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INTERACTIONS BETWEEN TERMITE MOUNDS, TREES, AND THE ZEMBA PEOPLE IN THE MOPANE SAVANNA IN NORTHWESTERN NAMIBIA

Chisato YAMASHINA
Graduate School of Asian and African Area Studies, Kyoto University

ABSTRACT Termite mounds comprise a significant part of the landscape in northwestern Namibia. The vegetation type in this area is mopane vegetation, a vegetation type unique to southern Africa. In the area where I conducted research, almost all termite mounds coexisted with trees, of which 80% were mopane. The rate at which trees withered was higher on the termite mounds than outside them, and few saplings, seedlings, or grasses grew on the mounds, indicating that termite mounds could cause trees to wither and suppress the growth of plants. However, even though termite mounds appeared to have a negative impact on vegetation, they could actually have positive effects on the growth of mopane vegetation. Moreover, local people use the soil of termite mounds as construction material, and this utilization may have an effect on vegetation change if they are removing the mounds that are inhospitable for the growth of plants. Consequently, both termite mounds and human activities should be taken into account as factors affecting mopane vegetation.

Key Words: Mopane vegetation; Termite mounds; Utilization of termite mounds; Vegetation change.

INTRODUCTION

Northwestern Namibia is semi-arid with a mean annual precipitation of less than 350mm. It is a part of the “mopane zone.” Mopane (*Colophospermum mopane*) is a semi-deciduous tree of the Caesalpiniaceae tree family. This tree is indigenous to southern Africa, and its distribution area is termed “mopane savanna” or “mopane woodland.” Physiologies of mopane tree and vegetation change in mopane savannas have not been established, but some features of the tree have been documented. White (1983) suggested that it is always dominant in a woodland community, forming almost pure stands of mopane trees. In northwestern Namibia, mopane vegetation displays this characteristic feature, forming sparse woodlands of mopane trees. The tree is sensitive to fire and to competition with other species (Werger & Coetzee, 1978: 352-363). Symbiotic root fungi living in the roots of mopane are also a characteristic feature of mopane trees (Timberlake, 1996).

Another remarkable characteristic of northwestern Namibia is the presence of widely distributed termite mounds. Termites live in all parts of the world and many build huge mounds, notably in tropical arid areas. The biomass of termites living within one mound is supposed to correspond approximately to one head of cattle, and termites substantially contribute to nutrient cycles as soil decomposers. Previous studies have revealed the positive impact of termite mounds on their surroundings. John & Stein (2004) and Ragnhild et al. (2005) revealed that some kinds of plants grow well on termite mounds in Kenya and Australia because the soil of the mounds is rich in nutrients. They also suggested that those plants contribute to maintaining animal populations in these areas, because herbivores prefer to eat the plants growing on the mounds. In some areas, people also use the soil of the mounds as fertilizer for field cultivation (Coaton, 1950). Furthermore, in many countries, people eat termites as an important source of protein. In Kenya and Zambia, the soil of termite mounds is also eaten and exchanged as a precious and expensive food, especially for pregnant women, because of its rich mineral content. Thus, termite mounds are deeply interrelated with their surroundings as well as with the activities of human beings. However, much of this research has been carried out in humid tropical regions, while few studies have focused on arid and semi-aid areas. Therefore, the relationships among termite mounds, vegetation, and human activities in these areas remain unclear. In the discussion of vegetation dynamics in the savanna, the competition among trees and grasses, moisture conditions, soil fertility, fire, and herbivory has mainly been dealt with in terms of disturbance factors (e.g., Scholes & Walker, 1993), and termite mounds have never been analyzed. In order to understand the vegetation dynamics and vegetation change in the mopane savanna, however, it is essential to examine the interactions of termite mounds, vegetation, and human activities, including the utilization of the mounds by local people.

In northwestern Namibia, many termite mounds coexist with trees, a distinguishing characteristic of the region as mopane savanna (Fig. 1). Both mopane trees and termite mounds are used by local people in their daily lives. This article focuses on the relations among termite mounds, trees, and human activities in northwestern Namibia, and aims to reveal the interactions among them, as well as the significance of termite mounds in mopane woodlands.

