REGENERATION PROCESS OF THE MIOMBO WOODLAND AT ABANDONED CITEMENE FIELDS OF NORTHERN ZAMBIA

Shuichi OYAMA
The Center for African Area Studies, Kyoto University

ABSTRACT In the miombo woodland of northern Zambia, the Bemba have practiced a unique shifting cultivation called citemene system, tree branches are collected into a garden area from the surrounding tree-cutting area and burnt. This study clarifies the impact of citemene system on the environment by analyzing 1) ecological fallow periods, 2) effects of burning on vegetation, and 3) optimum fallow periods in both the tree-cutting area and the garden area.

1) In the tree-cutting area, a fallow period of 30 years is required to reach a proto-climax stage of the woodland after cutting and burning trees (ecological fallow periods). In the garden area, fallow period should be more than 50 years.

2) At the early stage of regeneration, the miombo woodland species dominated the tree-cutting area, while species of the open woodland and chipya forest dominated in the garden area. The difference in vegetation between the two areas tended to become reduced as the fallow period increases.

3) Optimum fallow periods which may supply enough biomass for finger millet production and make sustainable utilization of miombo woodland possible, were estimated to be 16years for the tree-cutting area and about 35 to 40 years for the garden area. A fallow period shorter than the optimum fallow period, is likely to diminish wood biomass and yield of finger millet. To avoid such situations, the Bemba have traditionally moved villages or built seasonal dwelling for citemene cultivation which are far from the settlement.

Key Words: Miombo woodland; Citemene shifting cultivation; Wood biomass; Optimum fallow period; Regeneration process.

INTRODUCTION

In recent years, deforestation in developing countries is getting worse. Shifting cultivation in general is criticized as one of the main causes of the deforestation. However, slash-and-burn practices have many forms such as those based on traditional methods or large-scale farming conducted by companies or immigrants. In order to examine the causes of the deforestation, the differences in shifting cultivation must be studied.

In the miombo woodland of northern Zambia, there is a special type of shifting cultivation, called citemene system. Citemene system in this area has mainly two forms: Large-circle citemene practiced by the Bemba and small-circle citemene by the Lala living in the south of the Bemba territory. The main features of large-circle citemene can be summarized as follows: (1) Branches of large trees are lopped, (2) the areas of fields vary from 20 a to 70 a, and (3) the fields are managed under a 5-

years rotation system (Kakeya and Sugiyama, 1985). In small-circle citemene, the trees are felled at breast height. After the trees dry, the branches are carried and stacked in a neat and orderly manner in small circles, or in long narrow strips (Peters, 1950). The areas of fields vary from 0.2 a to 0.6 a, and the fields are managed under a two-year rotation system sowing finger millet for the first year and groundnuts in the second year (Allan, 1965).

There are several studies on the regeneration of miombo woodland under the small-circle citemene system carried out by the Lala (Peters, 1950; Trappnell, 1953; Allan, 1965). Stromgaard (1986, 1988) analyzed the regeneration of miombo woodland at abandoned large-circle citemene.

These studies have all concerned the deforestation of miombo woodland and the ecological crisis created by the citemene system. However, it is also important to analyze the human activities as a dynamic interactive process between people and environment.

The aim of this paper is to analyze the impact of the citemene system on the environment by analyzing the regeneration process of miombo woodland at abandoned citemene fields. In addition to an ecologically sound fallow period which is required to recover mature miombo woodland. this paper discusses a optimum fallow period which is defined as a fallow period necessary to produce a certain yield of the main crop, finger millet.

THE RESEARCH AREA

I. Study Site

Field studies were conducted at Mulenga-Kapuli Village (11°40'S, 31°10'E), located 27 km west of Mpika town, Northern Province, Zambia (Fig. 1). The study lasted 6 months in total from October to December 1993 and from May to August 1994. Anthropological studies have been carried out in the same area by Kakeya and Sugiyama since 1983 (Sugiyama, 1987, 1988, 1992; Kakeya, 1990; Kakeya & Sugiyama, 1985, 1987).

II. Environment

The research area belongs to the Northern Plateau region of miombo woodland with elevation between 1,200 m and 1,400 m above sea level. Along the rivers meandering in the woodland, there are seasonal marshes called "dambo" which are submerged in rainy seasons. The mean annual rainfall is 1,130 mm around Mpika Township (Survey Department of Zambian Government, 1986). The rainy season extends from November to April. The dry season is divided into two seasons: cold-dry season from May to the beginning of August, and hot-dry season from the middle of August to October (Fig. 2). The soil of the region is classified as Orthic Ferralsols (FAO/UNESCO, 1974) with sandy top soil.

