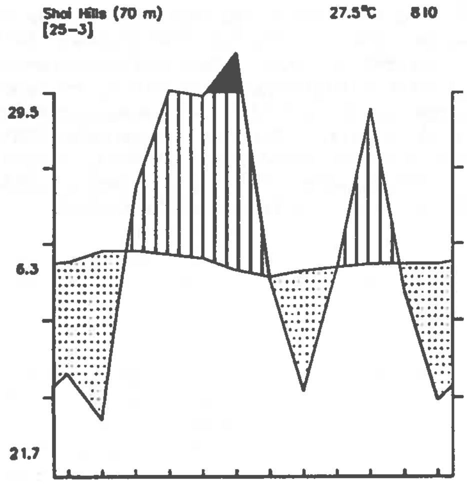

Fig. 9. Climatic diagram for Shai Hills (from Schmitt and Adu-Nsiah 1993d)

Walter and Lieth (1960-67) used the term N = 2T (N = rainfall, T = temperature) to distinguish relatively arid and relatively humid seasons. The y-axis divisions of the climatic diagram represent 10°C and 20 mm rainfall respectively. Arid periods (rainfall < 2 x temperature), ie. when the rainfall curve is below the temperature curve, are dotted; humid periods (rainfall > 2 x temperature), ie. when the rainfall curve is above the temperature curve, are marked with parallel lines; periods with rainfall above 100 mm are marked black and the scale is reduced to 1/10.

The name of the station, its altitude, the annual mean temperature and annual mean rainfall in mm are shown above the diagram. The number of years over which observations were made (for temperature and rainfall respectively) are shown in square brackets. The numbers left of the diagram, from top to bottom show: absolute maximum temperature, mean maximum temperature of the warmest month, mean daily temperature range, mean minimum of the coldest month and absolute minimum temperature.

One or several climatic diagrams can be used in combination with isohyets for the area concerned (see either 'Map of average annual rainfall' Survey of Ghana 1968 or Hall and Swaine 1981, p. 20) to illustrate the climatic setting of the protected area. An example is shown in Fig. 10.

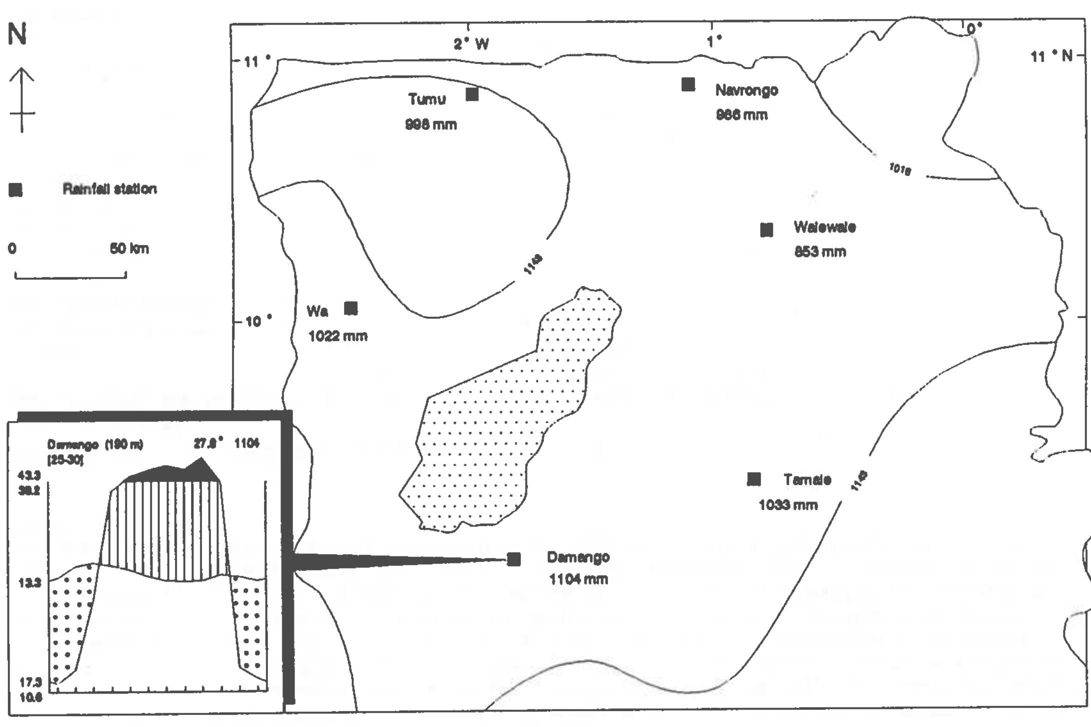

Fig. 10. Climatic setting of Mole National Park (modified from Schmitt and Adu-Nsiah 1993c).

6. VEGETATION MONITORING

This section provides an introduction to and gives some general guide-lines for vegetation monitoring.

Monitoring is a process which aims to detect changes, establish their direction and measure their extent or intensity. It checks whether the prevailing conditions match the previously defined standards or norms. Analysis of site characteristics and definition of the major biotopes and identification of species of conservation value in an area are fundamental prerequisites for the development of any monitoring strategy. Repeated surveys should be carried out at regular intervals in relation to clearly defined objectives.

Monitoring can be used to:
- assess the effectiveness of any management carried out to protect or enhance any special features, biotopes or particular species of the protected areas
- detect changes (ie. act as an 'early warning').

Ecosystems are rarely at equilibrium, they are continually perturbed both in space and time. Changes within ecosystems should be considered as natural and inevitable. Counteracting such changes should not be the aim of any management. An understanding of the biological processes underlying ecosystems is therefore essential in order to distinguish between **acceptable short-term changes** and **unacceptable long-term changes** which should be prevented.

High diversity is often used synonymously for stability which is not necessarily the case. Stability in an ecosystem means the stability of the number of species, ie. a system is stable if the number of species remains the same. This has been called more precisely **persistence** (Lewin 1986). The stability of population size is called **constancy**.

Conservation should aim for persistence and not for constancy. Fluctuation of the number of individuals within particular species is inevitable and is in fact necessary to achieve persistence.

Steps necessary for the design of monitoring strategies are:

1) What are the objectives?
2) What is to be monitored?
3) How can the objectives be achieved (methods)?
4) What does the data mean (analysis and interpretation)?
5) When should the monitoring stop?

