BIODIVERSITY OF INTERCROPPED FIELDS IN CENTRAL AFRICAN RAINFORESTS

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ABSTRACT This paper reports an example of agrobiodiversity in central African rainforests. In central Africa, people manage agriculture characterized by vegetative crops and shifting and intercropping culture. They plant many crop species and cultivars in a field simultaneously. Tolerated wild plants such as uncut trees and weeds also exist in fields. I found 29 species of uncut trees in 9 fields and 102 species of weeds in a field area of 750 m^2. People recognize these wild plants well and assign utilities to most of them, such as medicine, food, and other useful materials. These domesticated and wild plants generate biodiversity in farmlands. This fact cannot be explained only by functional aspects; therefore, I attempted to clarify the cultural and historical background of the agrobiodiversity in this region.

Key Words: Agrobiodiversity; Intercropping; Shifting cultivation; Tolerated Plants; Central Africa.

BIODIVERSITY IN FARMLAND

Farmland is generally considered to have reduced plant biodiversity through human choice. Mono-cropped and mono-cultivar field indeed have low biodiversity. Nevertheless, some farmlands support high biodiversity. Among these are the intercropped fields in rainforests of central Africa.

Intercropping, which is practiced worldwide, has been classified by order of planting sequence and subdivision of fields (Francis, 1986). In one central African version, a variety of crops are planted simultaneously more or less at random without rows, ridges, or mounds. This is termed mixed-intercropping, which is intercropping in a narrow sense (Miracle, 1967). Mixed-intercropped tracts have high diversities of crops and cultivars across the fields. Productivity and sustainability of the intercropping systems under tropical conditions have been re-evaluated in recent agricultural research in the tropics (Francis, 1986; Richards, 1985), although the agricultural practices there were first thought to have low levels of productivity and efficiency.

Intercropping is not the only way to enhance biodiversity of arable land. Here, I show that in the Cameroon rainforest, there are several other factors that increase biodiversity, including uncut trees and weeds.

The biodiversity of farmed fields gelled into the concept of agrobiodiversity or agricultural biodiversity in the 1990s. Agrobiodiversity is defined as "the variety and variability of plants, animals, and microorganisms at genetic, species and ecosystem level" (Stocking et al., 2003: 6).

There is a similar concept termed agrodiversity or agricultural diversity, which

refers to "the many ways in which farmers use the natural diversity of the environment for production, including not only their choice of crops but also their management of land, water and biota as a whole" (Brookfield & Padoch, 1994: 9). It includes the diversity of agricultural practices. Agrobiodiversity is a part of agrodiversity.

Here, I analyze plant composition, management, and use of fields. I also examine the relationship between agrobiodiversity and intercropping. Examples of agrobiodiversity and agrodiversity are presented.

THE HISTORY OF FARMING CULTURE IN CENTRAL AFRICA

My research area is located in southeastern Cameroon, at the north-western margin of the Congo Basin. The characteristics of the farming culture of the Congo basin include vegetative crops such as cassavas and bananas; shifting cultivation; mixed-intercropping; multiple subsistence including hunting, gathering, and fishing; common cooking tools such as mortar and pestle, and meals composed of a combination of ball-shaped starchy food as staple and stews.

The farming culture of central Africa has its origins in West Africa, where two types of farming developed; namely, the "Sudan Farming Culture Complex" of savannas and the "Guinea Farming Culture Complex" of coastal humid areas[(1)]. Central Africa has inherited the "Guinea Farming Culture Complex," which produces a variety of yams originating in West Africa (e.g., *Dioscorea cayenensis*, *D. rotundata*), oil palm, cola nuts, and gourds.

The first farmers are thought to have been the Bantu-speaking people. Proto-Bantu people established themselves near the border between Cameroon and Nigeria in about 3000 BC (Vansina, 1990). Some of them made their way into the forest with the "Guinea Farming Culture Complex" in about 1500 BC. These were the West-Bantu people. In the early period, they had stone tools and earthenware, but no ironware. Mortars and pestles were used, distinguishing their food culture from the vegetative farming culture of South-Eastern Asia. Unfortunately, yams were not sufficiently productive in tropical rainforest, because these plants need more than two months of clear dry weather and abundant sunlight. In the early forest-living period, Bantu people may have hunted, fished, and gathered wild yams within the forest. Population expansion is assumed to have taken place after the forest Bantu obtained ironware and a set of crops from South-East Asia, namely, bananas, taro, different varieties of yams, and sugarcane about 2,000 years ago. Bananas are more than 10 times as productive as yams in rainforests. Bananas in central Africa are classified mainly in the plantain sub-group of the AAB genome, which is one of many genome types (AA, AAA, AAB, AB, ABB etc.). There are many cultivars even within single plantain sub-groups. The Songola people in Congo-Kinshasa reportedly have 35 cultivars (Ankei, 1981), and the Bobanda in northeastern Congo-Brazzaville have 57 cultivars (Hanawa, 2002).[(2)]

Forest farmers accepted new crops from the Americas after the 16th century,

including maize, peanut, hot pepper, and cassava. Cassava, which spread along the Congo River with the slave trade, has become the most important staple crop in central Africa. A unique procedure for removing toxic hydrocyanic acid was developed in the Congo River region (Ankei, 1990)[3].

Commercial cultivation of coffee and cacao, which have become the most important tree crops in central Africa, was started by Europeans in the 19th century and incorporated into traditional shifting cultivation. The Belgians started commercial cultivation of robusta coffee (*Coffea canephora*), which was growing untended in central Africa at the end of the 19th century (Purseglove, 1968). Cultivated coffee and cacao were introduced as a means of tax payments by colonial governments in the early period. Later, these crops were sold for cash, necessary for children education, medical services, and industrial commodities. Introduction of coffee and cacao cultivation brought African farmers into a direct relationship with the global economy and considerably changed land use and division of labor in their society.

Today, commercialization of staple food crops is proceeding in the suburbs of large cities, and practices of mono-cropping and establishment of permanent fields are increasing. However, in more remote regions without developed infrastructure, people produce crops for their own needs, and an agricultural system based on mixed-intercropping and shifting cultivation has persisted.

RESEARCH SUBJECT AND METHODS

The research site was located in quartier Mondindim, Ngola village, Moloundou District, Boumba-Ngoko Department, East Region of Cameroon (2°41′ N, 15°18′ E). This village is situated on a road (penetrating the tropical forest) from north Yokadouma, the division's capital, to south Molondou on the border with the Republic of Congo. Ngola is situated 120 km south of Yokadouma and 100 km north of Molondou. There are logging company timber depots in the nearby forest, and tens of large, noisy timber-carrying trucks travel the road daily. Regular mini-bus service connects the villages along the road.

