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LAND USE IN SHIFTING CULTIVATION: THE CASE OF THE BONGANDO (NGANDU) IN CENTRAL ZAIRE[1]

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ABSTRACT Land use pattern of the Bongando, shifting cultivators living in central Zaire is studied, using data of remote sensing, land use map, and soil sampling. Cultivation-fallow cycle of the Bongando is not completed within the secondary forest, and the surrounding primary forest is successively cleared. It is because of sedentarization, population growth, and penetration of market economy. However, clear difference in soil fertility cannot be detected between forest and field, i.e. field soil is not extremely depleted by the cultivation. It suggests that by taking appropriate measures such as periodical village movement, tropical rain forest and its soil might be utilized continuously.

Key Words: Tropical rain forest; Shifting cultivation; Forest destruction; Soil deterioration; Remote sensing.

INTRODUCTION

The destruction of tropical rain forests has become a serious threat to the global environment as well as to the local communities concerned. FAO had already warned in 1957 that "shifting cultivation in the humid tropical countries is the greatest obstacle not only to the immediate increase of agricultural production, but also to the conservation of the production potential of the future, in the form of soils and forests" (FAO, 1957). To this, the sustainability of traditional shifting cultivation has been emphasized based on many case studies (e.g. Nye & Greenland, 1960; Fukui, 1995). In these studies, other factors than shifting cultivation, such as commercial logging or cash crop production were assumed to be the major cause for the forest destruction.

The environmental impact of shifting cultivation must therefore be precisely evaluated through field surveys. Most research has been conducted in savanna or savanna-woodland areas, particularly in Africa (e.g. de Schlippe, 1956; Miracle, 1967; Fresco, 1986; Kakeya & Sugiyama, 1985). This paper describes a shifting cultivation system in the tropical rain forest, based on fieldwork among the Bongando people living in central Zaire (Fig.1). In order to examine the sustainability of Bongando shifting cultivation, the following two points are analyzed.

1. The extent of primary forest being destroyed under the Bongando cultivation system.
2. The extent of soil deterioration occurring in the Bongando fields.

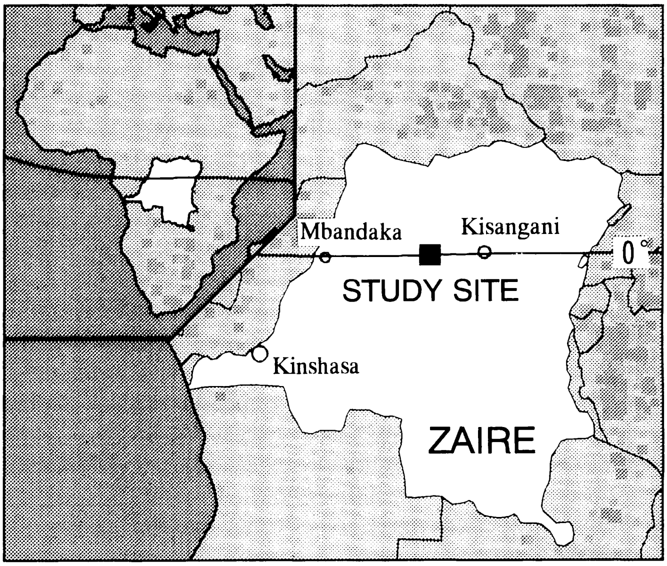

Fig. 1. Study site.

SUBJECT AND METHOD

I. The Bongando and Their Environment

1. The Bongando

The Bongando belong to the Mongo cluster of Bantu-speaking group (Murdock, 1959). They live in the eastern part of the Region de l'Equateur and the western part of the Region de Haut-Zaire of the Republic of Zaire.

While the Mongo people began to enter the central Zaire basin around the first century A.D. (Johnson, 1995), the Bongando arrived in the present area much later. According to the Bongando informants, their ancestors crossed the Ubangi River north of Kisangani. The period of this migration was estimated to be about 200 years ago by Kerken (1944). Upon crossing the river, the Bongando passed near Kisangani, proceeded to the west, and finally reached where they now live.

The population of the Bongando is estimated to be around 450,000 to 500,000 (Kimura, 1992). They live dispersed in an area of about 48,200 km^2.[2] The population density is 9.3-10.4 persons/km^2, lower than the total average for Zaire (17.1 persons/km^2).[3] The population growth rate in this area is estimated to be approximately 2% per year.[4] Fig. 2 is the population pyramid of the research area. The triangular shape of the pyramid suggests that the demographic type is marked by high fertility and high mortality.

2. Environment

(1) Topography and transportation

The Bongando land is composed of a low flat plain of 300-400 m above sea level

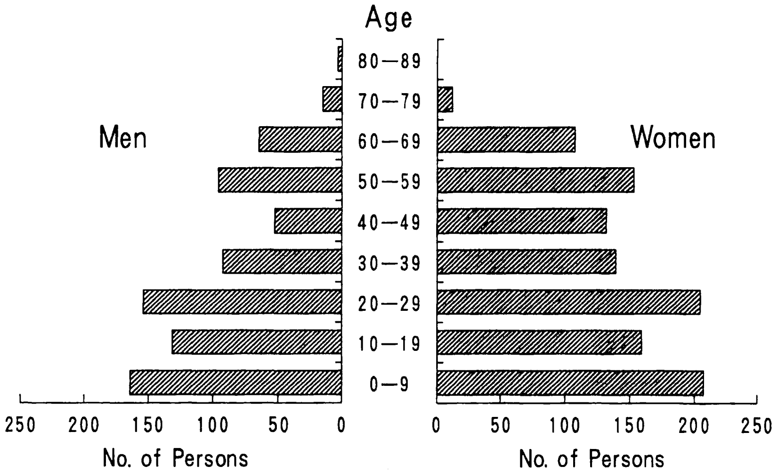

Fig. 2. Population pyramid of the study area. This graph is drawn from the name lists of the Groupement d'Iyondje, in which I stayed for the research. The population of the Groupement is about 2,000. As the list contains several women who have married out, women's numbers may be overcounted.

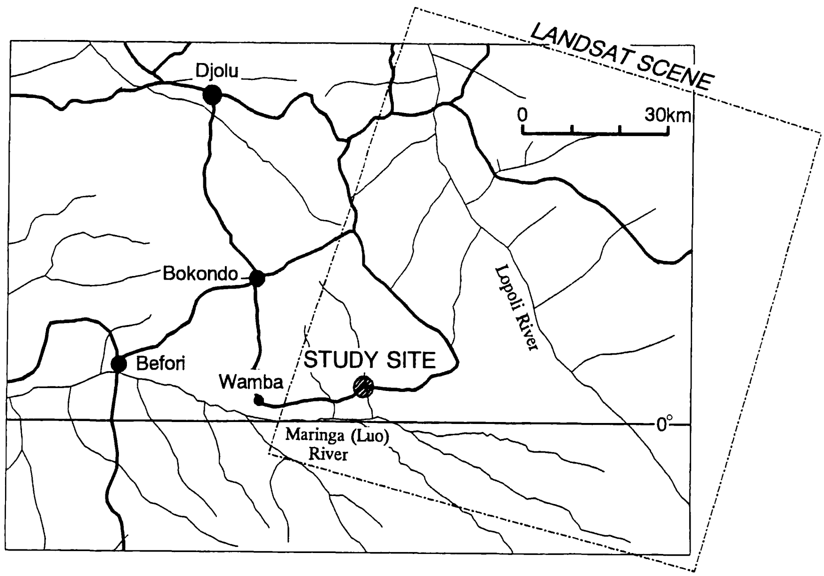

Fig. 3. Topography and transportation of the study area. Area of the Landsat scene is also shown.

