TREE SHAPE CLASSIFICATION AND LAND MANAGEMENT BY HAUSA FARMERS IN SAHEL REGION OF SOUTHERN NIGER

Hitomi KIRIKOSHI
African Studies Center, Tokyo University of Foreign Studies

ABSTRACT Land degradation and drought result in food shortage and malnutrition in people in Sahel region, West Africa. This paper clarifies Hausa farmers' strategies to overcome ecological vulnerabilities based on their local ecological knowledge of tree species and shapes. Hausa people recognise tree shapes by eyesight and classify them into the following four categories: *laubu*, *barau*, *matasi*, and *mayanci*, in Hausa language. *Laubu* indicates small saplings, younger than one year, whose lower branches are not cut. *Barau* indicates over two-year-old trees, whose branches are neither cut nor pollarded. *Matasi* represents small trees with pollarded branches. *Mayanci* represents big-trunk trees that are taller than millets. *Laubu* and *barau* are used for accumulating sand and preventing land degradation. *Matasi* is intended for crop protection from wind and solar heat. *Mayanci* provides shade for livestock and people. It also provides food for humans and fodder for livestock. The local farmers have ecological knowledge to manage forests by tree shape. They have innovative uses of trees for their millet fields, based on the soil condition and yield of their fields.

Key Words: Land degradation; Tree shape category; Tree management; Ecological knowledge; Hausa.

INTRODUCTION

Sahel region lies in the south edge of the Sahara Desert of West Africa. Land degradation, widely known as desertification, has been regarded as the major issue in this area after the droughts in the 1970s and 1980s (UNEP, 1992). The locals are facing chronic food shortage and malnutrition due to perennial droughts and strong erosions. This area exhibits constant ecological vulnerabilities attributable to its environmental condition.

Since the 1970s, afforestation has been recognised as an effective measure against land degradation in Sahel region, and several studies have been conducted in this regard (Weber et al., 1983; Molagnoux et al., 2007). Several projects and forest laws have been implemented to improve ecological system or living condition in this area with assistance from around the world. In the United Nations Conference on Desertification (UNCOD) held in 1977, global measures against desertification were decided to be undertaken, and several anti-desertification projects were introduced in West Africa (Thomas & Middleton, 1994: 28–30; Molagnoux et al., 2007). In the United Nations Environment Programme and the United Nations Conference on Desertification (UNEP-UNCOD) held in 1991, the cost of anti-desertification was estimated to be 292 billion US dollars; of which, 107 billion US dollars was allocated to support developing countries (Thomas & Middleton, 1994: 6–8).

Despite large investments and accumulation of activities against land degradation and food shortage in Sahel region, studies have indicated that several projects and forest laws have compressed the livelihood of the locals due to strict regulations and labour demands (Wezel & Lykke, 2006). This shows that several former projects were implemented without considering the perspective of locals. It is necessary to consider ecological knowledge, economic situation, and cultural life of the locals for sustainable development in Sahel region.

On the contrary, a few studies have focused on local practices for preventing land degradation by farmers and herders in Sahel region (Berkes et al., 2000). Additionally, Cunningham & Abasse (2005) reported a case where conservation technology from a reforestation program was shared and diffused among the locals via interaction with farmers or migrants. These cases show that people in Sahel region continue to make efforts to maintain ecological system by implementing local knowledge. Herein, I focus on one of the practices of locals for conserving environment using local ecological knowledge and their experiences.

The purpose of this study was to analyse Hausa farmers' practices and local knowledge for multi-purpose use and management of trees and clarify practical measures against land degradation and food shortage in southern Niger.

RESEARCH AREA

The research village (village D) is located in Sahel region, a belt up to 1,000 km wide that spans 5,400 km from the Atlantic Ocean to the Red Sea, and has distinct environment. Land degradation is one of the characteristics of this area. Here, I introduce geographical conditions, climate, land, soil, ethnic composition, household, and livelihood of village D.

Climate, Land, and Soil

The research area is village D located approximately 7 km from Dogondoutchi town, Department of Dosso, Republic of Niger (Fig. 1). It is an administrative and commercial centre of this area. This village is located approximately 250 km from Niamey, the capital of Niger. Village D lies in the southern edge of Sahel region. The rainy season is for four months from June to September and the dry season is for eight months from October to May. The highest temperature is more than 35°C from October to November and from February to May, often reaching over 40°C.

The climate factors in Dogondoutchi have been monitored since 1923. The average precipitation over the past 30 years was 465 mm (Direction de la Météorologie Nationale du Niger, 2010).