The vegetation of the area is dominated by semi-deciduous forest. There are two dry seasons (December to February, July to August) and two rainy seasons (March to June, September to November). Annual precipitation is about 1,500 mm, and there is no month with less than 50 mm of rainfall. Mean temperature is 25.2°C[4] (Tsuchiya et al., 1972).

Several ethnic groups practicing shifting cultivation live along the road. The Baka hunter-gatherers also live in areas adjacent to these cultivators, and now engage in farming as well. Residents of each village consist of a major ethnic group and various other groups. These groups are connected by marriage or other personal social networks. People speak French as a common language in addition to their native and neighbors' languages.

The majority people in Ngola village are ethnic Mbomam. Quartier Mondindim was set up by two Kako brothers, their uncle, and their families around 1960. Kako is an ethnic group of 70,000 people living mainly on the

border between savanna and forest from Batouri in East Cameroon to the Central African Republic. Mondindim is an ethnic exclave. There are other Kako villages south of Yokadouma, but not near Mondindim.

The founders of Mondindim came from Lindi village in the Kako area on the border between savanna and forest 160 km to the north. They had cultivated cassava as the main food crop in Lindi. They left Lindi in the 1950s because wild rubber fetched a good price from the colonial government and because of family conflict. They first settled near Mondindim and then moved south, avoiding colonial conflict between France and Germany. They returned to Mondindim after independence from France. When they arrived, there were already settlements on both sides of the present day Mondindim. These were occupied by Mbomam shifting cultivators and by the Baka hunter-gatherers who had camps in nearby forest. The new immigrants first depended on Mbomam neighbors for their livelihood, and subsequently developed independent settlement of Mondindim. After Mondindim village was established, the Baka developed two settlements near Mondindim, following government directives. The village population has increased with the arrival of the relatives from Lindi and other villages both within and outside the forest. The population of Mondindim was 200 in August 2008, including 47 Baka. Each patrilineal kin group forms its own section in the village, stretching over 2 km along the road. Marriages between Baka women and cultivator men are not rare.

The major livelihood in the area is shifting cultivation of food crops, cacao cultivation, and many kinds of fishing, hunting, and gathering. The Lokomo River runs along 1 km to the south, and the Boumba River 4 km to the west. Villagers fish in these rivers throughout the year by using hooks, lured hooks, gill nets, casting nets, fishing baskets, and by hands. Surplus cassava flour and plantain banana are sold to truck drivers, and fish, wild meat, and home-made spirits (made from cassava) bring some cash income, adding to the income from cacao harvest from September to December. The unit of production and consumption is the household consisting of husband, wife (wives), and unmarried children. Villagers often ask Baka to work for them or have seasonal partnership with a Baka household, although they do not have permanent partnerships with Baka. They rely on Baka women to cut and weed shifting fields for food crops and on Baka men to weed and harvest cacao fields.

The balance of subsistence changes according to the cacao price. In the 1970s when cacao fields were first developed, farming for this product was attractive because the Cameroonian government distributed free seeds and agrochemicals, showed how to grow seedling, and bought cacao seeds produced at a high price. Subsequently, the price of cacao has fluctuated greatly with changing government policy and international cacao prices.

Research at Mondindim was conducted on 10 intermittent occasions from 1993 to 2008, spanning a total of about 8 months. Data on existing plants in fields were collected from December 1993 to March 1994. Plants were identified by the National Herbarium of Cameroon at Yaounde.

PREPARATION OF A FOOD CROP FIELD

Agriculture in the tropical rainforest of Central Africa comprises shifting cultivation, mixed-intercropping, and vegetative culture. This combination is also seen in Mondindim, where the main food crop is bitter cassava.

Neighboring villages around Mondindim (Mbomam, Bangandou, and Baka) grow plantain banana as their main crop. In contrast, at Lindi, the mother village of Mondindim, people grow bitter cassava, maize, peanuts, and sesame in fields cleared in the savanna-woodland. The founders of Mondindim had two choices in the 1960s, either planting cassava of the mother village or plantain bananas of neighboring villages. They selected cassava as the main crop, and added to it plantain bananas as supplementary crop. In the second generation, the proportion of plantain bananas increased with increasing inter-ethnic marriages with neighboring people (Komatsu, 1998). In the third generation, the proportion of cassava seems to be rising again. Bitter cassava has always been the main food in Mondindim. For the evening meal, ball-shaped cassava hard porriage is always served. The importance of cassava has increased in recent years, with high demand for distilled spirits made from cassava. Plantain banana is considered to be a snack food, a substitute for cassava in the rainy season when drying of cassava meal is difficult, as well as a source of cash income.

People normally cut out new fields every year. Fields cut in primary or secondary forest in the major dry season from December to February (*ngwan liko*[5]) are the most important. Secondary field are also cut as need arises; *ngwan dobo* is cut in riverine forest in the major dry season, mainly for maize production, and *ngwan kongwe* is cut in primary or secondary forest in the minor dry season (from July to August), mainly for bitter cassava. People cut *ngwan liko* in primary forest when they intend to expand cacao fields, or in secondary forest when no expansion is planned. They often plant cassava for a second time after the first harvest. Fields replanted in this manner are termed *nyongun*. They fallow fields normally over 10 years or over 3 years when they have insufficient labor, because cassava is able to grow in a 3-year fallow cycle.

Ngwan liko is burned after drying for several weeks in February or March immediately before the minor rainy season. Most cut trees rot slowly without burning, because the humidity is very high, even in a major dry season. It is more difficult to burn out *ngwan kongwe* cut in a minor dry season. People sometimes plant crops without burning. The first planting is for maize, peanuts, or melon after the first rain of the wet season and then cassava one week later. When the field owner intends to grow a new cacao crop after harvesting food produce, he plants cacao simultaneously. They sow cacao seeds directly without transplanting seedlings. Plantain bananas are planted gradually before burning, after sowing of maize and peanuts or after harvesting them. Plantain bananas sometimes remain in a field in the secondary forest. They also plant yautia (*Xanthosoma* sp.), yam, sweet potato, pumpkin, sweet cassava, okra, sugarcane, chili pepper, and tobacco. In a broad sense, intercropping is the planting of two or more crops in a field, with considerable variation in time

and space. Intercropping at Mondindim involves planting many crops in a field simultaneously without rows, ridges, or mounds. This is also termed mixed-intercropping (Francis, 1986).