(Fig. 3). Malinga River,[5] a branch of the Zaire River flows in the southern part of the area. Roads were constructed in the 1930's by the Belgian colonial government. Most of the Bongando villages are located near the road, with fields and secondary forests along it.

The study area is quite remote from the economic and political center. The nearest large port Befoli, facing Malinga River, is 100 km away from the research village. It is also 100 km from the nearest small airstrip in Djolu, where only small aircraft can land. Airport for regular flights is located 400 km away at Boende.

(2) Climate

The daily maximum and minimum temperatures are about 30°C and 20°C throughout the year. The annual rainfall is about 2,000 mm. Rainfall is more frequent from September to November (about 200 mm per month), and less from December to February (less than 100 mm per month) (Vuanza & Crabbe, 1975).

(3) Vegetation

The vegetation of the study area (Fig. 4-7) has been documented by Kano and Mulavwa (1984).[6] The forest is roughly classified into the dry primary forest, the swampy primary forest, and the secondary forest.

In the dry primary forest, the canopy is usually closed with emergent trees reaching 50 m in height. The undergrowth is sparse. The forest is composed of a diversity of species, most belonging to the family Caesalpiniaceae.

The swampy primary forest near the river also has a variety of species, but the species composition differs from that of the dry primary forest. Tree height is lower than that of the dry primary forest (less than 30 m), because of the swampy ground. This area is flooded when the level of the river rises, hence fields are not cleared in this area.

The secondary forest is classified into three categories by the successional stage; (1) Secondary scrub predominantly *Aframomum* spp., (2) Young secondary forest predominantly *Musanga smithii*, *Albizia gummifera*, *Croton haumanianus*, and *Macaranga* spp., and (3) Aged secondary forest predominantly Marantaceae family such as *Sarcophrynium macrostachyum* and *Haumania liebrechtsiana* (Kano & Mulavwa, 1984).

Fig. 4. Dry primary forest.

Fig. 5. Swampy primary forest and river.

Fig. 6. Young secondary forest.

In the following pages, I use the terms, "primary forest" and "secondary forest." In other regions, it is generally difficult to distinguish these forest types from each other, because old secondary forest closely resembles the primary forest. However, these two forest types can be clearly detected in the study area, both from direct observation and remote sensing data. It is probably because the Bongando immigrated into the intact forest of this area relatively recently. In other words, very old secondary forest has not been formed yet in the study area.

Fig. 7. Village and courtyard.

3. Subsistence activities

The major crops of the Bongando are cassava as the subsistence crop and coffee as a cash crop, often planted next to cassava. Other crops are cultivated only in a small scale. While the Bongando are classified as "cultivators," a time budget study by Kimura (1992) showed that men and women spend only 18 and 6 minutes per day respectively for agricultural work on average.(7) A detailed description of the cultivation system will be given later.

Hunting, fishing, and gathering also comprise the main Bongando subsistence activities. According to Takeda (1990), the Bongando people eat at least 37 species of mammals, 10 birds, 29 fish, 12 reptiles, 21 insects, and 22 wild gathered plants.(8) Hunting activity includes collective hunting with nets, with bow and arrow, and individual hunting with shotgun. Fishing is mainly done with nylon net or with fishhook by men, and fish bailing by women. Fish poison is also used. A variety of wild plants and edible caterpillars are also gathered. Men and women spend 32 and 0 min/day hunting (including trapping), 28 and 7 min/day fishing, and 19 and 36 min/day gathering. From these time budget data, the Bongando people are best described as "multi-subsistence" people rather than "cultivators."

Animal husbandry is not so important. The Bongando keep goats, pigs, chickens, and ducks.(9) The number of each livestock kept by a family is mostly 0 to 5. These animals are mainly used as bridewealth, and rarely eaten. Goats are not milked, and eggs of chickens and ducks are eaten occasionally. Male goats and pigs are not castrated. In sum, not much time is spared for livestock care.

Opportunity for wage labor is rare. There were two coffee plantations near the study village, but one is now abandoned. No logging company operates in this area.

II. Methods

Field research was conducted in October-December 1986, June 1987 - February 1988, and June 1988 - February 1989. I stayed in Yalisanga village (0° 2'N, 22° 45'E) in the Groupement d'Iyondje, Zone de Djolu, Sous-Region de Tshuapa, Region d'Equateur. The population of this village was 119 (28 adult men, 36 adult women, and 55 unmarried children).

In addition to the direct observation of subsistence activities, the following three methods were employed.

1. Remote sensing analysis

For a general view of land use pattern, Landsat image[10] of the study area taken on 4 January 1986 was analyzed. For computer analysis, ERDAS Ver.7.5 on Sun SparcStation2 was used.

2. Land use map by pace measuring

To analyze the detailed land use pattern, paths and fields around Yalisanga village were measured by pace-measuring (Fig. 8). Measuring was conducted mainly in August - September, 1988. The data obtained ("number of steps" and "direction of walking") were analyzed with a portable computer charged with a solar battery (Kimura, 1991). Using this map, the kinds of crops, owner, clearing year, and vegetation before clearing, for each field was documented.

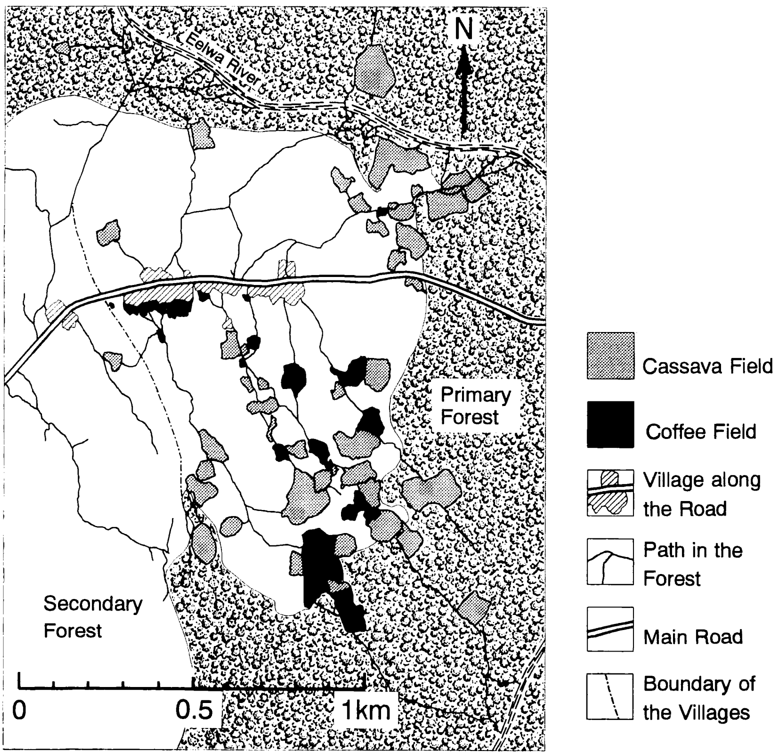

Fig. 8. Land use map around the Yalisanga village. The border of the primary forest and the secondary forest was drawn by direct observation, and the border of Yalisanga and the adjacent village territories was fixed by information from the villagers.

