Chapter 1

Sustainable Agricultural Development of West Africa during Global Environmental Crises

1. Peoples and history of West Africa

1-1. Countries and peoples of West Africa

West Africa contains 16 countries: Benin, Burkina Faso, Chad, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo (Fig. 1-1). Influenced by the suzerain states in the colonial years, English is an official language in five of these countries (Nigeria, Ghana, Sierra Leone, Liberia, and Gambia) and French, in 10 other countries. In Guinea-Bissau, Portuguese is spoken. But as shown in Fig. 1-2, there are so many diverse local languages spoken by West African peoples (Church, 1974). The distribution of these languages does not coincide with the borders of countries because of the influence of the old colonial regimes.

In West African countries, *Nigeria* is an outstanding example. As Table 1-1 shows, its population in 1998 is estimated at 106 million (FAO, 1998). West Africa's total *population* that year was about 216 million, which means that about a half were Nigerians. Ghana has a population of 19 million. Of all sub-Saharan countries in tropical Africa, the country having the second largest population after Nigeria is the Democratic Republic of the Congo (DRC) but its population was about 49 million in 1998; this clearly shows what a large population Nigeria has, compared with other African countries. Fig. 1-3 shows the distribution of *population densities* in West Africa based on the Times Atlas of The World, 9th edition (1992). A comparison between this figure and Fig. 1-2

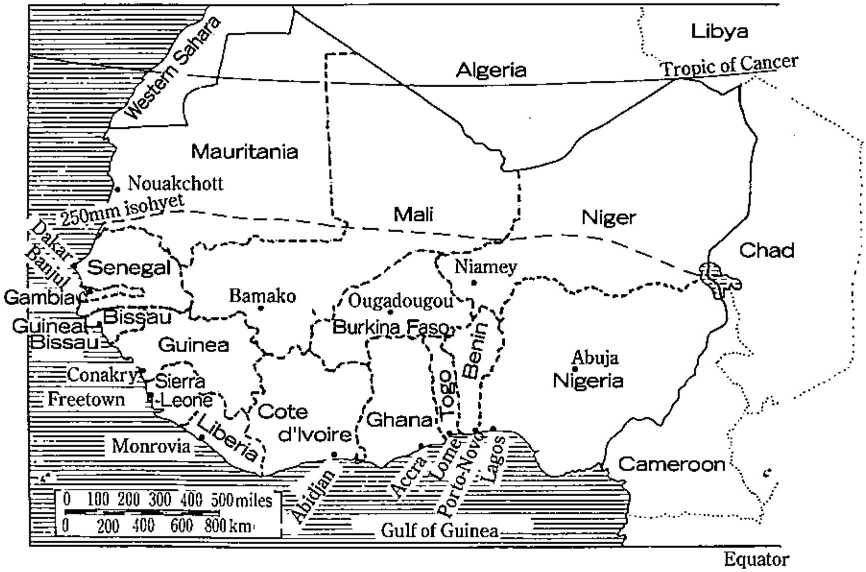


Fig. 1-1 West African countries

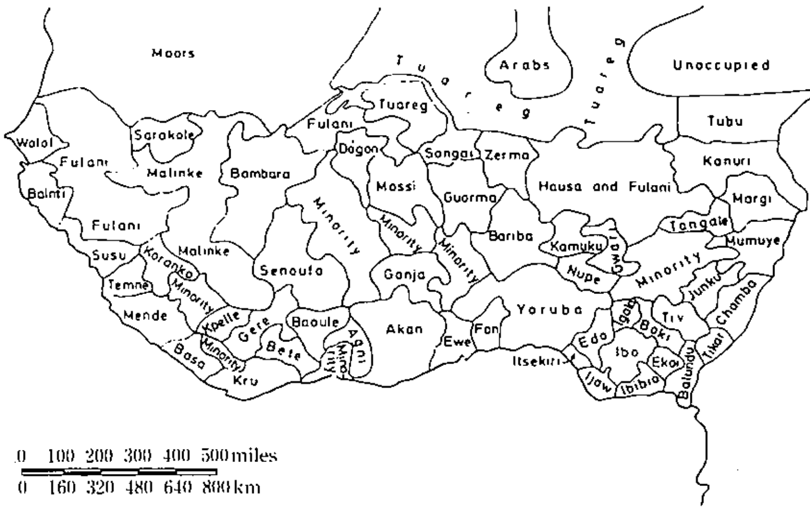


Fig. 1-2 Distribution of main languages in West Africa (Church, 1974)

Table 1-1 Change in population and agricultural productivity of West African countries, 1975 to 1999. (FAOSTAT, 2001)

	1975				1990				1999				
	Total pop. (×10,000)	Agro pop. (%)	PIN(Net per capita)*		Total pop. (×10,000)	Agro pop. (%)	PIN(Net per capita)**		Total pop. (×10,000)	Agro pop. (%)	Population density (hbt/km²)	PIN(Net per capita)**	
			Crops	Livestocks			Crops	Livestocks				Crops	Livestocks
Benin	305	74.2	64.4	89.0	466	63.5	153.1	112.9	594	55.0	55.2	215.5	97.6
Burkina Faso	611	92.1	85.7	76.8	906	92.4	107.0	132.0	1,162	92.2	42.5	125.1	143.8
Chad	403	90.1	110.8	96.2	575	83.2	80.7	103.5	746	76.1	5.9	108.3	98.2
Cote d'Ivoire	676	70.2	106.9	90.9	1,164	60.0	95.6	111.0	1,453	50.4	45.7	98.6	104.6
Gambia	55	85.6	200.6	162.8	92	82.0	40.2	60.9	127	79.3	126.8	46.6	51.0
Ghana	983	60.6	131.5	101.5	1,513	58.6	60.8	97.4	1,968	56.4	86.5	102.7	77.4
Guinea	415	91.6	117.7	152.6	576	87.2	85.0	65.2	736	84.2	30.0	97.1	74.6
Guinea-Bissau	63	88.4	92.9	101.7	97	85.3	111.7	98.7	119	83.1	42.2	114.0	98.5
Liberia	161	78.5	167.7	103.2	258	72.3	54.8	96.0	293	68.1	30.4	62.6	87.1
Mali	617	90.9	86.4	92.6	884	85.8	108.2	107.1	1,096	81.5	9.0	133.4	106.4
Mauritania	137	78.0	74.0	99.8	203	55.2	110.5	102.7	260	53.1	2.5	149.7	77.0
Niger	477	92.1	85.4	124.2	773	89.9	117.4	79.8	1,040	88.1	8.2	129.7	76.9
Nigeria	5,700	62.5	88.8	87.4	8,703	43.0	109.5	116.0	10,895	34.2	119.6	141.4	116.4
Senegal	481	81.7	212.2	85.5	733	76.7	44.3	115.4	924	74.0	48.0	41.7	128.4
Sierra Leone	293	72.6	110.1	95.9	399	67.5	90.2	104.9	472	62.7	65.9	59.9	101.5
Togo	229	71.6	99.4	84.6	351	65.6	100.7	123.2	451	60.3	83.0	115.9	108.9
West Africa	11,229	70.5	110.4	98.9	17,152	58.0	86.0	101.5	21,630	51.8	29.6	97.3	99.6
Africa	40,588	70.5	111.7	100.5	61,477	60.9	86.9	99.9	76,663	56.2	25.9	92.5	96.2
South America	21,614	36.5	89.5	88.6	29,509	23.3	110.2	113.0	34,075	18.8	19.4	128.7	134.4
Asia	235,483	66.1	82.5	60.1	311,381	59.2	122.4	166.1	363,428	53.8	117.8	138.7	244.9
Japan	11,152	14.0	127.8	75.7	12,354	7.2	79.6	131.8	12,651	4.2	336.0	68.0	121.5

Note: 1)*Net Production index number based on 1989-91 as 100
2)**Net Production index number based on 1975 as 100 (FAO 2001)

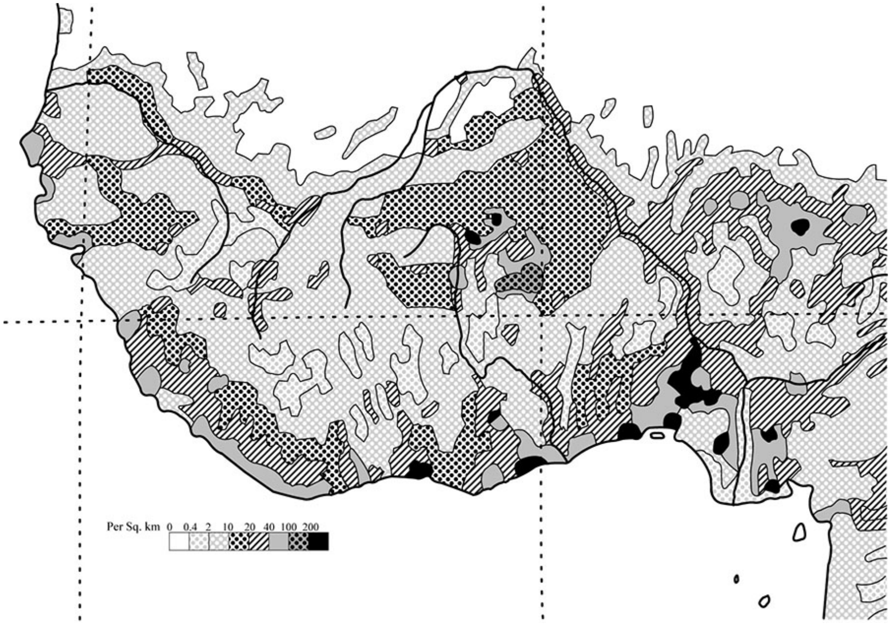


Fig. 1-3 Distribution of population density in West Africa
(reproduced partly from The Times Atlas of the World 1992, Barthlomew and Times Books)

showing the *distribution of main West African languages* reveals that population is concentrated in the areas of Nigeria's three largest ethnic groups (*Yoruba, Hausa* and *Igbo*), the *Mossi* area of Burkina Faso/ northeastern Ghana, and the Akan Ashanti area in Côte d'Ivoire and Ghana, and the *Ewe* area in Ghana and Togo (Church, 1974).

But owing to unstable political and social situations, no reliable censuses have been conducted in West Africa in many cases, and many countries estimate their population by multiplying the population at the time of independence by a given annual growth ratio. According to a census carried out in Nigeria in 1993 for the presidential election, the country's actual population was then only 80 million. But the census data are not so reliable, either. Since population statistics, which should be the most basic data of a country, are at such an undependable level in most of West Africa untill now, it should be noted in advance that the various agricultural statistics used here may contain not a few major errors (Shimada 1996).

1-2. West Africa's history of constant suffering

Around the eighth century, the Ghana Empire prospered in the region from the Senegal River to the inland delta of Niger, followed by the Mali Empire in the eleventh to fifteenth centuries and the Songhai Empire in the fifteenth to sixteenth centuries. It is said that these empires enjoyed prosperity from the trade in rock salt and gold across the Sahara. But there have not been many studies on the agricultural basis that supported them except for interesting reports by Takezawa (1984) and Shimada (1988, 1992). They emphasize the importance of *African rice* (*Oryza glaberrima*) that was first brought into cultivation in this region 2000 to 4000 years ago. In Nigeria, too, the *Hausa* constructed highly developed Islamic city-states in Kano, Katsina, Zaria, and other central and northern parts in the eleventh to fourteenth centuries. In its southeast, the Yoruba built a *holy city* in Ife and then created city-states in Oyo, Abeokuta and other locations.

But in the fifteenth century, the Portuguese began to surge into this region, followed by other Europeans, including the Spanish, the Dutch, and the British. The Songhai Empire had boasted of its large territory but was destroyed in 1591 by the guns of the Moroccan army. Europeans started the Atlantic slave trade ; they bought African slaves from the kings of these city-states in exchange for guns and sold them to the New World. Slaves and *slave trade* provided European countries before the Industrial Revolution with some of the motive power for development(Segal 1995). The trade radically destroyed communities in West Africa. Slave-hunting-battles using guns continued among African peoples and young African men and women, who were the most active and energetic, were lost from the Continent, mainly from the western parts. West Africa's history in the period 1500-1900 was that of guns and the slave trade. In those four centuries, a total of between 12 and to 20 million Africans were transported to the New World (Hugh 1997, Miyamoto and Matsuda 1997). In some of the worst cases, four out of five of them world lane had been died before arrival in the new world (Yoneyama, 1986). If we include the loss of life of slaves during transatlantic "transportation (*Diaspora*)" and hunting in West African countries, the estimated numbers of 12-20 million are very conservative. Far more young active people were lost from West Africa during those four centuries.

