Hindawi Publishing Corporation
International Journal of Biodiversity
Volume 2013, Article ID 401938, 10 pages
http://dx.doi.org/10.1155/2013/401938

Research Article

Decline of Indigenous Crop Diversity in Colonial and Postcolonial Rwanda

Jean Leonard Seburanga

College of Science and Technology, University of Rwanda, Huye Campus, P.O. Box 117, Butare, Rwanda

Correspondence should be addressed to Jean Leonard Seburanga; seburanga@yahoo.fr

Received 18 July 2013; Revised 28 September 2013; Accepted 30 September 2013

Academic Editor: Arianna Azzellino

Global influence of the wealthiest countries drives trends in crop diversity in the developing countries. In many countries, European colonization resulted in cultural disintegration and erosion of indigenous knowledge that made citizens lose interest in their own cultural heritage and adopt imperial know-how. During the same time, native biodiversity that was once maintained by the tradition it shaped declined. Alien crops prospered and finally dominated landscapes. In this paper, I looked at the apparent decline of indigenous crop diversity in Rwanda in the light of the "cultural disturbance" that occurred in the shadow of the European colonization. An integrated research methodology that combined desk-based, socioeconomic, and vegetation surveys was used. Indigenous crops now on the fringe of extinction and, thus, requiring immediate attention from conservation policy makers and managers were identified. These include *Vigna unguiculata* (L.) Walp. "inkoli" (Leguminosae), *Coleus dysentericus* Bak. "impombo" (Labiatae), *Dioscorea alata* Linn. "ibikoro" (Araceae), a sweet cultivar of *Lagenaria siceraria* (Mol.) Standl. "bunure" (Cucurbitaceae), white cultivar of *Sorghum bicolor* (Linn.) Moench "nyiragikori" (Gramineae), *Amaranthus graecizans* Linn. "inyabutongo" (Amaranthaceae), *Eleusine coracana* (Linn.) Gaertn. "uburo" (Gramineae), and traditional cultivars of Zea mays Linn. "nyakagori" (Gramineae) and *Solanum tuberosum* Linn. "kandore" (Solanaceae).

1. Introduction

The world's biological diversity is distributed in inverse proportion to scientific and technological capacity [1], with a full of 83% of known diversity and remaining in situ knowledge held in Africa, Asia, and Latin America [2].

This may have partly been due to indirect effects of the European colonization as a global sociopolitical institution that resulted in cultural disintegration, making citizens of developing countries disdain their own cultural heritage and adopt imperial know-how (Ling 1996). One of the many side effects of this cultural invasion is the decline of native plant diversity once maintained by the tradition they shaped. Soon after the arrival of colonizers, local communities started to pay more attention to the hegemonic "portmanteau biota" and adopted imperial ideologies [3]. As a result, despite rich indigenous biological diversity, 70% of developing countries depend on species domesticated elsewhere for more than half of their crops, and it is estimated that sub-Saharan Africa borrows about 87% of its domesticated crops from other regions [4].

In Rwanda, since the European contact at the end of 18th century, there has been a strong case against indigenous crops in Rwanda. Accused of being less tasty or old fashioned, indigenous bitter vegetables, African Spider Flower *Gynandropsis gynandra* (L.) Briq. "Isogi" (Capparidaceae), Black Nightshade *Solanum nigrum* L. "Isogo" (Solanaceae), and Turkey Berry *Solanum torvum* Sw. "Inkarishya" (Solanaceae) were rapidly dropped by the young generation, which adopted the newly introduced vegetables, mainly cabbages, tomatoes, onions, and carrots. To some extent, native dishes continued to be cherished by the old generation. Unfortunately, as the elderly passed away or finally decided to adopt European-inspired culture too, native crops significantly declined. Today, they almost disappeared. Conventional wooden dining tables "ameza", whose desks are raised to some 0.50–0.70 m above-ground and filled with modern-day porcelain, plastic and stainless steel tureens and glassy bottles

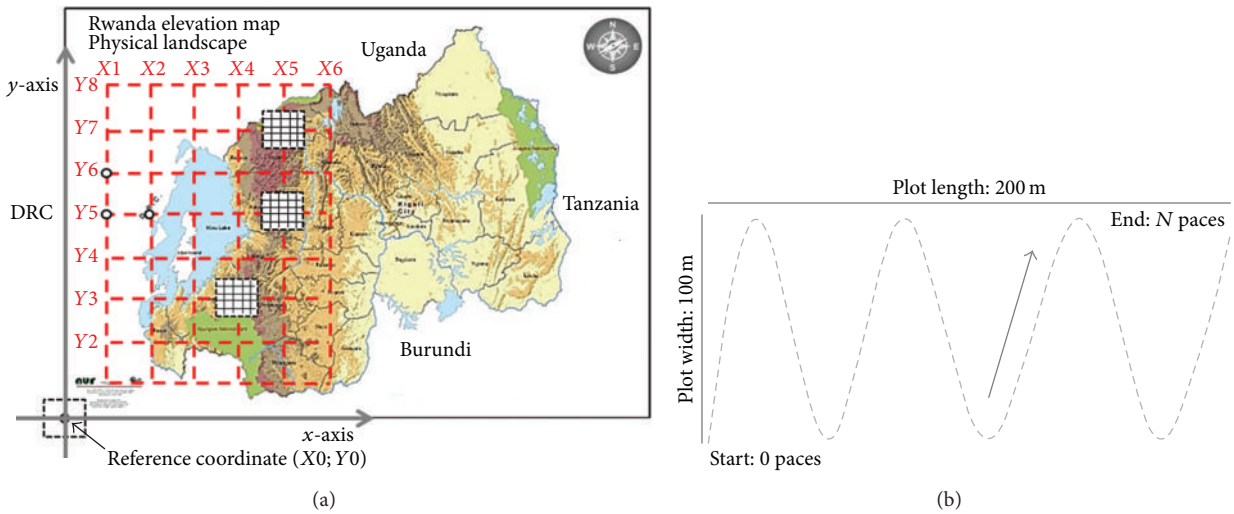

Figure 1: Sampling design: grid cells and quadrats layout in Cartesian coordinate system (a) and paced-97 meander walking path (b).