3. Soil sampling

The influence of cultivation on soil deterioration was examined by soil analysis. Soil samples were collected from 30 pits dug in the forest, field, and village courtyard. Four to five soil samples were taken from each horizon of a pit. Mechanical composition, exchangeable cations, pH, and organic matters were analyzed in the laboratory in Japan.

RESULTS

I. Agricultural System

1. Crops

Most of the Bongando fields are for cassava and coffee. The period of cassava introduction to the Bongando society is not certain, but a large-scale production began in the 19th century.[11] Coffee was introduced in the 1960's as a cash crop. Unlike many other Bantu farmers, maize and plantain banana are not staple foods. These two crops are mainly used for brewing spirits. Also planted are yam, rice (grown in dry field), potato, groundnut, sugarcane, pineapple, gourd, and some vegetables, such as pepper, onion, tomato, lisingo (*Phytolacca dodecandra*), losolo (*Solanum melongena*), and losiyo (*Cucurbita* sp.). Avocado, papaya, orange, and oil palm are semi-cultivated around the village.

Except for coffee, the crops are mostly used for consumption. The Bongando subsistence is almost self-sufficient.[12]

2. Cultivation system

The Bongando slash and burn both secondary and primary forests to prepare fields. While anyone can clear any part of the primary forest, the villagers actually prefer the forest behind their own homesteads. In contrast, the secondary forest is exclusively used by the person who cleared it, or his close relative.

Clearing is conducted only by men, mainly in the dry season from January to March.[13] First, small shrubs and vines are cut (this work is called *bengi*), and then large trees are felled (*bolemo*). After drying up, shrubs and trees are burnt (Fig. 9). The work is basically conducted individually.[14] Large charred logs remain in the field even after the crop grow (Fig. 10).

When clearing the field, the Bongando evaluate the forests as follows. The secondary forest is easier to clear than the primary forest, because trees there are small. However, in some cases, they choose to clear the primary forest because (1) the primary forest is believed to be good for growing coffee, and (2) the newly cleared field can be monopolized by his extended family.

In some fields, maize is planted before cassava. However I simply call them "cassava field" in this paper, because the cultivation period for maize is quite short (several months). Mixed cropping widely practiced in the tropical Africa is not conducted among the Bongando, probably because cassava is by far the most important crop in their cultivation system.

Fig. 9. Burning of the felled and dry trees.

Fig. 10. New field opened in the primary forest.

(1) Cassava cultivation

Cassava and coffee require different planting and harvesting processes.

Cassava planting and harvesting is conducted exclusively by women. When planting, pieces of cassava stalk are buried in shallow holes. The field is neither hoed, nor are ridges made. Weeding is seldom done. No fertilizer, compost, nor agricultural chemicals is used. Labor time required for cassava cultivation is very short, because of the simple cultivation style.(15)

Cassava tubers can be harvested about 6 months after planting. Tubers are pulled out from the soil. Sometimes stalks are cut into pieces and again planted there. Cassava has no clear harvesting season. Even mature tubers can be "preserved" in the ground for more than one year, during which they are harvested at any time. Cassava leaves are also an important vegetable. Fences to keep out the wild animals is not constructed, because baboons do not live in this area, while forest hogs and elephants have recently decreased due to overhunting.

Cassava fields naturally convert into fallow bush after 1 to 3 (mostly 1 to 2) years of cultivation. The Bongando explain the reason for abandoning fields as follows. (1) The spread of cassava roots near the soil surface makes it difficult to dig up the tubers. (2) Old cassava tubers becomes too fibrous. They do not, however, refer to the degradation of soil fertility as the reason for shifting the fields.

(2) Coffee cultivation

The clearing process of the coffee field is basically the same as that for the cassava field, except that the Bongando prefer the primary forest to grow coffee. In some fields, cassava is cultivated for a short period before planting coffee.

Coffee seedlings are grown in a nursery in the shade. After sufficiently grown, they are planted in the field. Weeding is seldom done. Coffee beans can be harvested about one year after planting. The beans are sun-dried in the shell, and preserved in sacks. Coffee is sold when the coffee broker comes in a truck.

A clear difference between cassava and coffee cultivations is that the coffee field is used for a much longer period, sometimes more than 20 years. In some cases, coffee fields once abandoned are renewed by clearing weeds and shrubs.

II. Distribution of Fields: How the Bongando Select Areas in the Forest to be Cleared

1. View from Landsat

A general view of the Bongando land from the orbit is shown in Fig.11 (see p. 202), the Landsat image of the study area (see also Fig. 3). Slight clouds cover a part of the area, but the image is clear. The clouds cast shadows northwest of their bodies. Almost the entire study area is covered with tropical rain forest. Tree-shaped blue lines show river courses, along which the riverine swamp forest develops. Light yellow-colored networks comprise the bare land, such as roads for car or fields just after burning. Villages, secondary forest and fields along the road appear like "rosaries." Dry primary forest, swampy primary forest, and secondary forest (together with field area), are clearly distinguishable from one another by color, whereas variation within these areas cannot be discerned.

2. Land use map near the village

The map around the Yalisanga village was drawn by pace measuring (Fig. 8). The Bongando settlements are located along the road. The houses are build in courtyards 10 to 30 m wide. Behind the courtyard, there is the secondary forest with scattered cassava and coffee fields. Small paths extend radially from the village. Beyond the secondary forest stretches, the vast primary forest spreads with river and small stream networks. There are several village clusters ranging westward along the road.

Comparing this map (measured in August - September 1988) with the magnified Landsat image taken in January 1986 (Fig. 12, see p. 203), I found the positions of the road and edge of the primary forest properly corresponding with each other. Some new fields cleared in the primary forest can be observed in the land use map.

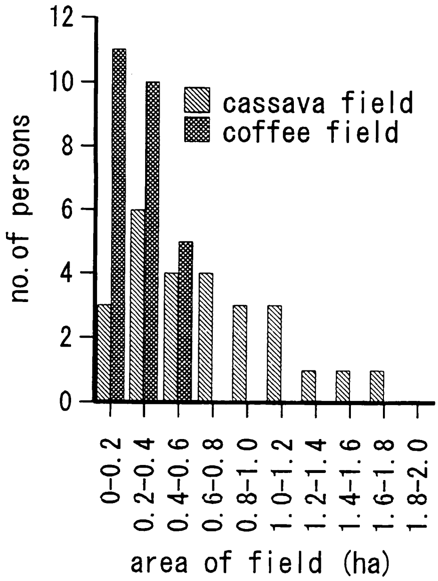

Fig. 13. Per capita area of cassava and coffee fields.

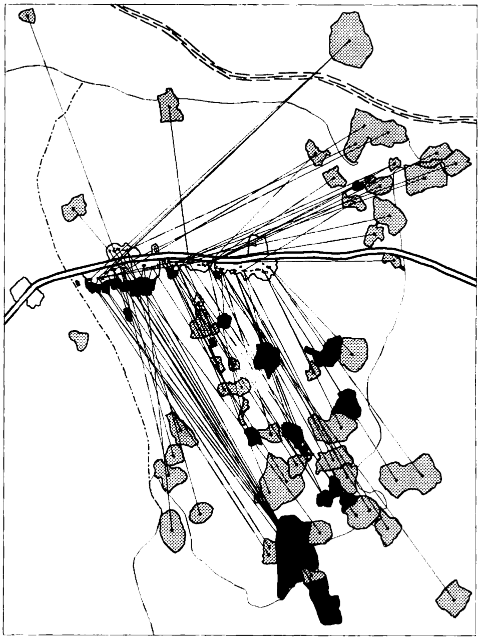

Fig. 14. Correspondence of houses and fields. Each line connects the field and its owner's house.