What are the objectives?
General objectives might include: to detect, record and present in a comprehensible form any changes, trends or impacts in the number or condition of the major biotopes or of any plant species of conservation value to the Park management and the GWD.

Objectives should be grouped according to their priorities. Possible groups are: top priority, recommended, optional but also desirable.

What is to be monitored?
This requires the identification of key features which are intrinsic to the site (eg. the presence of rare or endangered species) and the selection of standards or norms against which changes can be assessed (eg. acceptable minima and maxima).

NB. Many systems exhibit cyclical or stochastic changes! A period of surveillance is therefore necessary to establish a true baseline (eg. the lowest population number normally encountered). This baseline may need revision in the light of experience.

Many different measures may be used as yardsticks for monitoring: eg. the biomass of vegetation; growth, production or recruitment rates; checklists of species richness; the extent or structure (mosaic or diversity) of habitat; the presence and absence of indicator species etc..

How can the objectives be achieved?
It is essential to draw up a detailed monitoring prescription which contains information on:
- methodology
- frequency of sampling
- intensity of sampling
- sampling unit size
- sampling pattern
- the location of the plots, which must be relocatable (using metal posts, GPS readings and maps)
- time needed and best time of the year
- organisation of finance and administration

Simple schemes are likely to be the most effective. This does not have to mean unsophisticated but does mean simple to carry out and not too time-consuming. Ease of collection of data, ease of analysis of those data, ease of interpretation of results and ease of handing over responsibility to staff in the reserves are necessary conditions for securing the long-term viability of a monitoring programme.

Standardizing data collection is essential and requires:
- method forms (ie. a detailed manual)
- data collection forms (to be used in the field)
- data reduction forms (to be used in the office for initial analysis such as means etc.)
- summary forms (to condense data from several data reduction forms and provide a first analysis)

What does the data mean (analysis and interpretation) ?
For the analysis and interpretation of data collected please refer to standard textbooks such as: Greig-Smith, P. (1983): Quantitative Plant Ecology. - (3rd edn.) Butterworths, London. Moore, P.D. and Chapman, S.B. eds. (1986): Methods in Plant Ecology. - Blackwell. Oxford. Mueller-Dombois, D. and Ellenberg, H. (1974): Aims and Methods of Vegetation Ecology. - Wiley and Sons, New York.

NB. Data may reveal trends, cycles and 'noise'! Monitoring generally aims to reveal trends and these must be separated in the analysis from the effects of one or more cycles and baseline variation ('noise').

When should the monitoring stop?
It is often advisable to define an end-point at the onset of the programme. An alternative is to devise a rule for stopping the monitoring programme once certain objectives have been fulfilled.

6.1 Suggestions for methodology

Transects and permanent plots are often used for vegetation monitoring. Transects or a line of small quadrats (eg. across the boundary between two communities) can be used to measure <u>change</u> and the <u>rate</u> of change. Permanent plots in contrast do not necessarily reflect changes in the extent of communities but are suitable for sites which are managed in a fairly uniform way (ie. the quadrat is subject to exactly the same treatment as the rest of the habitat) or to show the effects of different treatments (eg. no burning, early and late burning) or impacts (eg. grazing, no grazing) on the vegetation.

Quadrats are used for recording within the samples (eg. permanent plots). Their size should be small enough to allow an easy search and recording of the data, but care must be taken about the edge effect (=area-to-edge ratio, which should be not too small).

The initial sampling should always involve a complete vegetation inventory and site description together with a map of the exact location, basal area and canopy area of shrubs and trees. In addition, photo-documentation of the subplots should be started.

The location of samples within a study area, ie. the sampling pattern can be:
- random (a requirement for subsequent statistical analysis of the data);
- systematic (eg. regular transects or grid);
- subjective (eg. in transects parallel to an environmental gradient) or
- stratified (stratification is the subdivision of the study area into zones using topography or vegetation types; nb. the latter may include the risk of circularity of argument) eg. stratified random sampling.

Vegetation parameters which may be recorded for monitoring purposes include:
- number of individuals (can be used for trees/shrubs and annuals),
- basal area (can be used for trees/shrubs and tussocks),
- height,
- damage (eg. degree of grazing/browsing or fire damage) and
- cover (eg. can be measured using pin-frames).

Data which can be calculated from the field measurements include:
- Density (number of individuals per unit area);
- Frequency (percentage of quadrats which contain a particular species). Frequency is a non-absolute measure, which means that the values are dependent on quadrat size. The advantage of this measure is that it is very easy to use and fast, however the values combine information about density and pattern which has to be considered in the interpretation;
- Dominance or size (sum of individual basal area for each species);
- Growth rate (can be calculated from height measurements).

Fixed point photos: Photographs taken from a view point at regular intervals are an easy way to document obvious changes.

Transects: The line-intercept method (Strong 1966, Walker 1970, Mueller-Dombois and Ellenberg 1974) can be used in grassland to calculate density, frequency and cover. The wheel-point method (Tidmarsh and Havenga 1955) is another easy and fast method to estimate cover.

Changes at the edges of communities can be detected using intercepts and a system of stratified systematically located permanent transects.

Plotless sampling: The point-centred quarter method (Cottam and Curtis 1956, Mueller-Dombois and Ellenberg 1974) has been used successfully to monitor browsing of woody vegetation (Vesey-FitzGerald 1973, Croze 1974).

Permanent plots: These are best used to assess the effects of different treatments on the vegetation (for an example see Lock 1972). They should consist of a system of fenced and unfenced plots (eg. 40 x 40 m each, at least the size of the minimal sample area in that vegetation type). Within each plot a central quadrat (eg. 30 x 30 m) can be used for monitoring of the shrub and tree vegetation. The herbaceous vegetation should be recorded in a number of smaller quadrats (eg. 20 1 x 1 m quadrats). Possible sampling patterns are:

- systematic stratified sampling: In each subplot quadrats are located along regular transects to enable easy relocation. This pattern is suitable for revealing the effects of different impacts and treatments.
- random: The quadrats need to be moved every second year to prevent the problem of autocorrelation (see textbooks listed above).