In sub-Saharan tropical Africa, only elderly people were left behind, just as in sparsely populated mountain villages and isolated islands in Japan today. Residents in the villages where young people had been taken away had no alternative but to devise shifting cultivation, slash and burn, which was highly dependent on the natural environment, because they had to cultivate a vast area of land with limited labor (Yoneyama, 1990). The destruction of a large amount of human resources by the slave trade and resultant community disruptions, together with subsequent deforestation and the destruction of farming resources by colonial rules and forced cash crop plantations, were the first cases of global environment disruptions and still remain the legacy of those times. These may be the main causes of stagnant agriculture in Africa.The West's modern civilization and modern science in the age of Christopher Columbus and afterwards developed these the sacrifice of Africa and the global environment. Here is the reason why Japan, which has benefited from modern civilization and modern science from Europe and America, should place efforts to protect the global environment and revitalize Africa in the central position of its international contribution for creating a new global community during the twenty-first century.

It was after 1807 that cruel slave trade was abolished. But then *colonial rule* in Africa was started by European countries, mainly Britain and France. It was an attempt to secure natural resources and inexpensive labor that Western countries needed in the age of the Industrial Revolution. It is said that nearly 800 ethnic groups live in Africa. They have languages, customs, and traditions that differ from one another. But European countries totally ignored the position of African peoples. They continued their invasions and battles for colonies, first by sending explorers and missionaries and then by using military force. As a result, Africa was divided at the Berlin Conference on the political partitioning of Africa. This resulted in the Treaty of Berlin, as Europeans liked it. The borders agreed then were used as the boundaries of African countries that became independent after World War II. Because of this, the ethnic groups who had long shared the same languages, customs, and cultures were cruelly separated in different countries. For example, as Fig. 1-2 shows, *Ewe* was torn apart in Ghana and Togo, *Yoruba* in Nigeria and Benin, *Wolof* in Senegal and Gambia, *Hausa* in Nigeria and Niger, and *Fulani*, a pastoral people, in Gambia, Guinea-Bissau, Guinea, Mali, Niger, and Nigeria. Behind the repeated occurrence of civil wars and coups d'etat, including the disturbances in the Congo in 1960 and again in the 1990s, the civil war in Nigeria in 1967, also known as the Biafran War, the civil war in Liberia that started in 1990, and the Tutsi-Hutu rivalries in Rwanda that erupted in 1994 and caused large-scale genocide, lie the after-effects of colonial division and the tribal opposition developed during the *divide* *and rule* era. Another serious problem is that the borders were artificially established, disregarding the ecological environment and traditional society. Limit the free movement of nomads resulted in overgrazing and desertification.

Fig. 1-4 summarizes a *historical outlook of the globalization* mentioned above (Wakatsuki 2000, Takase 1999). Africa's long-term "contact" with the West caused serious distortions in the ecological environment as well as in its community. These include intense opposition among ethnic group and *corruption among leaders*. A community that suffered from the slave trade and *colonial rule* for more than 500 continuous years had no great possibility of producing those leaders who would fight for a just cause. The fact that *Christian justice* accompanied this slave trade and colonization was a tragedy of global history. On the other hand, the 500 years when Africa was victimized continuously allowed the West to globalize itself and accumulate wealth which then brought the development of Western science and technology. The *globalization of Europe* and the development of the New World, created science and technology-based "affluent societies" in developed countries from the sacrifices of the African people and the global environment. Although Japan has been benefited directly from Euro-American science and technology since the Meiji Restoration in 1868, as shown in Fig.1-4, sub-Saharan Africa contributed indirectly to the No.2 economic power and the present "affluent society" of Japan.

If we understand this, we need to consider that Africa, the continent

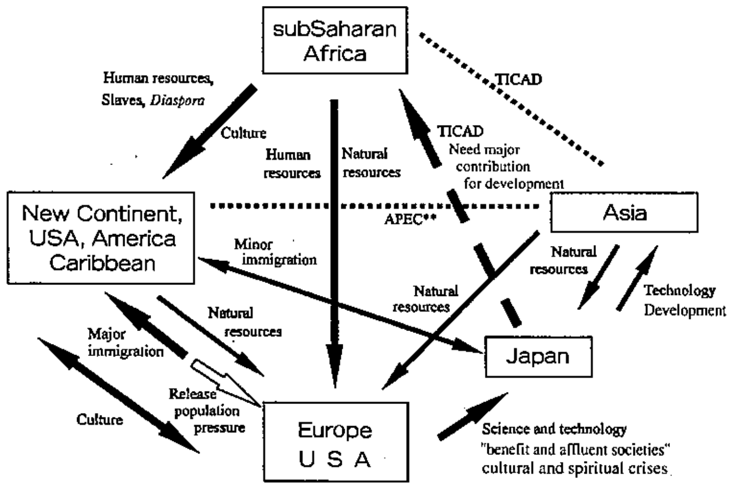


Fig. 1-4 *Historical outlook of globalization* (modified based on T. Wakatsuki, 2000 and K. Takase, 1999)
*TICAD : Tokyo International Conference for African Development
**APEC : Asia-Pacific Economic Cooperation

victimized by the West, is the "main battlefield" for global environmental issues. If we are to overcome the negative effects of Western modern civilization and science and build a new global community that could solve environmental and North-South problems, it is considered that Japan should based itself on Asia but should also involve itself positively in Africa rather than concentrating on Asia only. During the past 10 years, the amount of Japanese Official Development Assistance (ODA) for the developing countries was at the top among the OECD countries. Nevertheless, *Japanese ODA* hasn't evolved a clear strategy and philosophy so far. The above historical overview of the present globalization and global environmental issues clearly demand a major Japanese contribution for the developmentof sub-Saharan Africa and the restoration of her environment. This, the author hopes, in turn may vitalize the sprit and culture of Japan in the new twenty-first century.

2. Characteristics of recent agricultural production in West Africa

2-1. Crop production that cannot keep up with population growth

To examine the characteristics of agricultural production in West Africa in the 1975-1999 period, changes in total and farm population and in per capita *crop and livestock production indexes* by country are shown in Table 1-1, together with the figures for West Africa and the whole of Africa, South America, Asia, and Japan.

West Africa has the highest population increase rate among these regions: 2.2 times in the 24 year period. The figure for the whole of Africa is as high as 1.89 times. West Africa has much higher rates compared with 1.58 times in South America and 1.54 times in Asia. Its ratio of farm population is also considerably higher than in other regions of the world, though it decreased from about 71% to about 52%. The *farm population ratios* of South America are very small because of the large land-ownership system. In this respect, both in West Africa and Asia, most farmers are small-scale but agriculture has a very important position in people's life. While the percentage of farmers in the total population declined in West Africa, the total population increased. As a result, the actual number of farmers grew by as many as about 52 million in West Africa in the past 24 years.

If we suppose the average *crop production index* in the 1975 period was 100, it was only 86.0 in 1990, and 97.3% even in 1999 in West Africa. Between 1975 and 1990, it was the worst period. *Per capita production* decreased by as many as 14 points during those years. This was also the case in the whole of Africa where food production decreased by about 13.9% during the 15-year period. Although per *capita agricultural production* of Africa seems to have recovered to the level of 25 years ago (1975) at the end of the twentieth century, this situation is still far below of the present world standards. By contrast to Africa, in South America and Asia, while population grew in those 24 years, per capita crop production index increased by as much as 28.7% in South America and 38.7% in Asia. Growth in both crop and livestock production were especially remarkable in Asia during early 1990 and after wards. This shows that the Green Revolution spread widely in this region and strengthened the agricultural basis there. Recent Asian economic development has been supported by this improvement in farming productivity. On the other hand, although after the 1990s the crop production index shows some upward trend, in Africa and West Africa behind the stagnation, starvation, and frequent disputes of recent years lies the still continuing decline in agricultural productivity mentioned above. Though rapid population growth is the direct cause of this decline in per capita farming productivity, degraded farmland, desertification, and other kind of deterioration in the agricultural environment have much to do with it, too, as discussed in the next subsection. Recent political in-stabilities and civil wars in Gambia, Guinea-Bissau, Liberia, and Sierra Leone made these trends still worse. Some countries such as Ghana, however, showed a dramatic increase in crop production, although the *livestock production* index was still kept low.

Table 1-2 shows the trends of output and yields of main crops in West Africa in the period 1970-1998 by country and region (FAO, 1981, 1990a, b, 1998, 1999). During the years from 1970 to1998, West Africa's population increased 2. 2 times from 98 million to 216 million. Rice was the only crop that showed an increase in output higher than this figure. *Rice* has shown a continuous increase in *production* over the last three decades, while root and tuber crops could increace at the same pace as population. Nigeria is a giant of this region not only in population but also in agricultural production. Nigeria's trend determines the trend of the whole of West Africa. Nigeria's production of staple crops expressed as percentages of total West African production in 1967/71 was as follows: *rice* 23, *maize* 74, *sorghum* 61, *millet* 50, *roots and tubers* 72, *legume* 63. In 1999 the percentages were 45 (rice), 59 (maize), 61 (sorghum), 59 (millet), 71 (roots and tubers) and 66 (legumes). The production of rice increased 6 times and of roots and tubers 2.4 times. Nigeria increased its share of rice production

Table 1-2 Trends of output and yield of main crops in

	1969/1971							
	Rice (Paddy)	Maize	Sorghum	Millet	Root/ tuber crops*	Legumes	Rice (Paddy)	Maize
Benin	tr …	20 (0.6)	5 (0.6)	1 (0.4)	113 (7.0)	3 (0.3)	1 (1.4)	41 (0.9)
Burkina Faso	4 (0.9)	6 (0.7)	53 (0.5)	35 (0.4)	10 (4.2)	15 (0.4)	4 (2.1)	22 (1.0)
Chad	4 (1.0)	1 (1.9)	39 (0.7)	23 (0.6)	30 (3.9)	6 (0.4)	6 (3.0)	3 (0.6)
Cote d'Ivoire	34 (1.2)	26 (0.8)	1 (0.5)	3 (0.5)	229 (4.1)	1 (0.6)	69 (1.2)	48 (0.7)
Gambia	4 (1.4)	tr (0.6)	1 (0.9)	3 (1.0)	1 (3.8)	tr (0.3)	2 (1.6)	2 (1.5)
Ghana	6 (1.0)	42 (1.1)	15 (0.7)	12 (0.5)	367 (6.4)	1 (0.1)	8 (1.6)	55 (1.2)
Guinea	36 (0.9)	7 (1.2)	1 (0.7)	5? (0.8?)	65 (7.1)	3 (0.5)	50 (0.8)	10 (1.1)
Guinea-Bissau	3 (1.0)	tr …	tr …	1 (0.5)	4 (5.6)	tr …	16 (2.2)	2 (0.9)
Liberia	18 (1.2)	… …	… …	… …	30 (3.7)	tr …	24 (1.0?)	… …
Mali	16 (1.0)	7 (0.9)	58? (1.0?)	78 (0.8)	8 (8.9)	3 (0.4)	38 (1.5)	21 (1.5)
Niger	3 (2.1)	tr …	26 (0.4)	97 (0.4)	19 (9.6)	12 (0.1)	7 (2.3)	1 (1.6)
Nigeria	55 (1.3)	369 (0.9)	435 (0.7)	326 (0.6)	2,502 (9.6)	85 (0.2)	300 (2.1)	553 (1.1)
Senegal	12 (1.3)	4 (0.8)	13? (0.8?)	54 (0.5)	17 (4.4)	2 (0.3)	16 (2.1)	13 (1.1)
Sierra Leone	47 (1.4)	1 (1.0)	1 (1.3)	1 (1.1)	12 (4.3)	3 (0.5)	45 (1.4)	1 (0.7)
Togo	2 (0.7)	16 (1.1)	15 (1.0)	12 (0.6)	88 (13.1)	2 (0.3)	3 (1.2)	22 (1.0)
West Africa	244 (1.2)	499 (0.9)	663 (0.7)	651 (0.6)	3,495 (8.1)	135 (0.3)	580 (1.6)	794 (1.0)
Africa	734 (1.8)	2,171 (1.2)	911 (0.7)	968 (0.6)	6,840 (6.7)	478 (0.4)	1,145 (2.0)	3,379 (1.6)
South America**	957 (1.7)	2,567 (1.5)	405 (1.9)	17 (1.0)	4,662 (12.0)	300 (0.6)	1,622 (2.4)	3,615 (2.0)
Asia	28,415 (2.4)	5,041 (1.6)	1,878 (0.7)	2,076 (0.7)	18,597 (11.3)	2,137 (0.6)	47,869 (3.6)	12,326 (3.1)
Japan[1)]	1,628 (5.5)	3 (2.7)	tr …	1 (1.7)	68 (19.5)	22 (1.2)	1,312 (6.3)	tr …

Notes: 1)Japan's output of wheat and barley was 1.25 million tons(yield 2.7tons/ha)in 1970 and 1.3million tons (3.5 tons/ha) in 1990.

2)*The yields of root and tuber crops are very high. But in the case of cassava, whose output is high in tropical Africa, the calorie per unit weight is one-third and the protein content, one eighth, that of rice and maize.

3)**South America's wheat output sharply increased(by 1.7 times)from 11 million tons in 1970 to 19 million tons in 1999.

4)"tr"means that the output is trace.