STUDY AREA

I. Natural Environment

Fieldwork was conducted at Ombazu village in northern Kunene Region, northwestern Namibia. The village is located 40km north of Opuwo, the capital of the Kunene Region. The northern part of Kunene Region is mountainous, and the altitude is around 1,200–1,600m. The vegetation type in this area is classified as mopane savanna (Giess, 1971). Mean annual precipitation is less than 350mm; the rainy season is from December to April (Namibia M.E.T. Station).

Ombazu village is sited on pediment in the northern hilly area. The vegetation structure of the area varies by landforms. Various plants surrounding the village spring richly endow the area with natural abundance.[(1)] In addition, many termite mounds exist in this area. Over 30 genera of termites live in Namibia. Remarkably huge mounds often found around the village are built by *Macrotermes*, *Odontotermes* (Macrotermitinae) and *Trinervitermes* (Nasutitermitinae) (Coaton, 1972; Coaton & Sheasby 1973a-d; 1974; 1975). Both *Macrotermes* and *Odontotermes* are litter-feeder and fungus-growing termites (Contour-Ansel et al., 2000; Coaton, 1972) and *Trinervitermes* is a grass-feeder termite (Duponnois et al., 2005). The distribution of the mounds around the village is not consistent throughout the area. Most of the termite mounds have many trees growing on them, another characteristic of this area.

II. People in the Study Area

Prior to Namibian independence, this region was designated as the homeland of indigenous people. Until recently, many parts of mid- and southern Namibia were privately owned by white people, while indigenous people resided in the northern and western parts of the country. In Namibia's northwest, the area of study for this research, Herero and Himba pastoralists coexist with Zemba agro-pastoralists.

The population of Ombazu village is approximately 200. Herero, Himba, and Zemba people (Fig. 2) live together in the village. They migrated to southwestern Africa during the mass movement of the Bantu people in the 16th century (Carlos & Gobson, 1981). Herero people have continued to move toward southern areas, and they now live all over Namibia. In contrast, the Himba and Zemba have stopped moving and have remained in northern Namibia and southern Angola, their present residence. Some languages are spoken in the area, and the Herero language is the common language around Opuwo. The Zemba use their own Zemba language. The current population of Zemba language speakers is approximately 12,000 in Namibia and 18,000–23,000 in Angola (Cameron & Kunkel, 2002).

Herero and Himba people are pastoralists and make their living mainly from grazing cattle and goats, although some of them cultivate small fields. Himba people live in small groups based on kinship, and often move around in search of new pastures for their livestock. They construct small dome-shaped huts in

Fig. 1. Termite mounds and trees.

Fig. 2. Zemba people.

mountainous areas. Zemba people also raise cattle and goats, and have large land areas for cultivation.

People in Ombazu village utilize various natural resources including termite mounds. The soil of the mounds is an important material used in hut construction.

As noted above, in northwestern Namibia, local people live in a natural environment. The coexistence of termite mounds and trees is also characteristic of this region. Therefore, this region is most suitable for an investigation of the relationships among termite mounds, mopane vegetation, and the utilization of the mounds by local people, in order to clarify the interaction among these three factors.

METHODS

Fieldwork was conducted from August, 2006 to February, 2007, and during September, 2008. I conducted an ecological research on vegetation and termite mounds within the research plot (2km × 3km). This research area encompassed the village. I also conducted research on the utilization of natural resources by the local people.

Research on the termite mounds included documenting the distribution of the mounds, their relationships with plants, and their utilization by people. A distribution map of termite mounds was created by plotting them using a GPS unit, and the heights and diameter of the mounds were measured. In addition, all plotted mounds were classified by condition into two types: unused mounds and mounds used by people. I then divided partially used mounds from totally used mounds according to the degree of utilization by people (Fig. 3). Concerning used mounds, the mounds eroded by wind or water flow were divided from unbroken mounds. I observed the conditions of trees on each mound, recorded their heights and diameter at breast height (DBH), and identified the tree species. To gather information about the utilization of the mounds, I observed and interviewed Zemba people.