Desertification (land degradation) in Sahel is caused by the reduction in topsoil due to wind or water erosion (Ikazaki et al., 2011), and nutrient in soil surface gradually decreases with increasing rainfall until the end of rainy season (Suzuki et al., 2017). Village D is located on the west of inselbergs and extends downward of a gradual slope from inselbergs. The reduction in topsoil is severe upward of

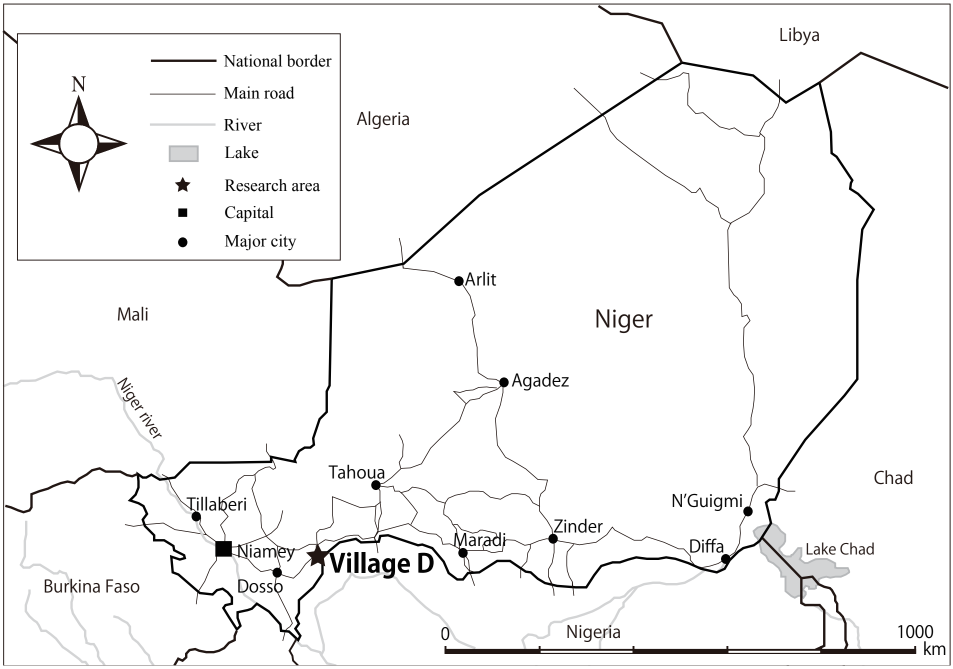

Fig. 1. Location of the research area.

the slope, and erosions (rill erosion, sheet erosion, and gully erosion) have been caused by heavy rainfall in this area. Additionally, wind erosion has caused land degradation. Because of these factors, land degradation around village D has occurred from eastward.

Hausa people recognise land from the condition of topsoil. They associate each category with land degradation progress and evaluate the nutrient state or crop productivity (Hayashi et al., 2000a; 2000b; Oyama, 2012). In village D, people describe the soil condition as follows: *kasa*, *leso*, and *foko*. *Kasa* is the soil containing high organic matter, resulting in high crop productivity. *Leso* is the soil with low nutrient content and productivity after a few years of continuous millet cultivation without manure input. *Foko* is the soil with relatively low organic matter and tight deposition of sandy soil. With degradation, the land category changes from *kasa* to *leso*, and finally to *foko*. People recognise that *foko* soil is not suitable for cultivation and that it is difficult to restore *foko* area to *kasa* area from their experience.

Ethnic Composition, Household, and Livelihood

In 2010, village D composed of 60 households with 390 people. In these households, 57 households were those of Hausa people, 2 households were of Fulbe people, and 1 household was of Tuareg people. All Hausa households engage in cultivation. Fulbe and Tuareg households also practice cultivation, but their original livelihood is herding the livestock.

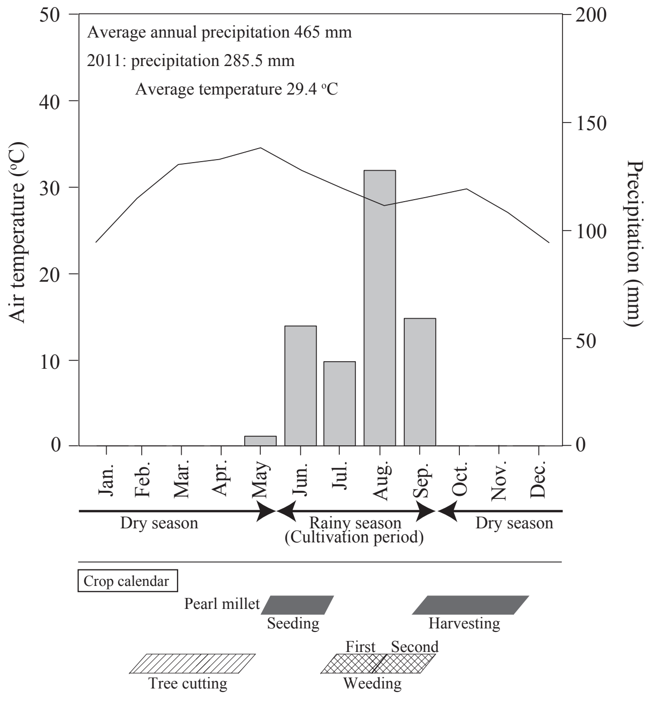

Fig. 2. Air temperature, rainfall and crop calendar.