have replaced on ground-laid sedge mats "imisambi", filled with traditional weaved plates "inkoko", wooden tureens "imbehe" and calabash gourd "uducuma". The gauge of a person's success is henceforth measured against the extent to which he has been able to transform his former lifestyle to mimic that of a "u-mu-zung-u," the white man, or, said in another way, to attain the status of the "evolved" one. However, the decline of native crops, indigenous food, and traditional utensils is unfortunate. Many of them were also medicinal plants or were embedded in the traditional cults and rituals. According to Gorenflo et al. [5], there is a reason to be concerned about this cultural loss. They found a positive correlation between cultural diversity and biodiversity hotspots. They argued that large-scale conservation of species and the ecosystems that contain them, their associated linguistic, and cultural diversity into biodiversity should be considered.

During the same time, more land was cleared for farming. Natural forest and fallow cover receded. Indigenous tree species declined. Not later than 1980s, Rwanda's most popular native timber species such as Nile Tulip *Markhamia lutea* K. Schum. "Umusave" [Bignoniaceae] and other valuable indigenous tree species had been supplanted in both heavy and domestic carpentry by exotic species, often praised for their rapid growth rate (productivity: 5–15 m^3 ha^{-1} $year^{-1}$ [6]) and durable wood. As of 1990, exotic species occupied 97% of total plantation area in Rwanda, with *Eucalyptus* alone standing for 65% [7]. In this paper, I attempt to establish a link between the decline of indigenous plant diversity and the "cultural disturbance" that occurred as a byproduct of the European colonization.

2. Materials and Methods

2.1. Study Area. The study was carried out in Rwanda, Central Africa, between 1°03–2°50 south of the Equator and 28°52–30°54 east of the Greenwich Meridian Line. The country's average altitude is 1250 m, with the lowest point lying within the Rusizi valley at 950 m and the highest point situated at the summit of mount Karisimbi at 4519 m. Four different cropping seasons are present: 2 short rainy/dry seasons and 2 long rainy/dry seasons. The temperature varies with both altitude and land topography. An average of 20–22°C is observed at 1545 m in Kigali city.

2.2. Data Acquisition. The diversity and range of invasive alien plants, crops, and wild edible taxa in Rwanda were studied.

2.2.1. Desk-Based Study. To collate available data on flora surveys, herbarium records, and electronic materials, a desk-based study was conducted. The National Herbarium of Rwanda and National Museum of Rwanda were visited. A systematic search into previous works, mainly those of Desouter [8], Egli and Kalinganire [9], and Troupin [10–15], was carried out.

2.2.2. Vegetation Survey. A 10 × 10 km^2 grid was overlaid over Rwanda's elevation map (Figure 1). The resulting grid cells were stratified by elevation and three grid cells were chosen per elevation class: Congo-Nile Divide (CND) highlands, central plateau, and eastern lowlands. Each grid cell was subdivided into 25 equal-sized quadrats (2 × 2 km^2) [16]. One quadrat was selected for sampling and subdivided into 200 × 100 m^2 sampling units (plots). Twelve sample plots were located per elevation class. Plots were searched using the "paced-meander" method (Figure 1), which is a modification of the "timed-meander" method as described by Huebner (2007), where the "time" factor is replaced by the "distance" dimension. Each plot was thoroughly walked recording indigenous crops, invasive alien plants, crops and wild edible taxa within every 25 m interval, which is the average width of an ecotope or the smallest ecologically distinct landscape feature [17].

When the number of new species did not decrease to zero in the last 25 m, additional distances were added. The search

effort (the paced distance per unity area) was 1 km·ha^{-1}. The total number of surveyed plots was 36, with an average 80 records per each plots.

2.3. Data Analysis

2.3.1. Scree Plotting. Most invasive and most threatened indigenous plant species were identified based on species occurrence data. All recorded species were ranked by simple scree plotting according to their unconditional detectability or the probability p of actually observing a specimen of given plant species in a plot (also referred to as "observability"), derived as the product of the probability of occupancy or "frequency of occurrence," ψ (the number of a species' records divided by the total number of 25 meter search intervals) and its conditional detectability, δ [18, 19]. The determination of δ was based on the assumption that the conditional probability of a plant expert seeing a plant specimen in a plot, given that it is not only present but also widespread, should be higher than that of not seeing it, $\delta > 0.5$ [20]. Therefore, $p = \delta\psi > 0.5\psi$.

2.3.2. Statistical Analysis and Model Fitting. Pearson correlation test was used to quantify the possible relationship between plant diversity and land use types. Model fitting helped compare plant diversity, population growth, and household socioeconomics [21, 22].

2.3.3. Species Identification. Species "indigenous" versus "alien" status was assigned based on Brenzel et al. [23], Fischer and Hinkel [24], and Troupin [10–15]. A species was considered "neo-immigrant" if its occurrence in Rwanda predated the arrival of Arab traders and European colonists in Rwanda during the second half of the 19th century [25]. Those with an introduction date that lies between 1000 and 1500 AD (or after the birth of Jesus Christ) were considered as "archaeo-immigrants." Species that do not appear in neither of the two introduced categories were considered as native to Rwanda.

Level of Threat

Extent of Species Decline. The extent of decline of food crop and wild edible plant species was reported using three categories: high; the species was referred to by more than 70% of informants as being rare and had an average frequency of less than 5% [9], fair; the species was referred to by 45% to 70% of informants as being rare and had an average frequency of 5% to 60% [16], and low; the species is referred to by not more than 30% as being rare and had an average frequency of at least 60% [26].