In order to research vegetation, all woody plants were measured and identified and grass conditions were described and recorded in 34 quadrates and along 13 transects set in the plot. One quadrate was $100m^2$ while the length of transects varied from 10 to 120m. In order to reveal the relationships of geologic condition with vegetation and termite mounds, soil profiles in three spots and the degree of gravel covering the ground surface in every quadrate were observed. I also observed and interviewed local people with regard to their utilization of natural resources.

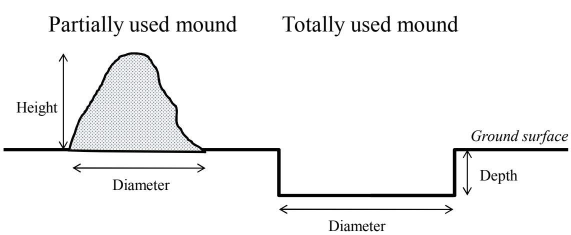

Fig. 3. Diagrams of partially used and totally used mounds.

RESULTS AND DISCUSSION

I. Distribution of Termite Mounds in Study Area

Fieldwork revealed that there were 276 mounds in the research plot ($6km^2$) and the average density of termite mounds was 0.5/ha. Their distribution was not consistent, with most of the mounds concentrated in the southern part of the plotted area and a few mounds in the northern part (Fig. 4). Particularly in the northern part of the plot, mounds were concentrated along seasonal streams and at the points at which the slope inclination changed. The results of soil texture research showed that the southernmost area was broadly covered with fine, reddish sediment,(2) which also covered the hillside riverbanks. On the other hand, the ground surface of the northern area, where few mounds were located, was covered with medium to large gravel, and much gravel existed in the ground. There were few mounds around the pan (3) in the southern part. The ground surface around the pan was also covered with gravel, and plants were absent there. This pattern may suggest that the distribution of termite mounds corresponds to the distribution of fine-grained sediment. The capacity of water storage of fine sand is superior to that of coarse sand. In arid areas, such as this study area, access to water is vital for life. Termites also make efforts to find better living conditions; for example, they construct mounds to protect their nests from aridity and heat. Water conditions at the point of change in slope inclination are generally better than those in other areas. Therefore, it is reasonable to assume that termites select relatively water-abundant places to build their mounds in rocky mountainous regions.

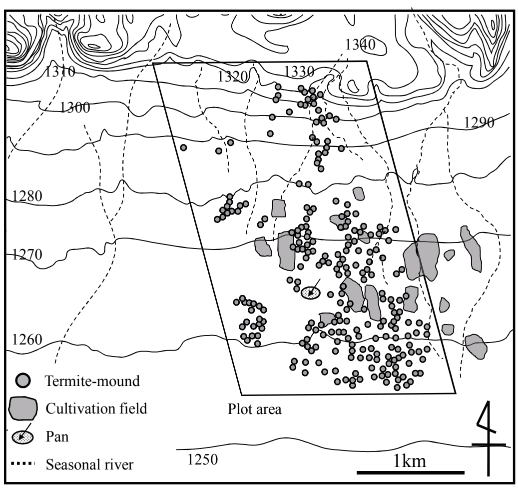

Fig. 4. Distribution map of termite mounds.
This figure is based on a topological map issued in 1980. Contour line drawn every 10m.

II. Interactions between Termite Mounds and Vegetation

Because many termite mounds coexisted with trees around the village, it seemed reasonable to assume that termite mounds and trees were linked by certain factors. Therefore, I examined the impact of termite mounds on trees, dividing all mounds into four groups in relation to trees: termite mounds with 1) living trees; 2) dead trees; 3) living and dead trees; and, 4) no trees.

The results of this analysis revealed that only 8% of all mounds did not coexist with trees (type 4), and over 90% of mounds coexisted with living trees and/or dead trees. In addition, no grass, seedlings, or saplings grew on the mounds.