3. Land ownership

Land is principally government-owned in Zaire, but customarily land usufruct is attributed to the residents in the Bongando society.

The area for cassava and coffee fields for each persons is shown in Fig. 13. The mean field area is 0.68 ha for cassava, and 0.22 ha for coffee. Variation in area per person is more marked for the cassava field. Probably it can be explained by the marriage system of the Bongando. Polygyny is allowed, and a husband-wife pair has the right to the cassava field. If a man has more than one wife, he must clear a field twice or more as large as usual. In contrast, coffee fields are owned by each adult man personally.

The new field is usually cleared in the forest behind the village yards. According to Bongando informants, the paths to the fields from each houses usually do not cross each other. It is probably because each path is exclusively used by a specific kin group. This principle can be clearly seen in Fig. 14. The lines connect the fields and their owners' houses, and most do not intersect.

4. Selecting the forest area for clearing

From Fig. 8, it is evident that more fields are found in the southern side of the road than in the northern side. The reason for this is that until 16 years ago, the road and the village were situated about 200 m north of the present site (Fig. 15). The trace of the old road can be confirmed in the Landsat image (Fig. 12). The Bongando do not clear fields in the former village area recently. It is because once the village yard is cleared, and always kept free from of weeds, the soil becomes siltated (Fig. 16).

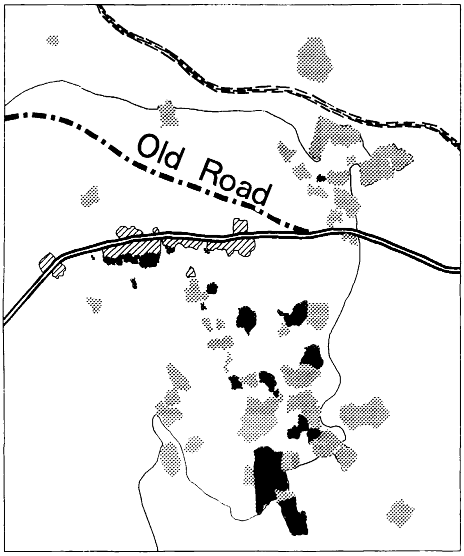

Fig. 15. Old road.

Fig. 16. The area in which Yalisanga village was situated until 16 years ago. The soil was siltated, and the vegetation has not recovered.

Still, the distribution of fields and secondary forest around the village is almost concentric. The Bongando principle of field clearing can be analyzed by focusing on the distance from the village.

(1) Areas classified by distance from the village

As shown in Fig. 17 (left), the area around the village is classified into strips by distance from the village. The areas of cassava and coffee fields, the secondary forest, and the primary forest in each strip are shown in Fig. 18. The secondary forest extends up to 900 m from the village, with a peak at 300 m. The primary forest appears from 300 m, and occupies the whole area over 1 km. Cassava fields disperse in the secondary forest with a peak at 500-600 m. This means that cassava fields around the village are scarce, but are frequently opened near the edge of the primary forest. In contrast, coffee fields are almost uniformly distributed, regardless of the distance.

(2) Areas classified by distance from the primary forest

A similar analysis is conducted by distance from the primary forest. Village, field, and secondary forest are classified into strips according to the distance from the primary forest (Fig. 17, right). The areas of each vegetation by each strip is shown in Fig. 19. The fields (especially cassava fields) are clearly distributed near the primary forest.

(3) Pattern of field clearing

The year of field clearing for each crop is shown in Fig. 20. Most cassava fields were made in the past 3 years, whereas coffee fields were made a longer time ago.

Fig. 21 shows the relationship between original vegetation and planted crop. Half the

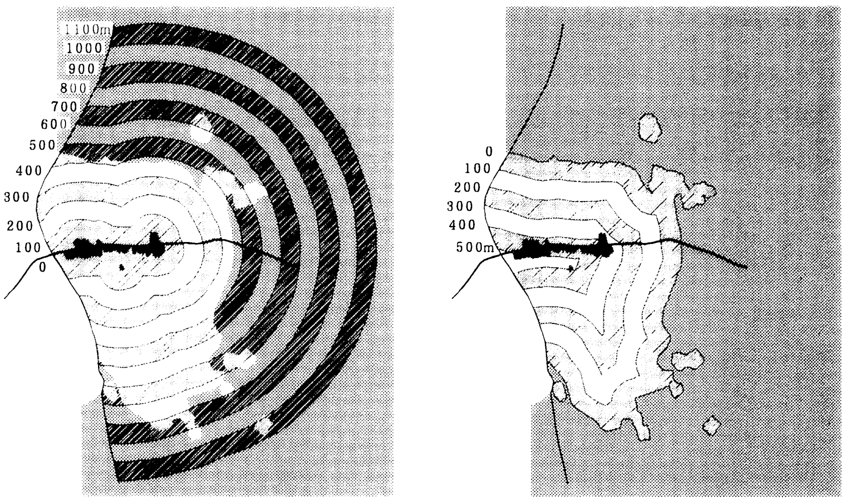

Fig. 17. Area classification by distance from the village (left), and from the primary forest (right).

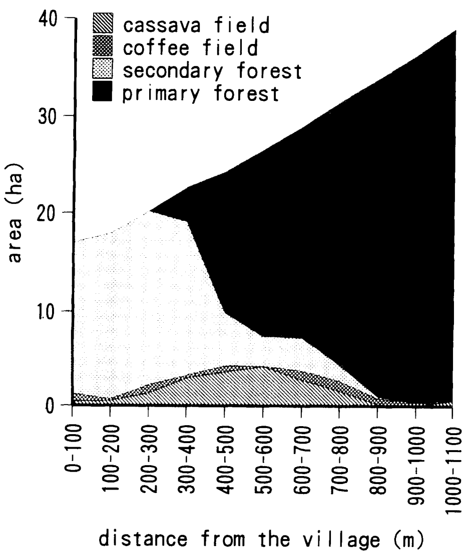

Fig. 18. Area of fields by distance from the village.

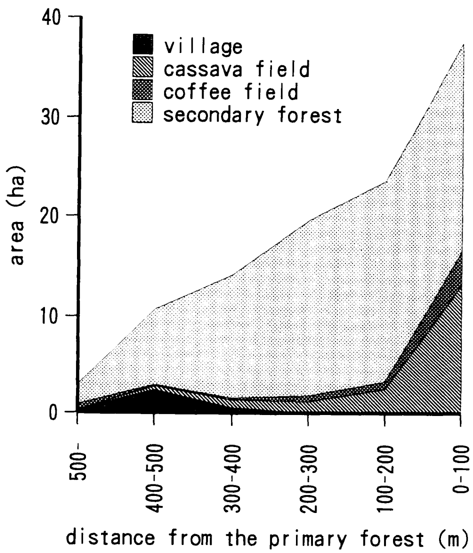

Fig. 19. Area of fields by distance from the primary forest.

cassava fields had been cleared in the primary forest, whereas most coffee fields had been cleared in the primary forest. According to Sato's research in the Boyela (the Bantu farmers living adjacent to the Bongando) in 1976-1979, only 5.4 % of the field was made in the primary forest (Sato, 1984). Assuming that the Bongando cultivation system in the 1970's was similar to that of the Boyela, intensive clearing of the primary forest has begun only recently.