Villagers harvest maize, peanut, and melon seeds three months after planting and then weed out the field. Precocious types of cassava can be harvested after 6 months, and the common type after one year. Plantain bananas can be harvested after 9 to 18 months, depending on the cultivar. Root and tuber crops are stored in fields until processed or cooked.

Suckers of plantain bananas sprout spontaneously for several generations. Cassava is replanted immediately after the first harvest, but is not planted for a third time, as this would produce only a small harvest. Plantain bananas and cassava remain in the field one year after cutting. After three years, there are plantain bananas, a few unharvested cassava plants, and many wild plants.

Most of field jobs are performed with only a machete. Men use axes for cutting trees, and women sometimes use strongly curved, short hoes for sowing peanuts. Women always go to the fields with matchets and large baskets on their backs.

There is a sexual division of work in shifting agriculture. Felling trees in the fields and burning are men's work, and other field chores are for women. The households without adult males hire Baka men to cut down trees, while women cut young secondary forest with no large trees.

Villagers often clear secondary forest for planting cassava. Primary forest is preferred for planting plantain bananas. However, they choose a primary or a very old secondary forest for cacao. All the works associated with cacao fields and cacao production are the responsibility of men. Women sometimes help harvesting, and children on summer vacations weed the fields, or Baka take on the work.

All lands legally belong to the state, but are actually managed by a lineage which dwells in the same quartier of a village. Anyone of the village can cut a new field in primary forest. A cut field in primary forest belongs to a groundbreaker and his successors after he dies. People do not, or cannot, sell or give away the land[(6)].

PLANT GROUPS OCCURRING IN FIELDS

I. Three Plant Groups

There are plants other than the planted crops in the cultivated fields, i.e., wild plants and unplanted crops. Within the vegetation of the field, there is a group of domesticated plants or crops that are intentionally planted. Many crops are mix-intercropped randomly and spontaneously. Fig. 1 shows a quadrat of 10×10 m in a field cleared in primary forest in 1994. There are 10 types of crops in the quadrat. There are also multiple cultivars of cassava, plantain bananas, and other root crops. The second group of plants comprises uncut trees that remain in the fields. Spontaneous wild crops ("weeds") form the third category.

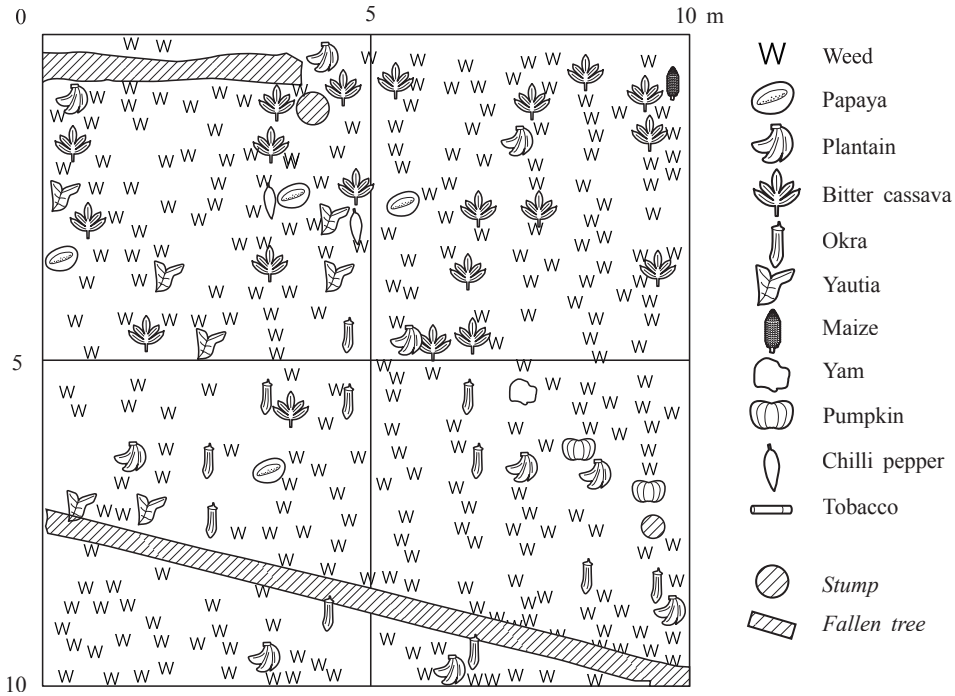

Fig. 1. Crops and "weeds" in intercropped fields.

II. Intercropping of Species and Cultivars

Shifting fields in Mondindim are mix-cropped in a manner common to the East Province (Figs. 1 & 2). Fig. 1 shows maize, yautia, yam, pumpkin, okra, chili pepper, and tobacco observed in the field, in addition to the main food crops such as bitter cassava and plantain bananas. Most farmers abandoned their cacao fields because prices for the cacao remained low in the 1990s. There was no new plantings; hence, cacao is absent in Fig. 2. Table 1 presents the list of crops in Mondindim. In addition to main crops, there are pineapples, sugarcane, tomatoes, leafy vegetables, and bitter fruits of the Solanaceae plant for drinks (*njo*, *pil*) in Table 1.

Some crops are not planted intentionally. Seeds of papaya and lemon are thrown away in fields after fruits are eaten as snacks during work. Seeds of oil palms and cacao often grow spontaneously in fields. These crops growing spontaneously are not weeded out.

There are 9 cultivars of bitter cassava, 7 cultivars of sweet cassava, 10 cultivars of plantain bananas, 4 cultivars of sweet bananas, 3 cultivars of peanuts, 5 cultivars of okra, and 4 cultivars of chili pepper[7]. These cultivars have been assigned names. There are also unnamed subgroups of yautia, maize, sweet cassava, papaya, and tobacco, which are distinguished from their related

Fig. 2. An intercropped field.

types by fruit color, shape, size, solidity and leaf shape. People often plant these cultivars or subgroups of crops mixed in a field.

I asked farmers why they mixed various crops in a field. At first, they gave me no particular reason. For them, it was a matter of course with no special meaning. After reflection, they put forth other explanations, such as to provide a variety of foods for consumption, to be able to harvest food crops throughout the year, and to maintain a food supply when one or more crops fail.

Year-round harvesting is one of the important objectives of mixed cultivar planting, especially for staple food crops. The staples in the region are comprised of root and tuber crops, and plantain bananas, that contain too much moisture for storing for a long time in tropical rainforests. People plant many cultivars and plant sequentially to extend the harvest time. Close attention is paid to year-round harvesting of bananas of multiple cultivars planted over several months; protracted planting is important because bananas must be harvested soon after bearing fruit. Planted cassava contain varieties of early growth and slow growth cultivars, even though cassava tubers can be kept in fields for months or even a year after maturity. However, the diversity of cultivars cannot be explained only by an endeavor to extend harvesting periods.