7. SPATIAL DISPLAY OF PLANT DISTRIBUTION DATA

IDRISI[6] is a grid-based geographic analysis system (Clark University) which has been used to simplify the display of plant and animal distribution data collected in the project.

A geographic analysis system is a computer-assisted system for the input, storage, retrieval, analysis and display of geographic data. IDRISI also includes a set of modules which allows it to perform analytical techniques of a geographic information system (GIS), ie. analysis and display of interpreted geographic data.

Information on how to apply IDRISI using the menu assisted set of programmes (Game and Wildlife - Distribution Maps) is given in a separate report (Wong and Schmitt 1993). Detailed information on input and editing of plant data and some points regarding the interpretation of the distribution data will be given in this chapter.

7.1 Data input and editing

Input of information on the distribution of the plant species is done in vector files (*.vec). For each plant species a separate file has to be created. The name of the file is an abbreviation of the plant name (see Table 7) with the extension .vec. So far the distribution data of 81 species have been entered (Table 7). Each vector file contains information on the location(s) (coordinates) at which the plant in question has been found. The format is as follows:

```
Abundance  1
Longitude          Latitude
.
.
0  0
```

Abundance: 1-6 are used for the Braun-Blanquet scale (see Fig. 5, page 8) with 1 = +, 2 = 1 etc.; 7 is used for distribution data from FROGGIE which includes the Hall & Swaine sampling plots (Hawthorne 1993b, Hall and Swaine 1981); data for Bui (Hall and Swaine 1976) are also included in this code; 8 is used for non-specific records such as herbarium records without exact location data.

1: This figure means that there is one set of coordinates for the plot. This applies to all plant data inputs.

<u>Coordinates are in DECIMAL DEGREES!</u> The GPS readings are in degrees, minutes and decimal 'seconds' and must be transformed before inputting in the vector files. The minutes can be transformed into decimal values by dividing them by 60; the decimal values of the seconds have to be added three places behind the point, eg. 5°33'78 = 5+(33/60)+0.0078 = 5.5578.

Longitude: Degrees west are negative and degrees east are positive numbers.

Latitude: Latitude is always a positive number, because Ghana is north of the equator.

0 0: This marks the end of the file.

The vector file for *Vepris heterophylla* (VEPHET.vec) is shown below:

```
2  1
-1.6787    9.5653
2  1
-1.7848    9.4008
1  1
-1.1780    7.2212
7  1
0.05970    5.9011
7  1
0.05667    5.8897
7  1
-.05167    5.8500
7  1
0.06667    5.9000
0  0
```

[6] Idrisi was a cartographer and geographer born in 1099 in Ceuta, a Spanish colony on the North African coast.

Table 7. Species of conservation interest in IDRISI (9/93). {1} Hall 1979, {2} Flora of West Tropical Africa, {3} Lock 1989. IUCN categories from WCMC 1993.

Plant name	File name	Star * rating	IUCN ** categ.	Distribution
Aeschynomene kerstingii	AEKE	-		Ghana, Côte d'Ivoire, Togo {3}
Afraegle paniculata	AFPA	Blue		
Aframomum stanfieldii	AFST	Blue		Common, but only from Côte d'Ivoire to Nigeria
Afzelia bella var. gracilior	AFZB	-		The var. is restricted to Ghana and Côte d'Ivoire, the species is Guineo-Congolian
Ammannia auriculata	AMAU	-		Disjunct {2} West Africa, Egypt and East Africa
Aneilema setiferum var. pallidiciliatum	ANSE	-	nt	Endemic {2}
Asparagus warneckei	ASWA	Gold		Upper Guinea endemic
Brachiaria falcifera	BRAFA	-	nt	Ghana, Togo {2}
Breonadia salicina	BRESA	-	I	Rare in Ghana, but otherwise fairly widespread {1}
Bulbostylis filamentosa	BULF	-		Côte d'Ivoire to Nigeria
Ceropegia gemmifera	CERGE	Black		Restricted to the dry vegetation in the Dahomey gap
Chlorophytum togoense	CHLTO	Blue		
Clerodendrum sinuatum	CLERS	Blue		
Cola chlamydantha	COLCHL	Blue		Common in Ghana on acid, base-poor soils (Hall and Swaine 1981), distribution Guinea wide; 126 recordings from Froggie not included in Idrisi
Combretum zenkeri	COMBZE	Blue		
Commiphora dalzielii	COMMD	Black		Endemic {1}
Craibia atlantica	CRAAT	Gold		Côte d'Ivoire to Cameroun {3}, uncommon in Ghana
Crossandra massaica	CROSMA	Blue		Disjunct {1}, widespread in East Africa, In West Africa only found around Shai Hills
Dictyandra arborescens	DICAR	Blue		
Drypetes parvifolia	DRYPA	Green		Guineo-Congolian (Sierra Leone to Nigeria) {2}
Eriosema molle	ERIMO	-		Côte d'Ivoire to Benin {3}
Eugenia coronata	EUGC	Black		Ghana, Togo {2}
Gongronema obscurum	GONOB	-	nt	Endemic to Ghana, but well distributed {1}
Grewia carpinifolia	GRECA	Blue		
Grewia megalocarpa	GREMEG	Black	nt	Endemic {1} to the coastal plains (Froggie)
Hildegardia barteri	HILBA	Blue		
Hybanthus thesiifolius	HYBTH	-		Ghana, Senegal, Burkina Faso {2}
Hymenostegia aubrevillei	HYMAUB	Gold	I	Rare in Ghana; also Côte d'Ivoire and Nigeria {3}
Indigofera barteri	INDBA	-		Ghana, Nigeria {3}
Indigofera conferta	INDCON	-		Côte d'Ivoire to Nigeria {3}, rare in Ghana {1}
Indigofera tetrasperma	INDTET	-		Côte d'Ivoire to Togo {3}
Indigofera trialata	INDTRIA	-		Ghana, Côte d'Ivoire {3}
Indigofera trichopoda	INDTRIC	-		Senegal, Ghana, CAR, Cameroun {3}
Jasminum kerstingii	JASKE	-		Ghana, Togo {2}
Jatropha neriifolia	JATNER	-		Ghana, Nigeria {2}
Kalanchoe lanceolata	KALA	-	R	Disjunct {1}
Kyllinga echinata	KYECH	-	nt	Endemic to Ghana, but well distributed {1}
Landolphia togolana	LANTO	Blue		
Loudetiopsis thoroldii	LOUTH	-		Ghana, Burkina Faso {2}
Millettia thonningii	MILLTH	Blue		Common in the dry forests in Ghana, occurs sporadically across Africa
Millettia warneckei	MILLWA	Blue		Upper Guinea endemic
Mischogyne elliotiana	MISEL	Blue		
Ochna afzelii	OCHAF	Blue		
Ochna ovata	OCHOV	Blue	R	Disjunct: Ghana and East Africa {2}
Ophrestia hedysaroides	OPHHE	-		Disjunct: Côte d'Ivoire to Benin, East Africa and Angola {3}
Ouratea glaberrima	OURGLA	Blue		
Pandanus candelabrum	PANCAN	Blue		
Parinari congensis	PARCON	Blue		
Polygala atacorensis	POLGAT	-		Ghana to Benin {2}
Polysphaeria arbuscula	POLSAR	Blue		Ghana to Cameroun {2}
Pouchetia africana	POUAFR	Blue		
Premna quadrifolia	PREMQ	Blue		Guinea wide
Pteleopsis habeensis	PTEHA	Black		
Raphionacme keayii	RAPKE	-		Ghana, Nigeria, Cameroun {2}
Raphionacme vignei	RAPVI	-		Ghana, Togo {2}
Rauvolfia cuminsii	RAUVC	Blue		Upper Guinea endemic
Rhinopterys angustifolia	RHINA	-		Endemic to Ghana {2}
Rhytachne furtiva	RHYFUR	-		Ghana, Burkina Faso {2}
Ritchiea reflexa	RITREF	Gold		Upper Guinea endemic
Ruellia togoensis	RUELTO	Black		Rare and confined to west African dry forests
Rytigynia nigerica	RYTNIG	Blue		Ghana, Togo, Nigeria {2}
Sabicea brevipes	SABBRE	Blue		Côte d'Ivoire, Ghana, Togo, Nigeria {2}
Sansevieria liberica	SANLIB	Blue		