From the above analysis, the following history of field clearing can be hypothesized (Fig. 22). Ten to twenty years ago, abundant primary forest was available near the

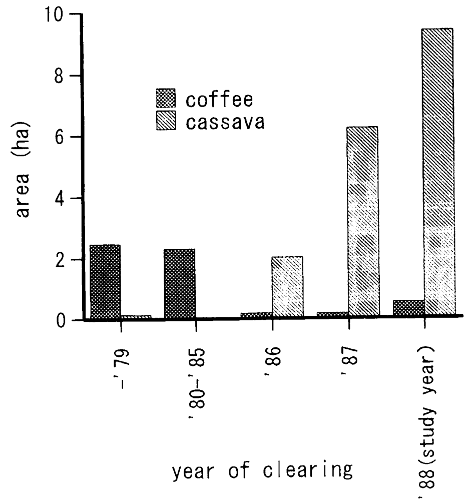

Fig. 20. Age of fields by crops.

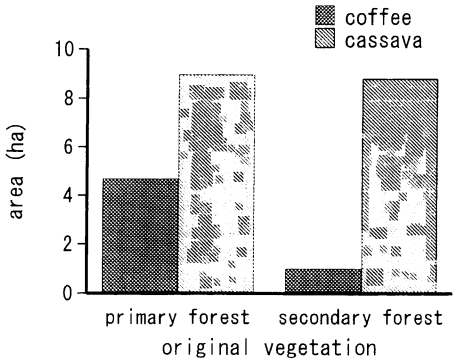

Fig. 21. Original vegetation of fields by crops.

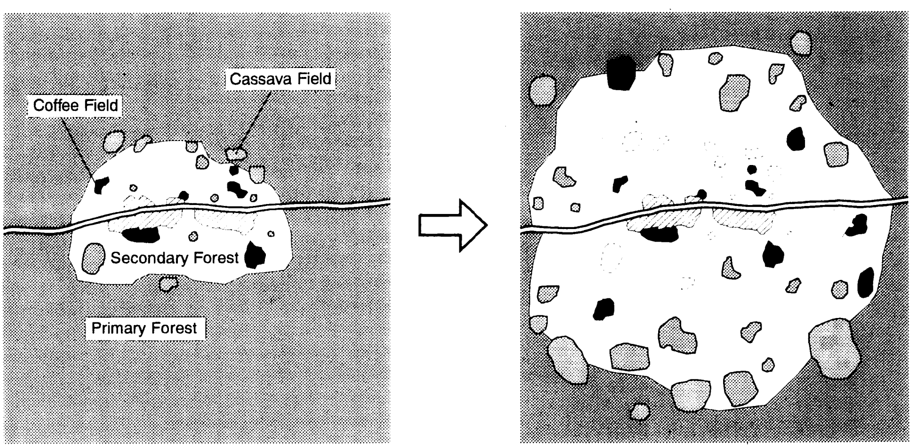

Fig. 22. Schematic representation of the field development around the village.

village, and so coffee fields could be cleared there. These coffee fields are still used now. On the other hand, cassava fields were made near the primary forest as the environment for cultivation worsened near the village. Cassava fields are abandoned 1 to 3 years after cultivation.

5. Cultivation-fallow cycle

To estimate the cultivation-fallow cycle of cassava, I measured the area of fields and the secondary forest belonging to the Yalisanga village (Fig. 8). The result is as follows: cassava fields 17.7 ha, coffee fields 5.8 ha, and the secondary forest 81.5 ha. In this estimation, coffee field area is neglected, because they are used far longer than cassava fields. Here I assume the following two points: (1) the cultivation-fallow cycle is completed in the area of secondary forest and cassava field, (2) whole cassava fields are used for two years. Then the fallow period is estimated by the formula below.

$$(81.5+17.7)/17.7 \times 2 = 11.2 \text{ (years)}$$

However, because some cassava fields are abandoned only after 1 year's cultivation, the actual fallow period would be more shorter.

In the study of Boyela cultivation in 1976-1979, Sato (1984) estimated that the cassava fallow period was about 15 years. Nye & Greenland (1960: 127) also wrote that in superhumid regions of South-east Asia and Central Africa, 1-2 years of cropping are normally followed by 10-20 years of fallow. Compared with these studies, the cultivation-fallow cycle of the Bongando seems even shorter.

From these analyses, it can be concluded that the cultivation-fallow cycle of the Bongando is not completed within the secondary forest. In other words, the Bongando successively clear new fields in the surrounding primary forest.

III. Soil Fertility

1. Sample points

The details on soil sample points is shown in Table 1. The following parameters were taken into consideration for selecting these points.(16)

- Whether original (or current) vegetation was the primary forest or the secondary forest.
- Whether the planted crop is cassava or coffee.
- Time since clearing.

In addition, samples from three special sites were collected.

- Sandy area sample, from the village yards in which siltation was progressing.
- Clay sample, from the place where the wall plaster is taken.
- "Deep hole" sample, from a 4m deep hole dug in the secondary forest.(17)

Four to five samples were taken from each point, but only two samples (surface horizon and sub-surface horizon 30-60 cm in depth) were examined for this analysis.

2. Soil properties

Results of the soil properties analyzed below are shown in Table 1.

Table 1. Soil properties. "Year" represents the duration of the current situation. "C-Sand" (coarse sand), "F-Sand" (fine sand), "Silt," and "Clay" are particles of 2-0.2 mm, 0.2-0.02 mm, 0.02-0.002 mm, and under 0.002 mm, respectively.

Surface Horizon

	Pit No.	Present Situation	Original Vegetation	Year	C-Sand%	F-Sand%	Silt%	Clay%	Ca me	Mg me	K me	Na me	Total Cations	pH (Water)	pH (1N KCl)	C%	N%	C/N
Primary forest (5cm)	15	Primary forest	-----		84.0	11.0	0.5	4.5	0.001	0.010	0.087	0.011	0.109	3.68	3.06	0.86	0.06	14.9
Secondary forest 1 (0cm)	5	Secondary forest	Cassava field?	10+	77.6	15.0	0.7	6.7	0.026	0.013	0.097	0.017	0.153	4.26	3.50	0.91	0.07	13.6
Secondary forest 2 (0cm)	16-2	Secondary forest	Cassava field	4	78.6	11.5	0.6	9.2	0.200	0.048	0.313	0.015	0.575	4.06	3.20	1.77	0.13	13.7
Secondary forest 3 (0cm)	10	Secondary forest	Cassava field	1	83.4	10.4	0.6	5.5	0.785	0.090	0.128	0.017	1.020	4.82	3.74	1.14	0.08	14.5
Field 1 (0cm)	11	Cassava field	Primary forest	0	85.6	11.0	1.2	2.2	0.070	0.030	0.164	0.011	0.274	3.67	2.83	2.18	0.12	17.9
Field 2 (0cm)	13	Cassava field	Primary forest	0	83.1	12.2	0.0	5.3	0.057	0.017	0.170	0.007	0.251	3.51	2.82	1.23	0.07	17.2
Field 3 (0cm)	9	Cassava field	Secondary forest	0	85.9	10.4	0.6	3.1	2.388	0.363	0.359	0.004	3.113	6.81	6.75	0.82	0.06	13.1
Field 4 (0cm)	16-1	Coffee field	Primary forest	7	83.8	9.1	0.3	6.8	0.165	0.012	0.174	0.005	0.356	4.03	3.14	1.44	0.10	14.8
Field 5 (0cm)	14	Coffee field	Primary forest	10+	81.6	10.9	0.7	6.7	0.342	0.015	0.109	0.002	0.467	4.00	3.24	1.38	0.09	14.6
Field 6 (0cm)	8	Coffee field	Primary forest	20	81.0	11.4	1.0	6.6	0.364	0.037	0.143	0.005	0.548	4.34	3.41	1.51	0.11	13.6
Sandy area 1 (0cm)	3	Sandy area	Courtyard	20	94.3	3.7	0.5	1.4	0.014	0.003	0.020	0.004	0.041	4.73	4.13	0.10	0.01	14.1
Sandy area 2 (0cm)	1	Courtyard	Secondary forest	1	91.2	5.5	0.3	3.0	0.211	0.013	0.041	0.003	0.268	5.67	4.02	0.19	0.01	14.2
Sandy area 3 (0cm)	2	Courtyard	Primary forest	16	89.4	7.6	0.3	2.7	0.008	0.001	0.035	0.006	0.050	5.10	3.95	0.21	0.01	16.7
Clay (10cm)	6	Place to collect clay	Secondary forest	20+?	79.5	11.9	0.7	7.9	0.004	0.003	0.067	0.006	0.080	4.46	3.63	0.56	0.04	15.6