Fig. 1. Location of research area.

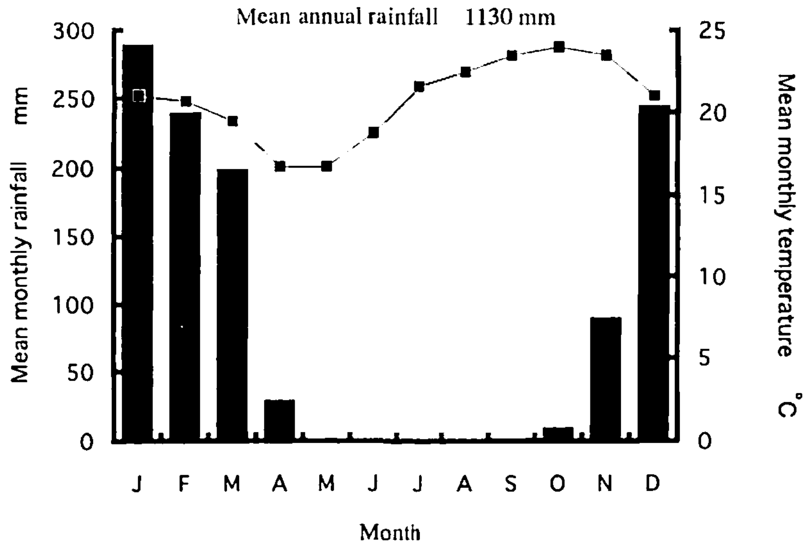

Fig. 2. Rainfall and temperature in Mpika District.

III. Vegetation

Miombo woodlands cover large areas of south-central Africa where annual rainfall varies from 600 mm to 1,400 mm, and mean annual temperature ranges between

18 and 24°C. (White, 1983). The miombo woodland is dominated by leguminous trees of genera such as *Brachystegia*, *Julbernardia* and *Isoberlinia* which all belong to the sub-family *Caesalpinoidae*. These trees compose a 10 m-15 m high canopy in normal stands. The ground is covered by grasses 0.6 m-2.0 m tall, such as *Hyparrhenia sp.* and *Loudetia sp.* The term, "miombo," is derived from a local word which refers to *Brachystegia sp.* in general.

The miombo woodland in the Northern Plateau of Zambia can be divided into three types (Trapnell, 1957). The research area belongs to the northern *Brachystegia-Julbernardia paniculata* woodlands type. The predominant species in the high storey are *B. floribunda*, *B. utilis* and *J. paniculata*, and the major species in the lower storey are *Uapaca kirkiana*, *Ochna pulchra*, *Faurea saligna* and *Monoteas africanus* (Kakeya and Sugiyama, 1985).

IV. Citemene System

The Bemba have traditionally practiced shifting cultivation called citemene in the miombo woodland of northern Zambia. Citemene system is an unique farming system, compared to shifting cultivation in other areas. After the onset of the dry season, men climb the trees and chop off the branches (called "*ukusaila*" in Bemba language) in the tree-cutting area. The pollarded stems are left standing. After the branches are dry enough, women carry the branches on their shoulders to the center of the tree-cutting area, the future garden area, and pile them up about 70 cm high (this area is called "*citemene*"). The tree-cutting areas vary from 1.0 ha to 4.2 ha, and the garden areas, from 0.2 ha to 0.7 ha. In the research area, both areas are circular. After burning the piled branches in the garden area from the end of October to early November (this area is called "*ubukula*"), cucumbers and gourds are sown along the edge, while tomatoes and other vegetables are sown in the center in December. Cassava is then planted in the middle of the field. Then follows the sowing of finger millet toward the end of December. Finger millet is harvested from May to July.

In the second years, groundnuts are planted. In the third and the fourth years, cassava is harvested, and in the fifth year mounds are often made in the middle of the fields for planting beans (these fields are called "*cifwani*"). After harvesting beans, the field is abandoned (this area: "*cifumbule*," Kakeya & Sugiyama, 1985).

In this paper, the fallow period is calculated as years after cutting and burning trees in the tree-cutting area, even in the garden area, because it is easy to identify the year that a citemene was cleared by satellite images and aerial photographs, but difficult to identify the year a citemene field was abandoned.

BIOMASS ESTIMATION

The biomass of the miombo woodland was variously estimated in previous studies (Stromgaard, 1985a; Chidumayo, 1988; Grundy, 1992). Chidumayo (1988) in Zambia and Grundy (1992) in Zimbabwe measured the circumference at 30 cm and tree-height. Grundy (1995) estimated the wood biomass for the specific two plant species. Strongaard (1985a) estimated the wood biomass using DBH and H in Zambia, but his model underestimated the weight particularly for the larger trees, which are important to estimate the wood biomass in the plot, because the sample trees were biased towards small DBH and H.