Trees on Termite Mounds

Focusing on tree species, 80% of all trees growing on the termite mounds consisted of mopane, followed by *Terminalia prunioides* (about 10%). Figure 5 shows the DBH of mopane tree both in and outside of the mounds. This figure implies that the number of trees outside the mounds was inversely proportional to their DBH: the number of large trees in terms of DBH in the mounds was high compared with that outside the mounds. The number of tall trees was also high in the mounds. The results of *t*-tests showed that trees in and outside of the mounds differed significantly in terms of both height and DBH; *Terminalia prunioides* showed similar trends to mopane. The absence of seedlings and saplings in the mounds indicates that few trees grow on termite mounds in the current environment. From these results, it is reasonable to conclude that termite mounds are a suppression factor for germination and renewal of trees and grasses in this area. The presence of many tall and large trees growing in the mounds could imply that termites build their mounds under large trees. Scott (2000) indicated that termites often construct their mounds under trees in order to prevent their nests from heat and aridity in tropical regions. The climate condition in this area is severe enough, and hence it is a reasonable explanation

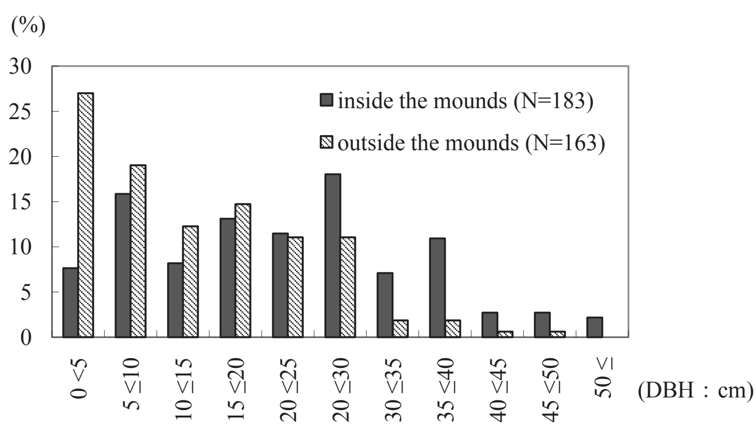

Fig. 5. DBH (diameter at breast height) of *Colophospermum mopane*.
N: Number of trees.

for the prevalence of mounds under trees here.

Only *Combretum imberbe* showed a trend different from mopane and *T. prunioides*. *C. imberbe* was the third most common plant to grow in the mounds, following mopane and *T. prunioides*. This tree appeared more commonly in the mounds than outside the mounds. It was noteworthy that, within the mounds, there were many small *Combretum imberbe* trees. The *t*-tests revealed that there was no significant difference for the DBH and the heights between the *C. imberbe* growing in the mounds and outside the mounds. Therefore, *C. imberbe* might have an exceptional relationship with termite mounds. Further researches are needed.

Termite Mounds and Dead Trees

The rate of tree withering in termite mounds was about three times higher than that of trees outside the mounds (Fig. 6). This finding suggests two possibilities. Firstly, it might be the case that a termite mound itself causes the tree to wither. Secondly, it is possible that termites build mounds under dead trees. Concerning the latter possibility, if termites feed on withered trees, they might make their mounds under dead trees. In the case of mopane and *Combretum* spp., this possibility was not, however, the case. Both trees have very hard heartwood, hence they are resistant to termites. In fact, mopane is widely used as a construction material by local people in South Africa because of this feature (Timberlake, 1996). Although the food of termites differs by species and region, they eat basically dead grass, litter, or soil. The termites in this region eat grasses and mushrooms cultivated in nests (Duponnois et al., 2005). Therefore, in this region, mopane and *Combretum* spp. are unlikely to be eaten by termites even if the trees are dead.

For these reasons, the possibility that the withering of trees in this region was caused by termite mounds seems persuasive. Roger et al. (1999) and Glover et al. (1964) suggested that the germination and renewal of plants are suppressed on active termite mounds in Australia and Kenya. They explained the factors of these suppressions as follows: the composition of the soil of mounds is poisonous for plants; the hardness of the surfaces of mounds prevents plants from germinating; and, termites remove the seeds and root of plants when they make their nests. Soil composition of the mounds varies depending on the way a nest is made. It has been pointed out that the soil comprising the mounds of *Macrotermes* contains only small amounts of nitrogen