Sub-surface Horizon

	Pit No.	Present Situation	Original Vegetation	Year	C-Sand%	F-Sand%	Silt%	Clay%	Ca me	Mg me	K me	Na me	Total Cations	pH (Water)	pH (1N KCl)	C%	N%	C/N
Primary forest (40cm)	15	Primary forest	-----		80.8	12.5	0.8	5.9	0.002	0.004	0.048	0.004	0.058	4.32	3.79	0.51	0.03	17.1
Secondary forest 1 (50cm)	5	Secondary forest	Cassava field?	10+	70.5	20.2	0.0	9.3	0.001	0.003	0.024	0.012	0.040	4.25	3.93	0.54	0.03	16.7
Secondary forest 2 (40cm)	16-2	Secondary forest	Cassava field	4	74.2	17.9	1.0	6.9	0.001	0.003	0.052	0.012	0.069	4.52	4.15	0.40	0.02	16.1
Secondary forest 3 (40cm)	10	Secondary forest	Cassava field	1	81.1	11.8	0.2	6.8	0.009	0.004	0.046	0.015	0.073	4.25	4.01	0.59	0.03	17.4
Field 1 (40cm)	11	Cassava field	Primary forest	0	78.6	16.6	0.5	4.3	0.009	0.003	0.039	0.009	0.060	4.16	3.34	0.58	0.03	21.8
Field 2 (40cm)	13	Cassava field	Primary forest	0	73.7	17.5	0.4	8.4	0.007	0.006	0.170	0.009	0.191	4.67	3.93	0.42	0.02	17.4
Field 3 (30cm)	9	Cassava field	Secondary forest	0	72.9	19.4	1.0	6.7	0.016	0.004	0.837	0.007	0.864	5.57	4.14	0.54	0.03	16.1
Field 4 (40cm)	16-1	Coffee field	Primary forest	7	76.9	16.4	0.4	6.3	0.015	0.002	0.027	0.002	0.046	4.64	4.05	0.55	0.03	16.7
Field 5 (50cm)	14	Coffee field	Primary forest	10+	69.7	20.9	0.8	8.5	0.014	0.003	0.028	0.009	0.055	4.30	3.71	0.55	0.03	17.5
Field 6 (40cm)	8	Coffee field	Primary forest	20	75.8	16.5	0.0	7.8	0.002	0.003	0.029	0.007	0.041	4.57	4.16	0.36	0.02	16.1
Sandy area 1 (40cm)	3	Sandy area	Courtyard	20	74.2	16.7	0.3	8.8	0.001	0.002	0.020	0.013	0.036	4.41	4.09	0.35	0.02	18.0
Sandy area 2 (60cm)	1	Courtyard	Secondary forest	1	76.2	14.7	1.2	7.9	0.017	0.004	0.039	0.009	0.069	4.31	4.17	0.23	0.01	16.6
Sandy area 3 (30cm)	2	Courtyard	Primary forest	16	74.3	15.8	0.0	9.9	0.004	0.002	0.030	0.021	0.057	4.10	3.87	0.36	0.02	17.3
Clay (60cm)	6	Place to collect clay	Secondary forest	20+?	62.2	23.6	1.5	12.6	0.000	0.003	0.029	0.011	0.043	3.95	3.69	0.58	0.04	14.9
Deep hole (100cm)	21	Deep hole	Secondary forest	16	69.3	22.6	1.0	7.2	0.000	0.001	0.022	0.020	0.042	4.35	4.31	0.26	0.02	14.5
Deep hole (400cm)	21	Deep hole	Secondary forest	16	67.1	18.8	0.7	13.4	0.001	0.001	0.020	0.006	0.027	4.66	4.28	0.01	0.01	1.2

(1) Type of soil

The soil of the study area is composed of sandy sediment of the Quaternary period. According to FAO-UNESCO (1977), general classification of the soil in this area is Fx26-1a (Xantic Ferralsols). However, it should be classified as Arenosol in a strict sense, because the clay ratio measured in this analysis is less than 20% in every samples.

The tropical podzol is observed in some pit profiles. A typical example is shown in Fig. 23 (see p. 203). This soil type is composed under high soil acidity and much rainfall. Organic matter, iron, aluminium, and cations are dissolved from the surface, and accumulate in the lower horizon. The upper horizon becomes sandy and poor in nutrition.[18] A part of the dissolved organic matter flows into the water, and the river becomes tinged with a coffee-color.

(2) Mechanical composition

The soil composition of each sample is shown in Table 1. Ratios of sand (coarse sand [2-0.2 mm] and fine sand [0.2-0.02 mm]) are mostly between 90 and 95%, and clay does not exceed 10% for the field and forest samples. Clay ratio of the Deep hole (400 cm) sample (13.4%) can be regarded as the original ratio of this area. In sum, the soil is extremely sandy.

Sand and silt contained in the field samples are almost the same as that in the forest samples. It means that the siltation caused by the cultivation is not remarkable in the field. I suppose it is because of the following reasons.

- Due to the generally flat topography, even little vegetation covering may prevent soil erosion.
- The soil surface is not heavily disturbed because there is no plowing durin cultivation.

In contrast, siltation is serious in the village yard (see Table 1, Sandy area 1-3). It is probably because the yard is continuously kept free of weeds.

(3) Exchangeable cations

Exchangeable cations (K, Mg, Na, K) were measured by flame photometry (Table 1). Compared with the sub-surface horizon, the surface horizon is generally cation-rich, i.e. the amount of cation steeply decreases from upper layers to lower layers.

The Field 3 sample is particularly rich in cations. This field had been burned just before the sampling period, so much ash was found there. Except for this sample, total cations of the forest sample and that of the field sample were almost the same. Although many studies on shifting cultivation have pointed out that the soil fertility of fields gradually decreased over time (e.g. Miracle, 1967), such a tendency was not detected from this analysis.

To examine this phenomenon, the correlation of clay and cations was analyzed (Fig. 24). The correlation is not significant both in surface and sub-surface horizons. This suggests that most of the cations are not kept in the clay. The cations must therefore be supplied from the surface biomass, in the form of ash and decaying fallen tree.