West Africa : 1970-1998 (FAO, 1981, 1990, 1998, 1999, Hsieh 2001)

1989/91				1997/99					
Sorghum	Millet	Root/ tuber crops*	Legumes	Rice (Paddy)	Maize	Sorghum	Millet	Root/ tuber crops*	Legumes
11	2	185	6	3	74	14	3	378	10
(0.8)	(0.7)	(8.5)	(0.6)	(2.1)	(1.2)	(0.8)	(0.7)	(10.7)	(0.7)
92	60	11	17	9	36	117	89	6	7
(0.7)	(0.5)	(5.9)	(0.4)	(1.9)	(1.4)	(0.8)	(0.7)	(30.3)	(0.8)
28	17	64	6	10	15	60	33	63	6
(0.6)	(0.5)	(5.5)	(0.4)	(1.3)	(1.2)	(0.7)	(0.4)	(4.4)	(0.6)
2	4	425	1	122	57	2	7	504	1
(0.5)	(0.6)	(5.7)	(0.7)	(1.6)	(0.8)	(0.3)	(0.7)	(5.7)	(0.7)
1	5	1	tr	3	1	1	7	1	0
(0.8)	(0.9)	(3.0)	…	(1.5)	(1.3)	(0.9)	(0.9)	(3.0)	(0.3)
14	8	520	2	20	102	34	16	1,182	2
(0.6)	(0.6)	(6.1)	(0.1)	(1.6)	(1.5)	(1.1)	(0.9)	(10.5)	(0.1)
3	6	72	6	74	9	1	1	104	6
(1.4)	(1.5)	(6.3)	(0.9)	(1.5)	(1.0)	(0.7)	(0.8)	(6.2)	(0.9)
4	2	4	tr	13	1	2	3	8	0
(0.9)	(0.8)	(6.2)	…	(1.9)	(1.0)	(1.0)	(0.9)	(7.1)	(0.5)
…	…	35	tr	20	…	…	…	36	0
…	…	(6.7)	…	(1.3)	…	…	…	(6.8)	(0.6)
75	70	14	7	58	34	55	89	4	11
(1.0)	(0.8)	(8.5)	(0.4)	(1.8)	(1.8)	(1.0)	(0.95)	(4.2)	(0.4)
42	113	25	37	9	1	42	100	24	54
(0.3)	(0.4)	(7.1)	(0.2)	(1.9)	(1.6)	(0.2)	(0.5)	(6.8)	(0.1)
479	467	4,960	146	331	542	561	577	5,982	207
(0.7)	(1.0)	(12.8)	(0.8)	(1.6)	(1.3)	(1.1)	(1.1)	(9.7)	(0.5)
15	51	9	3	18	6	13	45	6	3
(0.8)	(0.6)	(4.1)	(0.3)	(2.5)	(0.9)	(0.7)	(0.5)	(3.6)	(0.4)
2	2	16	4	33	1	2	1	32	4
(2.3?)	(1.3)	(3.2)	(0.7)	(1.2)	(1.1)	(0.8)	(0.9)	(4.6)	(0.7)
11	5	92	3	9	38	14	4	129	4
(0.9)	(0.7)	(7.9)	(0.2)	(1.9)	(1.0)	(0.7)	(0.5)	(7.1)	(0.3)
779	812	6,433	328	732	916	918	976	8,458	316
(0.7)	(0.8)	(10.6)	(0.6)	(1.7)	(1.3)	(0.9)	(0.9)	(9.2)	(0.4)
1,278	907	11,963	678	1,686	4,084	2,018	1,292	14,993	780
(0.7)	(0.7)	(7.9)	(0.6)	(2.2)	(1.6)	(0.9)	(0.7)	(8.0)	(0.5)
354	9	4,463	289	1,863	5,379	463	5	4,517	365
(2.6)	(1.7)	(12.2)	(0.5)	(3.4)	(3.1)	(3.3)	(1.2)	(12.6)	(0.7)
1,887	1,677	24,086	2,614	53,376	16,140	1,339	1,315	27,417	2,731
(1.0)	(0.8)	(12.4)	(0.7)	(3.9)	(3.7)	(1.03)	(0.9)	(16.1)	(0.8)
tr	0	56	15	1,173	…	…	…	491	10
…	(1.8)	(24.3)	(1.6)	(6.3)	…	…	…	(26.8)	(1.7)

dramatically over the last three decades. *Ghana* increased the production of rice and maize, 4.7times for rice and 2.4 times for maize during last 30 years. During this period, the output of sorghum, millets, and even maize, West Africa's important crops, was too small to cope with the increase in population. Although West Africa is the main region producing sorghum and millet in Africa, the cultivation of these traditional crops is stagnant.This is because these crops have been directly affected by the drier climate and degradation of farmland, which are occurring in sub-Saharan Africa.

West Africa, however, has been continuously importing not only wheat but also rice in appreciable amounts during the last three decades. Nigeria again was the biggest importer both of wheat, 1.8 million tons in 1998, and of rice, 1 million tons in 1998. Since other West African countries also imported rice, such as Senegal, 0.6 million tons, Cote d'Ivoire, 0.5 million tons, Sierra Leone, 0.25 million tons, and Ghana, 0.2 million tons, the total amounts of rice imported reach close to 3 million ton annually (Table 1-4). This is big *importation of rice* in the world rice market. This has made further reduced the *foreign exchange* balances of the governments in this region. Wheat importation also reaches similar amounts in this region. No appreciable amounts of maize are imported. Although the production of wheat is limited in this region for climatic reasons, ecologically the production of rice has a huge potential to increase in West Africa. Therefore an increase in the production of rice is now given the highest political priority in many of the countries in West Africa.

Cassava, yam, and other root and tuber crops had increase rates similar to that of population during the last thirty years. While the output and yield of these root and tuber crops are very high, their value as human food is much lower than that of rice, maize, and sorghum. Their calories per gram are only about one-third that of the other three crops and their protein content, about one-eighth. If these figures are converted based on protein content, which is apt to be a limiting factor of nutrition, their effective converted output and effective converted yield both become one-eighth that of the production figures. The author considers that too much *dependence on cassava* as described above will further decrease the protein and mineral intake of children and poor people, posing a serious problem. The converted output of root and tuber crops in West Africa in 1999 was 9.45 million tons and their converted yield, 0.8 ton per hectare in protein base. Although in 1980-1990s, root and tuber crops, mainly cassava, were the most important staple food crops in this region in terms of converted output, all five major crops showed almost the same weight of production now.

Among the five staple crops, rice is rapidly expanding its share in the highest rate last 30years.

Of West African countries, as we see, Nigeria has far higher outputs than others. Its output accounted for 50% to 70% of the total production of West Africa in all crops other than rice in 1970 and in all crops in the 1990s. In particular, the country's rice production showed a remarkable increase in those years. In 1970, Nigeria's rice production was 500 to 600 thousand tons, a similar level to that of Côte d'Ivoire, Guinea, and Sierra Leone, occupying only 23% of West Africa's total output. But in 1999, the figure increased to 3.27 million tons, an increase close to 6 times, and the country's share to 45%. If this trend continues, rice will, in about ten years, get ahead of sorghum, millet, and maize, and become the most important food not only in Nigeria but in the entire West Africa as well. The probable reason for such a rapid increase in rice production in Nigeria is that the country introduced a *ban* or restriction *on rice imports* in 1987. Ghana will start a similar policy from 2002. Nigeria's rice production showed a sharp growth from 0.55 million tons in 1970 to 3 million tons in 1990 and to 3.27 million tons in 1998. But the average yield during those years remained on a similar level: 1.3 tons (1970), 2.1 tons (1990), and 1.6 tons per hectare (1998). As we can see in Table 1-4, although *rice yield* increased slightly during 1970-1990, after that yield per hectare declined. This means that the doubled or tripled output was brought about only by doubling or tripling the planted acreage. Although these statistics are not very reliable (Shimada, 1996), from the sporadic observations by the authors and the researchers at the International Institute for Tropical Agriculture (IITA) and the West African Rice Development Associations (WARDA) in the period from 1988 to 2000, it is considered that the increased rice production was mostly as a result of rapid increases in *upland rice* cultivation in newly developed land. As discussed in Section 4 below, increased upland rice production is accelerating the deterioration of both forest and farmland in this region.

In other West African countries, too, rice production is increasing except for Sierra Leone and Liberia where long civil wars have caused grave situations over the last ten years. For example, *Côte d'Ivoire's* output of rice rose from 340 thousand tons to 690 thousand tons during 1970-1990. However, rice production of Côte d'Ivoire has been stagnated over the last ten years, mainly because of overdependence on unsustainable upland rice cultivation. Although the production of maize, sorghum, and millet in 1998 (Table 1-2) was remarkable, a change to rice, maize and cassava has occurred due to the inactive production of

Table1-3 The change in rice consumption and demand of West Africa
(WARDA 1992, 1993, S. Ito 2001, Hsieh 2001)

	Land area 1998	Rice cultivation area (1,000ha)		Rice production (paddy) (1,000t)		Yield 1999 (t/ha)		Consumption per capita(milled rice) (kg)				
	(10,000ha)	1990	1999	1990	1999	paddy	milled rice	1970/74	75/79	80/84	88/90	95/99
Benin	1,106	7	10	10	15	1.5	1.0	3.8	7.0	7.3	12.9	12.9
Burkina Faso	2,736	21	50	41	98	2.0	1.3	4.7	6.8	9.2	13.6	6.7
Chad	12,592	21	60	64	91	1.5	1.0	-	-	-	9.8	10.2
Cote d'Ivoire	3,180	580	800	644	1,240	0.9	0.6	43.1	52.6	60.2	72.9	56.1
Gambia	100	16	21	23	32	1.5	1.0	74.4	78.2	116.1	118.8	80.1
Ghana	2,275	58	130	77	190	1.5	1.0	7.4	8.0	6.6	9.9	14.4
Guinea	2,457	584	475	482	684	1.5	1.0	48.9	45.3	58.6	68.6	99.2
Guinea-Bissau	281	91	70	156	122	1.7	1.1	62.2	60.3	101.4	143.0	68.8
Liberia	963	206	175	243	243	1.4	0.9	109.6	113.3	119.9	127.6	94.1
Mali	12,202	228	375	334	760	2.0	1.3	19.5	12.6	25.8	27.8	38.7
Mauri tania	10,252	13	25	53	91	3.7	2.4	18.2	29.9	38.3	68.5	45.1
Niger	12,667	32	30	72	68	2.3	1.5	4.6	4.5	15.6	16.0	6.0
Nigeria	9,108	1,500	2,050	3,000	3,270	1.8	1.2	2.9	7.2	13.8	15.4	24.1
Senegal	1,925	77	75	157	149	2.0	1.3	45.3	55.0	65.8	67.5	63.7
Sierra Leone	716	320	275	433	350	1.2	0.8	125.6	130.7	95.3	104.8	63.8
Togo	544	22	50	27	61	1.2	0.8	5.9	8.8	11.6	15.3	19.0
West Africa	60,557	3,776	4,670	5,816	7,464	1.6	1.0	14.5	18.4	23.8	28.0	29.4

traditional crops, sorghum and millets (Sumi et al., 1996).

As noted above, *rice production* increased faster than population in West Africa, but as Tables 1-3 and 1-4 show, the *supply-demand gaps* (Import) of rice in this region widened in the three decades of the 1970s and 1990s. This is because of the multiplier effects of population growth and increases in per capita rice consumption, the latter being faster than the former (Table 1-3). Actually in the past 20 years West Africa's rice imports remained about 30% of the total rice trade in the world. Main exporters are China, Thailand, US, and Vietnam. West African countries are spending their precious foreign currencies, which are already scarce, for this purpose. This is another reason for increasing rice cultivation in this region. According to the West Africa Rice Development Association(WARDA) and USDA's statistics shown in Table 1-4, the *self-sufficiency ratio of rice* in West Africa showed some rise in 1990 mainly because of the effects of Nigeria's ban on rice import and increased output. Rice yield

Table 1-4 The change in statistical data on rice in West Africa(1960-1999)
(WARDA 1992, 1993, S. Ito 2001)