Schrebera arborea	SCHREA	Blue	I	Rare in Ghana, but otherwise fairly widespread {1}
Sorindeia warneckei	SORWAR	Blue		
Stachyanthus occidentalis	STAOCC	Blue		Côte d'Ivoire to Nigeria {2}
Tabernaemontana afromontana	TABAFR	Green		Ghana, Liberia {2} but common in Ghana
Tephrosia letestui	TEPHLET	-	R	Disjunct: Ghana, Burkina Faso, CAR {1,3}
Tragia akwapimensis	TRAAKW	-		Endemic to Ghana {2}
Triaspis odorata	TRIAOD	Gold		Ghana, Togo, Sierra Leone {2}
Triclisia subcordata	TRISUB	Blue		
Turraea heterophylla	TURRHE	Blue		
Uvaria chamae	UVCH	Blue		Senegal to Nigeria
Uvaria ovata	UVOVA	Gold		Côte d'Ivoire to Togo {2}
Vangueriopsis spinosa	VANGSP	Blue		
Vepris heterophylla	VEPHET	Gold	R	Disjunct {1} Ghana, Burkina Faso, N and E Africa {2}
Vetiveria fulvibarbis	VETFUL	-		Ghana, Mali, Togo {2}
Vigna filicaulis	VIGFIL	-		Côte d'Ivoire to Togo, Guinea Bissau, Chad {3}
Vincentella passargei	VINPAS	Blue	I	Rare in Ghana, but otherwise fairly widespread {1} new name Synsepalum passargei
Vitex grandiflora	VITGRAN	Blue		
Zanthoxylum xanthoxyloides	ZANXAN	Blue		

* for explanation see Hawthorne and Juam Musah (1993)
** for explanation see IUCN (1978) and WCMC (1993)

The creation of new vector files or the adding of coordinates to existing vector files is done using the MS-DOS Editor (EDIT). Type *new* followed by the *file name*, a *full stop* and the extension *vec*. After inputting the data press <Alt>FS to save the file and <Alt>FX to exit EDIT and to return to the 'Game and Wildlife - Distribution Maps' menu.
NB. the file name should be a unique abbreviation of the latin plant name and should not contain more than seven characters.

Before the information in the new vector file can be displayed three more files (*.doc *.dvc and *.img) have to be created. This is done automatically by typing *plant*. You will be asked to type the file name for the species (without an extension) and then the full latin name of the plant. After a moment you will be asked to type the file name twice (without an extension) and to type 1 to change cells to record the identifiers of points. Afterwards the distribution of the species will be displayed on the screen.

The coordinates for all the plots are stored in a file called plotloc.vec. This file should be updated whenever new plots are added to any vector file. A complete list of locations and coordinates contained in plotloc.vec is given in appendix E.

7.2 Interpretation of the distribution data

The 81 plants[7] displayed by IDRISI are from savanna areas, the transitional or dry semi-deciduous forest zone and the south-east outlier forest. They have been selected because of their conservation value. Distribution data of those species which are also found in the high forest zone were added from FROGGIE.

The high forest zone has been extensively surveyed (Hall and Swaine 1981, Hawthorne and Juam Musah 1993) and the botanical data have been included in a 'graphical information exhibitor' FROGGIE (Hawthorne 1993b). FROGGIE covers Ghana south of 8° North which does not include Bui, Mole and Gbele. The extension of FROGGIE to cover the whole of Ghana and the incorporation of the botanical data collected in this project was planned, but could not be done during the project period. It should, however, be envisaged for the future[8]. In the meantime the distribution data of the animal and some plant species will be displayed using the the GAS modules of IDRISI.

[7] In addition one widespread blue-star species and 54 species of limited distribution or disjunct species contained in the database have not been included in IDRISI, because not enough information on their abundance/rarity was available.
[8] The database pg_list already contains the fields necessary for incorporation in FROGGIE.

Fig. 11 shows the plot locations of all those plant species currently contained in IDRISI vector files. It shows that although the forest zone has been well surveyed, information outside it is restricted to the reserves sampled during this project and to data from Bui (Hall and Swaine 1976). This should not lead to the conclusion that no species of conservation value are found outside the areas shown in Fig. 11, it rather shows the 'gaps' which have not yet been sampled and which require botanical inventories.