(4) pH

pH of the samples were measured by dissolving the soil in pure water and 1N KCl

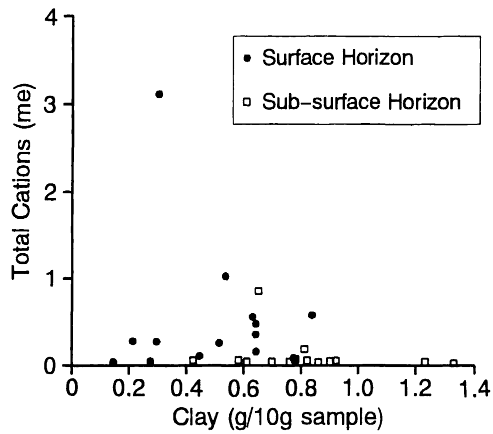

Fig. 24. Correlation between clay and cation.

solution. The Field 3 sample also showed especially high pH, from much ash. Except for this sample, all pH values of forest and field samples were between 3 to 5, as extremely high acidity for cultivation. Cassava can be cultivated even in such conditions, because of its high tolerance to soil acidity (Fresco, 1986).

The difference between pH of pure water and that of 1N KCl is not significant. It shows that almost all acidity dissolves into the water contained in the soil.

(5) Organic matters

The amounts of carbon and nitrogen in the soil were measured by the combustion method. C and N of field soil were not lower than those of forest soil, both in the surface and the sub-surface horizon. C/N ratios were almost between 15 and 20. If organic matter decomposition progress sufficiently in the soil, the ratio would be around 10. Organic matter in the soil therefore decompose very slowly.

3. Summary of the soil analysis

In the soil analyses, no clear difference between the forest and field could be detected. It means that field soil is not extremely depleted by the Bongando cultivation. The Field 3 sample was an exception, taken immediately after burning. Probably the effect of ash quickly declines.

The soil in this area is very sandy, i.e. lacking the clay which retains nutrition. Cultivation is possible even on such poor soil, probably because most nutrition is continuously supplied from the surface.[19] One of the most important nutrition sources might be the large logs remaining in the field (Fig. 10).

In the Bongando cultivation system, soil nutrition is not fully exhausted during the cultivation period. If so, why have cassava fields become scarce near the village? I suppose it is because the secondary forest as the source of nutrition does not fully recover in a fallow period.[20]

DISCUSSION

I. Present Condition of Land Use

The questions asked in the introduction were:

- The extent of the primary forest being destroyed under the Bongando cultivation system.
- The extent of the soil deterioration occurring in the Bongando field.

The answer for the first question is, unfortunately, disappointing. Field distribution analysis showed that newly cleared fields gradually intrude into the surrounding primary forest. In other words, the cultivation-fallow cycle is not completed in the secondary forest.

On the other hand, the answer to the second question is more hopeful. The field soil is not seriously siltated, nor does its fertility decline. If the fallow period is maintained long enough, the Bongando shifting cultivation does not heavily deplete the soil. However, the fallow period has shortened in current land use. If such a cultivation cycle continues, the soil near the village will be inevitably deteriorated.

II. Traditional Residence Pattern and Land Use System

The recent relationship between human and forest has become unbalanced in the Bongando cultivation. For understanding this historical change, traditional residence pattern and land use system of the Bongando was investigated.

1. Dispersed residence and frequent migration

According to the Bongando informants, they lived dispersed in the forest before the roads were constructed. They had changed the village site every several years. Migratory custom partially remains in their residence pattern even now. The Bongando frequently make temporary hunting and/or fishing camps (*kumbo*) in the primary forest, and stay there for several months. Moreover, some people permanently leave the roadside area, and construct small villages (*behetsia*). In the Landsat image (Fig. 11), these villages can be observed as yellow spots scattered in the primary forest. I traveled in the Bongando land for nine days with some informants, where, even in the deep forest, there was a *kumbo* or *behetsia* to stay at night.

Another style of migration habit also remains in the Bongando society. I collected many examples of shifting roadside villages (Fig. 25). In such cases, the main road must have shifted together with the village, so the migratory distances are not so long, mostly less than 1 km(21). Although it takes much labor to construct a new road, the villagers choose to do so to shift the village site.

2. Frequent use of the primary forest

The Bongando subsistence activities such as hunting, fishing, and gathering are closely connected with the primary forest. Some studies (e.g. Sato, 1984) have described sophisticated secondary forest use by other Bantu farmers. Compared with these peoples, the Bongando seem more primary forest oriented people. They have so adapted to the primary forest that they are inseparable from it. Their frequent shift of the village site is possibly to live closely to the primary forest.

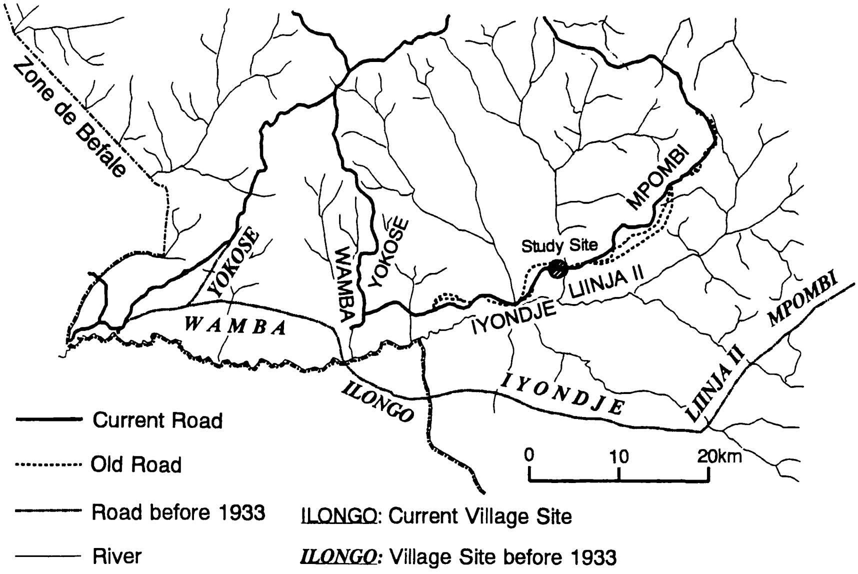

Fig. 25. Examples of village movement. Most of the villages in the shown area was transferred from the south in 1933. After that, village movement has been conducted near the main road only in a small scale.

III. Recent Changes

The following serious changes have occurred to the traditional life style of the Bongando recently.

1. Sedentarization

The nomadic way of life has been disappearing all over the world. The people are either compelled to or choose to reside permanently in a fixed area. This tendency is conspicuous in the hunting-gathering and the pastoral societies, but the farmers are not an exception. The Bongando began to settle near the road around the 1930's. According to some reports (e.g. Takeda, 1990), it was a "forced" migration, but I suppose it might be partially a spontaneous one, because roadside is convenient for the Bongando themselves.

2. Population growth

Population growth is another serious change which affects the land use pattern. As is often the case in Africa, the Bongando population has been increasing in this century. The improvement in medical services and the introduction of new subsistence techniques are the main causes.

Population growth increases the food demand, and consequently disturbs the balance between humans and forests. Nye & Greenland (1960) roughly estimated that land under shifting cultivation has traditionally supported a population of fewer than 20 persons/mile^2 (=7.7 persons/km^2). The current Bongando population density (9.3-10.4 persons/km^2) already exceeds this level. Moreover, the population density calculated for the roadside area is far higher. People are compelled to clear the surrounding primary forest to support the increasing population.