People in village D practice rain-fed cultivation. They cultivate pearl millet (*Pennisetum glaucum*) and cowpea (*Vigna unguiculata*). As shown in Fig. 2, seeding of millet and cowpea starts in June, the onset of rainy season, and weeding is practiced twice from July to September. In October, the end of rainy season, people harvest millet and cowpea.

Rain-fed cultivation is strongly affected by annual rainfall amount and its pattern. People often face hunger; they experience food shortage in rainy season. In this village, it is necessary to manage land conditions to maintain high crop yield. People take efforts to maintain good land condition, *kasa* area, using natural resources and ecological knowledge.

RESEARCH METHOD

I conducted research in Niger since 2010, and the research period was 8 months. I stayed in village D and carried out land and vegetation surveys. The author collected ground truth data using WorldView-2 high-resolution satellite sensor image (captured on November 20, 2011; Digital Globe Inc., 0.5 m resolution) and Global Positioning System (GPS). I analysed the colour tone of the satellite image and classified the land in accordance with people's recognition (Fig. 3).

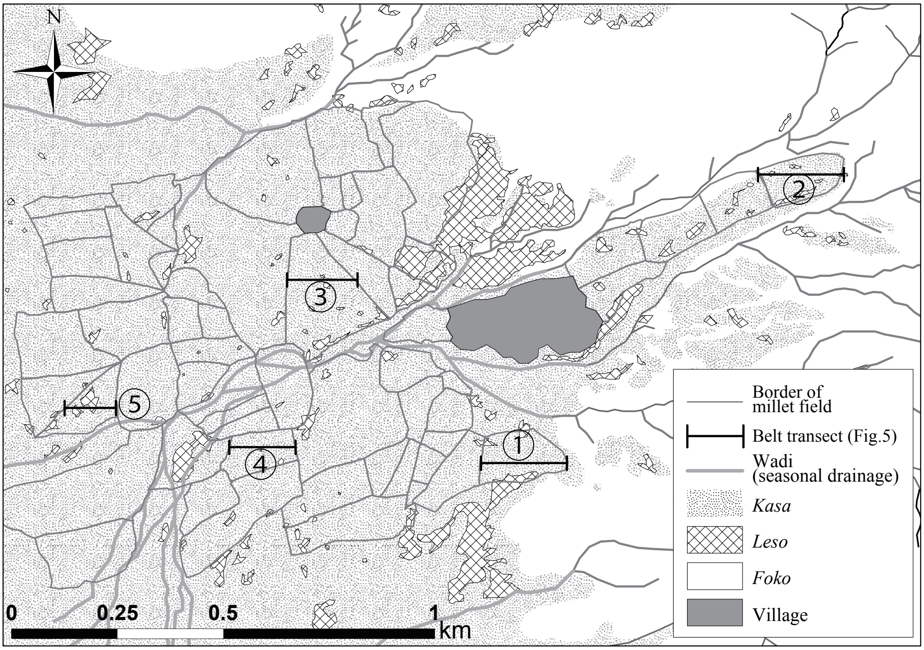

Fig. 3. Land classification and location of belt transects.

Additionally, I surveyed trees in the range displayed in Fig. 3 and counted the number of trees of each species, obtained the Hausa name, and classified them by shape (Table 1). I surveyed 4,460 trees and identified 49 species in the research area range.

I chose places where five belts transected depending on the land classification shown in Fig. 3. I made five belts of 20-m wide in the east-west direction (Belt 1: 200-m long, Belt 2: 232-m long, Belt 3: 208-m long, Belt 4: 146-m long, Belt 5: 122-m long). Each belt was set as a connecting west edge and east edge of one owner's field. I investigated elevations and depressions in the land, ethnic classification of soil, and distribution of trees in each belt.

Belts 1 and 2, located in the boundary between *kasa* area and degrading area (*leso* or *foko* area), were the places prone to become less nutrient areas due to wind and water erosions. Belts 3 and 4 are the places with good management, including weeding and others, by the land owners. Belt 5 is a field abandoned for over four years, because the owner is an old woman who could not manage the land.

First, I investigated simple topography of the land by a hand level in each belt, and obtained the information of distribution of trees, breast height diameter of trunks, and height from ground to branches. Additionally, I researched the local name of trees, ethnic classification of tree shapes, and land condition. I conducted these investigations with the support of four men of village D and obtained local ecological knowledge from them.

Table 1. Observed number of trees of each species, Hausa name, and shape classification.