3. Results

3.1. Ornamental Crops. Results from the desk-based study suggest that Rwanda's early ornamental and amenity flora appeared to have been limited to 15–20 native species. These included *Erythrina abyssinica* "umurinzi," *Ficus thonningii* "umuvumu," *Euphorbia candelabrum* "umuduha," *Euphorbia tirucalli* "umuyenzi," *Dracaena afromontana* "umuhati," *Dracaena steudneri* "igihondohondo," *Markhamia lutea* "umusave," *Tetradenia riparia* "umuravumba," *Ricinus communis* "ikibonobono," *Solanecio mannii* "umutagara," *Cajanus cajan* "umukunde," *Gynandropsis gynandra* "isogi," *Solanum torvum* "inkarishya" and *Vernonia amygdalina* "umubilizi."

This low species richness seems to have been maintained or did change a little at least until the dawn of the 20th centuries. However, a drastic increase is observed in 1940s (Figure 2(a)), often in inverse relationship with household income (Figure 2(c)).

Results from the vegetation survey show that there was more ornamental tree species richness in cities than in surrounding rural areas. Among cities, species richness correlated with city development index ($r_{N=3} = 0.997$; $P = 0.034$) (Table 1). Kigali, the far most developed city in Rwanda, had the highest species richness.

The majority (67%) of species are exotic. Half the number of species is from Tropical Asia, Tropical America, and Australia. Alien taxa comprise the most frequent garden species, *Duranta repens*, and represent 40% of that occurred in 70–100% of sampled units. Ninety-five percent of native taxa have a frequency of occurrence of less than 15%.

3.2. Food Crops. Twenty-three crop species were identified as composing crop flora in precolonial Rwanda (Table 2). These once cherished crops succumbed to agricultural and diet change during the last century. As early as the beginning of the colonial period a number of selected crops, including banana, beans, sorghum, sweet potato, and coffee, were purposefully promoted or, at least, blessed by the colonial authority. By 1990, beans, banana sorghum, and sweet potato were far the most dominant crop species, with a fraction of 46.4% of total crop land cover (data retrieved from Clay and Lewis [27]).

3.3. Forest Crops. In terms of forestry development, *Eucalyptus* species were far ahead of tree species that replaced native taxa on cleared land. The diversity of eucalypts in forests plantations, like other cultivated alien species, also increased with time. Two species (*E. camaldulensis* and *E. tereticornis*) were used in reforestation until 1948, when *E. maidenii* and *E. saligna* were added. Except *E. grandis*, which was introduced in Rwanda's forestry around 1955, these above-listed eucalypt species and many others (*E. botryoides*, *E. crebra*, *E. globulus*, *E. melliodora*, *E. paniculata*, *E. polyanthemos*, *E. punctata*, *E. robusta*, *E. sideroxylon* and *E. viminalis*) had been at the Arboretum of Ruhande since its creation in 1934. By 199, the collection of eucalypts at Ruhande Arboretum had expanded to comprise 66 different species (data extracted from [28]). In our records from 2010 to 2013, up to 14 species of eucalypts were identified in rural and urban landscapes across the country: *E. albens*, *E. camaldulensis*, *E. cinerea*, *E. citriodora*, *E. globulus*, *E. grandis*, *E. microcorys*, *E. maculata*, *E. maidenii*, *E. polyanthemos*, *E. saligna*, *E. tereticornis*, *E. torelliana*, and *E. Viminalis*. Such eucalypt-dominated forestry expanded steadily, at least until the late 20th century (Figure 2(a)). As