In this paper, diameter at breast height (DBH: in centimeters), tree-height (H: in meters) and fresh wood biomass (W: in kilograms) were measured in two 10 m×10 m plots in order to estimate the wood biomass above ground. Sample trees were also measured without setting up quadrats because it is necessary to select various sizes and species. The 153 sample trees representing 22 species (Table 1) were measured for H, DBH and wood biomass. Tree-height was measured by a 12 m measuring bar. For multi-stemmed trees, all the DBHs were measured but H was measured only for the tallest stem.

A calibration curve of 153 sample trees was made from DBH (BA: $DBH^2/4$) and H (Fig. 3). Sample trees included various sizes of H and BA. Multi-stemmed trees had lower tree height than single-stemmed trees, comapring with the same BA. Most of them had been influenced by human activities, such as citemene cutting or fuel wood collection.

The regression between log ($DBH^2 \times H$) and log(W) gives high r^2 value, 0.878 (Fig. 4). To estimate the above-ground biomass, the following equation was obtained.

$$\log(W) = 0.759 \times \log(DBH^2 \times H) - 0.371$$

Table 1. Sample trees measured for calculation of the wood biomass.

species	number of trees measured
Anisophyllea boehmii	7
Brachystegia boehmii	4
B. longifolia	16
B. spiciformis	8
B. utilis	32
Dalbergia nitidula	3
Diplorhynchus condyrocarpon	1
Erythrophleum africanum	1
Faurea intermedia	1
F. speciosa	4
Isoberlinia angolensis	16
Julbernardia paniculata	24
Parinari curatellifolia	5
Phyllocosmus lemaireanus	3
Proteas welwitschii	5
Pseudolachnostylis maprouneifolia	1
Pterocarpus angolensis	1
Strychnos innocua	1
Swartzia madagascariensis	2
Uapaca kirkiana	14
U. sansibarica	3
not identified	1
22 species	153 trees

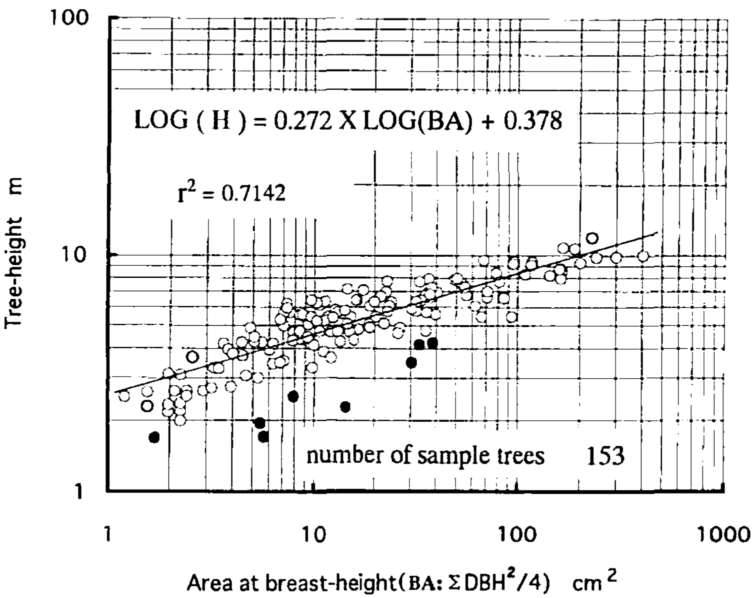

Fig. 3. Relation between the areas at breast-height and the tree-heights of the sample trees.
Trees which have a single-stem at breast height were shown by open circles, while trees with multi-stems due to coppice growing at breast height were shown by closed circle.