	Species	Hausa name	Number of trees in millet fields				
			Laubu	*Barau*	*Matasi*	*Mayanci*	Total
1	*Guiera senegalensis*	*sabara*	1,089	198	313	34	1,634
2	*Piliostigma reticulatum*	*kalgo*	561	48	1,380	384	1,373
3	*Combretum micranthum*	*geza*	35	65	8	6	114
4	*Balanites aegyptiaca*	*aduwa*	79	61	28	129	297
5	*Cassia sieberiana*	*malga*	14	15	27	47	103
6	*Faidherbia albida*	*gao*	2	2	38	183	225
7	*Azadirachta indica*	*mili*	2	20	24	55	101
8	*Croton zambesicus*	*koriba*	0	0	2	5	7
9	*Sclerocarya birrea*	*danya*	22	7	26	61	116
10	*Annona senegalensis*	*gwada*	72	7	33	4	116
11	*Acacia nilotica*	*bagaruwa*	1	7	10	18	36
12	*Mimosa asperata*	*gumbi*	0	1	0	1	2
13	*Borassus aethiopum*	*kaba*	16	19	0	17	52
14	*Ziziphus mauritania*	*magariya*	27	7	10	3	47
15	*Combretum glutinosum*	*taramuna*	7	2	10	16	35
16	*Dichrostachys cinerea*	*dudun*	28	4	4	1	37
17	*Calotropis procera*	*tonfahiya*	10	7	10	1	28
18	*Entada africana*	*batara*	8	6	6	3	23
19	*Bauhinia rufescens*	*driga*	8	5	7	7	27
20	*Tamarindus indica*	*tsamiya*	1	0	1	6	8
21	—	*shibrishibri*	4	6	1	2	13
22	*Albizia chevalieri*	*katsari*	5	2	4	3	14
23	—	*shama*	1	1	4	5	11
24	*Acacia senegal*	*akwara*	0	2	5	0	7
25	—	*tsakulukulu*	0	1	0	0	1
26	—	*miyafa*	0	0	7	0	7
27	—	*gaude*	0	1	1	4	6
28	*Pterocarpus erinaceus*	*madobia*	0	0	0	0	0
29	*Grewia* spp.	*grudugu*	0	0	1	0	1
30	*Cadaba farinosa*	*bagai*	0	1	0	1	2
31	*Combretum nigricans*	*tsiriri*	2	0	0	1	3
32	—	*tsa*	3	1	0	0	4
33	*Boscia angustifolia*	*agajini*	0	0	0	0	0
34	*Combretum aculeatum*	*bubukiya*	3	0	0	0	3
35	*Detarium microcarpum*	*tagara*	0	0	3	0	3
36	—	*takwasaramadawa*	0	0	0	0	0
37	—	*maburukaki*	0	0	0	0	0
38	*Acacia macrostachya*	*gardaye*	0	0	0	0	0
39	*Boscia senegalensis*	*anza*	0	0	0	0	0
40	*Grewia bicolor*	*daraza*	0	0	0	0	0
41	*Mangifera indica*	*mangaro*	0	0	0	0	0
42	*Carica papaya*	*gonda*	0	0	0	1	1
43	*Euphorbia balsamifera*	*kwaka*	0	0	0	0	0
44	*Prosopis africana*	*krinya*	0	0	0	0	0
45	—	*dagarmi*	0	0	0	0	0
46	*Strychnos spinosa*	*kokiya*	0	0	0	0	0
47	—	*kamomoa*	0	0	1	0	1
48	*Adansonia digitata*	*miya-kuka*	0	0	1	0	1
49	—	*babursa*	0	0	0	1	1
	Total		2,000	496	965	999	4,460

—: unknown

RECOGNISATION AND EXPECTED EFFECT OF TREES BY THE LOCALS

Hausa people use trees grown in fields as food and animal fodder, and also to prevent land degradation. The locals mentioned that 'trees maintain good soil condition if you maintain trees in appropriate condition,' and emphasised not only on the species but also on the tree shape. They recognise the tree shape by eyesight and classify them into four categories (Fig. 4), and expected particular effects of tree shapes in their millet fields.

The trees were characterised as follows (Fig. 4). *Laubu*: small saplings, younger than one year old, whose lower branches were not cut. *Barau*: over two-year-old trees, whose branches are neither cut nor pollarded. *Matasi*: small trees with pollarded branches. *Mayanci*: big-trunk trees taller than millets.

Laubu grows to become *barau*. The trees of *laubu* or *barau* become *matasi* if the lower branches are pollarded. *Matasi* will become *mayanci* when the tree is pollarded, but the tree will be *barau* if it is not pollarded. The classification of trees changes by growth or pollarding. The distribution of trees in the belt transects, as shown in Fig. 5, indicates the recognition and expectation of Hausa people of trees in millet fields. The east end of the belts was aligned according to the recognition that land degradation is progressing from the east. Here, I will specify the recognition and expectation of people for each tree classification.