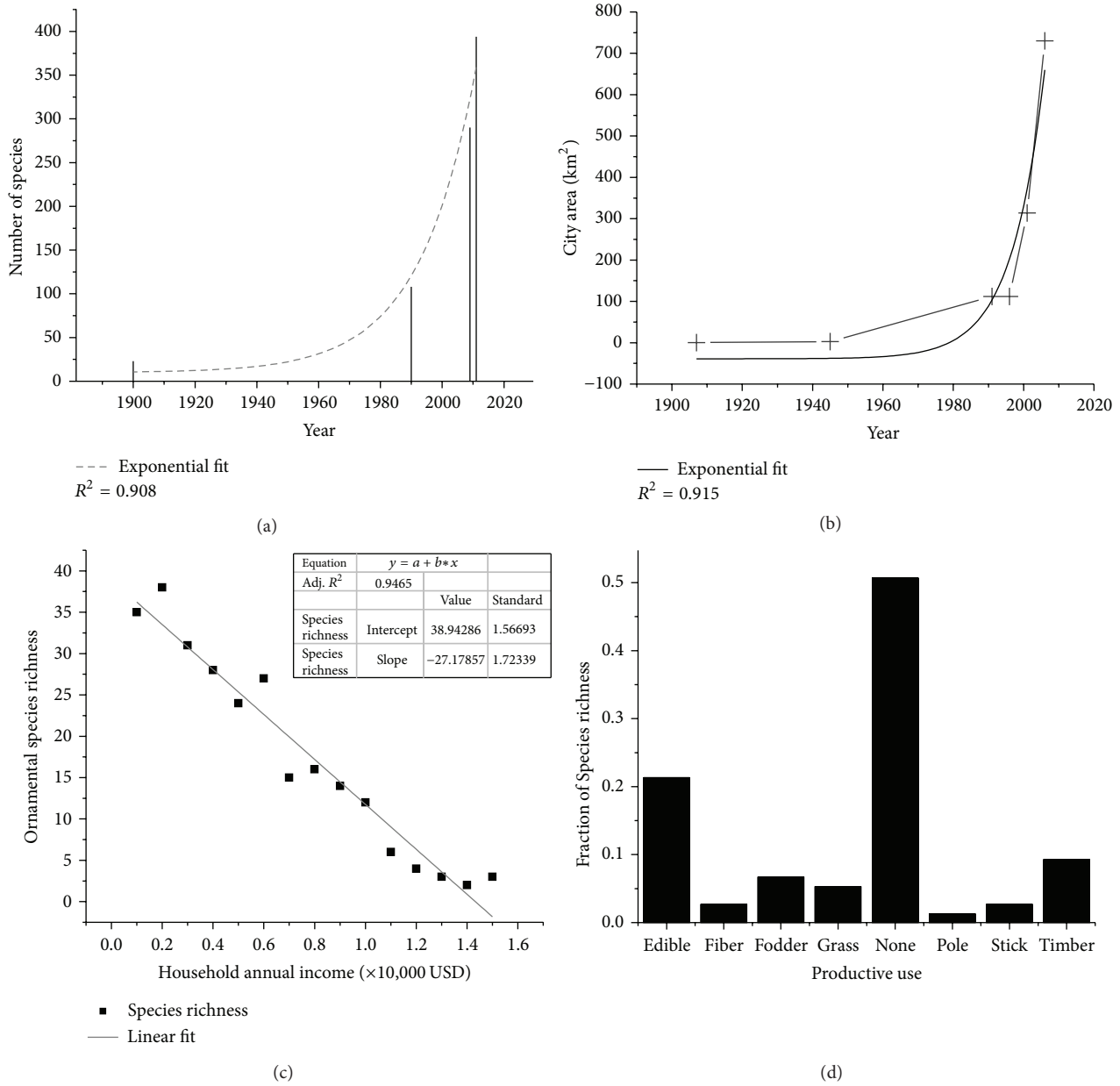

Figure 2: (a) Exponential fit illustrating the dynamics of ornamental plant richness from 1900 to 2012 (R^2 = 0.908). (b) Exponential fit depicting expansion of Kigali city area from 1907 to 2006 (R^2 = 0.915). (c) A linear regression of domestic garden plant richness on household annual income. (d) Relative importance of garden plants with regard to their readiness to productive use [9]. Both Kigali city area and the number of garden plant species increased exponentially from late 1800s to early 21th century. Gross national income also followed a similar trend, suggesting that the influx of new plant species followed patterns of wealth accumulation. It was estimated at US$440 per capita in 1981, US$540 in 1991, US$610 in 2001, and US$1240 in 2011 (http://data.worldbank.org/, 03.10.2012). Note that the growth rate was the highest in the last 10 years (203%, from 2001 to 2011) ((a) and (b)) [16]. Other factors hold constant, socio-economic factors such that household income appears to be a powerful predictor of ornamental plant diversity around human settlements and Rwanda's residential neighborhoods. Edible ornamentals account for more than 20% of recorded garden plants. The percentage is raised up to twofold in low-to-middle-income settlements. It decreases to 0–5% in high standard residential neighborhoods, where showy ornamentals are the most common feature ((c) and (d)).

of 1990, in terms of land cover, eucalypts represented roughly 2/3 of cultivated forests in Rwanda (Table 3).

The expansion of cultivated food and forest crops aligned with a steady population growth. However, it negatively correlated with change in fallow and pasture land cover (Figure 3), resulting in a significant decline of wild-extracted products.

Among most threatened indigenous forest resources are wild edible plants whose occurrence significantly decreased as natural forests, fallows, and pastures receded (Table 4).

Table 1: Ornamental tree species richness in rural and urban areas of modern-day Rwanda.

City	Land use type	Number of species	Number of families
Kigali	Urban	186	64
	Rural	99	43
Huye	Urban	84	31
	Rural	39	16
Musanze	Urban	67	29
	Rural	23	14

4. Discussion

4.1. Ornamental Crops. Many essentially ornamental species flourished in Rwanda in postcolonial era as people abandoned traditional landscape architecture and strived to go western. As a result, ornamental and amenity plant diversity increased with the degree of deculturation or the extent to which communities had embarassed western culture. This was reflected in the fact that species richness increased with urbanization and household socio-economic status, with Kigali, the capital city, having the highest number of species. With regard to differences observed between big and small cities in terms of ornamental plant species richness, our results are well in line with the findings of Nshimiyinama [29] and Ndayisenga [30] who recorded 164 and 78 ornamentals in Kigali and Huye, respectively, supporting the hypothesis of supremacy of Kigali, the capital city, as compared to provincial cities.

The fact that the fraction of native taxa in gardens declined from 100% to less than 25% over one century (from early 1900 to date) aligns well with rates of conversion to Christianity (by year 2001, the proportion of converts had already reached 93.6% from 0% in 1890, when Rwanda was given to the German Empire as colonial territory (http://www.religionfacts.com/, 28.09.2013)) and illustrates to what extent European colonization may have impacted on indigenous plant diversity. Interestingly, Desouter [8] clearly indicated that the colonial-nursed disdain of traditional culture by local communities in Rwanda had had a profound effect on the erosion of indigenous knowledge. The high proportion of introduced taxa within contemporary landscapes in Rwanda was independently reported by other studies, including Seburanga and Zhang [31], Ndayisenga [30], Nshimiyimana [29], and Uwamahoro [32]. Interestingly, these results corroborate those obtained by Bigirimana et al. [33] in neighboring Burundi, suggesting that conclusions of this study with regard to the relative high weight of native taxa in the overall flora may be generalized to encompass sub-Saharan Africa as a whole.

Elsewhere, Crosby [3] recognized the impact of sociopolitical superpower on biological diversity in developing countries, proposing the expression "ecological imperialism." However, such global sociopolitical dimension of plant diversity has been increasingly discussed by researchers in the specific context of European colonization. In the United States, Clines [34] suggested major floristic transformation in California since European Contact at the end of the 15th century. In Australia, social disruptions resulting from colonial entreprise caused erosion of traditional knowledge that once was used by indigenous people for savanna management [35].

4.2. Food Crops. Native crops had been a reliable source food for millennia in Rwanda. The trend was reversed by the westernization of [or shift from local to western-like] dishes and "groceries" since the advent of European contact with East Africa, which saw the importance of native food declining, especially from the early 1900s. The trend observed in land use change not only aligns with human population growth, but also reflects the substitution of European-bred cash crops for indigenous crops and western-inspired farming techniques for traditional agricultural practices. *Amaranthus dubius* "Dodo" [Amaranthaceae] and *A. hybridus* "Imbwija" [Amaranthaceae] aside, no other indigenous vegetables makes it to markets. Where they still exist, they only are used domestically. Never actively cultivated, their produce is usually gathered during crop weeding or collected later on specimens purposefully preserved or outside agricultural fields by hunter-gatherers.