	Area	production (paddy)	Yield(t/ha)		Consumption (milled)	Import (milled)	Consumption (milled)	Self-sufficiency
	(1,000ha)	(1,000t)	paddy	milled rice	(1,000t)	(1,000t)	(kg/capita)	(%)
1960	1,439	1,425	0.99	0.83	1,014	261	10.4	74.3
1961	1,553	1,447	0.93	0.67	1,021	278	11.5	72.7
1962	1,612	1,770	1.10	0.75	1,112	349	12.0	67.9
1963	1,464	1,631	1.11	0.69	1,234	285	12.9	76.7
1964	1,535	1,639	1.10	0.76	1,238	387	12.7	69.7
1965	1,691	1,867	1.10	0.75	1,279	292	12.7	69.6
1966	1,461	1,816	1.11	0.77	1,411	416	13.6	78.4
1967	1,773	2,120	1.20	0.81	1,334	395	12.7	71.6
1968	1,746	2,118	1.21	0.78	1,449	371	13.4	77.6
1969	1,861	2,120	1.14	0.78	1,483	383	13.3	72.3
1970	1,893	2,422	1.28	0.77	1,599	444	14.0	72.8
1971	2,019	2,367	1.17	0.81	1,849	552	15.8	70.7
1972	2,027	2,287	1.13	0.76	1,807	500	15.0	72.2
1973	2,028	2,412	1.19	0.75	1,893	690	15.3	71.9
1974	2,268	2,463	1.09	0.75	1,755	635	13.9	76.9
1975	2,216	2,743	1.24	0.83	1,856	265	14.3	82.8
1976	2,285	2,989	1.31	0.83	2,143	476	16.1	71.4
1977	2,254	2,931	1.30	0.87	2,761	1,104	20.2	60.5
1978	2,416	3,150	1.30	0.78	2,813	1,187	20.0	57.8
1979	2,336	3,017	1.29	0.79	2,812	1,050	19.5	62.7
1980	2,561	3,200	1.25	0.76	3,225	1,776	21.8	51.8
1981	2,665	3,344	1.26	0.79	3,567	1,819	23.5	49.8
1982	2,714	3,460	1.28	0.82	3,920	2,048	25.1	47.6
1983	2,569	3,165	1.23	0.79	4,189	2,251	26.1	46.2
1984	2,739	3,278	1.27	0.73	3,733	1,998	22.7	46.9
1985	2,884	3,810	1.32	0.80	3,748	1,814	22.7	51.5
1986	3,014	3,677	1.22	0.80	4,071	1,719	24.3	57.8
1987	2,995	3,564	1.19	0.78	4,325	1,997	25.1	53.8
1988	3,117	3,709	1.19	0.78	4,045	1,641	22.8	59.4
1989	3,122	3,622	1.16	0.76	4,086	1,719	22.3	57.9
1990	3,776	5,816	1.54	1.23	5,223	1,721	28.0	67.0
1991	3,814	7,933	2.08	1.37	6,347	1,580	32.6	75.1
1992	3,701	8,142	2.20	1.45	7,108	2,048	35.4	71.2
1993	3,388	6,098	1.80	1.20	6,278	1,882	30.3	70.0
1994	3,818	6,262	1.64	1.08	5,843	1,588	27.4	72.8
1995	3,809	6,361	1.67	1.10	5,800	1,839	26.4	68.3
1996	3,982	6,252	1.57	1.03	6,118	1,870	27.0	69.4
1997	4,065	6,260	1.54	1.01	6,499	2,504	27.8	61.5
1998	4,023	6,115	1.52	1.00	6,880	2,807	28.5	59.2
1999	4,670	7,452	1.60	1.04	7,323	2,840	29.4	61.2

was increased some what during the early 1990s. However, as the Table 1-4 shows, rice yields decreased from 2.2 t/ha in 1992 to less than 1.6 t/ha in 1999. Self-sufficiency decreased from 75.1% in 1991 to 59.2% in 1998. It is now clear that the long established major strategy to improve upland rice cultivation is not the correct way to achive sustainable rice production in West Africa, even after the birth of *NERICA*, new rice of Africa(WARDA 1999).

2-2. Changes in *land use* in the period 1974-1998 in West Africa

Changes in land use in West Africa in the 24 years from 1974 to 1998, compared with those in other regions, are shown in Table 1-5 (FAO, 1981, 1990a, b). In the whole of West Africa, *forest areas* decreased by 21 million hectares while arable

Table 1-5 The change in land use pattern of West Africa within 24 yers.

	1974*					1994			
	Arable land	Permanent crops	Permanent pasture	Forest and Woodland	Others**	Arable land	Permanent crops	Permanent pasture	Forest and Woodland
Benin	133	9	44	497	424	166	14	55	402
Burkina Faso	243	2	600	474	1,417	338	5	600	427
Chad	292	tr	4,500	1,234	6,570	339	3	4,500	1,103
Cote d'Ivoire	178	185	1,300	1,213	305	291	380	1,300	547
Gambia	17	tr	19	10	54	18	1	20	9
Ghana	170	160	840	1,100	5	280	170	840	902
Guinea	69	43	1,070	756	520	82	60	1,070	670
Guinea-Bissau	26	3	108	107	38	30	4	108	107
Liberia	13	24	200	489	238	18	20	200	451
Mali	177	3	3,000	1,321	8,064	316	4	3,000	1,165
Mauritania	20	tr	3,925	55	6,252	47	1	3,925	56
Niger	260	tr	1,018	250	11,139	449	1	1,100	250
Nigeria	2,742	248	4,000	1,694	424	3,017	254	4,000	1,378
Senegal	235	tr	570	807	313	233	3	570	745
Sierra Leone	42	5	220	202	247	49	6	220	131
Togo	180	8	100	158	98	220	10	100	125
West Africa	4,797	691	21,514	10,357	35,740	5,892	936	21,608	8,468
Africa	15,212	1,784	89,386	61,400	128,579	17,481	2,340	89,648	52,399
South America	7,473	1,440	46,576	99,095	20,707	9,128	1,995	50,194	88,969
Asia	49,789	3,368	100,536	56,812	98,036	50,166	5,656	105,946	47,756
Japan	498	64	19	2,529	655	466	42	9	2,514

Notes: 1)*Recalculated based on the total area of Asia was $3,085\times10^9$ ha instead of $2,757\times10^9$ ha because of the division of formar USSR.

2)**Others include built on areas, roads and barren desertified lands.

3)***Percentage of afforested area among Forest and Woodland area land increased by 12 million hectares and permanent crops by 3 million hectares, *permanent pasture* decreased by 3 million hectares. The area of uncultivated land resulting from *desertification* or urbanization grew by 9 million hectares. Though it is hard to say definitely what percentage of was due to desertification and what ratio of it was a result of urbanization, the expansion in urbanized areas is probably taking several million hectares or less, and so the increase in unplanted land caused by desertification is considered to be larger. In any case, it is true that forests decreased and *barren land* (deserts and urban deserts) expanded. The ratio of decrease in forests in the 24 years from 1974 was 20% : the total forest area in West Africa was 104 million hectares in 1974, of which 21 million hectares were lost by 1998. This region's ratio of forests to the total area was 11% in 1998, much lower than in other regions, and in addition its

(FAOSTAT 2001, World Resouces 1998-2000, Kokuseisha 2000/2001, FAO 1999)

(Unit : 10,000ha)

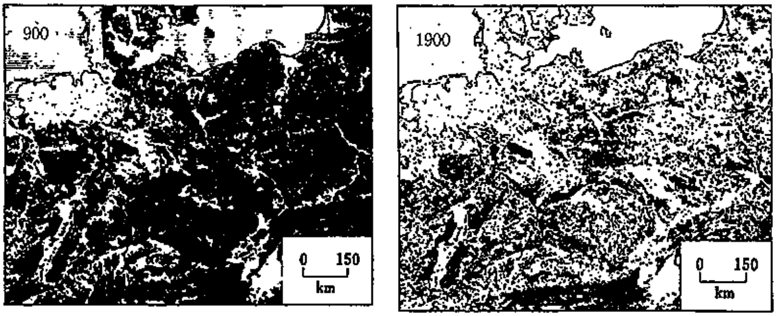
	1998					Land area	Total afforestation by 1990		Forest area 1998 (%)	Canopy closed original forest area (%)
Others**	Arable land	Permanent crops	Permanent pasture	Forest and Woodland	Others**		Area	Ratio*** (%)		
469	170	15	55	330	536	1,076	12	3.6	30.7	15.5
1,366	340	5	600	427	1,366	2,736	2	0.5	15.6	0.0
6,647	352	3	4,500	1,103	6,634	12,592	0.4	0	8.8	0.0
663	295	440	1,300	547	598	3,180	6	1.1	17.2	74.9
53	20	tr	20	8	53	100	0	0	8.0	39.1
83	360	170	833	880	33	2,275	5	0.6	38.7	65.9
575	89	60	675	637	997	2,457	0.4	0	25.9	75.6
32	30	5	108	107	31	281	0	0	38.1	100.0
274	19	20	200	451	274	963	0.6	0.1	46.8	99.6
7,717	461	4	3,000	1,125	7,612	12,202	1.4	0.1	9.2	0.0
6,233	49	tr	3,925	56	6,222	10,252	0	0	5.5	0.0
10,867	499	tr	1,200	250	10,718	12,667	1.2	0.5	2.0	0.0
460	2,820	254	3,920	1,378	736	9,108	15	1.1	15.1	45.1
374	223	4	565	725	409	1,925	11.2	1.5	37.6	14.2
311	48	6	220	131	311	716	0.6	0.5	18.2	100.0
89	220	10	100	80	134	544	1.7	2.1	14.7	32.9
36,203	5,995	995	21,221	8,235	36,664	73,074	58	0.7	11.3	17.1
134,489	17,773	2,423	88,767	50,900	136,493	296,357	442	0.6	17.2	2.9
25,007	9,612	1,972	50,298	85,625	27,785	175,293	726	0.8	48.8	55.6
99,023	49,666	5,958	105,510	46,481	100,990	308,541	5,612	10	15.0	49.1
734	454	37	8	2,512	754	3,765	1,130	45	66.7	91.4

deforestation ratio was higher than in any other part of the world. In the whole of Africa, the ratio of forests was 17% in 1998 and their decline was 17.1% during the period 1974-1998. The figures were 48.8% and a decrease of 13.6% for South America and 15% and a decline of 18.3% for Asia. These statistics clearly suggest that in West Africa where agricultural productivity did not improved but population continued to grow, forests and farmland were endlessly destroyed. This resulted in a vicious circle : population growth brought environmental disruption, which then reduced food productivity and promoted the destruction of the environment. The situation is considered to be on the verge of collapse.

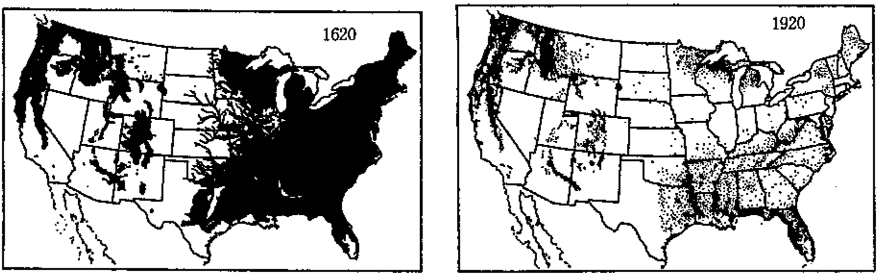
While this plight is typically observed in West Africa, other parts of the continent are probably in a similar state. In the whole of Africa, about 105 million hectares of forests disappeared during 1974-1998, while *arable land* increased by 26 million hectares and permanent pasture decreased by 6 million hectares, while others, including deserts and city areas (urban deserts) increased by 79 million hectares during 1974-1998. By contrast, in South America, while forests were lost by 135 million hectares, grasslands expanded by 37 million hectares, farmland by 21 million hectares and tree crop land by 5 million hectares. The cities, road, and barren lands increased by 71 million hectares. During 1980-1990, South America has been criticized for tuming tropical forests into hamburgers (grass and cattle raising) and these data provide some bases for the criticism. However after 1990, the expansion of grasslands was not clear. In Asia, whereas 104 million hectares of forests were lost, permanent grasslands increased 50 million hectares and treecrop land 26 million hectares. The increase of permanent grasslands in Asia might have contributed to the rapid increase in animal production over 24 years. Arable land, however, decreased by one million hectares. The *urbanization* and *desertification* produced 30 million hectares of uncultivated land. This indicated how much increased farm production in Asia was achieved. Given the size of population growth in Asia (by about 1.2 billion) and its economic development in the 24 years, the expanded uncultivated land of 30 million hectares mentioned above was probably created more by urbanization than by abandoned farmland and desertification.

2-3. Comparison of *historical forest cover changes in Europe, America* and *Japan*

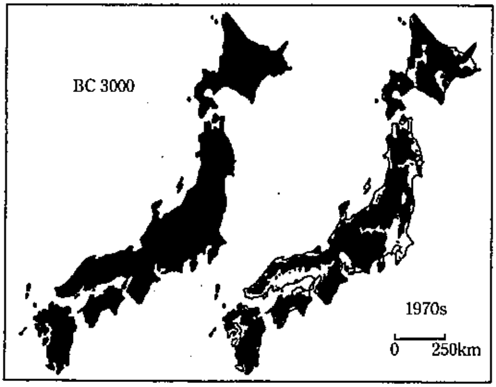
As Fig. 1-5 shown, major forest covers in Europe and America had disappeared



a. Forest cover of Europe in 900 and 1900 (Darby 1956) *Forest coverage about 25% in 1995



b. Forest cover of USA in 1620 and 1920 (Goudie 1981) (One dot shows 25,000 acreage of forest)
*Forest coverage about 23% in 1995



c. Forest of Japan in BC 3000 and 1970s
*Forest coverage about 67% in 1995

a. Darby. H. C. 1956:
The cleaning of woodland in Europe in: Man's role in changing the face of the earth (Thomas. W. L., Dred) vol. 1. pp183-216 The Univ. Chicago Press.
b. Goudie. A. 1981:
The human impact on the Natural Environment pp38-39 Basil Blackwell
c. Y. Yasuda, 1996:
Forest and Civilization 1-18.
Kouza Mori to Bunmei, Forest and Environment, vol. 9. Forest and Civilization Y. Yasuda and S. Sugawara ed. Asakura pub., Tokyo, pp259.