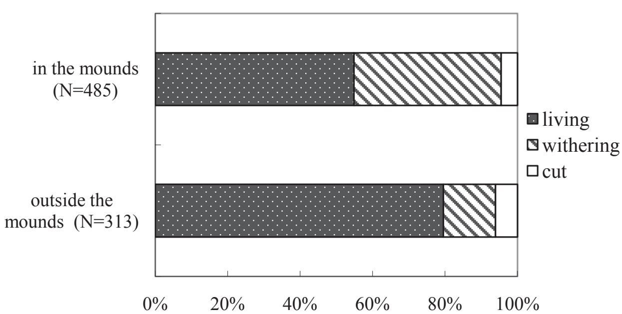

Fig. 6. Rate of living, withering, and cut trees in and outside the mounds. N: Number of trees.

and phosphorus because they use soil from deep underground, and hence, the soil of the mounds built by this genus is not suitable for plants (Duponnois et al., 2005; Danilo et al., 2005; Contour-Ansel et al., 2000). For these reasons, it is reasonable to assume that termite mounds can cause trees to wither. This hypothesis is also appropriate for explaining the relationship between the lifespan of trees and the cycle of termite mounds. Generally, the duration of termite mounds, from construction to disintegration, is several decades. Meanwhile, mature mopane trees can be from 100–200 years old (Timberlake, 1999). I also observed many small trees withering in mounds in the field. Therefore, it is reasonable to assume that trees growing in termite mounds wither because of the influence of the mounds.

Termite Mounds in Mopane Vegetation

From the above observations and considerations, it seems reasonable to assume that termite mounds cause trees to wither and can suppress the germination and renewal of plants in this region. If termite mounds prevent plants from growing and cause trees to wither, a high density of mounds could be a negative factor for vegetation change in mopane vegetation. Both, however, have coexisted in this region for a long time, and it is therefore doubtful that one of them is harmful to another. The relationship between termite mounds and mopane vegetation requires further consideration.

The relationship between the specific features of mopane trees and termite mounds may be instructive in this regard. Some typical features of mopane have been outlined in previous research. First, we should focus on the relationship between termite mounds and the root system of mopane. Roux et al. (1994) pointed out that these trees have widespread shallow roots concentrating at a depth of 20–60cm underground. On the other hand, termite nests also extend widely near the ground surface. The range of nest expansion can be up to several times the area of a mound. Consequently, mopane roots are assumed to expand to share almost the same range as the termite nests. Second, mopane seeds need light to break their dormancy (Styles & Skinner, 1997; Moller, 2000). As mentioned above, the seeds of plants are unlikely to germinate on mounds because of the shape and hardness of the mounds. Meanwhile, because termites carry and save grasses and litter in their nests as food, the seeds of plants could possibly germinate in the nest. In the case of mopane seeds, however, the seeds are unlikely to germinate in the nests because they require sunlight to break their dormancy. Due to these features, mopane is strongly affected by termite mounds.

Although termite mounds seem to negatively affect plants, termite mounds may actually have positive effects on mopane vegetation due to some other features of mopane trees. Mopane have symbiotic root fungi, and these fungi assist the tree in obtaining some of its nutrient requirements. Although nitrogen-fixing activity is well known as a characteristic feature of legume plants, mopane does not have this capability (Timberlake, 1996). As mentioned above, the soil in mounds of *Macrotermes* has poor nutrients. In general, the nutrient condition of the research area where many termite mounds are located is poor. The supply of nutrients by fungi, however, may help mopane to grow under such severe conditions in comparison with other plants. Furthermore, mopane have no resistance to fire and are vulnerable to competition from other species (White, 1983). Where termite mounds coexist with mopane, a high density of termite mounds could prevent other plants from invading areas of mopane vegetation, enabling mopane to flourish for a long time. Sankaran et al. (2005) investigated the key factors involved in the coexistence of woody and grassy plants. They suggested that arid and semi-arid savannas where mean annual precipitation is less than 650mm are considered stable coexistence systems for trees and grasses, as low precipitation constrains woody plants from forming a covering canopy and permits grass to coexist with trees. As the current study indicates, the environmental condition around Ombazu village is suitable for trees and grasses to coexist. However, few grasses grow, not only on the mounds but also outside the mounds in mopane vegetation in northwestern Namibia. Therefore, it is reasonable to take other factors into account. This study suggests that termite mounds could be an important disturbance factor in mopane vegetation.