At the beginning of last decade, in the context of economic globalization (sometimes referred to as a new kind of colonization [36]), there has been intention to industrialize Rwanda's agriculture and forestry. In such conditions, even those crops that had survived the effects of European have been losing their importance to a few ever expanding cash-crops: rice, wheat and maize. Crops whose fraction of land cover decreased significantly during the last ten years include banana, beans, sorghum, and sweet potato. Of course there was a need to intensify agriculture as human pressure on cultivable land increased ($Y = 0.14X - 275$; $R^2 = 0.98$, with X = years and Y = human density per cultivable land, Figure 3(b)). However, the pace these transformations took was more of western-style mimicry than of home-grown problem solving.

The trend could have been different if Rwandans had been able to stick to the culture of their own and adopt new fashion cautiously. As Rwanda thrives to become a globally positioned country, the revisitation of its abandoned heritage is needed. Such revitalization of indigenous knowledge and practices recommended by Whitehead et al. [37] and Russell-Smith et al. [38] in the specific case of savanna management could also be applied to indigenous crop diversity. This would, for example, allow the promotion of traditional crafts and restore the impact of native crop species in the landscapes. It may also help rebuild communities' confidence in native and archaeo-migrant crops and relax the rush to introduce new species. Louis [39] goes further to propose the integration of indigenous methodologies in conventional research, reflecting how conservation of indigenous heritage is likely to be of great concern in the future.

Although such "unfair" treatment against alien plants may yield little impact on already established invasive species, this would have dramatic impact on potential new invasive species as introductions would have been significantly reduced. Indeed, this approach, building upon the principles

Table 2: Checklist of precolonial food crops in Rwanda, residence time, and level of threat status**.

Lifecycle	Family name	Species name		Introduction date	Threat
		Latin	Kinyarwanda		
Annual	Gramineae	*Eleusine corocana* (Linn.) Gaertn.	Uburo	Native	High
	Gramineae	*Sorghum bicolor* (Linn.) Moench	Amasaka	Native	High
	Cucurbitaceae	*Cucurbita pepo* Linn.	Ibihaza	Neo-immigrant	Fair
	Cucurbitaceae	*Lagenaria siceraria* (Mol.) Standl.	Imyungu	Native	High
	Amaranthaceae	*Amaranthus graesizans* Linn.	Inyabutongo	Neo-immigrant	High
	Amaranthaceae	*Amaranthus cruentus* Linn.	Imbwija	Neo-immigrant	Low
	Amaranthaceae	*Amaranthus hybridus* Linn.	Imbwija	Neo-immigrant	Low
	Amaranthaceae	*Amaranthus dubius* Mart. ex Thell.	Dodo	Neo-immigrant	Fair
Seasonal	Leguminosae	*Pisum sativum* Linn.	Amashaza	Neo-immigrant	Fair
	Leguminosae	*Phaseolus vulgaris* Linn.	Ibishyimbo	Neo-immigrant	Fair
	Leguminosae	*Vigna unguiculata* (Linn.) Walp.	Inkoli	Native	High
	Gramineae	*Zea mays* Linn.	Ibigori	Neo-immigrant	Low
	Solanaceae	*Solanum tuberosum* Linn.	Ibirayi	Neo-immigrant	High
	Solanaceae	*Solanum nigrum* Linn.	Isogi	Archaeo-immigrant	High
	Brassicaeae	*Gynandropsis gynadra* (Linn.) Briq.	Isogi	Native	High
Perennial	Leguminosae	*Cajanus cajan* (Linn.) Millsp.	Umukunde	Native	High
	Labiatae	*Coleus dysentericus* Bak.	Impombo	Native	High
	Convolvulaceae	*Ipomoea batatas* (Linn.) Lam.	Ibijumba	Neo-immigrant	Fair
	Euphorbiaceae	*Manihot esculenta* Crantz	Imyumbati	Neo-immigrant	Low
	Euphorbiaceae	*Manihot glaziovii* Müll.Arg.	Isombe	Neo-immigrant	Fair
	Araceae	*Colocasia esculenta* (Linn.) Schott	Amateke	Archaeo-immigrant	Fair
	Araceae	*Dioscorea alata* Linn.	Ibikoro	Archaeo-immigrant	High
	Musaceae	*Musa sapientum* Linn.	Ibitoki	Archaeo-immigrant	Fair
	Solanaceae	*Ensete ventricosum* (Welw.) Chees.	Itembatembe	Native	Fair
	Musaceae	*Solanum torvum* Sw.	Inkarishya	Archaeo-immigrant	Low