Fig. 1-5 Changing of forest cover in Europe, USA and Japan during past 5,000 years by the early 1900s. Forest cover in Europe and USA was only 25% and 23% respectively in 1995. In 1995, forest cover was only 9.9%, (UK) 9.8% (the Netherland) and 16.8% (Spain). Germany (30.7%) and France (27.5%) have more forest cover (World Resources 1998-2000). This is not so strange, since for the European styles of upland farming their forests have long been their natural enemy. Their farming needs to cut the forest to develop the agricultural land. Thus the *globalization of European Civilization* and the population explosion have been destroying the world's forests (Darby 1956, Goudie 1981, Y. Yasuda 1996).

In Japan on the contrary, the forest cover has survived even after the period of a major population explosion and industrialization. As shown in Table 1-5 and Fig. 1-5, Japan's forest cover was still 67% even in 1998. The characteristics of *Japanese civilization* as a part of *Orient Civilization* will be important for its contribution towards solution of the present global environmental problems (Umehara T. 1996). There are two reasons why Japan's forest cover are so extensive even now. (1) As we will explain in this book, lowland sawah and rice-based farming systems do not necessarily consume upland forest. Carefully managed upland forests are instead useful for the lowland sawah because of water conservation and a supply of fertile topsoil to lowland sawah (sawah hypothesis and *geological fertilization theory* in the subsections of 5-2 and 5-3 of this chapter). (2) Among the 25 million ha of Japanese forest, 11 million ha are afforested by long continued efforts starting 17 centuries before 1970s. About 50% of Japanese forests are man-made (C. Totman, 1989).

Afforestation is negligible, less than 1%, in Africa and South America. Although Asia has a relatively wide area of afforestation, still the absolute area is very small compared to their huge population. The per capita afforested area of Japan is 0.089 ha, whereas Asia is only 0.013 ha, about one seventh. Africa as a whole as well as South America have actually almost no man-made forest, less than one percent. This is the very important fact that Japanese culture can contribute to solve the present global environmental problems. The motive of this book also depends partly on this historical consideration of the Sawah and forest-based Japanese culture which can contribute to food and environmental issues in Africa.

3. Situations of *farmland degradation* and *desertification* in the tropics and West Africa

3-1. Agricultural production, farmland, and *soil degradation*

Few estimates are available of reduced crop production resulting from farmland degradation in the entire world and in the tropics. This is because there were no results of global level investigations concerning farmland deterioration. But estimates are possible to some extent on the basis of the reports of United Nation's Environmental Program/International Soil Reference and Information Center (UNEP/ISRIC) on the situations of soil degradation and desertification (Oldeman *et al*., 1991, Middleton, N. and D. Thomas, 1992, 1997). Desertification is land degradation in *susceptible dry-land* (arid, semiarid and dry sub-humid) areas resulting from various factors, including climatic variations and human activities (Middleton, N. and D. Thomas, 1997). According to the report, about 750(427) million hectares of farmland in the whole world have been lightly degraded by human activities ; 910(470) million hectares, on a moderate level ; 300(130) million hectares ; on a severe level ; and 9(8) million hectares are extremely degraded the data for susceptible dry-land are shown in parenthesis. Total degraded area was 1964(1035) million hectares and the non-degraded area was 11050(4134) million hectares. About 18% of the total land area and 25% of susceptible dry-lands are becoming degraded.

The total area of world farmland was about 1500 million hectares, total cereals production was 2054 million tons, and average yield was 1.4ton/ha in 1998. Although we don't know what percentage of farmlands degraded and how severely, the area of moderate and severe degradation totalled 1210 million hectares. This suggests at least about 80 equivalent % of total farmland is degraded. If the mean potential ratio of decrease in output due to the soil deterioration is 50%, the total potential reduction in output becomes as much as about 822 million tons in the entire world.

The impact of farmland and soil degradation on farming production differs according to the type of crops and the characteristics of soils, ranging from having a latent influence to producing at all no harvest. But except in very extreme cases, actual damage usually shows up after several decades or later. Since it is known that land and soil deterioration will pose a problem in the future but it does not manifest itself for the time being, no action is taken in many cases. If it shows up finally, it seriously affects the harvest but it is too late and it costs a great deal to restore farmland and soil. This is the character-

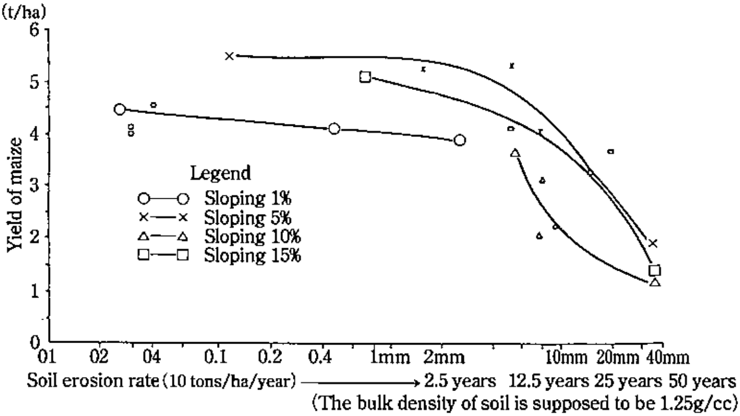


Fig. 1-6 Effects of soil erosion on the yield of maize

Source: Soil erosion rates are added to Lal (1985)

Table 1-6 Effects of soil erosion on crop production (Lal, 1986, 1988)

Soil	Crop	Region/country	Decrease in yield / topsoil erosion	Source
Aridisol	Millets	Burkina Faso	320kg/10cm=0.32kg/t	Fournier(1963)
Alfisol	Maize	Western Nigeria	50%/5cm, 23%/2.5cm	Lal(1976)
Alfisol	Maize	Western Nigeria	0.08~0.26t/ha/mm	Lal(1983 b, c)
Ultisol	Maize	Cameroon	500%/2.5cm	Rehm(1978)
Ultisol	Maize	SouthernNigeria	82~100%/5~20cm	Mbagwu *et al.*(1984)
Ultisol	Cowpea	SouthernNigeria	14~52%/5~20cm	Mbagwu *et al.*(1984)
Ultisol	Cowpea	Malaysia	Sharp decrease in yield resulting from 15cm of topsoil loss	Huat(1974)
Oxisol	Various crops	Guatemala	90%decrease in yield/?	Freeman(1980)

istic common to the other global environmental issues that face us now.

Fig. 1-6 shows how the yield of maize decreases as a result of topsoil loss. This is a case reported by IITA (Lal, 1985). Supposing the *soil erosion rate* is 10t/ha/y, the soil's bulk density, 1.25g/cc, and the *soil formation rate*, zero, the yield is halved if 10mm of topsoil is lost, that is, 125/10 = 12.5 years after. During this period, soil formation takes place, too, but almost no studies have been conducted on the rates of soil formation. According to a recent report, the rate of soil formation is estimated at about 0.7t/ha/y on a global average and at about 1-5t/ha/y in the tropics (Wakatsuki and Rasyidin, 1992, Wakatsuki *et al.*, 1993, Rasyidin *et al.*, 1994). Suppose 2.5t/ha/y of soil formation offsets soil erosion, the yield will be halved 16.7 years later. This is a somewhat extreme case, but according to Table 1-6 (Lal, 1986), the yield was halved as a result of *topsoil loss* of 5-10cm (equivalent to soil loss of 600-1,300t/h) in many cases. In this example, the time needed for halving the yield is 80 to 167 years, or two to three generations later. This is one reason why soil conservation measures are not taken readily and quickly. In the case of sever erosion, the rate reaches to 100t/ha/y, in this case severe soil degradation becomes evident within 10 years.

The effects of soil erosion on crop production are different according to soil type. As shown in A and B of Fig. 1-7, the soil having a thick topsoil layer like

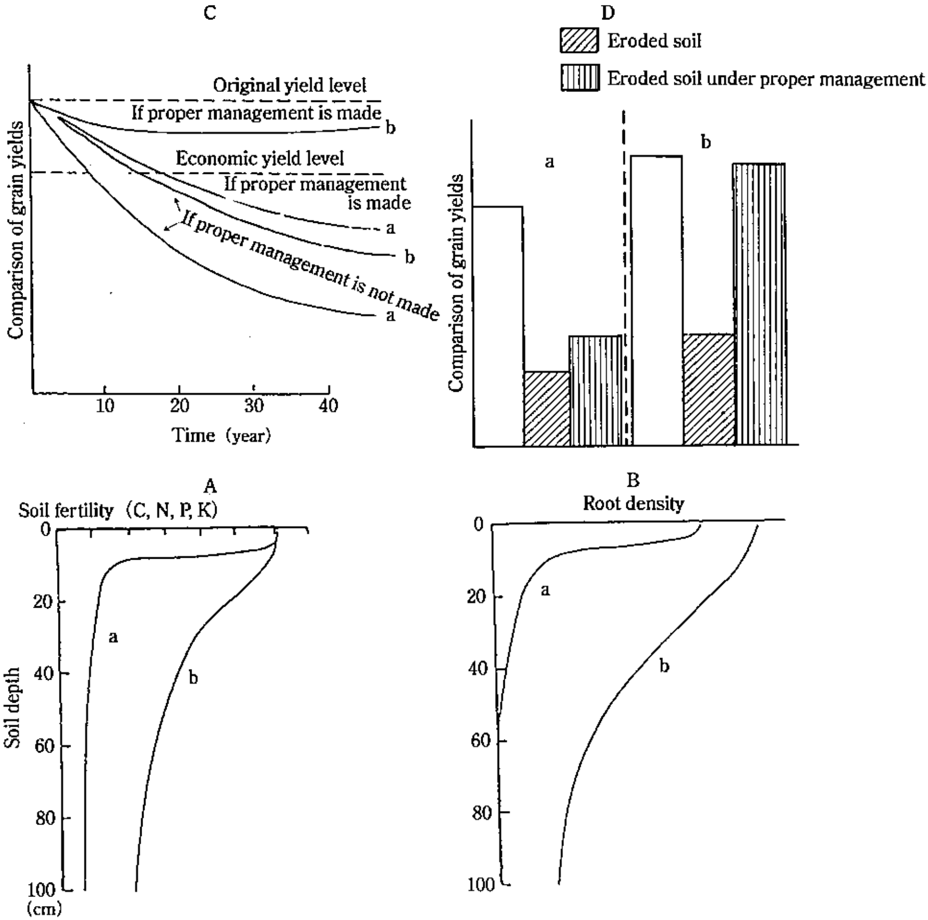


Fig. 1-7 Relations of soil erosion and the vertical profile distribution of nutrients, root density and yield (Lal, 1988, partly adapted)

- Water erosion (W)
  - Topsoil loss (W_t)……Sheet and rill erosion
  - Topographic degradation (W_d)……Rill and gully erosion
  - Sedimantation and flooding (W_s)……Sedimentation of lakes, reservoirs, burial canal
- Wind erosion (E)
  - Topsoil loss (E_t)……Wind erosion
  - Topographic change (E_d)……Movement of sand dunes
  - Over blowing (E_o)……Encroachment on structures such as road and buildings
- Chemical deterioration (C)
  - Nutrient loss (C_n)……Improper shifting cultivation, etc.
  - Salinization (C_s)……Improper irrigation
  - Acidification (C_a)……Improper development of mangrove forests
  - Pollution (C_p)……Synthetic organic compounds, heavy metals
- Physical deterioration (P)
  - Topsoil crust hardening (P_c)……Crust formation, compaction
  - Waterlogging and submerging (P_w)……Improper dam construction and irrigation
  - Subsidence (P_s)……Improper peat land development
  - Aridification (P_a)……Human-induced changes of the soil moisture regime towards on aridic regime
- Biological deterioration (B)
  - Loss of soil organic matters (B_o)……Deforestation, heavy fertilization
  - Decrease in soil biodiversity (B_r)……Results of B_o, monoculture
  - Increase in soil-borne diseases (B_p)……Results of B_o and B_r

Fig1-8 Types of soil degradation(UNEP, 1997)

b has a longer period of economic yield even without special soil conservation and management measures than the soil with a thin topsoil layer like a, as evident from part C of the same figure. However, in tropical upland areas, the types of soil are mostly a-type of shallow topsoils (*Oxisols*, *Ultisols*, and *Alfisols*) and b-type of deeper topsoils (*Andisols*, etc.) are very limited.

Fig. 1-8 summarizes the types of soil degradation considered to be caused mainly by human activities. They include *water erosion* (W), *wind erosion* (E), *chemical deterioration*(C), and *physical deterioration* (P) (Oldeman *et al.*, 1991, GLASOD, Global Assessment of Soil Degradation, in UNEP 1997). These kinds of complete soil degradation result in the deterioration of the soil's biological characteristics and to support biological production too.