● single-stem at breast height

○ multi-stems at breast height

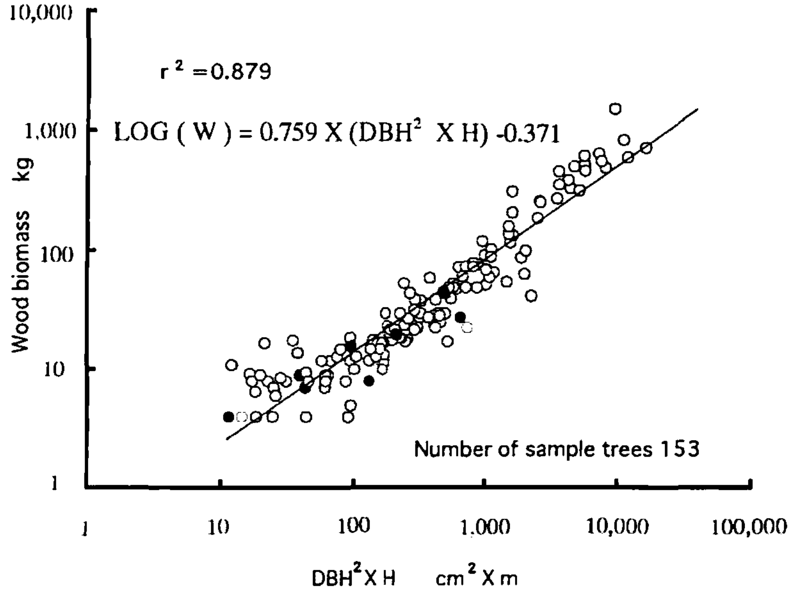

Fig. 4. The relation between the wood biomass and (DBH^2)×(tree-height).

● single-stem at breast height

○ multi-stems at breast height

The figure shows that there was no difference between single-stemmed trees and multi-stemmed trees in log(W)-log(DBH) relationships, which justifies applying the single equation shown above to all trees.

REGENERATION PROCESS OF ABANDONED CITEMENE

The wood biomass and the follow period were examined as indicators of the regeneration process of miombo woodland after citemene fields are abandoned. Locations of newly cleared citemene were identified in aerial photographs (1965, 1980), Landsat TM images (1984, 1992) and information from villagers. For each tree above 1.3 m height within 0.25 ha plots with fallow periods of 0 year (just after tree-cutting), 7 years, 10 years, 15 years and 30 years, the following measurements were made after identifying the tree species: (a) height of tree (in meters), (b) num-

Table 2. Biomass estimation in the tree-cutting area after a 30-year fallow period. (50 m × 50 m quadrat: 0.25 ha)

species	number of trees	estimated biomass (kg)
Anisophyllea boehmii	1	31.9
Brachystegia longiforia	25	3,074.3
B. utilis	1	96.4
Combretum molle	2	57.7
Diplorhynchus condylocarpon	1	19.5
Erythrophleum africanum	2	56.4
Flacourtia indica	3	52.3
Isoberlinia angolensis	12	1,104.4
Julbernardia paniculata	49	3,510.3
Monotes katangensis	6	3,204.2
Ochna pulchra	10	192.8
Parinari curatellifolia	1	875.8
Pericopsis angolensis	4	109.0
Phyllocosmus lemaireanus	5	177.2
Proteas welwitschii	2	59.0
Pseudolachnostylis maprouneifolia	7	317.0
Pterocarpus angolensis	1	100.3
Steganotaenia araliacea	2	99.1
Strychnos pungens	2	38.9
Syzygium guineese	15	549.3
Uapaca bengnelesis	10	1,284.3
U. kirkiana	54	6,674.8
U. nitida	4	473.2
U. sansibarica	3	319.1
not identified	1	21.6
not identified	1	17.0
not identified	3	56.2
total 27 species	227 trees	22,572.1 kg (90.3 tons/ha)

* DBH and H of a tree were measured in the quadrat after identifying the species.
Then, W of a tree was calculated by applying DBH and H into the equation below:
$\log(W) = 0.759 \times \log(DBH^2 \times H) - 0.371$
The estimated biomass of each tree species is the total of individual trees.

ber of stems, and (c) diameter of each stem at breast height (in centimeter). For the remaining stumps below 1.3 m high on the 0 year fallow plots, the diameter at the top of the stumps was measured instead of DBH. For 3-year old fields where cassava had been cultivated, DBH and H were measured in a belt-transect survey (2 m × 100 m). The calculation procedure is shown in table 2, giving an example of the tree-cutting area of 30-year fallow plots.

For the tree-cutting area (Fig. 5), the wood biomass of stems (28.7 tons per ha) remained after tree-cutting because only branches were chopped off from the stems larger than 15 cm DBH, which could be seen as a normal biomass residue for this practice. The wood biomass rapidly recovered in the initial stage of regeneration for the tree-cutting area. In the tree-cutting area, the new branches and stems sprout up from the surviving branches or stems. The wood biomass in 7-year fallow plots increased to 68.7 tons per ha, more than twice the biomass left just after tree-cutting. A gradual increase in the biomass was found from 7 to 30 years up to 90.3 tons per ha. The wood biomass in 30-year fallow plots seem to reach the proto-climax stage of the woodland after which the rate of growth slows down.