**Note: [9] Five of the seven species listed above as native food crops in precolonial Rwanda were also established sacred taxa as they were used in almost all rituals that involved food preparation such as at bereavement meals "kurya imboga z'igicaniro." during the "kubandwa" cult or at "ubunnyano" feast, the equivalent of "kwita izina." Among these were the popular bitter vegetables *Gynandropsis gynadra* and *Lagenaria siceraria* [the highly cherished sweet cultivar of bottle gourd came in afterwards but is now extremely rare]. They also include their counterpart source of energy *Eleusine corocana* and *Sorghum bicolor* (especially the white grain cultivar or "nyiragikori." in the local language) that were used in the form of bread, porridge, or beer. In addition, seeds of sorghum were munched uncooked at daybreak before talking to anybody to ensure good luck or, at least less troublesome day. They also include one legume species *Cajanus cajan*, mainly used in preparation of love potions, either at weddings or at other romantic occasions. Alone or along with nonedible *Ricinus communis* "ikibonobono," *Momordica foetida* "umwishywa," *Cassia didymobotrya* "umucyuro," *Ficus thonningii* "umutabataba," *Erythrina abyssinica* "umurinzi," *Phragmites mauritianus* "umuseke," *Entada abyssinica* "umusange," its branches were used to sprinkle people with the holy liquid, a mixture of water and white clay "ingwa." In particular, *Lagenaria siceraria* was highly valued for several utensils that were made out of its mature fruits: calabash "uruho," funnels "umubirikira" and "umukondo," gourd "agacuma," milk jars "imirere," and churn "igisabo." The gourd was also used to make the speaker of the traditional music instrument "igobore" and its seeds were famous in divination practices. The dried reeds and straws of banana, millet, and sorghum plants were used to make thatched roofs, widespread in the period that followed semiunderground settlement or "-sakazataka" architecture and before the introduction of tile and iron roofing by the Europeans [16]. The list includes 7 native species, 5 archaeo-immigrants (present at least since 1000 BC) mainly from Asia, and 10 neo-immigrants (arrived some time after 1500 BC) mainly originating from Tropical America. Although not to the point of being sacred, due to their longer period of usage compared to neo-immigrants, the above archaeo-immigrant plant species were much embedded in the Rwandan culture at the arrival of Europeans. For example, a unique banana wine "inkangaza" had been developed and was used at special gatherings and in postcolonial kubandwa cult. In contrast, neo-introduced species such as *Phaseolus vulgaris, Zea mays, Pisum sativum, Ipomoea batatas*, though they became the cornerstone of diet in precolonial Rwanda, were not involved in any ritual. For example, it was prohibited to eat beans at kubandwa cult [26]. Limited agricultural means and skills may have kept farming a laborious activity and the recurrent famines characterized colonial and pre-colonial Rwanda. It can also partly explain the great value that was given to cattle and how people were willing to spend years on service in order to acquire a cow of their own [3]. Average frequency of occurrence was found to be positively correlated with the length of residence time. It was highest for neo-immigrants (50–70%) and lowest (0–20%) for native species, except for *Sorghum bicolor*. Many of them went through a steady decline since early 1900s and are now on the fringe of extinction. They include finger millet "uburo" (*Eleusine coracana*), African spider flower "isogi" (*Gynandropsis gynandra*), less weedy amaranth "inyabutongo" (*Amaranthus graesizans*), Pigeon Pea "umukunde" (*Cajanus cajan*), Cow Pea "inkoli" (*Vigna unguiculata*), *Coleus dysentericus* Bak. "impombo" [Labiatae], *Dioscorea alata* Linn. "Ibikoro" [Araceae], and bottle gourd "umwungu w'ibamba, igicuma or igisabo" (*Lagenaria siceraria*) (Table 1). One of the most threatened crop species appears to be native *Vigna unguiculata* "inkoli." The red grain cultivar of *Sorghum bicolor* was seemingly not threatened until recently when it succumbed to the political will to replace it with maize in many parts of the country. The same applies for dessert banana, precolonial bean, and Irish and sweet potato. Significantly declining cultivars of these crops are the long-held cultivars such as dessert banana "kabaragara," sweet cassava "gacyacyari", or "iminderi," short-season Irish potato "kandore." They also include disease-resistant "nyirabukara" bean and drought resistant sweet potato "gakoba." Despite the fact that maize is currently a favorite crop in Rwanda, its traditional small and multicolored-grain cultivar "nyakagori" almost disappeared from both fields and granaries.

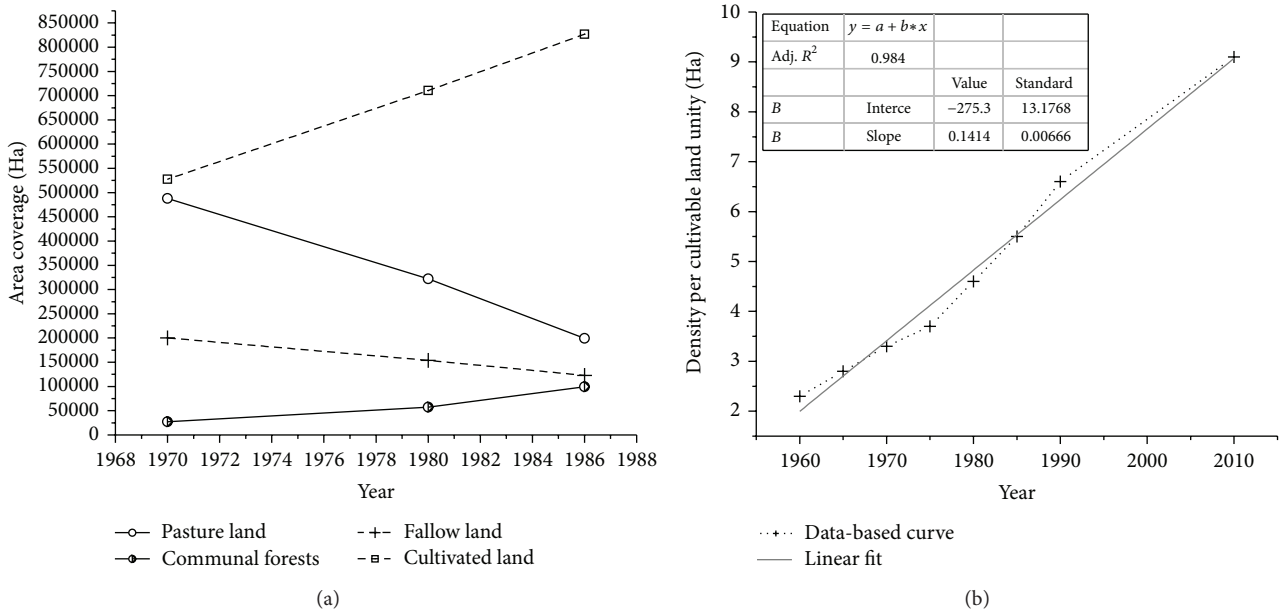

Figure 3: (a) Pasture, farm, and forest land cover change over eighteen years (1970 to 1988). (b) Evolution of human pressure on cultivable land over the last 50 years. Fallow and pasture land cover had shrunk to 60% and 40% by 1986 from their respective area coverage of 200,000 ha and 487,884 ha in 1970 (a). During the same period, cultivated land cover had expanded to 156% while communal forests had more than tripled their area coverage. By year 2010 pressure on cultivable land had reached 4-fold the 1960 estimated human density of 2.3 persons per cultivable hectare (b). Unless otherwise indicated, the data used for the above charts were adapted from May (1995).