There are 8 main food crops in shifting fields that provide diet staples year-round. Condiments are also produced in the field. There are 11 types of condiment crops processed to make 34 kinds of condiments. Some crops have multiple parts for human consumption, e.g., rootstock and leaves of cassava

Table 1. Crops in Mondindim

Local name (Kako)	English name	Number of cultivars
kwende	plantain banana	10
yombo	bitter cassava	9
kili yombo	sweet cassava	7
tuku	yam (bulbil)	
tun	yam	
mekabo	yautia	
nbusa	maize	
boku	pumpkin	
njako	melon (for seed)	
wuwundu	peanut	3
nbolo	okra	5
kan	tobacco	
ndon	chilli pepper	4
nomba	sweet banana	4
jeki	pineapple	
?	sugar cane	
tomate	tomato	
njo	Solanaceae bitter fruit	
pil	Solanaceae bitter fruit	
nbololala	leafy vegetable	
nbule	leafy vegetable	
ngano	leafy vegetable	
njan	leafy vegetable	
lamusi	lemon	
guenda	papaya	
cacao	cacao	
banga	oil palm	

and rhizome and young leaves of yautia. Sap of the cacao bud is used as a peculiarly viscid condiment. Leaves of cassava, okra, and field vegetables are cooked as side dishes to accompany fish, wild meat, and wild vegetables. A diversity of species and subspecies in the fields contributes to diversity on the table year-round (Komatsu, 1998).

III. Uncut Trees

Fields are dotted with uncut trees (Fig. 3). Farmers precisely remember which kind and how many trees they leave in their fields. Eighty-three trees of 29 species were left in 9 shifting fields cut between 2002 and 2005 by 7 farmers (Table 2).

Why these trees were left in fields? Farmers gave me various answers. First, they explain that they do not cut trees with diameter of more than 70 cm at breast height or with large buttress roots for saving labor. They say these big

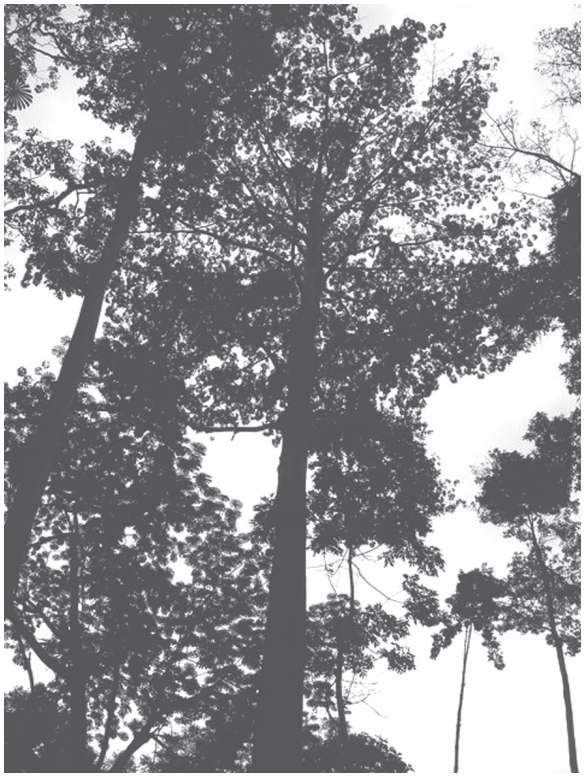

Fig. 3. Uncut trees in a field.

trees would not be burnt well, and felled trunks become obstacles to fieldwork. However, in practice, some large trees are felled and do obstruct field work, while some small trees are left in fields. Tree size is not the only reason for leaving individuals uncut.

A second answer provided by farmers is that crops and soil need shade to some extent for protection against excessive sunlight or heavy rain. Plantain bananas need over 1,500 mm annual rainfall and over 50 mm monthly rainfall, requirements that are met in Mondindim. However, these plants need some canopy protection as excessive sunlight stops growth in dry seasons. Some farmers say that even cassava needs some canopy, although they should not be shaded under natural conditions in the area. More trees are left in cacao fields than in others. Farmers say that cacao becomes weak in intense sunlight and needs considerable shade. They also say that cacao has preferences for certain types of shade trees. Trees with branches only in the uppermost canopy are preferred as these allow for airflow. Trees with crowded branches or branches in lower positions obstruct the growth of cacao. Trees that absorb too much water or drop many fruits are not suitable for cacao growing. However, some "bad trees"—4 *sen*, 3 *hayahaya*, one *duko*, one *kolo*, one *mombu*, and one

Table 2. Uncut trees in fields

Local name (Kako)	Num. of trees	Family	Species
loso	12	Sterculiaceae	*Triplochiton scleroxylon* K. Schum.
ngbolo	11	Ulmaceae	*Celtis zenkeri* Engl.
kanga	10	Lauraceae	*Hypodaphnis zenkeri* Stapf.*
saka	5	Leg.-Mimosoideae	*Albizzia zygia* (DC.) J.F. Macbr.
gopo	4	Euphorbiaceae	*Ricinodendron heudelotii* (Baill.) Pierre ex Pax
sen	4	Cecropiaceae	*Musanga cecropioides* R. Br.
banga	3	Palmae	*Elaeis guineensis* Jacq.
dumo	3	Bombacaceae	*Ceiba pentandra* (L.) Gaertn.
gboku	3	unknown	unknown
hayahaya	3	Moraceae	*Ficus exasperata* Vahl
banjo	2	Rubiaceae	*Morinda lucida* Benth.
bemban	2	Ulmaceae	*Celtis adolfi-friderici* Engl.
gbeli	2	Clusiaceae	*Garcinia Kola* Heckel
kulu	2	Sterculiaceae	*Mansonia altissima* (A. Chev.) A. Chev.
nbeno	2	Olacaceae	*Heisteria* cf. *parvifolia* Smith
nbundulu	2	unknown	unknown
duko	1	Cecropiaceae	*Myrianthus arboreus* P. Beauv.
kando	1	Moraceae	*Ficus* cf. *lutea* Vahl.
kolo	1	Moraceae	*Ficus sur* Forssk.
lombo	1	Apocynaceae	*Alstonia boonei* de Wild.
long	1	Moraceae	*Milicia excelsa* (Welw.) C.C. Berg
mombu	1	Annonaceae	*Anonidium mannii* (Oliv.) Engl. & Diels
nbongo	1	unknown	unknown
nbungu	1	Lecythidaceae	*Petersianthus macrocarpus* (P. Beauv.) Liben
ngolugwake	1	Leg.-Papilionoideae	*Baphia leptobotrys* Harms
sei	1	Meliaceae	*Entandrophragma cylindricum* (Sprague) Sprague
selele	1	Leg.-Mimosoideae	*Tetrapleura tetraptera* (Schum. & Thonn.) Taub.
solobo	1	Myristicaceae	*Pycnanthus angolensis* (Welw.) Warb.
unknown	1	unknown	unknown

* It may be *Terminalia sperba* Engl. & Diels.