3-2. Comparison of human induced soil degradation in three main tropical regions

Fig. 1-9 shows, on the basis of the *world map of desertification* and soil degradation published by UNEP/ISRIC (1991), the situation of these phenomena mainly in the tropical regions according to the divisions described below. The "Heavy," "Medium" and "Light" levels of soil degradations used in the maps have the following meanings.

"Light" : The area where lightly degraded soils account for 25-50% of all the area, soils degraded on a medium level, 10-25%, heavily degraded soils, 5-10%, or severely degraded soils, less than 5%.

"Medium" : The area where lightly degraded soils account for 50-100% of all the area, soils degraded on a medium level, 25-50%, heavily degraded soils, 10-25%, or severely degraded soils, 5-10%.

"Heavy" : The area where soils degraded on a medium level, 50-100%, heavily degraded soils, 25-100%, or severely degraded soils, more than 10%.

The four degrees of soil degradation (light, medium, heavy, and severe) referred to above are defined as follows (Oldeman *et al.*, 1991) :

Lightly degraded : Crop productivity is decreased a little by soil degradation but can be restored by improving the soil management method. The soils have not lost their basic biological functions to support production.

Degraded on a medium level : Crop productivity is decreased considerably but farming by a traditional agricultural system is possible. To restore the soil, degradation, there is the need for radical land improvement by individual farmers. The soil's biological functions to support production have partly been destroyed.

Heavily degraded : It is impossible to restore the soil by any radical measures taken by individual farmers. Restration requires more systematic ecological engineering. The soil's biological functions to support production have mostly been destroyed.

Severely degraded : The soils have been degraded too much for restration. The soil's biological functions to support production have totally been destroyed.

Fig. 1-9 indicates that *soil degradation in tropical Asia* is caused mostly by water erosion. The total area of degradation is estimated at 150 million hectares (Table 1-7). Water erosion is in a serious condition mainly in Indochina, northeastern and northern Thailand, India's west coast, western Java, and the Philippines. An important cause of the intensified soil erosion in Thailand and the Philippines is the fact that their forest area ratio fell to 20% level as a result of commercial tree cutting and expansion in upland farmland for cashcrops, mainly cassava for livestock feed, in the 1960s and afterwards (Kumazaki, 1993). In southern China, Hainan and Taiwan, in addition to the topographical factor of steep slopes, many years of cultivation, high population density, and recent

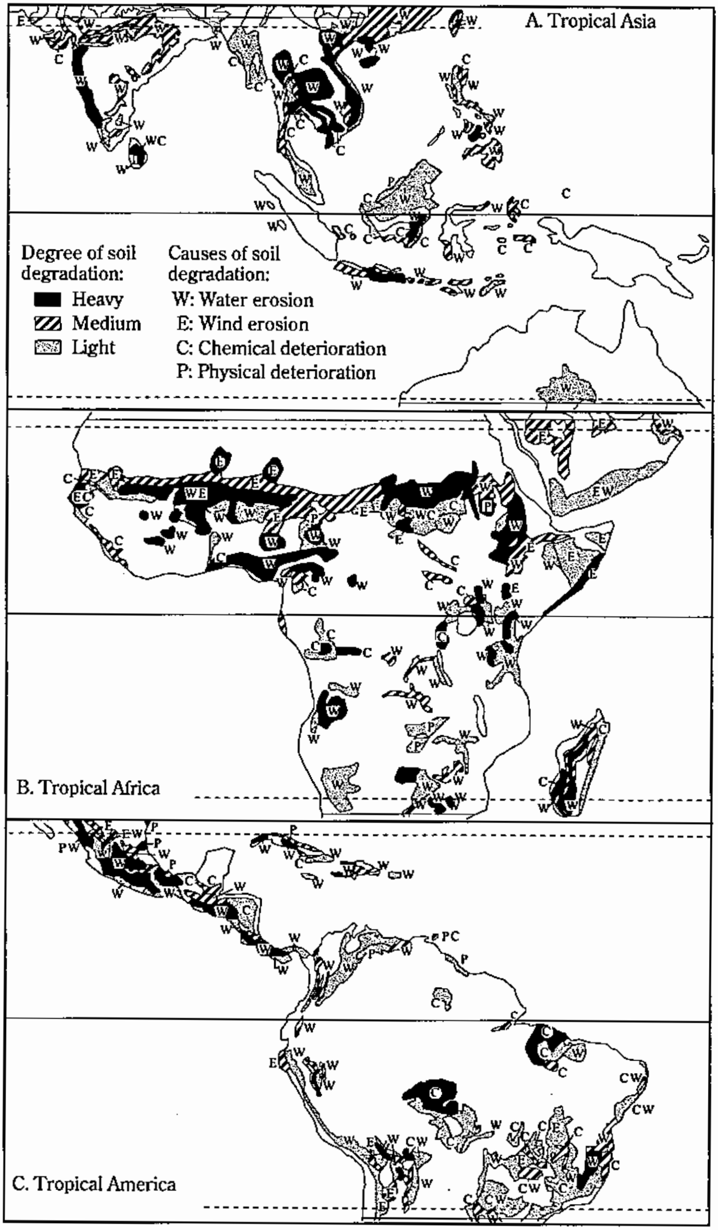


Fig.1-9 Human-imduced soil degradation in the tropics (simplified versions of UNEP/ISRIC, 1991) (Wakatsuki, 1994)

Table 1-7 Human induced soil degradation

(Million ha)

	Light	Medium	Heavy	Total	
Tropical Asia(total area : 1,100), Whole Asia(total area : 4,300)					153.2(737.9)×10^6ha(13.9%)
Wt : Topsoil loss	26.3	55.9	13.1	95.3(365.2)	
Wd : Topographic change (gully erosion, etc.)	6.4	6.9	6.0	19.3(74.4)	
Total, water erosion	32.7	62.8	19.1	114.6(440.6)	74.8%(59%)
Et : Topsoil loss	1.5	2.5	…	4.0(165.8)	
Ed : Topographic change (movement of dunes, etc)	1.0	5.5	…	6.5(56.4)	
Total, wind erosion	2.5	8.0	…	10.5(222.2)	6.9%(30%)
Cn : Nutrient loss	4.6	9.0	1.0	14.6(14.6)	
Cs : Salinization/alkalinization	3.5	2.0	2.0	7.5(52.7)	
Ca : Acidification	0.4	2.5	1.2	4.1(4.1)	
Total, chemical deterioration	8.5	13.5	4.2	26.2(73.2)	17.1%(10%)
Ps : Peat land subsidence	0.7	1.0	0.2	1.9(1.9)	1.2%(1%)
Tropical Africa(total area : 2,500)				Total	416.5×10^6ha(16.5%)
W_t	45.8	51.4	76.8	174.0	
W_d	3.1	5.9	10.2	19.2	
Total, Water erosion	48.9	57.3	87.0	193.2	46.4%
E_t	67.2	71.6	6.3	145.1	
E_d	7.8	4.3	1.3	13.4	
Total, wind erosion	75.0	75.9	7.6	158.5	38.1%
C_n	20.4	18.8	6.2	45.1	
C_s	3.0	1.0	0.5	4.5	
C_s*(North Africa only)	1.7	6.7	1.9	10.3	
C_a	1.1	0.3	…	1.5	
Total, chemical deterioration	24.5	20.1	6.7	51.1	12.3%
Pc : Compaction	1.4	7.5	4.8	13.7	3.2%
Tropical America(total area : 1,700)				Total	242.5×10^6ha(14.3%)
W_t	28.0	55.2	13.1	96.3	
W_d	8.9	18.5	19.9	47.3	
Total, Water erosion	36.9	73.7	34.0	143.6	59.2%
E_t	2.0	9.4	0.5	11.9	
E_d	0.1	2.4	…	2.5	
Total, wind erosion	2.1	11.8	0.5	13.4	5.5%
C_n	24.6	35.5	12.7	72.4	
C_s	2.1	1.8	0.5	4.4	
Total, chemical deterioration	26.7	37.3	13.2	76.8	31.7%
P_c	1.5	0.5	0.3	2.3	
P_w : Waterlogging	2.3	3.3	0.8	6.4	
Total, physical deterioration	3.8	3.8	1.1	8.7	3.6%

Source : Based on Oldeman *et al.*, 1991 and UNEP/ISRIC 1991.

rapid economic growth are aggravating soil erosion. This is the case with Java and Bali as well as western India, too. However, *sawah based agriculture* has long been practiced in these areas and so soil erosion does not directly result in reduced soil productivity unlike the cases of tropical Africa and America. It can rather be considered that since active soil formation takes place to cope with soil degradation, soil restoration (or regeneration) occurs actively, too, in tropical Asia. We should also take account other related factors, such as the balance between soil erosion and compensatory soil formation and the ratio of the fertile topsoil formed in watersheds that is carried to and accumulated in lowland sawah fields. As discussed in subsection 6 of this chapter, the sustainable productivity of sawah field in tropical Asia is considered to be on a high level. The problems of sawah based farming in this region are if it can support further population growth and how it will be possible to raise its sustainable productivity (Kyuma and Wakatsuki, 1995). However, as a result of rapid inclusion of agriculture in a market economy in recent years, the tendency to pursue short-term profits is increasing. There are many areas where even those forests that used to be protected as water and soil resources for lowland sawah fields, topsoil supply sources, or forests sacred to the gods are being cut down and turned into *alang alang* (*Imperata cylindrica*) grasslands.

The cases of soil degradation resulting from recent development activities can be observed in Borneo and southern Indochina. In these areas, in addition to water erosion caused by tree cutting, subsidence (*Ps, physical deterioration*) and the formation of acid sulfate soils due to the clearing of wetland, peat and mangrove forests and their conversion into farmland lead to severe acid soil damage (*Ca, acid, chemical deterioration*). The chemical deterioration (Cs, salt) seen in the Punjab District in India and Pakistan is caused by salt and alkali damage because of improper irrigation.

Aged and strongly weathered soils, such as *Oxisols* and some *Ultisols*, originally contain only a small quantity of inorganic nutrients. Thus, deforestation and conversion into farmland result in decomposition of humic substances in the topsoil and loss of inorganic nutrients, leading to a rapid lowering of productivity. This is also a type of chemical deterioration (*Cn, nutrition*). In the whole of tropical Asia, the areas of Cn-originated degraded soils are estimated at about 15 million hectares and are distributed mainly in the Malay Peninsula, Borneo, and the Moluccas. They are the largest areas of chemically deteriorated soils in Asia. Degraded soils due to loss of inorganic nutrients (Cn) like these exist far more in tropical America and Africa than in their Asian counterpart :

its area is estimated at 72 million hectares in tropical America and at 45 million hectares in tropical Africa (Table 1-7).

As shown in Fig. 1-9, soil degradation caused by occurs water erosion most extensively in *tropical Africa*, too (Table 1-7 ; about 46% of total degraded land). Also important is wind erosion, which accounts for 38%. While climatic changes have some impact, the problem of desertification or the Sahara's southward expansion following the destruction of vegetation is growing more grave in this region (Kadomura *et al.* 1991 ; Kadomura and Katsumata 1992). The figure suggests that in sub-Saharan West Africa, areas of soil degradation due to wind erosion are increasing, mainly in the Sahel and Sudan savannas. These areas are in the front line of desertification. Another noteworthy fact is that in these regions wind and water erosion combine to accelerate farmland degradation. The areas are attacked by drought and flood damage by turns. This suggests that in semi-arid regions, too, the control of water circulation is the key to the conservation of the farmland environment. Wind control by windbreak forests is also important.

Soil degradation caused by water erosion takes place mostly in the highlands situated in the Great Rift Valley, such as the Ethiopian Plateau, Kenya, Tanzania, and other parts of East Africa. These areas coincide with those having highly fertile soils derived from volcanic ash and a high population density. The main crop grown in the highlands in East Africa is maize. The recent introduction of high-yielding varieties, coupled with fertile soil there, has increased the yield of maize but maize cultivation is also aggravating up soil erosion in these areas. On the other hand, since temperatures are low in the highlands and rice can only grow in the areas lower than 1,200m, the potential area for sawah and rice-based agriculture is small except in Tanzania. In West Africa, the highlands in Cameroon are also densely populated areas with fertile soil derived from volcanic ash. Like the Yoruba and Ibo areas in Nigeria, these areas are suffering serious water erosion. In Madagascar, water erosion resulting from deforestation is observed in the central highlands and soil degradation caused by nutrient loss, in lowland areas. However, because of the influence of *Indonesian sawah culture*, rice yield and production are rather high in Madagascar. Regions suffering chemical deterioration because of nutrient loss have spread not merely in Madagascar but all over the African continent as well, especially in Oxisol and Ultisol zones in the DRC, Togo, Benin, Liberia and Sierra Leone.