Table 3: Fraction of forest cover by category of tree species in 1990 (data retrieved from Mihigo [26]).

Species category	Area ($\times 10^3$ ha)	Fraction of cover (%)
Eucalyptus	161	65.18
Pine	32	12.96
Cypress	21.5	8.70
Other	32.5	13.16

of precaution and prevention, would be many times less costly than waiting until there is a need to deal with already established invaders.

The significant decline ancient crops (<1200 AD) such as *Sorghum bicolor* (white-grained cultivar "nyiragikori or amasaka y'igitare"), Eleusine corocana, and Gynandropsis gynandra started as early as the dawn of 20th century and was triggered by the decision by the colonial power to promote non-ancient crops (beans and banana), which, together, as of 1990, occupied 28.1% of total cropland [27]. This phenomenon similar to what occurred in neighboring Burundi and Chrétien [40] refers to it as a "social, political and ideological mutation". The red-grained cultivar of sorghum survived and played the traditional role of the ever declining white-grained cultivar until early 21st century when it succumbed to unparelled maize expansion (30.3 annual production growth rate from 2004–2010 [41, 42]). Sekanabanga and Nduwumwami [43] noted that sorghum was a very important crop in early 1980s. Some ten years after, it was still third, only after beans and banana, and far ahead of corn in terms of land cover: 8.8 and 2.3% of total cropland, respectively [27]. Pottier [44] documenting food flow in markets he visited in the then Kibuye Prefecture (now Karongi District) in mid 1980s, he stressed there were very small quantities of maize and vast quantities of sorghum; again depicting the importance of sorghum precolonial and early postcolonial Rwanda. Expansion of maize at the expense of Sorghum continued to date such that from 2004–2010 production of sorghum declined by 0.3 percent per year [41, 42].

Also declining was banana with a modest annual growth rate of 1.8 percent while production of maize increased at a 15-fold higher rate [41, 42]. The substitution of maize for banana can be justified if considered the fact that maize yields three-fold more calories per unit weight [45]. However, banana produces throughout the year and over many years [46]; thus insuring a greater certainty of yields, at a lower labor cost [47]. We argue that replacement of banana by any cereal crop should be considered cautiously, unless there is a sociopolitical motive that dictates otherwise.

4.3. Forest Crops. Shrankage in fallow and pasture land cover recognized in this study corroborated the findings of [27]. Their findings suggest that the majority of informants stated that there was no significant change in land use. However, interestingly, they realized that most of those informants that thought there had been change also believed that fallow and pasture land cover was receding while woodlots were expanding.

Table 4: Checklist of key wild edible plants of Rwanda and their respective levels of threat of extinction[****].

Family name	Species name		Status	Threat
	Latin	Kinyarwanda		
Euphorbiaceae	*Acalypha bipartita* Müll.Arg.	Ingese, Umuheka	Native	Low
Apocynaceae	*Acokanthera schimperi* (A.DC.) Schweinf.	Umusagwe	Native	High
Apocynaceae	*Ancylobotrys amoena* Hua	Umukamire	Native	High
Aspleniaceae	*Asplenium monanthes* Linn.	Injugushu	Native	Fair
Rubiaceae	*Canthium lactescens* Hiern	Umukondokondo	Native	High
Capparidaceae	*Capparis erythrocarpos* Isert	Umutugunguru	Native	High
Capparidaceae	*Capparis tomentosa* Lam.	Umutugunguru	Native	High
Brassicaceae	*Cardamine obliqua* Hochst. ex A. Rich.	Isaga	Native	Low
Caricaceae	*Carica cundinamarcensis* Hook. f.	Ipapayi	Exotic	High
Apocynaceae	*Carissa edulis* Forssk. Vahl	Umunyonza	Native	Fair
Cyperaceae	*Cyperus papyrus* Linn.	Urufunzo	Native	Fair
Flacourtiaceae	Dovyalis macrocalyx (Oliv.) Warb.	Umutegengeri	Native	High
Flacourtiaceae	*Dovyalis spinosissima* Gilg	Amakome	Native	High
Leguminosae	*Eriosema nutans* Schinz	Inanka	Native	High
Leguminosae	*Eriosema pauciflorum* Klotzsch	Inanka	Native	High
Asteraceae	*Galinsoga parviflora* Cav.	Kimari	Exotic	Low
Clusiaceae	*Garcinia buchananii* Bak.	Umusarasi	Native	High
Anarcardiaceae	*Lannea schimperi* (Hochst.) Engl.	Igisenzegwa	Native	High
Anarcardiaceae	*Lannea fulva* (Engl.) Engl.	Umumuna	Native	High
Urticaceae	*Laportea alatipes* Hook. f.	Igisura	Native	High
Moraceae	*Myrianthus holstii* Engl.	Umwufe	Native	High
Nymphaeaceae	*Nymphaea lotus* Linn.	Amarebe	Native	High
Nymphaeaceae	*Nymphaea nouchali* Burm. f.	Amarebe	Native	Fair
Oxalidaceae	*Oxalis corniculata* Linn.	Munyuwanyamanza	Native	Low
Sapindaceae	*Pappea capensis* Eckl. & Zeyh.	Umumena	Native	Fair
Sapindaceae	*Pappea ugandensis* Baker f.	Umuremampango	Native	Fair
Chrysobalanaceae	*Parinari curatellifolia* Planch. ex Benth.	Umunazi	Native	High
Sapindaceae	*Paullinia capensis* Eckl et Zeyh.	Umuremampango	Native	High
Solanaceae	*Physalis peruviana* Linn.	Umuhuhu	Exotic	Low
Anarcardiaceae	*Rhus vulgaris* Meikle	Umusagara	Native	Fair
Rosaceae	*Rubus apetalus* Poir.	Umukeri	Native	High
Rosaceae	*Rubus kirungensis* Engl.	Umukeri	Native	High
Rosaceae	*Rubus rigidus* SM.	Umukeri	Native	High
Rosaceae	*Rubus steudneri* Schweinf	Umukeri	Native	High
Polygonaceae	*Rumex usambarensis* (Engl.) Dammer	Umufumba	Native	Low
Solanaceae	*Solanum aurantiacobaccatum* De Wild.	Igitagarasoryo	Native	High
Solanaceae	*Solanum taitense* Vatke	Intagashya	Native	High
Loganiaceae	*Strychnos innocua* Del.	Umuhonnyo	Native	High
Loganiaceae	*Strychnos potatorum* L. f.	Umuhonnyo	Native	High
Loganiaceae	*Strychnos spinosa* Lam.	Umuhonnyo	Native	High
Loganiaceae	*Strychnos lucens* Bak.	Umuhonnyo	Native	High
Typhaceae	*Typha latifolia* Linn.	Umuberanya	Native	Fair
Olacaceae	*Ximenia caffra* Sond.	Amashereka	Native	Fair
Gramineae	*Yushania alpina* (K. Schum.) W. C. Lin	Intoke	Native	Fair