In the garden area, all the trees and *Hyparrhenia* grass were burnt. Villagers dislike fields which are burnt insufficiently, leaving grasses and shrubs. The wood biomass could be regarded as approximately 0 ton per ha. For the garden area, the wood biomass at 3 years after burning was 2.4 tons per ha. The wood biomass at 7 years was 6.5 tons per ha, and 13.3 tons at 10 years. The woody species of a 7- and

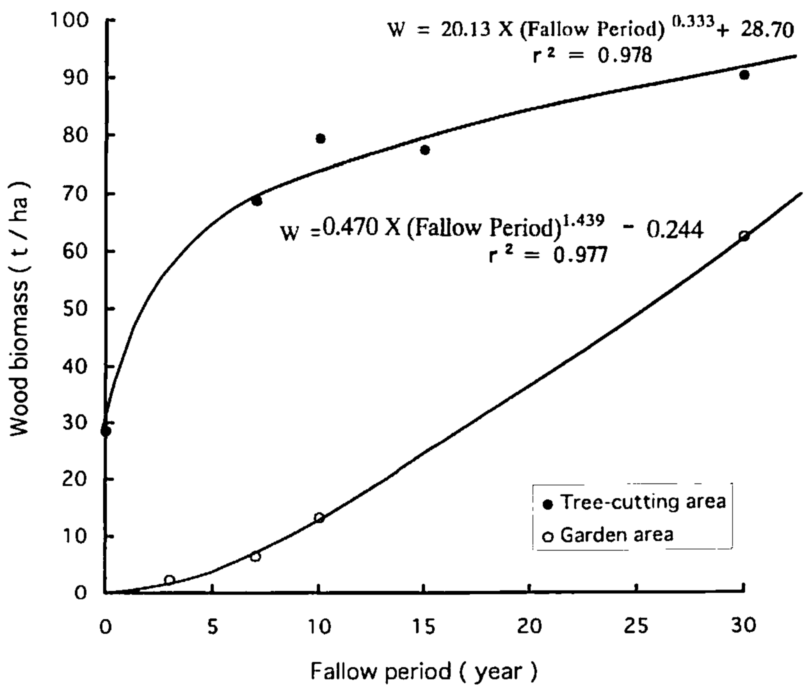

Fig. 5. Relation between fallow period and wood biomass.

10-year old garden areas were sparsely distributed among grasses dominated by *Hyparrhenia*. In 30-year fallow plots, the woody species grew higher than grasses and the wood biomass reached 62.4 tons per ha. As this biomass is quite close to the value of a 7-year old tree-cutting area. the regeneration for the wood biomass in the garden area might be estimated to be about 20 years behind the tree-cutting area.

The tree-cutting area needs at least a 30-year fallow period to reach the proto-climax stage, while the garden area needs more than 50years because regeneration of garden may be 20years slower than in the tree-cutting area. These conditions should be maintained to allow the citemene system to remain ecologically sustainable.

THE EFFECT OF BURNING ON VEGETATION

At the early stage of regeneration, i.e., 7-year, 10-year and 15-year fallow periods, the miombo species such as *Brachystegia-Julbernardia-Isoberlinia* dominate the tree-cutting area. In contrast, the shrub species, chipya species, and species which can be found in open woodland dominate in the garden area. The chipya forest is thought to be a degraded dry evergreen forest found in between the miombo woodland and dambo (Lawton, 1964). The vegetation types and typical species are as follows; miombo species are the *Brachystegia-Julbernardia-Isoberlinia sp.* group, the shrub species are *Phyllocosmus lemaireanus, Rothmania englerana* and *Pericopsis angolensis*, the chipya species is *Harungana madagascariensis* and the species found in open woodland are *Parinari curatellifolia, Anisophyllea boehmii, Rhus longipes* and *Syzygium guineese*.

The effect of burning and successive cultivation on the number of trees and tree species was evaluated by comparing the garden area with a nearby tree-cutting area of the same fallow period. In order to examine the tree species composition in both the garden area and the tree-cutting area, a similarity index (C_S) was applied. The similarity index is calculated by the following formula (Sørensen, 1948):

$C_S = (S_C \times 2)/(S_A + S_B)$
C_S: Similarity index
S_C: Number of common species on Plot A and Plot B
S_A: Number of species on Plot A
S_B: Number of species on Plot B

On 7-year fallow fields, there were 26 species and 218 trees in the tree-cutting area (Table 3). There were 14 species and 98 trees in the garden area. The 7-year fallow garden is estimated to have been abandoned 3years. The regeneration of vegetation in the garden area was poor, because the impact of burning remained strong and the presence of *Hyparrhenia* grass made it difficult for pioneer tree species to invade the ground. The similarity index was 50.0 %.