Table 3. Utilization of uncut trees

Use	Number of species*
Trunk as materials for building and others	9
Bark as medicine	4
Fruit or seed as food	4
Caterpillars swarming on trees as food	4
Leaf as medicine	3

*An overlapping acount out of 29 species.

Fig. 4. Grinding gopo fruits for condiment.

ngolugwake—remained in surveyed fields.

There are consequences of leaving trees uncut that were not put forth as reasons for not felling them. First, some of the uncut trees have some uses. Sixteen of 29 tree species remaining in 9 surveyed fields have some utility (Table 3). The most common use is as materials for building and making dug-out canoes. There are local uses of uncut trees without cutting down, such as "bark or leaves as medicine," "fruit or seeds as food," and "caterpillars feeding on trees as food" (Fig. 4). Bark of large trees is specially important because it is often used as medicine for critical diseases like malaria. Standing trees protect soil in fields from excessive sunlight or rain. Before crops start growing, the soil surface is exposed and in danger of erosion and laterization; this is also the case after harvesting maize or peanuts, after the first cassava harvest and after weeding. The left trees act as umbrellas until crops and wild plants cover the fields. Finally, the remaining trees contribute to quick forest recovery by reducing light and encouraging the growth of shade-tolerant trees. Some cut trees regenerate from buds left behind by incomplete burning, and these contribute to the forest recovery.

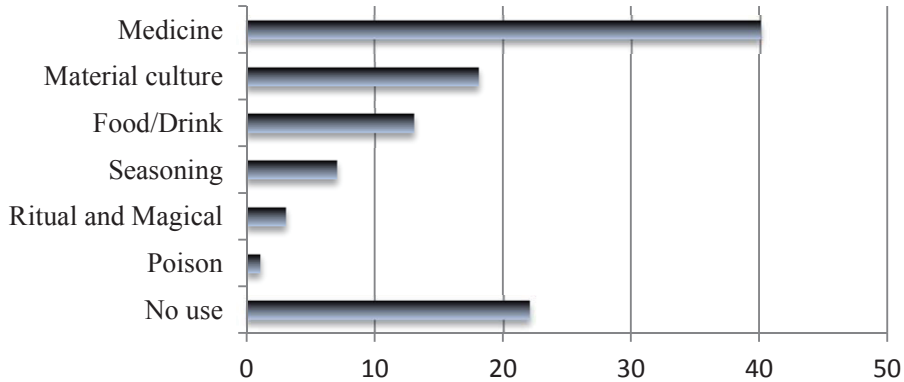

Fig. 5. Utilization of "weeds." An overlapping account out of 102 species.

IV. Unchecked Weeds

In tropical rainforests, "weeds" invade fields in enormous quantities. While burning partially defends fields against weeds by killing their seeds, the invaders stand above crops in several months. One of the limiting factors for farming in shifting cultivation of tropical rainforests is the labor needed for weeding. The first reason for moving fields in tropical rainforests is prevention of uncontrolled weed growth (Sasaki, 1995; Tanaka, 1997).

I found 34 kinds of herbaceous and woody "weeds," as shown in Fig. 1. I also found 102 kinds of "weeds" in 750 m^2.

The weeding effort differs by area. Some people remove weeds as they grow. Others avoid weeding and try to harvest most of the crops before thick growth of wild plants, and then cut new fields (Sugimura, 1995; Suehara, 1990). Farmers in Mondindim believe that weeding makes crops grow. They weed their fields during planting or harvesting and sometimes visit fields only for weeding. However, they say that they cannot weed completely because "they are busy." In other words, other work has higher priority. In Kako language, weeding is expressed as "cutting *bokasa*." *Bokasa* is *Chromolaena odorata*, a wild plant species that spread into this area around 1970. Farmers do not have a general term for weed or weeding.

Most of the "weeds" are considered useful in Mondindim. Twenty-eight of 34 species (85%) in Fig. 1 species have one or more uses. Eighty of 102 species (78%) in 750 m^2 of surveyed area are considered useful (Fig. 5). The uses include medicine (13 spp.), materials for utilities (9 spp.), food and drink (6 spp.), condiments and luxury (2 spp.), poison and material for ceremonies (3 spp.). Fruits and leaves of herbaceous plants are put on the affected part or drunk after squeezing in water for common ailments or slight injury (Fig. 6). Bark of large trees is boiled in water to use the decoction . Large trees are

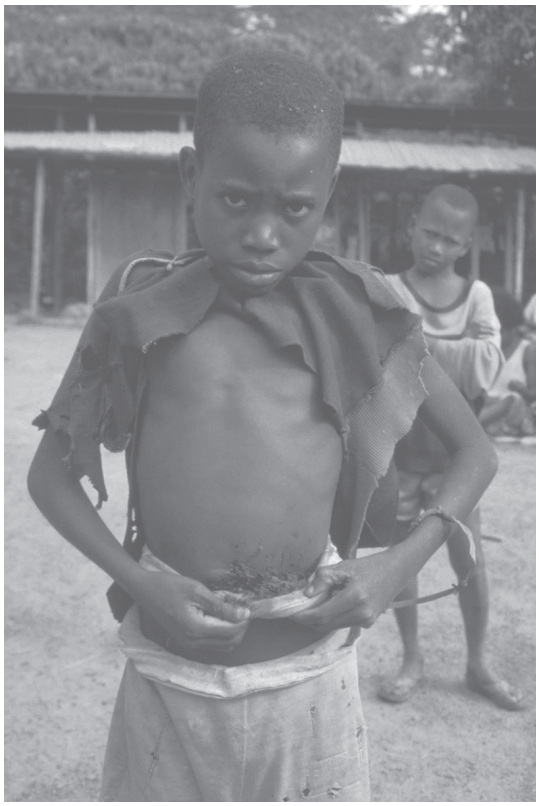

Fig. 6. Treatment of abdominal pain with ground "weed."

considered particularly effective for serious illnesses such as malaria.