The star species displayed represent forest species which are also found in the savanna zone, where they are often restricted to riverine forests and forested hills. An analysis based on the number of these species found in a designated area is not valid, because not all savanna species have been classified according to the star rating system.

IUCN categories are from WCMC (1993) and no attempt has been made to classify additional species according to these categories. This information can therefore not be used for an overall interpretation, but rather provides additional information for particular species.

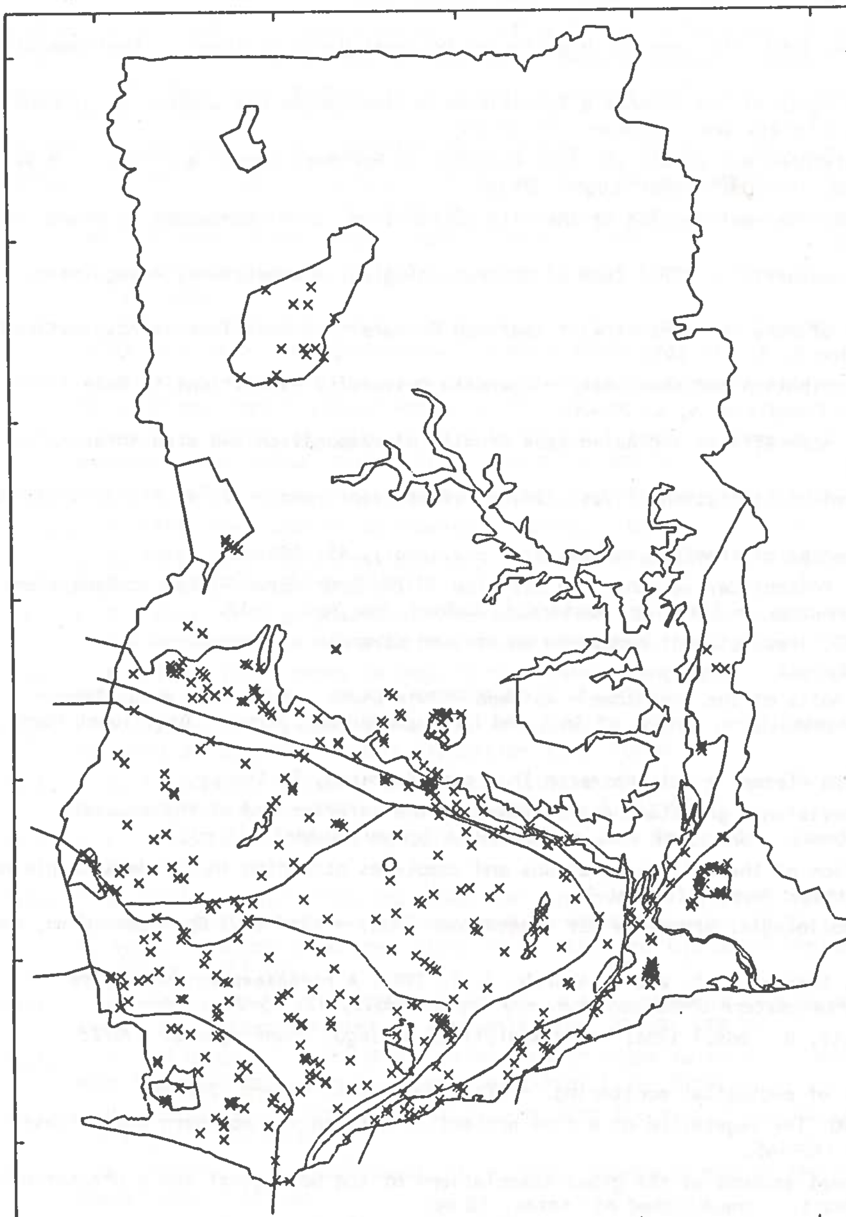

Fig. 11. Plot locations of all plant species shown in IDRISI. Each X represents a sampling spot. The map shows the outline of all GWD reserves, of Lake Bosumptwi and the Volta Lake. The lines in the south-western part of Ghana demarcate the different forest zones (for details see Hall and Swaine 1981).

Abbiw, D. K. 1990: Useful plants of Ghana. - Short Run Press: Exeter. 337 pp.

Ackermann, W. and Durka, W. 1992: Sort 2.2. Programm zur Bearbeitung von Vegetationsaufnahmen. - Bayreuth. 76 pp.

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APPENDIX B

Vegetation Inventory: Relevé/Collection locations Page ....

Relevé/Collection No.	Date	Area Code	Location	Latitude (N)	Longitude (E/W)	Alt. (m)	Coll.

Vegetation Inventory: Collected plants

Page ....

Plant no.	Relevé/ Collection No.	Area Code	Date	Description	L-form TSCH GEPF	Hab. FRMG SAW	Name	Family

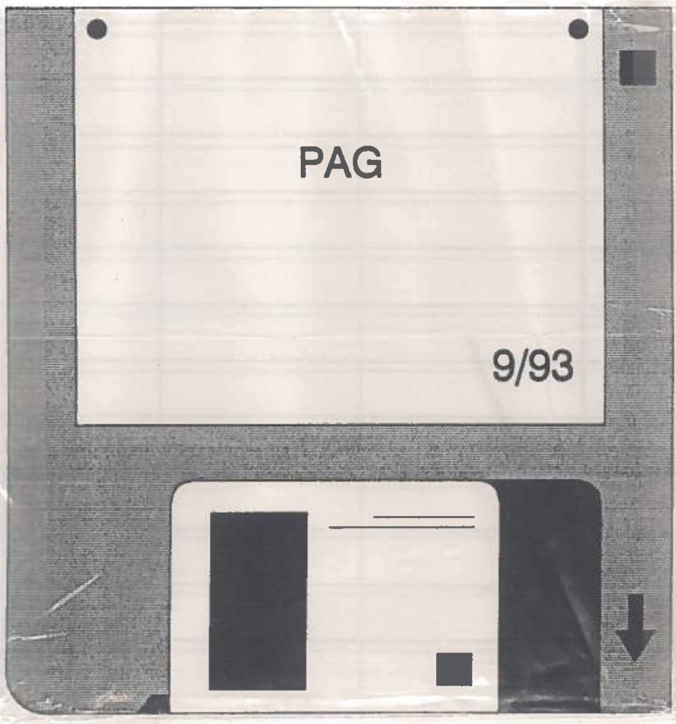
The diskette below contains the condensed dBase data and programme files of the database on the Plants of the Protected Areas of Ghana (PAG).