3. Penetration of market economy

The third significant change is the introduction of coffee as a cash crop. In the study village, coffee is planted in 24.7% of field area. Coffee cultivation is not directly related to the subsistence of the people, but the penetration of the cash economy has forced them to earn money to buy necessities such as cloths, salt, and soap. However, staple crops such as cassava or banana are scarcely sold outside, and the cash crop is almost confined to coffee in the current Bongando economy. It is because this area is far from the city market.

IV. Conclusion

Presumably the Bongando agricultural system had been in balance with the forest in the past. The cultivation-fallow cycle used to be long enough for the recovery of the secondary forest, and the field soil was not seriously depleted. Recent changes in the Bongando society have altered such a balance. The village site is fixed, field area is expanding outward, and siltation has progressed in the village area. Thus I cannot be optimistic about their traditional shifting cultivation.

Among the recent changes, the most readily addressable might be the population growth. However, more discussion on this problem is beyond this paper. Periodical change in residence may also be a desirable solution. The Bongando (and many other shifting cultivators) have practiced this so far. Even so, their current social condition partially involved in the market economy would not allow distant moves. The roadside is so convenient for trade and transportation.

It must also be pointed out that compared with the ongoing large scale logging and plantation development, influences on the forest from the traditional shifting cultivators is not so significant. Evaluation of these activities is, of course, another important subject for the protection of the tropical rain forest.

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NOTES

(1) While the state name for Zaire changed to the Democratic Republic of Congo in 1997, I use the former name in this paper, because it was written when the state was still called Zaire.
(2) The area of the Bongando territory was measured by referring to the ethnic map of l'Institut Geographique du Zaire (1982) and that of G. Hulstaert (cited by Philippe (1965)). Information from the Bongando was also consulted.
(3) 40,000,000 persons/2,345,000km^2.
(4) This rate was estimated based on three statistical reports (Conceil de Gouvernememt, 1957; Cabinet du Ministre d'Etat, 1970; Departement du Plan 1984).
(5) The Bongando people prefer the name "Luo."
(6) They are the researchers of the Bonobo (*Pan paniscus*)
(7) These results may be biased by the sampling period (June to December) in which clearing of new fields is not conducted. Even so, men's cutting work is unlikely to exceed one hour per day on average in the dry season.
(8) These products are sometimes sold to other villagers, but are not traded with the merchants.
(9) Dogs are also kept for hunting.
(10) Thematic Mapper (TM) scene (northwest subscene of path 177 - row 60, 100 km × 100 km in width) was used. The spatial resolution was 30 m × 30 m.
(11) According to Fresco (1986), cassava was widely grown in the Zaire Basin by the end of the 18th century, but it remained a crop of local importance.
(12) The only imported main foodstuff is rock salt. The Bongando also use salt made from plant ashes.
(13) If the cleared field is not sufficient, a second clearing is conducted from June to July.
(14) Sometimes labor exchange is conducted on small scale.
(15) Fresco (1986: 145) wrote as follows: "Cassava has the lowest field labour input requirements of all tropical staple crops. ... It was feared that its ease of cultivation would encourage laziness."
(16) However, samples do not correspond with all possible combinations for these parameters.
(17) Samples were taken from 1m and 4m horizons only in this site.
(18) This layer is called "arbic horizon."
(19) However, it is possible that such nutrition contained in the deeper horizon is effective for crop growing.
(20) This hypothesis should be verified by subsequent field surveys.
(21) However, the Bongando informants mentioned that a large-scale migration was conducted in 1933.

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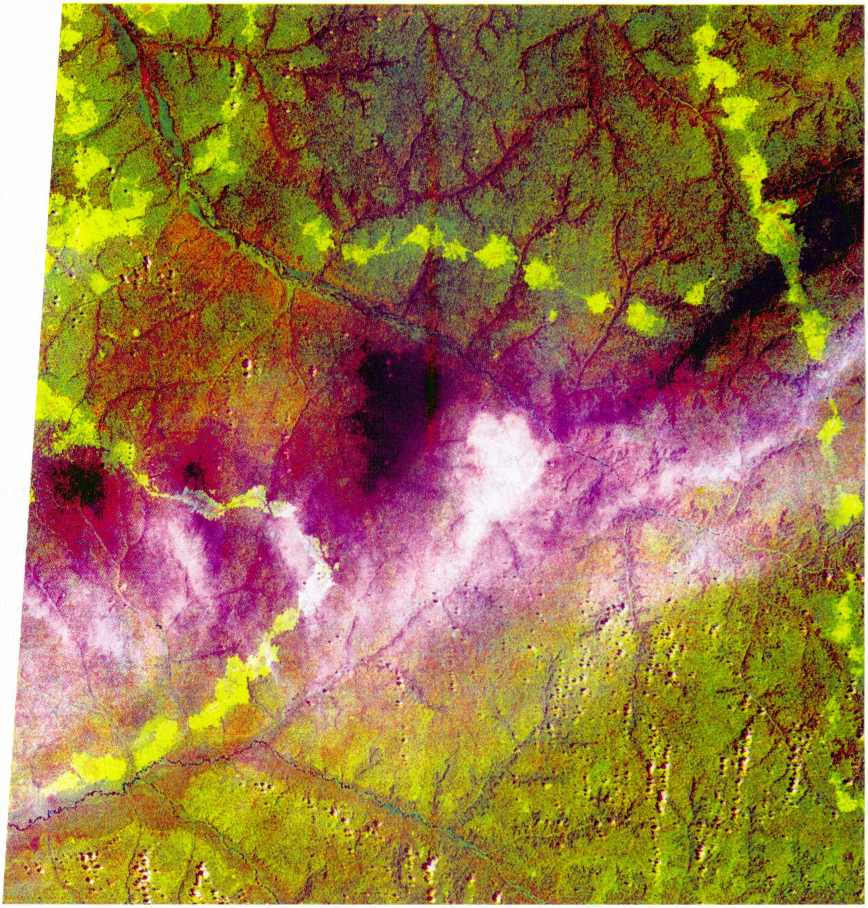

Fig. 11. Landsat image of the study area. Bands 5, 4, 3 (mid-infrared [1.55-1.74 μm], reflective-infrared [0.76-0.09 μm], and red [0.63-0.69 μm], respectively) are synthesized. These bands are indicated by red, green and blue in the picture.

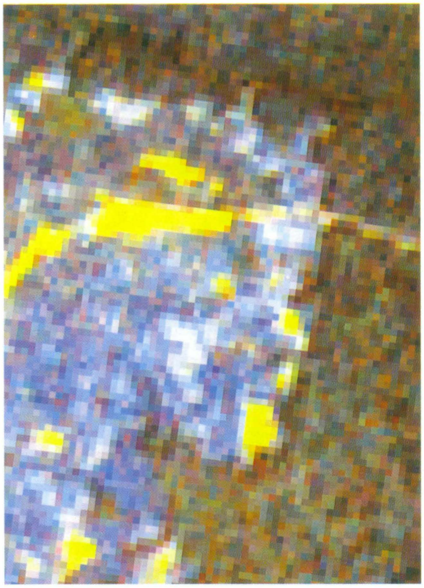

Fig. 12. Landsat image of the study village. Bands 7 (mid-infrared [2.08-2.35 μm]), 5, 4 are used in this scene. This combination makes the difference of the vegetations conspicuous.

Fig. 23. Tropical podzol.