After cutting a new field, herbaceous plants such as *bokasa* grow first, followed by sun trees such as *sen* (*Musanga cecropioides*). Herbaceous plants, including *bokasa*, *nyanji* (*Costus afer*), *njonju* (*Aframomum* sp.) proliferate, making tree growth difficult after the second cassava harvest. Trees preferring full sunlight, such as *sen*, oil palm, *kolo* (*Ficus sur*) grow well after the first cassava harvest.

There are various types of wild plants in fields ranging from annual herbaceous plants to woody plants that grow into tall trees over decades. The stages of plant growth that have use for human populations vary among species. Most large trees are useful at maturity. Availabilities of useful stages of weed species change with field development. Farmers cut a new shifting field once or twice a year. Over a few years, a field supplies weeds for daily use until most of the cassava and plantain bananas have been harvested. One household manages several fields in various vegetational succession stages simultaneously, each providing many useful "weeds" in each stage of development.

AGROBIODIVERSITY IN INTERCROPPED FIELDS

I. Agrobiodiversity Factors in Intercropped Fields

Mixed-intercropping is common in tropical rainforests of central Africa (Ankei, 1981; Sugimura, 1995; Komatsu & Hanawa, 2000; Shikata, 2004), South-East Asia and South America (Spencer, 1966; Bass & Morrison, 1994; Descola, 1996). Agronomists have recently identified various "scientific" benefits of intercropping, in addition to "variety of food," "sustainability of food supply throughout the year" and "stability of food production" as explained by the Mondindim people. These are (1) efficient use of space and sunlight by mixing crops that vary in height and shape, (2) efficient use of soil components by mixing crops with varied nutrient requirements and root depth, (3) prevention of disease and pestilence by interpolation of immune species into target species, which function as infection barriers, (4) spreading human effort across seasons by varying planting and harvest periods, (5) protection of soil through provision of continuous crop cover (Richards, 1985; Francis, 1986). Intercropping of several cultivars with different tastes, use, growing periods, and tolerances for disease and pestilences reportedly have similar benefits.

Furthermore, "uncut trees" and "unweeded weeds" raise biodiversity in the fields of Mondindim. The resulting vegetation provides human with a variety of uses, as explained above. In these ways, wild plants in the fields bring many benefits to the human population. In a sense, these wild plants are also "intercropped." The "intercropped" wild plants can be considered as extension of unplanted crops such as oil palm and papaya that grows spontaneously.

Shifting cultivation preserves biodiversity in fields from the start. Farmers open a field in a forest leaving some of the trees. Crops are planted and wild plants sprout thickly. Subsequently, wild plant biomass exceeds that of crops, the field is abandoned and turn into a secondary forest. The elements of intercropped and shifting fields continue to change through human intervention and by natural succession. Fukui (1983) termed the production system that enhances productivity of useful plants by taking advantage of vegetational succession the "succession field." He believed that the "succession field" was an early stage of agricultural development in Japan in which farmers were simultaneously growing domesticated and wild plants in fields using artificially changed vegetation; wild plants assumed considerable importance as food. The shifting field in Mondindim produces biodiversity, which is utilized by farmers in much the same manner as "succession fields" in former Japanese agricultural system, though the levels of intent for growing wild plants differ between the two systems.

"Uncut trees" are important elements of agroforestry. Agronomists focus on agroforestry in which annual crops and tree crops are combined. Shifting fields in Mondindim are one form of such agroforestry. Agroforestry with uncut trees has also been reported in West Africa (Amanor, 1993; Schroth et al., 2004). Agroforestry using local trees is attracting attention also from the perspective of rapid vegetation recovery and agrobiodiversity.

II. Interaction for Biodiversity

Intercropping is a reasonable form of farming that is well adapted to the natural environment (Richards, 1985; Francis, 1986). However, there are other viewpoints. Biodiversity in fields is generated by the interaction between humans and vegetation. There is not only a human perspective but also a vegetation perspective.

Conklin (1957) and Geerts (1963) were the first to identify the importance of biodiversity in farmland from a cultural perspective. Conklin (1957) reported farmland with high biodiversity maintained by the Hanunoo people in Philippines. Geerts (1963) emphasized the high biodiversity of tropical forest farmland in Indonesia and pointed to the ecological similarity between shifting fields with high biodiversity and the surrounding forest. He termed the shifting field a "canny imitation" of nature.

Sugimura (1995) discussed two contrastive ideologies of agriculture in tropical Africa, developing the views of Tsuboi (1983), a folklorist who examined different ideologies between shifting field and paddy field agriculture in Japan. Sugimura (1995) compared shifting and intercropping field system, which aims at producing a diversity of crops, with sedentary and mono-cropping field system, which aims at producing large yields and efficient performance in terms of yield per unit area. Geerts (1963) pointed out that shifting field agriculture in tropical forests imitates the biodiversity of surrounding wild forests, and Sugimura (1995) showed that biodiversity in fields reflects a sense of value in farmers, which in turn supports their life style. It is important that biodiversity in farmland is now being reconsidered from the perspective of a view of the world, a sense of value, or a way of life for farmers (Komatsu, 2005).

It is also necessary to consider the interaction between human beings and plants which grow without intentional intervention by farmers. A discussion of cultivar diversity is illustrative. "Cultivar" is a classification under the level of species, recognized and named by humans, and its definition is difficult because standards are different among researchers (Shigeta, 2009). Some researchers have attempted to determine whether cultivar diversity is explained only by practical intent or by other factors. Boster (1985) was interested in cultivar diversity in Amazon, and insisted that farmers have two levels of selection, namely, selection for perceptual differences and selection for utilization. Boster emphasized that selection for perceptual differences (SPD) precedes selection for utilization. People first recognize difference, give names, and finally define a new use (Boster, 1985). Shigeta (2009) distinguished artificial cultivar selection into "cognitive selection," which is unintended distinction, and "utilitarian selection," which is distinction for practical purpose. He insisted that cognitive selection was an unintentional effect of aimless interaction between humans and plants and points out the risk of resolving all relationships between humans and plants by human intention.

Cultivar diversity of vegetative crops is first generated by mutation. The mutation is remarkable because it is easy to fix. Considerable cassava cultivar diversity has been reported in Amazonia (Boser, 1985), potato in the Andes

(Yamamoto, 2004), and sweet potato in New Guinea. Bananas have cultivar diversity across the world (Komatsu et al., 2006). Maruo (2002) reported 72 cultivars in one west Tanzanian village. This diversity cannot be explained only by utility, although bananas have many uses as a staple food, as dessert, or for beer brewing.