[****] Most of plant species in this table are edible fruits, of which two are Tropical America-originated species (*Carica cundinamarcensis* and *Physalis peruviana*) that may have been introduced in post-Columbian era such that they had already naturalize at the arrival of Europeans. The few edible leaves include *Laportea alatipes* (Urticaceae), *Rumex usambarensis* (polygonanaceae), and *Acalypha bipartita* (Euphorbiaceae). The sour berries of *Solanum taitense* (Euphorbiaceae) are said to be usable as condiments. Ashes of leaves of *Typha latifolia* (Typhaceae) were traditionally used as salt. Edible roots include those of *Nymphaea nouchalii* and *Nymphaea lotus* (Nymphaeaceae).

Compared to cultivated and communal forest land, fallows and pastures harbors greater wild and native plant diversity. It follows that, as a result of their decline, native plant resources increasingly became rare outside protected areas. Those directly concerned by this decline are wild edible plants. Our results with regard to decline of wild-extracted food are well in accordance with findings of other studies conducted in Rwanda and in the region. For instance, Munyangeri [48] suggested that indigenous fruits were never processed nor sold on market in Kirehe District. Only 12% of interviewed women [3% of men] identified themselves as indigenous fruit users. The bulk of these fruits were collected and eaten by kids (80%). She further found that the majority of fruits were collected from the wild. She notes that those collected on farms were usually from trees purposefully preserved by farmers when clearing the land. She stressed that indigenous fruit trees in Kirehe (eastern province) were threatened by extinction because they were considered by farmers as less important compared with (introduced) trees, thus less worthy to be conserved. Safari [49] came up with the same conclusion, noting that populations of indigenous fruit trees in Musanze and Nyamagabe (northern and northern provinces) were generally declining.

Also noteworthy, but not listed in the table above, are threatened nonedible tree species such as *Pterygota mildbraedii* "Umuguruka" (Sterculiaceae), *Prunus africana* "umwumba" (Amygdalaceae) and *Newtonia buchananii* "Umukereko" (Leguminosae), and *Hagenia abyssinica* "Umugeshi" (Rosaceae). In general, native home compound-fencing plant species are significantly declining as brick- and concrete-walled fences become popular in Rwanda. *Euphorbia tirucalli*, *Erythrina abyssinica*, *Ficus thonningii*, *Euphorbia candelabrum*, and *Dracaena afromonana* are some of those whose populations seem to be seriously affected. Among native timber species, *Markhamia lutea* is at the highest risk of extinction among those solely maintained through cultivation.

5. Conclusion

In this study, the decline of traditional crops was found to be associated with the "cultural disturbance" that occurred in the shadow of the European colonization. Indigenous crops now on the fringe of extinction and, thus, require immediate attention from conservation policy makers and managegers were identified. These include *Vigna unguiculata* (L.) Walp. "inkoli" [Leguminosae], *Coleus dysentericus* Bak. "impombo" [Labiatae], *Dioscorea alata* Linn. "Ibikoro" [Araceae], a sweet cultivar of *Lagenaria siceraria* (Mol.) Standl. "bunure" [Cucurbitaceae], white cultivar of *Sorghum bicolor* (Linn.) Moench "nyiragikori" [Gramineae], *Amaranthus graesizans* Linn. "inyabutongo" [Amaranthaceae], *Eleusine corocana* (Linn.) Gaertn. "uburo" [Gramineae], and traditional cultivars of Zea mays Linn. "nyakagori" [Gramineae] and *Solanum tuberosum* Linn. "kandore" [Solanaceae]. We argued that cultural integrity could contribute in preserving native plant diversity whose survival depends on indigenous knowledge and beliefs of local communities. This could also reduce the number of new introductions of species, which, unfortunately, may include potential invasive plants.

Conflict of Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

This work was produced in the context of the author's ongoing Ph.D. research project on "*Plant Invasion Risk Assessment in Rwanda: Implications for Biodiversity Conservation*" at the University of Rwanda, under the mentorship of Professor Beth A. Kaplin (Antioch University, New England, US), Dr. Elias Bizuru (University of Rwanda, Rwanda), and Dr. Edward N. Mwavu (Makerere University, Uganda). He thanks all the participants who agreed to provide the valuable information this paper needed to be scientifically informative. He also acknowledges the technical support of Madame Theodette Gatesire, Research Assistant at Karisoke Research Center of the Dian Fossey Gorilla Fund International.

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