Requirements:
An IBM compatible computer with dBase IV V1.1 (or above) and at least 2.8 Mbytes free hard disk space is required to install and access the database.

Installation:
Insert the 720 K disk in drive A (or B), type PAG and press <return>: A subdirectory called PAG will be created on your hard disk, the data and programme files will be copied into C:\PAG and extracted. Providing that dbase is included in the path in your autoexec.bat file you can start the programme by typing DBASE PAG and pressing <return>.

If you want to copy the files on a different drive (eg. D) or into a different subdirectory this is best done by changing lines 19, 20, 23 and 24 in pag.bat accordingly.

The data files are as of 29 SEPT 1993



Acacia albida *
Acacia dugeoni
Acacia gourmaensis
Acacia hockii
Acacia macrothyrsa *
Acacia nilotica *
Acacia polyacantha
Acacia senegal *
Acacia sieberiana
Adansonia digitata
Afraegle paniculata
Afzelia africana
Albizia chevalieri *
Albizia coriaria
Allophylus cobbe
Amblygonocarpus andongensis
Annona senegalensis
Annona squamosa *
Anogeissus leiocarpus
Antiaris toxicaria
Antidesma vonosum
Azadirachta indica
Balanites aegyptiaca
Bauhinia rufescens *
Blighia sapida
Bombax costatum
Borassus aethiopam
Boscia salicifolia *
Boswellia dalzielii
Bridelia ferruginea
Bridelia micrantha
Bridelia scleroneura
Burkea africana
Cassia siamea
Cassia sieberiana
Ceiba pentandra
Celtis integrifolia
Chaetacme aristata
Combretum collinum ssp. binderanum
Combretum collinum ssp. hypopilinum
Combretum collinum ssp. lamprocarpum
Combretum fragrans
Combretum glutinosum
Combretum molle
Commiphora africana *
Crateva adansonii
Croton zambesicum
Cussionia arborea
Cynometra vogelii
Daniellia oliveri
Diospyros elliotii
Diospyros mespiliformis
Ekebergia senegalensis *
Entada abyssinica
Entada africana
Erythrina senegalensis *
Erythrophleum africanum
Faurea speciosa *
Ficus glumosa
Ficus gnaphalocarpa
Ficus ingens
Ficus platyphylla
Ficus sur
Ficus vallis-choudae *
Flacourtia flavescens
Gardenia aqualla
Gardenia erubescens
Gardenia ternifolia
Grewia mollis *
Grewia ventusa
Haematostaphis barteri
Harrisonia abyssinica
Hexalobus monopetalus
Hymenocardia acida
Isoberlinia doka
Khaya senegalensis
Kigelia africana
Lannea acida
Lannea kerstinigii
Lannea microcarpa
Lonchocarpus laxiflorus
Lophira lanceolate
Maerua angolensis
Malacantha alnifolia
Maytenus senegalensis
Millettia thonningii
Mimosa pigra
Mitragyna inermis
Monotes kerstingii
Nauclea latifolia
Newbouldia laevis
Xeroderris stuhlmannii *
Olax subscorpioidea
Oncoba spinosa
Parinari curatellifolia
Parinari macrophylla *
Parinari polyandra
Parkia biglobosa
Parkinsonia aculeata *
Pericopsis laxiflora
Phoenix relinata
Phyllanthus discoideus
Piliostigma thonningii
Pseudocedrela kotschyi
Pterocarpus erinaceus
Pterocarpus santalinoides
Quassia undulata
Sapium ellipticum *
Sclerocarya biriea
Securinega virosa
Sesbania sesban
Spondias mombin *
Stereospermum kunthianum
Strychnos spinosa
Swartzia madagascariensis *
Syzygium guineense
Tamarindus indica
Terminalia avicennioides
Terminalia glaucescens
Terminalia macroptera
Trema orientalis
Uapaca togoensis
Vernonia amygdalina
Vitex doniana
Vitex simplicifolia
Ximenia americana
Ziziphus abyssinica
Ziziphus mauritiana
Ziziphus spina-christi

* not in PG_LIST.dbf

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18	SHAI	0.06800	5.91750
19	SHAI	0.06680	5.93420
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1035	A55	-0.56800	6.65833
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1037	A58	-1.03967	6.83667
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1080	A127	-1.85483	5.32167
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1082	A132	-2.18850	6.20667
1083	A133	-2.25067	6.10833
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1091	A145	-2.23667	5.40367
1092	A146	-2.43850	5.45183
1093	A147	-2.47350	5.37100
1094	A150	-2.65417	5.21983
1095	A154	-2.22283	5.17167
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1097	B9	-1.13800	5.26800
1098	B10	-0.53667	5.47650