The dynamic of cultivar diversity generation stems from the flexibility of farmers who are always ready to accept new things and ideas. Agricultures in tropical forests of central Africa have changed through the acceptance of new crops and rearrangement of systems: selection of field land, combinations of crops, cropping turn and amount of shade trees (Komatsu, 2010). Successful agriculture is more than a repetition of perfected methods; it is a dynamic activity. Plain and Piniero (1999) reported such a dynamic of cultivar selection among farmers of vegetative crops in the Philippines. The farmers distinguish many cultivars but do not keep all cultivars to hand. They have selected their set of cultivars repeatedly by successive evaluations through testing of new cultivars and by exchanging cultivars. Plain and Piniero emphasized this dynamic dimension of farmers.

SEMI-CULTIVATION IN CENTRAL AFRICAN FORESTS

In the central African forest, there is a form of interaction between humans and plants, which is termed semi-cultivation or semi-domestication. Semi-cultivation encompasses the various relationships between humans and plants. It is positioned between the utilization of wild plants and the cultivation of domesticated plants that have been changed genetically by human intervention.

Hanawa (2002) reported various relationships between shifting cultivators and 8 categories of vegetation shaped in a rainforest by interaction between humans and nature in the Republic of Congo. People used raffia palm and oil palm for a variety of purposes depending on their characteristics, but these are not managed intentionally.

Practices similar to semi-cultivation also occurs in hunter-gatherer societies. Dounias (2001) reported that Baka Pygmies in Cameroon sometimes re-plant remaining yam heads while gathering. Dounias calls this "para-cultivation," which is different from proto-cultivation, in that the latter does not involve transplantation, hence would not lead to cultivation stage. Yasuoka (2009) reported that Baka women sometimes transplanted the yam heads in more convenient places. He considered whether human habitation and activities had affected the present distributions of yam patches, which is uneven but concentrated in limited places near the ancient human settlements. These examples show the variety, in the relationships between "gathering" and "cultivation" practices in the forest (see also Yasuoka, 2012).

Harlan (1992) offered a perspective for grasping the relationships among wild plants, crops, and weeds successively. He opined that crop and weed were continuous categories and that it was impossible to distinguish them or consider them in binary opposition. A weed is a plant genetically adapted to

an artificially disturbed environment (from an ecological botany perspective). On the other hand, most people see weeds as trash species that obstruct human intent. Harlan identified 5 continuous levels of human attitude to plants in farmland: 1. domesticated crops, 2. encouraged weed crops, 3. tolerated weeds, 4. discouraged weeds, 5. hated, despised, etc. (noxious) weeds. He emphasized that these levels were continuous and the treatment of specific plants was different by place, time, and person. There are many reports on the cases that weeds considered useful became domesticated plant going through encouraged weed crops and the opposite cases (Harlan, 1992).

All the above categories exist in shifting fields in Mondindim. "Unweeded weeds" and "Uncut trees" fit the "tolerated weeds" or tolerated wild plant category. The fields in Mondindim keep being the actual spots of domestication process.

However, the tolerated wild plants in shifting fields do exist without clear human intention. Farmers tolerate many wild plants in the fields through hands-off management[8], although they recognize that it is desirable to cut most trees before planting crops and weed as much as possible. Tolerance of wild plants is an unintentional effect of aimless interaction, as Shigeta (2009) discussed in his treatment of "cognitive selection" of cultivars. Hands-off management brings biodiversity in farmland. Humans and nature may contribute equally to producing biodiversity. Hanawa (2002) expressed the view that people and nature "co-create" diverse landscapes.

Most of "tolerated weeds" are found their value in use and they eventually increase usefulness of fields in shifting fields as a result. When considering biodiversity in farmlands, it is important to appreciate the diversity is not always be generated through deliberate management or intentional actions of farmers; it often results from aimless interaction between humans and nature.

While Agrobiodiversity increases usefulness of farmlands, it will also contribute to the preservation of biodiversity in tropical forests without exclusion of shifting fields. Studying the variety of human-plants interactions in tropical rainforest of central Africa contributes to the development of this viewpoint. It will be very important to extend this approach to human-plants relationships to other parts of the world.

NOTES

(1) Named by S. Nakao (Nakao, 1993).

(2) There are three banana farming areas in Africa, (i) a plantain area in West and Central Africa, (ii) an East African Highland area where people raise their own cultivars of the AAA genome type, and (iii) the Indian Ocean Complex area in coastal East Africa where people cultivate bananas that are similar to the genome cultivars of South-East Asia (De Langhe et al., 1994).

(3) Bitter cassava spread along the Congo River on a large scale, followed by the spreading of sweet cassava into East Africa and bitter cassava into West Africa (by liberated slaves from South America who brought with them procedures for processing and cooking) (Miracle, 1959).

(4) Data for Molondou.
(5) *Ngwan* means field. *Liko* means primary forest, but *ngwan liko* means field cut in the major dry season. *Kongwe* means infertile. *Dobo* means riverine forest.
(6) There is an increasing number of sales of land titles (usufruct) in neighboring villages in recent years. However, I have never observed this in Mondindim.
(7) A cultivar is subspecies of crop distinguished and named by local people.
(8) "Hands-of management" is an expression from Plain & Piniero (1999).

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Appendix. Unweeded "weeds" in fields (750 m^2)

Family	Species	Local name (Kako)	Form
Acanthaceae	*Whitfieldia elongata* (P. Beauv.) De Wild. & T. Durand	njongon	arbor
Amaranthaceae	*Achyranthes aspera* L.	ngolungoso	herb
Annonaceae	*Cleistopholis patens* (Benth.) Engl. & Diels	ndolo	arbor
Annonaceae	*Pachypodanthium* cf. *staudtii*	tomo	arbor
Apocynaceae	*Alstonia boonei* De Wild.	lombo	arbor
Apocynaceae	*Funtunia elastica* (Preuss) Stapf	ndanba	arbor
Apocynaceae	*Rauvolfia macrophylla* Stapf	ngbo	arbor
Apocynaceae	*Tabernaemontana* sp.	kpando	arbor
Asparagaceae	*Asparagus* cf. *racemosus*	anyadje	bine
Bignoniaceae	*Markhamia* sp.	bolebole	arbor
Bombacaceae	*Ceiba pentandra* (L.) Gaertn.	dumo	arbor
Cecropiaceae	*Musanga cecropioides* R. Br.	sen	arbor
Cecropiaceae	*Myrianthus arboreus* P. Beauv.	duko	arbor
Combretaceae	*Combretum* sp.	sulumbie	bine
Combretaceae	*Combretum* sp.	uyo	bine
Commelinaceae	*Palisota* sp. cf. *hirrsuta*	njanju	herb
Compositae	*Acmella caulirhiza* Delile	ndonmeleti	herb
Compositae	*Ageratum conyzoides* L.	anjemben	herb
Compositae	*Bidens pilosa* L.	anjonmisi	herb
Compositae	*Chromolaena odorata* (L.) King & H. Rob.	bokasa	herb
Costaceae	*Costus afer* Ker-Gawl.	nyanji	herb
Cucurbitaceae	*Momordica cissoĬdes* Planch. ex Benth.	njombu	bine
Cyperaceae	*Scleria* sp.	kangi	herb
Dioscoreaceae	*Dioscorea alata* L.	ngonbiya	bine
Ebenaceae	*Diospyros bipindensis* Gürke	babango	arbor
Ebenaceae	*Diospyros canaliculata* De Wild.	gbenle 2	arbor
Euphorbiaceae	*Antidesma Chevaleri* Baill.	gbaya	arbor
Euphorbiaceae	*Erythrococca* sp.	komie	herb
Euphorbiaceae	*Euphorbia hirta* L.	kon'nieno	herb
Euphorbiaceae	*Mallotus oppositifolius* (Gersel.) Müll. Arg.	badonabidi	herb
Euphorbiaceae	*Ricinodendron heudelotii* (Baill.) Pierre ex Pax	gopo	arbor
Euphorbiaceae	*Uapaca heudelotii* Baill.	ngenjo	arbor
Gnetaceae	*Gnetum africanum* Welw.	koko	bine
Lamiaceae	*Clerodendrum buchholzii* Gürke	ndolu	bine