As evident from Fig. 1-9 and Table 1-7, water erosion accounts for 60% of

Table 1-8 Estimated areas of soil degradation by cause and continent
(Oldman *et al* 1991, GLASOD in UNEP 1997)

(Million ha)

	Deforestation	Overgazing	Improper farming method	Excessive firewood collection	Industrial activities
Africa	67 (19)	243 (185)	121 (62)	63 (54)	+
Asia	298 (112)	197 (119)	204 (97)	46 (42)	1
South America	100 (32)	68 (26)	64 (12)	12 (9)	-
Middle and North America	18 (4)	38 (28)	91 (41)	11 (6)	+
Europe	84 (39)	50 (41)	64 (18)	1 (0)	21 (1)
Australasia	12 (4)	83 (79)	8 (5)	- (0)	+
World total	579 (210)	679 (478)	552 (235)	133 (111)	23 (1)

Note : Figures in parentheses are susceptible dryland areas.

all soil degradation in *tropical America* (140 million hectares) just as it does in the two other tropical areas. However, unlike in Africa, there is not much wind erosion here. One important characteristic of tropical America is that because of a wide distribution of Oxisols and much precipitation, the percentage of *chemically deteriorated soil (Cn)* due to a rapid loss of topsoil functions and soil nutrients resulting from agricultural use is the highest in the three tropical areas (32% of all degradation). Newly developed areas along the Amazon are representative of this. Chemically deteriorated soil is increasing mainly in the areas in and around Belem and in reclaimed land in Cerrados.

Table 1-8 shows the estimated areas of degraded soil by cause and by continent. These figures are not limited to those for the tropics but are helpful in understanding the causes of soil degradation. The table also includes the data in parenthesis on susceptible dry-land (GLASOD in UNEP 1997). In Africa, the most important cause is overgrazing, followed by improper farming methods, deforestation (shifting cultivation, commercial tree cutting, etc.) and excessive collection of vegetation (firewood gathering, etc.). In Asia, deforestation is the most important cause and then come improper farming methods and overgrazing. The trend in South America is similar to that in Asia. This has no direct relation to the discussion here but the major problem in Middle and North America is the inadequate application of conservation-type farming methods. In

Europe, deforestation ranks first but it is also worthy of note that the areas of soil degradation and pollution by industrial activities have reached as many as 23 million hectares. Just as in Africa, soil degradation and desertification caused by overgrazing are the most serious problems in Australia.

3-3. Estimate of *effective population density* of the *three major tropical regions*

Fig. 1-10, A, B and C show the distribution of main soil types in tropical Asia, Africa, and America. To draw these charts, FAO/UNESCO's Soil Map of the World (1974) was used making the necessary changes by referring to the Keys To Soil Taxonomy (Soil Survey Staff, 1998) and it has been simplified by disregarding the classifications below the order level. Table1-9/Fig. 1-11 show in what kinds of topography and moisture environment in the tropics major soil orders are formed as well as the estimated areas of each soil order in the three major tropical zones (Sanchez, 1976 ; Kyuma, 1984 ; Okagawa, 1984 ; Wambeke, 1993 ; Eswaran, *et al*., 1992 and 1997). The Keys To Soil Taxonomy (Soil survey staff 1998) and Soil Taxonomy (Soil survey staff 1999) establishes 12 soil orders, but both in Table 1-9 and Fig. 1-11, *Psamments* (large quartz group), a suborder belonging to the *Entisol Order*, is dealt with in an order-equivalent soil category. This is because Psamments have a wide distribution especially in tropical Africa and also because they are quartzitic sandy soils containing almost no weatherable primary minerals. So like Oxisols, they contain only weathered end products of rocks and soils, are not suited to agricultural production, and have a very low level of productivity. The Soil Taxonomy (Soil Survey Staff, 1975 and 1999) classifies these soils into Entisols, young immature soils, because their soil profiles are immature, but the soil's parent materials themselves are aged soils highly weathered and leached. Since they can be distinguished from Oxisols whose main constituents are clayey weathered end products (kaolinite, iron and aluminum oxides), but are comparable in this respect, Psamments are shown as an independent soil type equivalent to 10 other soil orders and a new Gelisols order in Soil Taxnonomy (soil survey staff 1999). As shown in Fig. 1-10, the distribution of Oxisols in Africa and South America is almost all limited to the shields composed of very old and stable *cratons*, which formed the basis of these continents more than two billion years ago. Since Psamments are observed around these shields where Oxisols are found, these soils and Oxisols are supposed to have been formed in connection with each other.

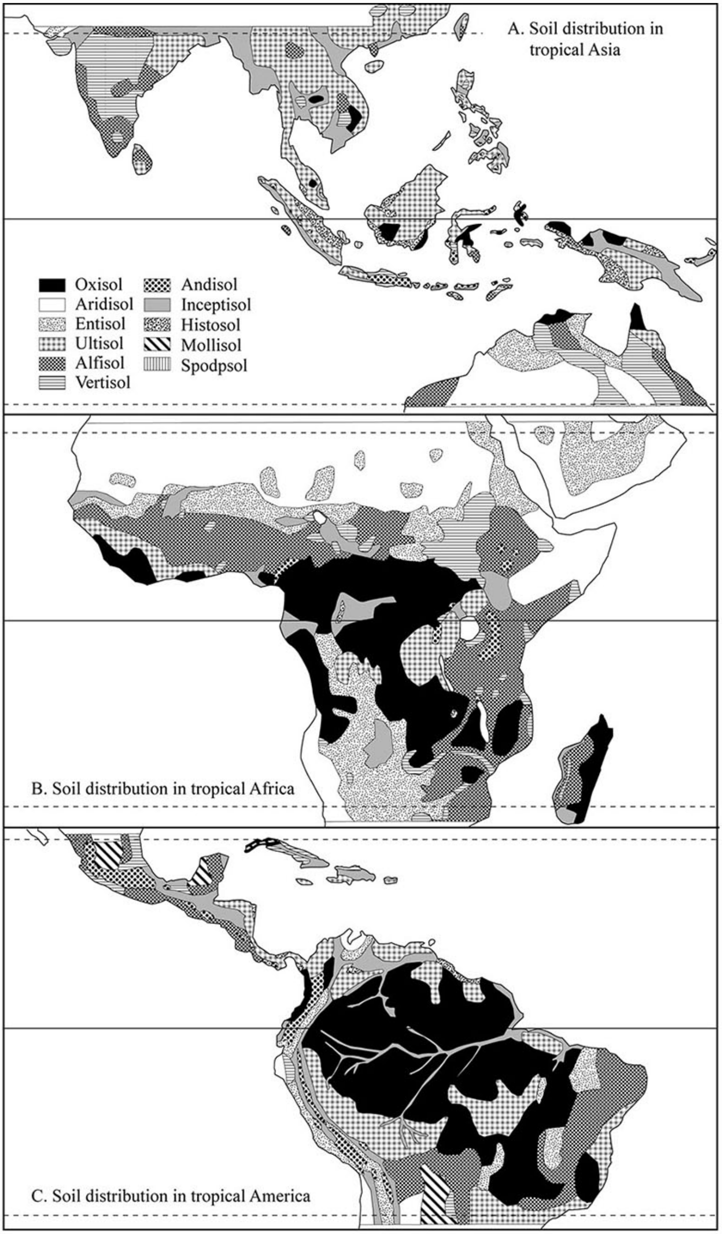
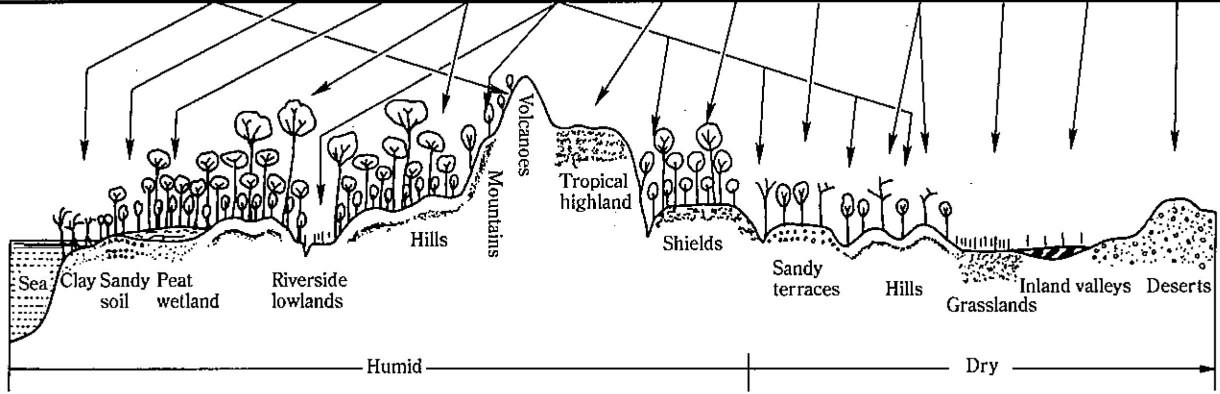


Fig. 1-10 Soil distribution in the three tropics (FAO/UNESCO, 1974 used making necessary changes referring to the keys to Soil Taxonomy 1994) (Wakatsuki, 1994a)

Table. 1-9/ Fig. 1-11 Typical topography and areas of major soil distribution in the tropics based on the Soil Taxnomy

	Entisol	Spodosol	Histosol	Ultisol	Inceptisol	Andisol	Oxisol	Psamment	Alfisol	Mollisol	Vertisol	Aridisol	Total
Soil Characterristics	Immature, parent materials	Sandy, leaching	Peat wetland	Strongly weathered, acid	Young vitality	Volcanic ash,fertile	Aging, leaching	Quartz leaching	Eutrohpic, low activity	Grasslands, dry season	Black, semi-arid	Dry, desert	(excluding no-soil surface)
Toropical Africa	50	3	2	190	240	5	440	340	320	4	100	810	2,504
Tropical America	90	0.5	5	330	130	90	660	20	120	15	20	50	1,531
Tropical Asia	250	3	22	300	200	50	tr	tr	80	tr	100	10	1,015
Total tropics (million ha)	390	7	30	820	570	145	1,100	360	520	19	220	870	5,050
Total tropics (ratio in %)	7.7	0.1	0.6	16.2	11.3	2.9	21.8	7.1	10.3	0.4	4.4	17.2	100
Japan (ratio in %)	4	3.5	1.0	2.5	58	16	0	tr	tr	0	0	0	100



Souce: FAO/UNESCO, 1974; Sanchez, 1976; Kyuma, 1984; Ogawa, 1984; Wambeke, 1993; Eswaran, *et al.*,1992, and 1997.

In tropical Africa, the combined area of Oxisols and Psamments, the aged, leached and nutrient-depleted soils mentioned above, and *Aridisols* containing little moisture accounts for 63.5% of all land. These types of soils, unsuitable for agriculture, are little distributed in tropical Asia. In tropical America, Oxisols have a wide distribution (43.1%) mainly in the *Amazon basin* and the ratio of soils unsuited to farming is 47.7% (Table 1-9 and Fig. 1-11).

Alfisols in a semi-humid climate are the main soils for agriculture in tropical Africa. But these soils have a number of problems: the severe dry season, a relatively *low cation exchange capacity* (CEC), and thus a *low activity*. Another problem is that the structure of this soil is weakly developed and so they are liable to erosion. Vertisols have a high chemical fertility but in tropical Africa, they exist mainly in the areas having a precipitation of 500mm or less and not blessed with a water supply and so have only a low productivity. By contrast, in tropical Asia, these soils are distributed mostly in the areas with a rainfall of 800-1,000mm, chiefly in India, making *intensive farming* possible (Here, tropical Australia shown in Fig. 1-10 is excluded from the calculation of the area of tropical Asia). Of tropical soil types, Andisols derived from volcanic ash mainly on highlands of 500-3000m and Inceptisols distributed in lowlands are those with both good moisture and fertility conditions. The distribution of Andisols in tropical Africa is very limited (Table 1-9). While intensive farming is practiced on Andisols in all of the three tropical zones, Inceptisols in lowlands are not very much used in tropical Africa and America. The latter is utilized for sawah fields in tropical Asia and produce food for more than two billion people on a sustainable basis. Ultisols are distributed in the humid tropical zones and are found on relatively stable hilly areas having gentle slopes (see the illustration as Fig. 1-11 below Table 1-9). Though they are heavily weathered and are acid because their bases have been leached, these soils are younger than Oxisols. They retain feldspar and other primary minerals and thus has some sustainable nutrient-supplying capacity. These soils are used for shifting cultivation-type extensive farming or for plantations of rubber trees and other crops. However, efforts should be made to use these soils, together with *Spodosols* and *Histosols* (peat soils), for the development of forest reserves or for forestry purposes rather than for intensive farming. *Mollisols* are the main soil for agriculture in the temperate zone but their distribution is very low in the tropics. Only a small area of these soils exists in Mexico and Paraguay in tropical America and in the border areas between *Vertisols* and Alfisols in tropical Africa.