1099	B11	-1.13667	5.20667
1100	B12	-1.00183	5.25667
1101	B14	-1.22533	5.15483
1102	B15	-1.27167	5.12650
1103	B17	-0.21800	5.70000
1105	B18	-0.24150	5.68850
1106	B19	0.28333	6.26800
1107	B20	0.30000	6.28500
1108	B21	0.06667	5.90000
1109	B24	-1.03967	5.27533
1110	B25	-1.08667	5.33850
1111	B38	-0.45183	6.03967
1112	B40	-0.76983	6.01683
1113	B42	-0.33967	5.55483
1114	B44	-0.18850	5.77650
1115	B48	-0.55483	5.48667
1116	B51	-1.65667	5.00667
1117	B53	-1.30367	6.93667
1118	B55	-1.37350	6.86983
1119	B61	-1.63500	6.05483
1120	B62	-2.11800	7.60367
1121	B64	-2.55367	7.63967
1122	B70	-2.60833	6.91983
1123	B72	-2.86683	6.74150
1124	B75	-0.62650	6.70000
1125	B85	-1.71683	5.93500
1126	B86	-1.75367	6.20667
1127	B96	-2.55367	5.76983
1128	B107	-2.51683	5.57167
1129	B110	-2.46983	5.03967
1130	B111	-2.33667	5.00367
1131	B119	0.17500	6.48667
1132	B120	0.25333	6.55367
1133	B122	-1.13500	6.77533
1134	B123	-1.90183	7.35367
1135	B124	-2.52167	7.84150
1136	B126	-2.44150	7.80000
1137	B127	-2.43667	7.80183
1138	B128	-1.70667	5.16683
1139	B129	-0.67350	5.45833
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1141	ABIHS1	-0.53500	6.60367
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1148	AFHPL1	-1.69217	7.18667
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1153	ANGPSW1	-2.20967	5.80900
1154	ANKCHK1	-2.58333	5.28333
1155	ANKHU1	-2.67050	5.21800
1156	ANMFL1	-1.15483	6.82650
1157	ANNFL1	-2.26667	6.31667
1158	ANSRS1	-2.20067	6.19033
1159	APAPSW1	-1.88333	6.31667
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1163	ASAHT1	-1.30717	5.56683
1164	ASAPSW1	-1.37400	5.55717
1165	ASEHT1	-2.11667	6.45000
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1167	ATEHT3	-0.55533	6.25600
1168	ATEPSW2	-0.57233	6.21683
1169	ATEX1	-0.57233	6.20716
1170	AWURK1	-1.35117	7.34267
1171	AWURS1	-1.33967	7.32650
1172	AYUFL1	-2.67467	6.80900
1173	AYUFL2	-2.72100	6.65783
1174	BAKPSW1	-1.08667	5.55967
1175	BBRFL1	-1.36800	6.67050
1176	BEDFL1	-0.94033	6.18433
1177	BEESL1	-1.73617	5.60833
1178	BEWSL1	-1.90533	5.50967
1179	BFMFL1	-1.05367	6.90667
1180	BFMFL2	-1.15783	6.88367
1181	BHLFL1	-0.99150	6.79267
1182	BHLFT1	-0.89100	6.79267
1183	BHLX	-1.03733	6.78967
1184	BHNFL1	-0.90300	6.86983
1185	BIACHK1	-3.08333	6.55000
1186	BIMHT1	-1.36933	5.68800
1187	BIRRS1	-1.15000	5.91667
1188	BISFL1	-2.65967	7.02400
1189	BOFFL1	-1.70000	7.70000
1190	BOFFL2	-1.70000	7.70500
1191	BOIHS1	-2.85900	5.75967
1192	BONRS1	-1.73800	5.63800
1193	BONSL1	-1.73550	5.73367
1194	BORHT3	-1.87350	5.43917
1195	BORLG1	-1.85367	5.35417
1196	BORPSW2	-1.90717	5.25967
1197	BORRS1	-1.81933	5.34217
1198	BORRS2	-1.83367	5.41800
1199	BORRS3	-1.88550	5.43667
1200	BORSL2	-1.87167	5.42533
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1202	BOWFL1	-1.96933	5.80183
1203	BOWRS1	-2.00600	5.78617
1204	BRIRS1	-1.30000	5.20000
1205	BTFRS1	-0.23333	6.20000
1206	BTSFL1	-3.10367	6.58800
1207	BTSFL2	-3.00900	6.39217
1208	BURFL1	-2.30417	5.85667
1209	BURSL1	-2.30067	5.75900
1210	C3PFL1	-2.05000	4.77650
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1221	DRRSW1	-2.30417	5.20367
1222	DRRSW2	-2.30783	5.20300
1223	EBIHS1	-2.33367	5.07583
1224	EBIPRS1	-2.34100	5.07583
1225	EBIRS1	-2.34267	5.10000
1226	EBIX2	-2.38367	5.12100
1227	ESKHT1	-0.80000	6.36667
1228	ESPSL1	-0.86667	5.81667
1229	FUHO	-2.35667	5.56800
1230	FUHSW1	-2.37233	5.55717
1231	FUMFL1	-1.37583	6.23617
1232	FURSW1	-2.25117	5.33850
1233	GIARS1	-1.59150	7.10667
1234	JABRS1	-1.85000	6.77167
1235	JEAPSW1	-2.70183	5.43433
1236	JEARS1	-2.70000	5.41800
1237	JENSL1	-1.93550	6.52100
1238	KABHT1	0.48500	7.56683
1239	KAGPSW1	-0.96683	6.36933
1240	KAKRS1	-1.37100	5.38667
1241	KOKSW1	-1.26666	6.00367
1242	KRKFL1	-2.90900	6.47467
1243	KRKHT1	-2.92650	6.37283
1244	KRKRS1	-2.72583	6.48850
1245	KROFL1	-1.15967	5.65417
1246	KWAHT1	-1.90533	7.12283
1247	MAMHT2	-2.36683	5.66683
1248	MAMHU1	-2.35533	5.66683
1249	MAMSW1	-2.37400	5.68617
1250	MANFL1	-2.06750	7.35417
1251	MANFL2	-2.10483	7.37050
1252	MANRS1	-2.09217	7.38850
1253	MINHT1	-1.68617	5.79100
1254	MIRSL1	-1.16983	6.33800
1255	MPAFL1	-2.88333	7.08333
1256	MURFL1	-2.61683	6.50300
1257	MURSL1	-2.58500	6.44267
1258	NFOSL1	-0.98333	6.68333
1259	NGNRS1	-2.06683	5.20117
1260	NGNSL1	-2.05117	5.22533
1261	NGSHS1	-1.97650	5.15967
1262	NGSRS1	-2.02100	5.16867
1263	NKBHT1	-1.89033	5.62533
1264	NKBPSW1	-1.90067	5.61800
1265	NUMSW1	-1.40233	6.03433
1266	OC1FL1	-1.28617	5.72400
1267	OC1PSW1	-1.25967	5.71867
1268	OFSSW1	-2.01800	6.62400
1269	ON2HT1	-1.43617	6.96800
1270	ON2SL1	-1.41867	6.97533
1271	ONBSL1	-1.30000	6.14000
1272	OPMPSW1	-1.96933	5.65900
1273	OPMRS1	-1.93800	5.65600
1274	OPRSL1	-1.79033	7.18967
1275	PAMFL1	-2.82400	7.37350
1276	PAMPPL1	-2.76750	7.48550
1277	PRBSW1	-1.21667	5.96667
1278	PRSHT1	-1.54100	5.28733
1279	PRSPSW1	-1.40117	5.35300
1280	PRUFL1	-1.40967	7.45483
1281	SAWFL1	-2.20300	7.62467
1282	SBSSL1	-1.85300	6.06800
1283	SHICHK1	0.06667	5.90000
1284	SOFPSW1	-0.95533	6.60833
1285	SOSRS1	-0.83433	6.66933
1286	SUBFL1	-1.76867	5.30900
1287	SUBPSW2	-1.80000	5.40417
1288	SUBSW1	-1.76683	5.30117
1289	SUHFL1	-2.56800	6.10367
1290	SUHX1	-2.42467	6.01683
1291	SUIHT1	-2.70533	6.12400
1292	SUIHT2	-2.73617	6.03967
1293	SUISW1	-2.77283	6.10783
1294	SUPPSW1	-1.05967	5.56983
1295	SUPPTL2	-1.12283	5.63967
1296	SUPPX10	-1.13367	5.60717
1297	SUPPX18	-1.08800	5.56933
1298	SUPPX21	-1.06983	5.52583
1299	SUPPX4	-1.10183	5.60717
1300	SUPPX5	-1.10300	5.61683
1301	SUPPX7	-1.13733	5.65067
1302	SUPPX9	-1.12467	5.60717
1303	SUPRS1	-1.08733	5.60533
1304	SUPRS2	-1.11683	5.62400
1305	TA1FL1	-2.22583	7.41750
1306	TA2FL1	-2.30000	7.47100
1307	TA2FL2	-2.57533	7.60783
1308	TA2FL3	-2.56983	7.57533
1309	TA2FL4	-2.62167	7.62167
1310	TA2FL5	-2.43800	7.56983
1311	TA2FL8	-2.41683	7.48850
1312	TA2HT1	-2.56683	7.61683
1313	TA2PPL1	-2.82650	7.57650
1314	TA2RS2	-2.44150	7.43850
1315	TA2RS3	-2.62167	7.60000
1316	TA2RS4	-2.45667	7.58500
1317	TA2RS5	-2.37167	7.45000
1318	TA2SW1	-2.50667	7.52650
1319	TAOHT1	-2.05783	6.83667
1320	TASFL1	-2.37467	6.30067
1321	TAWFL1	-2.57533	5.87350
1322	TAWRS1	-2.57050	5.77233
1323	TINRS1	-1.94217	6.92400
1324	TINSL1	-1.98433	6.98917
1325	TNMHS1	-2.62533	5.60667
1326	TNSFL1	-2.46667	6.33333
1327	TNSPSW1	-2.46667	6.33333
1328	TONFL1	-2.07650	6.00000
1329	TONRS1	-2.07650	6.00000
1330	TOTFL1	-2.32467	5.86683