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Family	Species	Local name (Kako)	Form
Lamiaceae	*Clerodendrum formicarum* Gürke	totongolo	bine
Lamiaceae	*Ocimum basilicum* L.	welele	herb
Lauraceae	*Hypodaphnis zenkeri* (Engler) Stagf	kanga	arbor
Leg.-Caesalpinioideae	*Erythrophleum* sp.	ngungu	arbor
Leg.-Mimosoideae	*Acasia kamerunensis* Gandoger = *pennata* (L.) Wild.	kano	bine
Leg.-Mimosoideae	*Albizzia zygia* (DC.) J. F. Macbr.	saka	herb
Leg.-Papilionoideae	*Baphia leptobotrys* Harms	ngolugwake	arbor
Leg.-Papilionoideae	*Desmodium adscendens* (SW.) DC.	wowundu liko	herb
Leg.-Papilionoideae	*Millettia* sp.	njopo2	arbor
Leg.-Papilionoideae	*Millettia* sp.	njopo1	bine
Loganiaceae	*Mostuea brunonis* Didr.	akwanjen	arbor
Malvaceae	*Hibiscus* cf. *esculentus* L.	nbaya	herb
Malvaceae	*Sida rhombifolia* L.	simbili	herb
Malvaceae	*Sida urens* L.	anjutukan	bine
Maranthaceae	*Haumania danckelmaniana* (J. Braun & K. Schum.) Milne-Redh.	sesi	bine
Maranthaceae	*Hypselodelphys zenkeri* (K. Schum.) M.-Redh	poso (buse)	herb
Maranthaceae	*Marantochloa* sp.	nbolu bobongo	herb
Maranthaceae	*Marantochloa* sp.	nbolu poso	herb
Maranthaceae	*Marantochloa* sp. or *Megaphrynium* sp.	bolu (bolu ngun)	herb
Meliaceae	*Entandrophragma cylindricum* (Sprague) Sprague	sei	arbor
Moraceae	*Ficus exasperata* Vahl	hayahaya	arbor
Moraceae	*Milicia excelsa* (Welw.) C.C. Berg	long	arbor
Moraceae	*Sloetiopsis usambarensis* Engl.	ndimbo	arbor
Myristicaceae	*Pycnanthus angolensis* (Welw.) Warb.	solobo	arbor
Olacaceae	*Olax* sp.	kemo	bine
Palmae	*Raphia* sp.	nbolu	arbor
Pandaceae	*Microdesmis* sp.	mopipi	arbor
Pandaceae	*Panda oleosa* Pierre	kana	arbor
Phytolaccaceae	*Hilleria latifolia* (Lam.) Walt.	sumba	herb
Polygalaceae	*Carpolobia lutea* G. Don	njopinjo	arbor
Rubiaceae	*Morinda lucida* Benth.	banjo	arbor
Rubiaceae	*Rytigynia* cf. *pauciflora*	akobakobi	bine
Rubiaceae	unknown	kilinjanjo	bine
Rutaceae	*Zanthoxylum tessmannii* (Engl.) Ayafor Comb. Nov.	njototo	arbor

(continue)

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Family	Species	Local name (Kako)	Form
Samyndaceae	*Paulinia pinnata* L.	nbolu njambolo	herb
Sapindaceae	*Paullinia pinnata* L.	ginjambolo eliko	bine
Solanaceae	*Capsicum frutescens* L.	ndonbeala	herb
Solanaceae	*Physalis angulata* L.	agbogbos	herb
Solanaceae	*Solanum nigrum* L.	njan	herb
Solanaceae	*Solanum* sp.	abui	herb
Solanaceae	*Solanum torvum* Sw.	abiyako	herb
Sterculiaceae	*Cola ballayi* Cornu ex Heckel.	gba (nban)	arbor
Sterculiaceae	*Cola cordifolia* (Cav.) R. Br.	boko	arbor
Thelypteridaceae	*Cyclosorus afer* (Christ) Ching	ndele	ferm
Tiliaceae	*Grewia coriacea* Mast.	nbolu liko	arbor
Ulmaceae	*Trema orientalis* (L.) Blume	woso	arbor
Urticaceae	*Laportea ovalifolia* (Schum. & Thonn.) Chew	anjutukan npiya	herb
Violaceae	*Rinorea batesii* Chipp	nbeso	arbor
Zingiberaceae	*Aframomum* sp.	njonju liko	herb
Zingiberaceae	*Aframomum* sp.	njonju	herb
unknown	unknown	bojimbo	bine
unknown	unknown	dukulo ngoya	bine
unknown	unknown	gbenle 1	herb
unknown	unknown	gbogbo	herb
unknown	unknown	jeti banga	arbor
unknown	unknown	kpondu	herb
unknown	unknown	mala	arbor
unknown	unknown	marguerite	herb
unknown	unknown	mazut	herb
unknown	unknown	metomba	arbor
unknown	unknown	njagbe	bine
unknown	unknown	njanju	arbor
unknown	unknown	njenje	herb
unknown	unknown	njinbon	arbor
unknown	unknown	njuka	herb
unknown	unknown	pumbaenge	arbor
unknown	unknown	salo	arbor
unknown	unknown	sambo	?