On 10-year fallow fields, there were 27 species and 293 trees in the tree-cutting area. There were 36 species and 245 trees in the garden area. Compared to the 7-year fallow garden area, the number of trees was increasing in the 10-year fallow garden area. The 10-year fallow garden area had been abandoned before 6 years. By exam-

Table 3. Relation between fallow period and vegetation (number of species and trees, and biomass in 50 m×50 m quadrats), and the similarity index in the both garden and tree-cutting areas.

Fallow years	Garden area			Tree-cutting area			Similarity index
	Number of species	Number of trees	Biomass t/ha	Number of species	Number of trees	Biomass t/ha	
0				16	176	28.7	
3			2.4				
7	14	98	6.5	26	218	68.7	50.0
10	36	245	13.3	27	293	79.4	66.7
15				30	327	77.4	
30	27	206	62.4	27	227	90.3	70.4

All plots are investigated with 50 m×50 m quadrats except the 3-year-old garden area. The wood biomass in the 3-year-old garden area is estimated by a 2 m×100 m belt transect survey.

ining the relation between number of trees and time after abandoning citemene, 30 to 40 trees are estimated to germinate or grow from residual roots every year in the garden area at the early stage of regeneration. The difference in number of trees between the garden area and the tree-cutting area is much smaller in 10-year fallow than 7-year fallow fields. The number of species in the garden area at a 10-year fallow was larger than the tree-cutting area. This might be because most species present on the garden plot, but not present on the tree-cutting plot, have small seeds less than 2 cm in diameter which might be easily transported into the garden area from remote places, such as *Rhus longipes*, *Uapaca sansibarica* and *Syzygium guineese* (Palmer & Pitman, 1972; Palgrave, 1977). Since these species were not found in the tree-cutting area, it is presumed that these species can germinate only under good light conditions, such as the garden area in short fallow fields. The similarity index for 10-year fallow fields was 66.7 %, higher than in the 7-year fallow fields.

The general trend shows that the difference in vegetation between the tree-cutting area and the garden area is getting smaller as fallow period increases.

On a 30-year fallow fields, there were 27 species and 227 trees in the tree-cutting area. There were 27 species and 206 trees in the garden area. There was no difference in both the number of trees and species between the two plots. The similarity index was 70.4%, higher than in the 7- or 10-year fallow fields.

It is assumed that the seeds of predominant species, which germinate in the garden area, are carried back from the nearby tree-cutting area after the pioneer species build a suitable environment for woody species at the early stage of regeneration. Then, as the fallow period increases after the early stage, the pioneer species tend to be gradually driven away by the predominant species of the miombo woodland. Thus the number of trees and species become stable.

CALCULATING THE OPTIMUM FALLOW PERIOD

In order to probe an interactive relationship between food production and environment, it is important to calculate the optimum fallow period. Optimum fallow period is defined as a period which is necessary for the Bemba people to sustainably reproduce a certain yield of finger millet in citemene fields.

The optimum fallow period is estimated on the basis of the tree biomass which provides enough ashes after burning to produce the standard yield of finger millet. In this paper, an average ratio of the garden area to the tree-cutting area (Kakeya and Sugiyama, 1985) and a relationship between ash content and yield of finger millet (Araki, 1993), along with my data are applied for calculating the optimum fallow period of the tree-cutting area and the garden area around Mulenga-Kapuli Village.

Kakeya and Sugiyama (1985) surveyed areas of the garden area and the tree-cutting area of 9 households in Mulenga-Kapuli Village in 1984. The average garden area was 0.45 ha and the average tree-cutting area was 2.96 ha per household. The average ratio of the garden area to the tree-cutting area was 1 : 6.6. Moore and Vaughan (1994) examined reports on the citemene system and indicated that the ratio of the garden area to the tree-cutting area varied from 1:6 to 1:10. In general, the ratio is an index reflecting the degree of deforestation. A lower ratio can be regarded as a lower degree of deforestation. The average ratio in Mulenga-Kapuli Village, 1:6.6, was close to the minimum ratio indicated by Moore and Vaughan (1994). The average ratio of 4 households, which cultivated citemene near the village, was 1 : 6.1. And the average ratio of the other 5 households which built seasonal dwellings ("mitanda") far from the village to open citemene in well-regenerated or undisturbed miombo woodland, was 1:6.8. Contrary to the prediction, in Mulenga-Kapuli Village in 1984, this ratio for citemene far from the village was a little bit higher than near the village. It could be that the villagers in Mulenga-Kapuli Village have been sustainably utilizing the miombo woodland by maintaining the average ratio of the garden area to the tree-cutting area, about 1:6.6. This average ratio in Mulenga-Kapuli Village is applied to calculate optimum fallow periods.