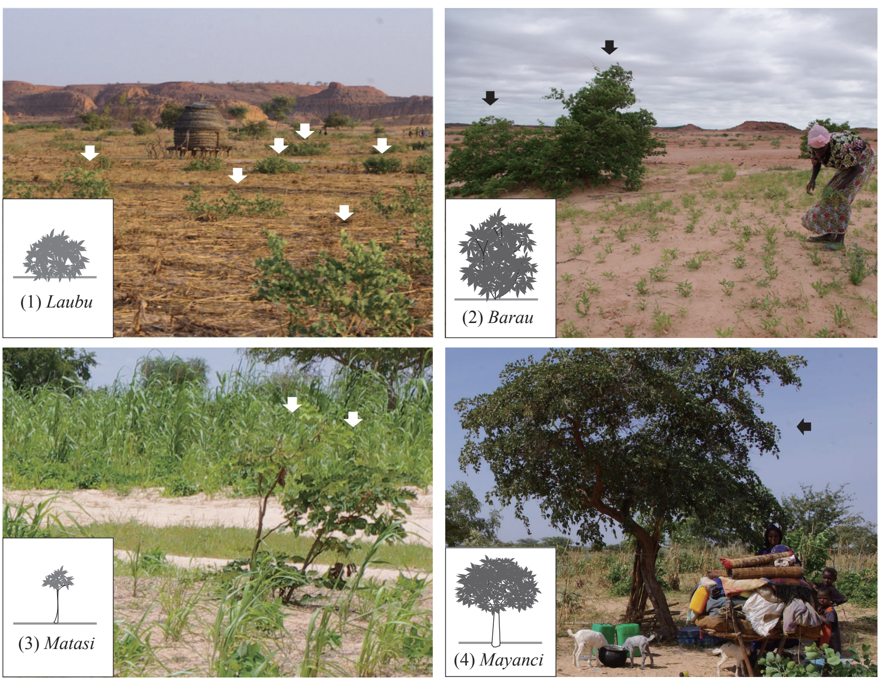

Fig. 4. Tree shape classification of Hausa.
(1) *Laubu*: small saplings, younger than one year old, whose lower branches are not cut. (2) *Barau*: over two-year-old trees, whose branches are neither cut nor pollarded. (3) *Matasi*: small trees with pollarded branches. (4) *Mayanci*: big-trunk trees taller than millets.

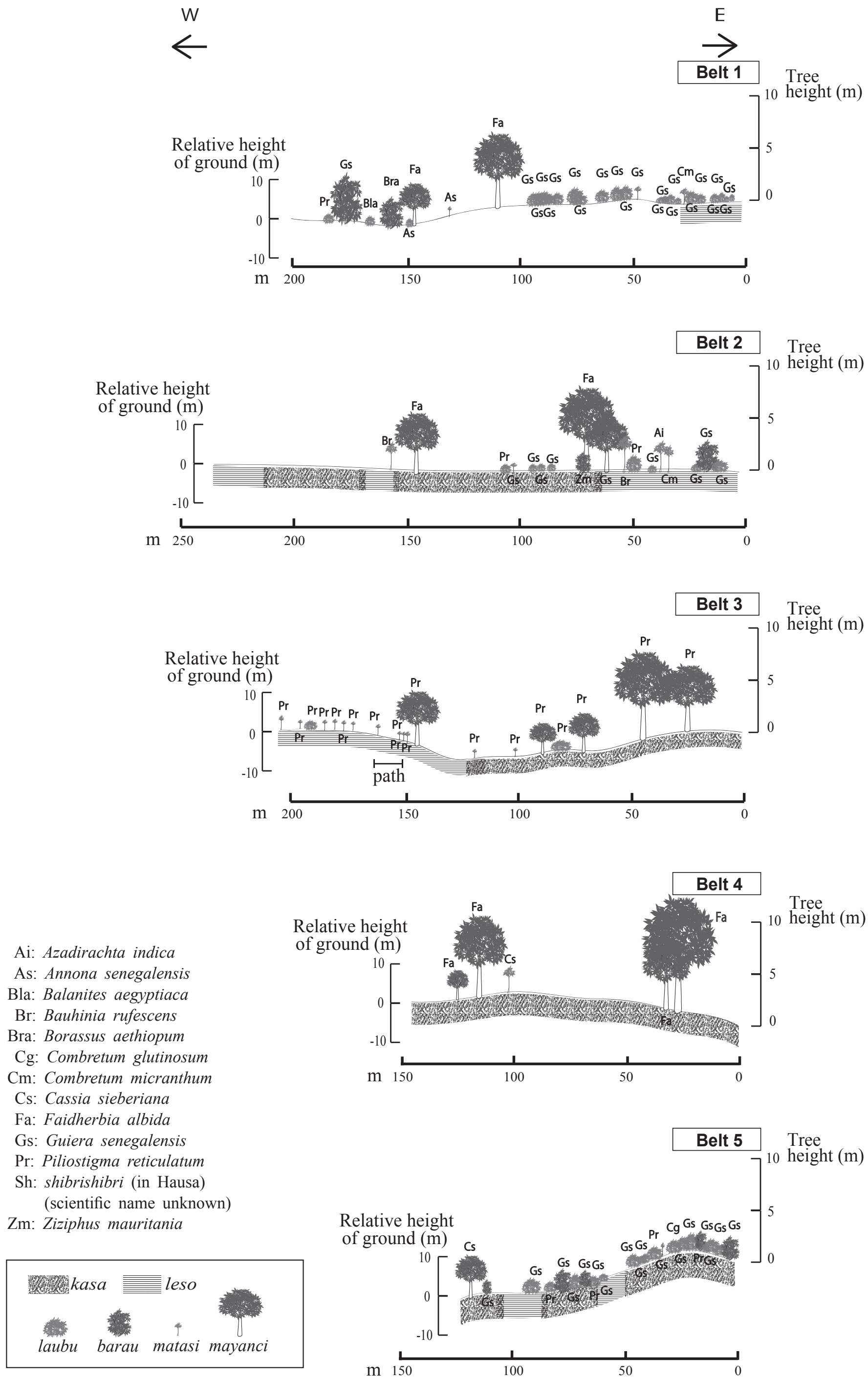

Fig. 5. Distribution of trees in five belt transects.
Distribution of soil indicates the surface condition of the lands.