III. UTILIZATION OF TERMITE MOUNDS IN OMBAZU VILLAGE

1. How are Termite Mounds Utilized?

Zemba people call termite mounds "*otjivanda.*" They use the soil of such mounds as construction material for their huts and the base of *elao*, sacred spaces for Zemba. When they use the soil, they break down the mounds and dig a hole up to 80cm deep (Fig. 3). They mix the soil of the mound with the dung of cattle and water and smear it on the walls, which are made of mopane stems. For the roofs of their huts, they use grass, which is called *ehodhi* (one species of rice) and *engenge* (one species of reed) in Zemba. Two or three mounds are consumed in the construction of a single hut, and the total amount of the soil may reach 15–20m^3. When the walls of a hut deteriorate, people repair them using the same substances. Individuals have ownerships of some mounds, though ownership rules can be flexible.(4)

The people also use the soil for the base of *elao*, which is a sacred place where they place their holy fire. Zemba people explained that children get their name from God at *elao* a few months after their birth. People build *elao* using the soil taken from mounds. In addition to the materials used for the walls of huts, people add ash to the base of *elao*.

In this village, some children and livestock eat the soil of mounds. Children often eat the soil for a snack. Sometime I observed goats licking termite mounds on the way to their pasture. However, I could not establish any clear explanation for eating the soil in Ombazu village.

2. Effects of Utilization on the Distribution and Shape of Termite Mounds

As described above, people use termite mounds as construction material. Such utilization of mounds may affect the distribution and shape of the mounds.

The heights and diameters of mounds in this region are mostly 1–2m and 2–3m, respectively, but some mounds reach sizes of over 4m and 10m, respectively. The total area of 276 mounds accounted for 0.06% of the ground surface of the research area (2km × 3km). Calculating from the measured value of heights and diameter of all mounds in the plot, it is clear that over 1,900m³ of soil was carried above ground by termites (Table 1). Approximately 13% of the material in the 276 mounds was used by local people (Table 1). The mounds that have been used, as opposed to those remaining unbroken, are clearly recognizable and their distribution is clear (Fig. 7). My observations indicate that people tend to use the soil of mounds near their huts (Fig. 7). Therefore, tall mounds over 2m in height are located only in the southern area, far from the people's residences, and there are few tall mounds in the northern area.

Consequently, it is reasonable to assume that the utilization of termite mounds by local people has caused this non-uniform distribution in mound shape. As mentioned in the previous section, people break down many mounds

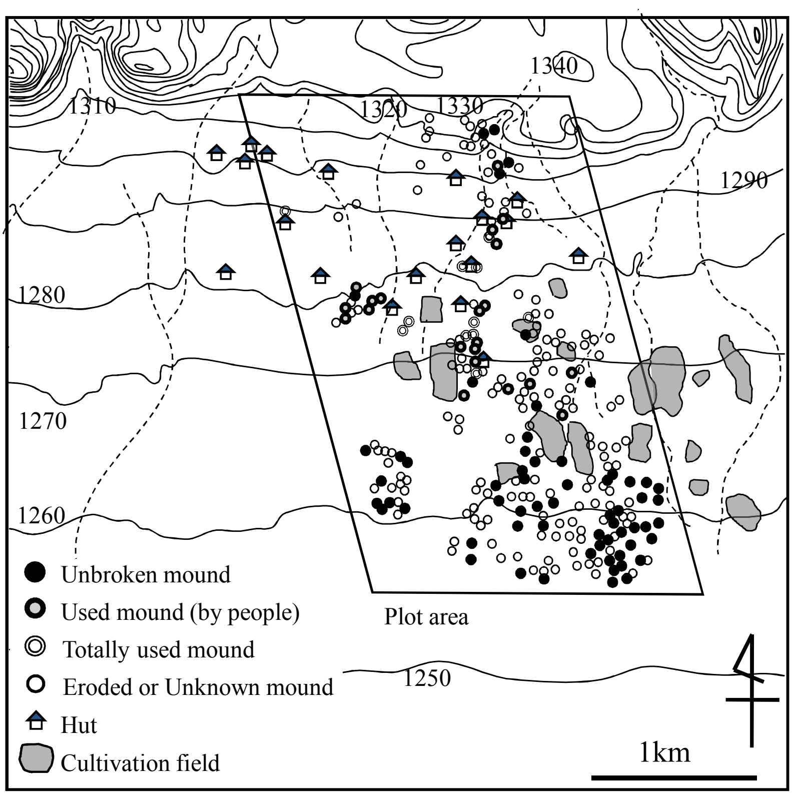

Fig. 7. Distribution map of termite mounds, specifying which are used and which are unbroken. This figure is based on a topological map issued in 1980. Contour line drawn every 10m.