1331	TOTRS1	-2.43617	5.96933	2006	FROGGIE	-0.55220	6.22147	2026	FROGGIE	-0.40040	5.82037
1332	TOTSW1	-2.37100	5.90533	2007	FROGGIE	-2.58713	5.60140	2027	FROGGIE	0.35180	7.11787
1333	TSEHT1	-2.40783	6.29100	2008	FROGGIE	-0.51967	5.47037	2028	FROGGIE	-1.38823	7.43893
1334	TSESL1	-2.40117	6.27467	2009	FROGGIE	0.05430	5.82037	2029	FROGGIE	-0.63863	6.68793
1335	WAWRS1	-1.10067	5.63967	2010	FROGGIE	-1.42077	5.13863	2030	FROGGIE	0.06787	6.28683
1336	WRNFL1	-0.46983	6.62167	2011	FROGGIE	-1.23393	6.28683	2031	BUI	-2.28333	8.30000
1337	WRSRK1	-0.49267	6.49267	2012	FROGGIE	-1.43713	7.28573	2032	BUI	-2.30000	8.31666
1338	YAYPFL1	-2.13800	7.46983	2013	FROGGIE	0.06787	6.06787	2033	BUI	-2.30500	8.33333
1339	YAYRS1	-2.12350	7.42650	2014	FROGGIE	0.06787	6.28683	2034	BUI	-2.23333	8.27166
1340	YOYHT1	-2.75300	5.88733	2015	FROGGIE	-2.43643	7.80320	2035	BUI	-2.30000	8.33333
1341	YOYRS1	-2.69033	5.92650	2016	FROGGIE	-2.15140	7.46787	2036	BUI	-2.25000	8.28333
1342	YOYRS2	-2.90117	5.90233	2017	FROGGIE	-2.80360	6.41867	2037	BUI	-2.30000	8.32000
1343	YOYSW1	-2.80117	5.87650	2018	FROGGIE	-2.53823	6.13753	3000	MOLE	-1.80500	9.73633
1344	YOYSW2	-2.88500	5.85233	2019	FROGGIE	-2.20520	5.38643	3001	MOLE	-1.85000	9.40000
2000	FROGGIE	-2.42217	7.55540	2020	FROGGIE	-1.22037	7.05220	3002	MOLE	-1.97167	9.40000
2001	FROGGIE	0.28683	6.25400	2021	FROGGIE	-0.42217	6.42187	3003	MOLE	-1.74167	9.35333
2002	FROGGIE	-2.60320	6.90290	2022	FROGGIE	-0.92007	6.13353	3004	MOLE	-1.82333	9.63833
2003	FROGGIE	-2.05440	7.33683	2023	FROGGIE	-1.16897	5.92257				
2004	FROGGIE	-2.18643	7.61717	2024	FROGGIE	-2.65220	5.20430				
2005	FROGGIE	0.17077	6.38533	2025	FROGGIE	-2.61677	7.58463				

ID	1- 999	relevé/collection locations from re_loc.dbf (database)
	1000-1344	plot locations from FROGGIE (file plot.sip)
	2000-2030	plot locations from FROGGIE (source screen display)
	2031-2037	sampling locations from Hall and Swaine 1976
	3000-3004	non-specific sampling locations from herbarium records