Laubu

Laubu is the shrub covering ground. '*Laubu*' means trees sprouted from rhizomes or stubs, or small trees of less than one year from germination (Fig. 4). Hausa people cut trees in millet fields every year before seeding, from February to April. However, they leave the rhizomes in expectation of tree sprouts. A large number of *laubu* trees in millet fields were *Guiera senegalensis*, *Piliostigma reticulatum*, and other species, which sprout smoothly. Forty of 51 *laubu* trees were *G. senegalensis*, and eight were *P. reticulatum* in the vegetation surveys.

In the survey on the recognition of *laubu* in millet fields, people mentioned that their first expectation from *laubu* in millet fields is trapping sands blown by wind and the second is prevention of soil eroded by rain or wind. They emphasised the importance of trapping sand. In Belts 1 and 2, which were located in the boundary between fertile (*kasa* area) and degrading areas (*leso* or *foko* area), *laubu* trees were distributed every 1–10 m in a 100-m range from the east edge of each belts. These *laubu* trees were *G. senegalensis* or *P. reticulatum* of 0.5–1.0 m long (Fig. 5).

People mentioned *laubu* trees can cool the ground. Millets grow well in the field with *laubu* trees. They expect that *laubu* trees prevent an increase in ground temperature during periods of drought. In Belt 3, which was evaluated to have good management, *laubu* trees of *P. reticulatum* of height 0.5 m were left at 80–190 m point as a countermeasure against periods without rainfall.

Barau

Barau is the bush widely covering ground and is left for more than two years without pollarding (Fig. 4). A large number of *barau* trees were *G. senegalensis* in the degrading areas, *leso* and *foko*.

Barau is evaluated as an efficient tree shape to trap blown sand and to protect crops from strong wind. People expect *barau* trees to capture sand and protect crops. Several *barau* trees were observed in Belts 1 and 2, which were located in the boundary between *kasa* area and degrading area. *Barau* trees of *G. senegalensis* and *Borassus aethiopium* of height 3.0–5.0 m were observed in the 150–180 m range from the east edge of Belt 1 (Fig. 5). In Belt 2, *barau* trees of *G. senegalensis* and *Ziziphus mauritiana* were observed in the 0–70 m range from the east edge (Fig. 5).

Insect damage by desert locusts in Sahel region has been reported by several studies (Sanchez-Zapata, 2007; FAO, 2012). Insect damage has caused significant reduction in crop yield and serious food shortage in the past. People are aware of the danger with the existence of *laubu* and *barau* trees in millet field, besides the importance of these tree shapes. They called the bush of *laubu* and *barau* as *gidan fara*, 'the house of desert locusts' in Hausa language.

According to the locals, the bush of *laubu* and *barau* can act as a habitat for desert locusts. Therefore, they believe that it can be a cause of reproduction of desert locust if the bush of *laubu* and *barau* is more than required.

The condition of *laubu* and *barau* directly influences the management of millet fields because it is associated with the infestation of desert locusts. Sixteen *laubu* trees and five *barau* trees were observed in Belt 5 located in deserted cultivated land. The distribution density of *laubu* trees and *barau* trees in Belt 5 was comparatively higher than that in the other belts, and people mentioned that it is a bad management condition because the land consists of only *laubu* and *barau* trees. Besides, *barau* was not observed in Belts 3 and 4 with good management condition.

Matasi

Matasi is a small tree pollarded under branches to prevent the formation of bush. It is recognised as the tree in the process of growing into *mayanci* (Fig. 4).

According to the land owner of this millet field, *matasi* observed at a 100-m point from Belt 4 is the tree managed to grow into *mayanci*. Twelve *matasi* trees of *P. reticulatum* were observed in Belt 3. *P. reticulatum* is a species that sprouts and grows smoothly from rhizomes.

People do not expect *matasi* to have significant effects on millet fields, but they recognise that *matasi* can protect crops from wind and ground temperature increase not allowing the reproductions of desert locusts. As shown in Fig. 5, *matasi* trees were observed in *leso* area of Belt 2 (0–70-m range) and Belt 3 (100–208-m range). *Leso* area, early phase of land degradation, is vulnerable to wind and ground temperature effects. *Matasi* is required especially in *leso* area of millet fields.

Mayanci

Mayanci is the tree taller than millet and has a thick trunk (Fig. 4). *Mayanci* tree of *Cassia sieberiana* was used as shade tree by farmers in Belt 5. *C. sieberiana* is a suitable species providing good shade with big leaves. In Belt 4, located in non-degrading area, only *mayanci* of *Faidherbia albida* is used as a shade tree and *matasi* trees of *C. sieberiana* growing into *mayanci* were observed (Fig. 5).