Araki (1993) found a very close relationship between ash content and yield of finger millet in 1990, as follows:

(finger millet yield) = 0.23 × (ash content) + 0.04
finger millet yield: panicular tons per ha
ash content: tons per ha

However, finger millet yield varies every year according to many factors, such as the seasonal distribution and amount of the rainfall. For example, the average yield of finger millet in Mulenga-Kapuli Village was 3.4 tons per ha in 1984, and 2.77 tons per ha in 1990. In 1984, the yield of finger millet was estimated to be very good by the villagers. In this paper, 2.77 tons per ha in 1990 was considered an average yield of finger millet and the wood biomass is calculated from the ash content by applying the regression above to estimate ash content from the yield of finger millet. The ash required to produce of 2.77 tons per ha of finger millet is calculated to be 11.87 tons per ha. The ratio of dry wood weight to fresh wood weight was 7:20 (Stromgaard, 1985b), and the ratio of ash weight including charcoal to dry wood weight was 1:10 (Araki, unpublished data). With these ratios, 11.86 tons of ash can be converted to 339.14 tons per ha of wood biomass in fresh weight. As the wood biomass of 339.14 tons per ha is carried into the garden area from the 6.6 ha tree-cutting area including the garden area, 51.4 tons per ha wood biomass (dividing 339.14 by 6.6) is needed in a citemene.

In the tree-cutting area, not all the biomass is utilized in order to produce ash, because only the branches are pollarded and the stems were left standing. The wood biomass left just after cutting trees is 28.7 tons per ha. Assuming that the same wood biomass would be left when the citemene is cut again, the minimum wood biomass which is essential to reproduce finger millet, is therefore estimated at 80.1 tons wood biomass per ha adding the biomass of trees cut (51.4 tons) and left standing (28.7 tons). The wood biomass, 80.1 tons per ha is equivalent to the wood biomass of the tree-cutting area in a 16-year fallow period (fig. 5).

In the garden area, the DBH of the trees are small until 30 years of fallow, mostly less than 15 cm (Fig. 6, 7) because the cut or chopped trees were destroyed by fire, and regeneration mainly depended on the new trees germinated from the seeds and surviving roots. The Bemba men generally cut down the trees less than 15 cm in DBH and all the biomass could be carried into the garden area. In the abandoned garden area where most of the trees are less than 15 cm, the regenerating the wood biomass is estimated to be enough to reproduce finger millet in a citemene field. The wood biomass, 51.4tons per ha is equivalent to the total wood biomass of the garden area after a 26-year fallow period (fig. 5).

However, cutting down and burning all the wood biomass on the abandoned garden area after a 26-year fallow period, cannot be considered as sustainable utilization of miombo woodland. One of the most characteristic factors of citemene which makes possible the sustainable utilization of the woodland, is to chop off the branches ("*ukusaila*") without cutting down the trees, because the new branches and

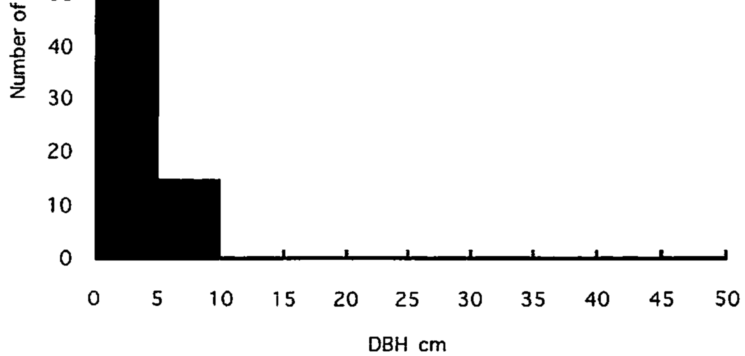

Fig. 6. Distribution of DBH in the garden area of 7year fallow periods (50m×50m quadrats).