Table 1. Number of termite mounds and soil amounts.

	Number of the mounds (%)	Soil amounts (m^3)	
Unused mounds*	240 (87)	1831.1	**
Used mounds	20 (7)	78.6	
Totally used mounds	16 (6)	(123.1)	***
*Tota*l	276	1909.7	

* Unused mounds include unbroken mounds and eroded mounds (in Fig.7).

** Soil amounts of unbroken and used mounds are calculated as follows:
(Soil amounts)= (the volume of termite mounds)-(the volume of tunnel in the mounds)
1. The volume of termite mounds is calculated as the volume of a circular cone, using the measured value of heights and diameter of all the mounds in the plot.
2. The volume of the tunnel follows Scott (2000):
The volume of mound : the volume of tunnel=0.94 : 0.17.

*** Soil amounts of totally used mounds are calculated as the cylindrical volume, using the measured values of depth and diameter of the holes (totally used mounds).

to use. As the one of causes of the differences in mound shape, utilization of the mounds by people may have a significant effect. In addition, people may use new mounds rather than only old ones. Although active mounds are always maintained, the mounds are eroded by wind and rain after being abandoned by termites and finally disappear. Because of the low level of precipitation in this area (under 350mm per year), the mounds erode slowly and take a long time to disappear naturally in this region. The utilization of termite mounds by local people, however, might make the time for disintegration shorter than usual.

CONCLUSION

Termite mounds seem to be a negative factor for plants in that they cause trees to wither and suppress plants' growth. If we focus on symbiotic root fungi of mopane and some features of mopane vegetation, however, a high density of termite mounds could create a suitable condition for mopane habitat, because of the adaptation capability of mopane to soil with poor nutrients and the suppression effect on other plants by termite mounds. We could also assume that termite mounds make a contribution to maintaining mopane vegetation over the long term. Therefore, termite mounds and mopane vegetation may coexist together symbiotically.

The soil of these mounds is an important resource for local people as construction material. Additionally, utilization of the soil by people may reduce the negative impact of mounds on vegetation, because people break down mounds and remove their hard surfaces. This activity could lead to better conditions for plants to grow.

Termite mounds, which form a part of the landscape of the area, could play a crucial role in the establishment of mopane vegetation. Human activities should also be taken into account as one of the factors precipitating vegetation change.

Previous research on termite mounds has identified many of the positive impacts of the mounds for plants and animals. Research has also shown how termite mounds and termites are used by people as fertilizer and food. However, the effects of termite mounds on vegetation in arid and semi-arid areas have remained unclear, and discussion about the impact of human activities as a consequence of utilizing the mounds is incomplete. This study pointed out the negative impacts of termite mounds on plants, but revealed another side of the effect of termite mounds on mopane vegetation. This study is a contribution to understanding vegetation dynamics, including the effects of termite mounds and human activities, in the semi-arid mopane savanna.

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NOTES

(1) The term "Ombazu" in the Zemba language has a meaning similar to "nature" in English.

(2) The fine and reddish sand of this area is considered to be a mixture of Kalahari and Namib sand, blown by the wind from the Kalahari and the Namib Deserts.

(3) The pan is a type of landform made by wind erosion. Limestone is accumulated inside the pan.

(4) From a case study in December 2006:
Mother and her daughter repaired their huts around the same time. Mother brought soil from the mound located near her hut, and her daughter brought soil from other mounds located far from her hut. The daughter said, "I can't use that mound because it's my mother's."

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Author's Name and Address: Chisato YAMASHINA, *Graduate School of Asian and African Area Studies, Kyoto University, 46 Shimoadachicho, Yoshida, Sakyo-ku, Kyoto 606-8501, JAPAN*

E-mail: yamashina@jambo.africa.kyoto-u.ac.jp