The big trees of *mayanci* are necessary to make a contract with pastoral people. The contract is to set up camps in the fields of their farming partners for several weeks to provide domestic animal excreta, improving soil fertility in their fields (Shinjo et al., 2008; Oyama, 2012). Pastoral people require *mayanci* tree for the contract because they make camp near a suitable shade tree. The field in Belts 1–4 meet the condition for the contract because of the existence of *mayanci* trees.

Females of village D use the leaves and fruits of *mayanci* as food and livestock fodder, or cash crops to earn money for food. However, people recognise that *mayanci* trees shield the sunlight and have the danger of reducing crop yield. The owners of fields have to maintain the space for crops and manage the density of *mayanci* with considerable usability for their life. In the field of Belts 2–4, *mayanci* of *F. albida* or *P. reticulatum* of height more than 5 m were observed at the interval of 100 m (Fig. 5). Females of the village obtain leaves and fruits from these trees during long dry season.

DISCUSSION: MULTI-TREE USE IN FIELDS AND FUTURE TASKS

Forests in cultivated fields are widely found in the savanna area and people utilise useful trees for their survival. Several studies have focused on vegetation in cultivated fields and discussed the selection and growing method of useful trees (Pearce, 1988; Bielders et al., 2002). Herein, I have clarified that the locals categorise trees into four types based on shape and expect specific effects of each shape category. I showed the importance not only tree species but also tree shapes, in degrading area of Sahel region.

Additionally, it is necessary to consider using wild trees in cultivated fields. Since the 1970s, afforestation has been recognised as an effective measure against land degradation in Sahel region (Weber et al., 1983; Molagnoux et al., 2007). However, several afforestation projects failed due to severe environment and unsuitable method for locals' life. On the other hand, some local greening techniques are reported. These local techniques are based on indigenous knowledge and daily practices, for example inputting trash from their homesteads, livestock corralling, and establishing fallows (Suzuki et al., 2014; Oyama, 2015). Some of these practices were developed by villagers in 1973 and 1974, the period of severe drought and famine (Oyama, 2018). Additionally, local knowledge shows the sustainability of land management applying wild trees.

The bush shapes, *laubu* and *barau*, are required to prevent land degradation or to trap blown sand. In the research area, the wind of Harmattan containing dust blows from north east in dry season from December to February. In the survey, it was observed that the bush of *laubu* and *barau* catches blown sand by Harmattan. It is obvious that *laubu* and *barau* act as sand trap as expected by people because deposition of dust was observed under the trees of *laubu* and *barau* in dry season.

Trees of *mayanci* have an indirect effect of fertilising fields. They act as shade trees for making contract with pastoral people. Approximately 0.6–2.0 kg/m^2 animal excreta was observed in a contract period in the fields with *mayanci* trees. Enough accumulation of animal excreta makes fertile land. Suzuki et al. (2014) mentioned that animal manure is important for the improvement of the fertility of Sahelian soils, and corralling is economical and useful practice for locals in Sahel region. Additionally, *mayanci* is expected to provide leaves and fruits as food or animal fodder to villagers. The collection amount by female in the village was as follow: 5.0–35.0 kg of *Balanites aegyptiaca* leaves as food, 20–150 kg of *F. albida* leaves as animal fodder. These collections were used as the livelihood strategies of each household.

Trees in fields were recognised as having dangers of preventing crop growth besides expectation on various specific effects to improve land condition and crop yields. If people hope to grow trees into *mayanci*, they have to pollard branches suitably to prevent obstruction to crop cultivation. Tree training to grow into *mayanci* is the management method equivalent to training of *F. albida* in the Sereer society of Senegal (Hirai, 2017). People pollard branches every two or three weeks and manage *matasi* as an investment to the future because they recognise various positive effects of *mayanci*.

In Sahel region, rapid population growth and narrowing cultivated fields are occurring concurrently with land degradation and drought. People retain and manage trees in their fields to survive in the severe environment of Sahel region. However, it is necessary to validate the evidence based on quantitative data to discuss land degradation and tree management in Sahel region. We should continue to investigate the effects of tree management and use by people.

ACKNOWLEDGEMENTS I would like to express my gratitude to the financial support via the Kondo Grant from the Asahi Glass Foundation for Environmental Research (23-74) and the Japan Geographic Data Center (AY2012). I also acknowledge that this work was supported by the Environment Research and Technology Development Fund by the Ministry of the Environment (E-1002), RIHN Research Project 'Desertification and Livelihood in Semi-Arid Afro-Eurasia' of the Research Institute for Humanity and Nature, and Grants-in-Aid for Scientific Research of Japan Society for the Promotion of Scientists (JSPS KAKENHI Grant Numbers 13J02096, 17H04506, 18H03439, 19K20517) to conduct fieldworks.

REFERENCES

Berkes, F., J. Colding & C. Folke 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, 10: 1251–1262.