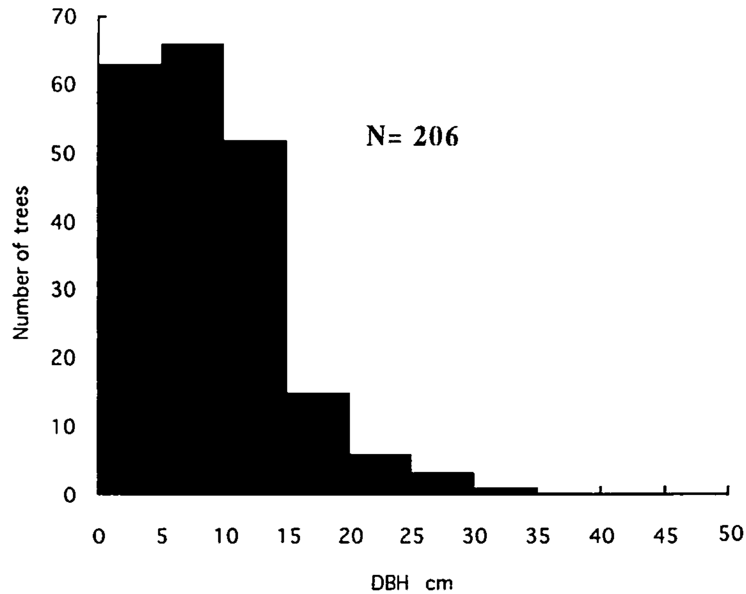

Fig. 7. Distribution of DBH in the garden areas of 30 year fallow periods (50 m × 50 m quadrats).

stems sprout from pollarded stems which are left standing and the vegetation can rapidly recover. Thus, it is necessary to consider the optimum fallow period of the garden area as the period that the trees grow large enough to climb and have branches chopped off. As the vegetation following a fallow period of more than 31 years was not investigated, it is supposed that the wood biomass of 80.1 tons per ha can be one standard in calculating the optimum fallow period of the tree-cutting area. The wood biomass of 80.1 tons per ha would be equivalent to the wood biomass of the garden area from a 35- to 40-year fallow period (fig. 5).

Thus, optimum fallow periods are 16 years for the tree-cutting area and about 35 to 40 years for the garden area.

However, optimum fallow periods depend also on the way trees are cut, which varies among persons choosing various ratios of trees to cut down ("*ukutema panshi*") and chop off branches ("ukusaila"). For example, one man climbed the trees and chopped off the branches for nearly 60 % of the trees over 15 cm in DBH. Another man cut down almost all the trees, no matter how large the trees. The larger the ratio of trees cut down, the longer the regeneration period. Under such conditions, the optimum fallow period is estimated to be shorter than the estimate. In case of the latter, perhaps more than a 20-year fallow period is necessary in the tree-cutting area. If the citemene system is practiced before the optimum fallow period, there is a danger of diminishing the yield of finger millet and miombo woodland biomass.

SUMMARY AND DISCUSSION
EXAMINING THE ESTIMATE OF THE FALLOW PERIOD

The fallow periods reported in the literature were 20 years (Trappnell, 1953), 22-25 years (Allan, 1965) and 35 years (Peters, 1950) for small-circle citemene. However, these values are rather speculative except for those of Peters who measured 17 sites with varying fallow periods. It is difficult to compare them with the values of large-circle citemene because the rotation system and the diameter of the garden area are quite different.

Stromgaard (1986, 1988) studied the regneration of abandoned miombo woodland after abandoning large-circle citemene by the Bemba. He analyzed vegetation after a 6- and 16-year fallow periods, but not more than a 20-year fallow period. Araki (1993) estimated recovery time to be 25 years for the tree-cutting area and 50 years or more for the garden area to recover soil organic matter to levels of 1.5 % organic carbon.

In order to regenerate the wood biomass to a proto-climax stage, fallow periods should be about 30 years in the tree-cutting area and more than 50 years in the garden area. These figures agree well with the proceding studies and substantiate them. Furthermore, the optimum fallow periods are estimated to be 16 years in the tree-cutting area and approximately 35 to 40 years in the garden area, in order to achieve the sustainable utilization of the miombo woodland, and a certain level of finger millet production. The sustainability of the system does not always require until the complete regeneration of the woodland (ecological fallow period), because the Bemba can sustainably utilize the miombo woodland while producing a certain level of food before ecological regeneration (optimum fallow period). These optimum fallow periods have the possibility to become an index for evaluating the food production strategy of the Bemba.

However, if the fallow period becomes shorter than the optimum fallow period, woodland biomass and finger millet yields are likely to diminish. This is why the Bemba used to shift the settlement and village at 5-year to 20-year intervals (Sugiyama, 1992) and to build seasonal dwellings for citemene cultivation ("mitanda") far from settlements for the woodland to be kept at a steady level of regeneration. The recent concentration of villages around roads presents a totally different situation.

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Author's Name and Address: Shuichi OYAMA, *The Center for African Area Studies, Kyoto University, Shimoadachi-Cho, Yoshida, Sakyo-ku, Kyoto 606-01, Japan.*