Bielders, C.L., J.L. Rajot & M. Amadou 2002. Transport of soil and nutrients by wind in bush fallow and traditionally managed cultivated field in the Sahel. *Geoderma*, 109: 19–39.

Cunningham, P. & T. Abasse 2005. Reforesting the Sahel: Farmer managed natural regeneration. In (A. Kalinganire, A. Niang & A. Kone, eds.) *Domestication des espèces agroforestières au Sahel: Situation actuelle et perspectives*, pp. 1–6. ICRAF Working Paper, ICRAF, Nairobi.

Direction de la Météorologie Nationale du Niger 2010. *Annual Data 2010*. Direction de la Météorologie Nationale du Niger, Niamey.

Food and Agriculture Organization of the United Nations (FAO) 2012. *The Food and Nutrition Crisis in the Sahel: Urgent Action to Support the Resilience of Vulnerable Populations 'Desert Locust Threat in the Sahel'*. FAO, Rome.

Hayashi, K., O.O. Fashola, T. Masunaga & T. Wakatsuki 2000a. Indigenous soil knowledge for sustainable agricultural development in the Sahel zone of Niger, West Africa 1: Soil quality characterization of a small inland valley watershed. *Tropics*, 9: 245–258.

——— 2000b. Indigenous soil knowledge for sustainable agricultural development in the Sahel zone of Niger, West Africa 2: Indigenous soil classification system. *Tropics*, 9: 259–273.

Hirai, M. 2017. Changes and local adjustment in the *Faidherbia albida* use as fodder and fuelwood among the Sereer, Senegal. *African Study Monographs*, 38: 27–49.

Ikazaki, K., H. Shinjo, U. Tanaka, S. Tobita, S. Funakawa & T. Kosaki 2011. "Fallow band system," a land management practice for controlling desertification and improving crop production in the Sahel, West Africa 1: Effectiveness in desertification control and soil fertility improvement. *Soil Science and Plant Nutrition*, 57: 573–586.

Molagnoux, M., E.H. Sène & N. Atzmon 2007. Forests, trees and water in arid lands: A delicate balance. *Unasylva*, 58: 24–29.

Oyama, S. 2012. Land rehabilitation methods based on the refuse input: Local practices of

Hausa farmers and application of indigenous knowledge in the Sahelian Niger. *Pedologist*, 55(3): 466–489.

——— 2015. Land degradation and ecological knowledge-based land rehabilitation: Hausa farmers and Fulbe herders in the Sahel region, West Africa. In (T. Reuter, ed.) *Averting a Global Environmental Collapse: The Role of Anthropology and Local Knowledge*, pp. 165–185. Cambridge Scholars Publishing, Newcastle upon Tyne.

——— 2018. Reverse thinking and "African potentials" to combat desertification in the West African Sahel: Applying local greening techniques born from drought and famine in the 1970s. *African Study Monographs Supplementary Issue*, 57: 95–120.

Pearce, D. 1988. Natural resource management and anti-desertification policy in the Sahel-Sudan zone: A case study of gum arabic. *Geojournal*, 17: 349–355.

Sanchez-Zapata, J.A. 2007. Desert locust outbreaks in the Sahel: Resource competition, predation and ecological effects of pest control. *Journal of Applied Ecology*, 44: 323–329.

Shinjo, H., K. Hayashi, T. Abdoulaye & T. Kosaki 2008. Management of livestock excreta through corralling practice by sedentary pastoralists in the Sahelian region of West Africa: A case study in southwestern Niger. *Tropical Agriculture and Development*, 52: 97–103.

Suzuki, K., R. Matsunaga, K. Hayashi, N. Matsumoto, R. Tabo, S. Tobita & K. Okada 2014. Effects of traditional soil management practices on the nutrient status in Sahelian sandy soils of Niger, West Africa. *Geoderma*, 223–225: 1–8.

Suzuki, K., R. Matsunaga, K. Hayashi, N. Matsumoto, S. Tobita, A. Btiono & K. Okada 2017. Effects of long-term application of mineral and organic fertilizers on dynamics of nitrogen pools in the sandy soil of the Sahel region, Niger. *Agriculture, Ecosystems and Environment*, 242: 76–88.

Thomas, D.S.G. & N.J. Middleton 1994. *Desertification Exploding the Myth*. John Wiley & Sons, New York.

United Nations Environment Programme (UNEP) 1992. *World Atlas of Desertification*. Edward Arnold, New York.

Weber, F.R., F.J. Nolman & V.C. Palmer 1983. *Reforestation in Arid Lands, Appropriate Technologies for Development: Manual M-5*. Peace Corps, Washington D.C.

Wezel, A. & A.M. Lykke 2006. Woody vegetation changes in the Sahelian West Africa: Evidence from local knowledge. *Environment Development and Sustainability*, 8: 553–567.

——— Accepted *July 8, 2019*

Author's Name and Address: Hitomi KIRIKOSHI, *African Studies Center, Tokyo University of Foreign Studies, 3-11-1 Asahi-cho, Fuchu-shi, Tokyo 183-8534, JAPAN.*

E-mail: hitomi_kirikoshi [at] tufs.ac.jp