From the soil distribution and characteristics of soil degradation mentioned

Table 1-10 Estimated effective population density in the three major tropical zones

	Tropical Africa	Tropical America	Tropical Asia
Population in 1990(100million)	4.9	3.9	17
Area(10^4km^2)	2,500	1,530	1,000
Population density(per km^2)	20	25	170
Poor soil*(%)	63.5	47.7	1.0
Yeild decrease due to shotage of precipitation**(%)	50	0	0
Yeild decrease due to nutrient shotage***(%)	25	25	0
Effective population density****(pers/km^2)	146	64	170

Notes: 1)*Poor soils=Aridisols+Psamments+Oxisols
2)**Yeild decrease due to shortage of precipitation=Alfisols, Vertisol, etc. in Africa
3)***Yeild decrease due to nutrient shortage=Ultisols, etc. in Africa and America(See also Table. 2-8)
4)****Effective population density=population density $\times \frac{100}{(100-1)^{*})} \times \frac{100}{(100-2)^{**})} \times \frac{100}{(100-3)^{***})}$

above, the effective population density of the three major tropical zones can be calculated. The results are shown in Table 1-10. The population density estimated on the basis of the population and area in 1990 is 170 persons/km^2 in tropical Asia and 20 persons/km2 in tropical Africa, the difference being ten times. This fact is used to explain that population density is low in Africa and so intensive farming is not established or necessary there. But let's exclude Aridisols, Psamments, and Oxisols, the poorest soil types on which no agricultural land use can be expected. Then suppose that the yield decrease is 50% because of shortage of precipitation in Alfisol and Vertisol zones which are major farming soils in the African Continent, in comparison to Asia and America. Also, estimate the yield decline owing to nutrient shortage in Ultisol areas and other base-leached soils that are widely distributed in tropical Africa and America at 25% (see also Table 2-8 in Chapter 2). These estimated figures of yield decrease due to insufficient rainfall or nutrients have no scientific background. Table 1-11 compares Asia's and Africa's agricultural productivity based on FAO (1990ab FAO STAT 2001) data, picking out tropical countries only and confirming the tendency mentioned above. As shown in Table 1-11, the yield of rice in tropical Africa (here, the data for West Africa are used) was about 42% that of tropical Asia (1.5/3.6 in 1990 an 1.6/3.9 in 1999). The average yield of various main crops in West Africa (rice, maize, sorghum, millet, cassava) is about 1.2 t/ha or about 33% that of crops in Asia (cassava is based on converted yiels). Though these are rough estimates, they support the general validity of the above estimate ($0.5 \times 0.75 = 0.375$). In the above calculation, the

Table 1-11 Comparison of agricultural productivity between tropical Asia and tropical Africa

(FAO, 1990 a, b, FAOSTAT 2001)
(t/ha)

	Tropical Asia			Tropical Africa		
	1970	1990	1999	1970	1990	1999
Rice	1.8	3.6	3.9	1.3	1.5	1.6
Maize	1.2	2.7	3.7	1.1	1.5	1.3
Sorghum	0.54	0.97	1.0	0.83	0.75	0.9
Millets	0.45	0.77	0.9	0.66	0.69	0.8
Cassava	8.5	11.3	16.1	6.7	7.6	9.2

yield of cassava in rice equivalent is supposed to be one-fifth on average (converted yield), because the unit calorie value of cassava is 1/2.8 that of rice and its protein content, 1/7.2.

Based on the assumptions described above, the effective population density is calculated using the following equation:

$$\text{Effective population density} = \text{population density} \times \frac{100}{100-a} \times \frac{100}{100-b} \times \frac{100}{100-c}$$

a : area percentage of soils of extremely poor or almost no potential for agricaltural use,

b : estimated yield reduction percentage due to water shortage in cultivated area.

c : estimated yield reduction percentage due to nutrient shortage in cultivated area.

The *effective population density* calculated using this equation is, as shown in Table 1-10, 146 persons/km^2 in tropical Africa and 64 persons/km^2 in tropical America. This suggests that while tropical America still has some room to support increased population, tropical Africa's effective population density is close to that of its Asian counterpart. Behind the recent crisis of agriculture, food, and environment in tropical Africa lies this high effective population density, too. This clearly indicates that there is an urgent need for establishing intensive and sustainable farming systems. While the agricultural crisis in Africa has social, economic, and political reasons, it can be understood that the continent is in a very critical situation from the viewpoint of basic natural and ecological factors, such as soil fertility, (also see Chapter 2.)

3-4. Situations of farmland degradation and desertification in West Africa

(1) Desertification : southward movement of the desertification front

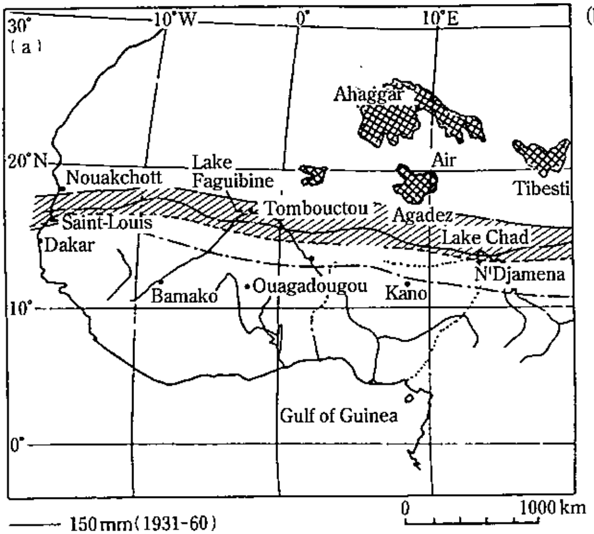
Kadomura, *et al.* summarize the environmental changes in West Africa in the last 100 years (1991, 1992). During the spell of drought that started around 1896 and reached a peak in 1913/1914, 30-50% of the population was said to have been lost in the *Sahel* in Chad, Niger, Mali, etc. Thereafter, the humid period continued for some time but the trend of drought began to become prevalent. Consequently, as shown in, for example, Fig. 1-12 (Shinoda, 1989, UNEP 1997), both the *desertification front* of a rainfall of 150mm and the *starvation front* of 300mm (minimum rainfall needed for millet cultivation) moved southward by as much as 200-400km from their average-year positions in 1984 when drought damage was especially grave, expanding the area of deserts. If the two periods 1931-1960 and 1960-1990 are compared, the *rainfall decline* has been of the magnitude of 20-40% (Hulme and Kelly1993). As evident from Fig. 1-13 (Ojo, 1985), this tendency of rains fall to decline occurred not merely in 1984 but has continued for the past 25 years. This phenomenon is observed in areas other than the Sahel, that is, in the Sudan and Guinea savanna zones. The present trend of *global warming* is attacking this area as enhancing the *warmer-drier relationship* (Hulme 1996). Global warming is likely to further reduce the already limited availability of moisture in this region (UNEP 1997).

Fig. 1-14 shows the state of *southward movement of the isohyets* of 900mm, 1,100mm, 1,300mm and 1,500mm in *Nigeria* in the 1961-1990 period (IITA, 1992). During these three decades, all of the isohyets moved south by about 200km. The Sahara's southward movement brought a decrease in precipitation in all parts of sub-Saharan Africa. As noted below, this decline in rainfall followed the rapid decrease in forests in the period from the 1900s to 1960s, which may suggest that human activities have had great effects on decreasing precipitation in this region.

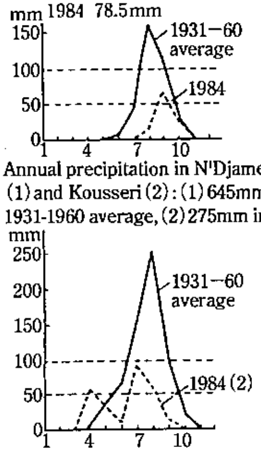
(2) Decrease in forests

Table 1-12 shows the decreasing trends of forests in the 70-90 years in the twentieth century in Thailand, Ghana, Nigeria, and Côte d'Ivoire. In Ghana, Nigeria and Côte d'Ivoire in West Africa, forest areas showed a sharp decline during the colonial years from 1900 to 1960 (Mather 1990). This is because *colonial policies* forced local farmers to grow cash crops and because the forced

(a) Southward movement of the "desertification front" and "starvation front" in 1984, the worst year of drought



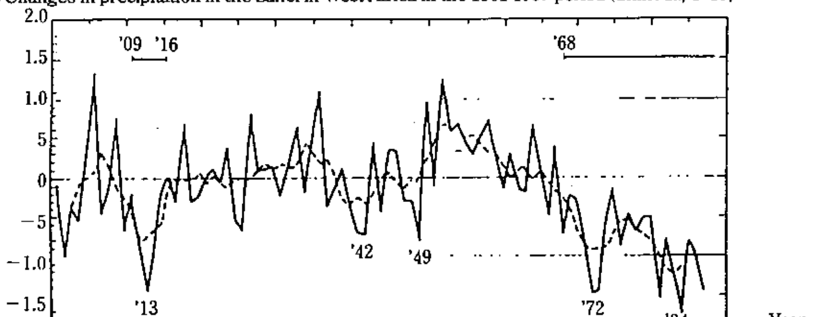
(b) Annual precipitation in Saint-Louis: 346.9mm on 1931-1960 average



150 mm (1931-60)
150 mm (1984)
300 mm (1931-60)
300 mm (1984)
Areas where old dunes may become active again
Highland parts of the Sahara (500m above the sea level or more)

Southward movement of the "desertification front" (line of annual precipitation of 150mm) and "starvation front" (300mm) (a), and monthly precipitation (b) in the Sahel in West Africa in 1984, the worst year of drought.
Kousseri is a town on the other side of N'Djamena across the Logone River.
In the humid period from the 1950s and the first half of the 1960s, these isohyets existed 200~300km north of the average year's positions.

(C) Changes in precipitation in the Sahel in West Africa in the 1901-1987 period (Shinoda, 1989, with corrections)



Values shown are the standardized ones obtained by dividing the differences between the average precipitation in the whole period and that in each year by the standard deviation. Remarkable drought occurred in 1909-1916 period with a peak in 1913, the 1972-1973 period and the period after 1968 with peaks in 1983-1984.

Fig. 1-12 Southward movement of the "desertification front", "starvation front" in1984 and changes in precipitation in the Sahel in West Africa in the 1901-1987 period (C).

(Hiroshi Kadomura and Makoto Katsumata, 1992)

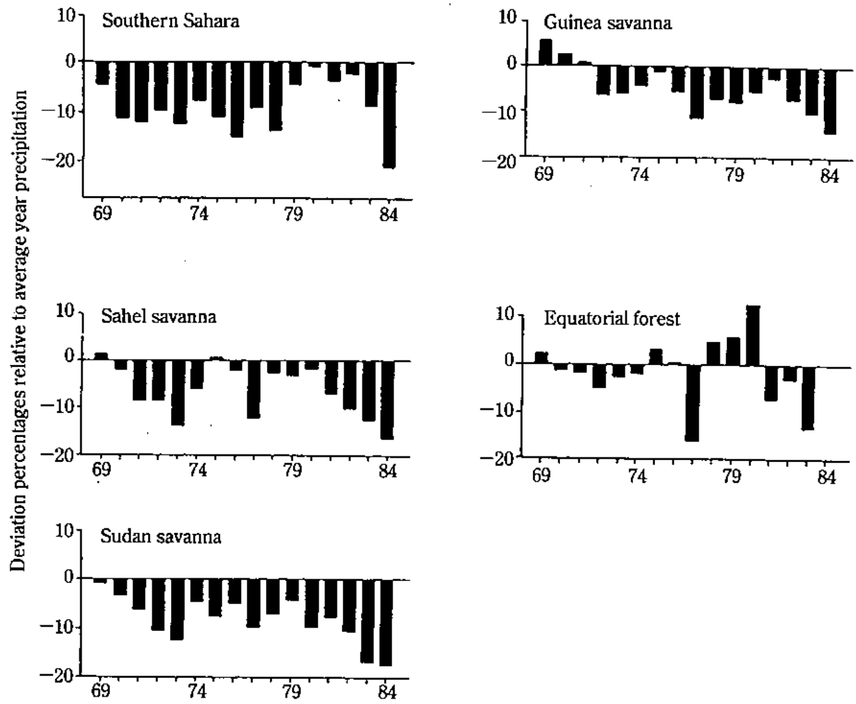


Fig. 1-13 Record of abonormal precipitation in West Africa in each agroclimatic zone (based on Ojo, 1985)

of cultivation cash crops resulted in the destruction of forests in neighboring areas from the development of new fields for growing crops for the farmers' own consumption. No data of Nigeria's colonial years are available but in 1964, just after its independence, the ratio of forest areas dropped as low as 23%. During the two decades from independence to 1984, the country's forests decreased further to 16%. These figures show that Nigeria's stock of usable forests had already run short at the time of its independence and that the country had no alternative after that but to use even the few remaining forests to support a rapidly increasing population. As evident from Table 1-12, this trend can be observed in the whole of West Africa as well as in Nigeria. These countries need to establish a system for increasing sustainable food production without deforestation as soon as possible and thus to find ways to restore their forest resources.

As a result of the forest destruction, as shown in the "Others" column of

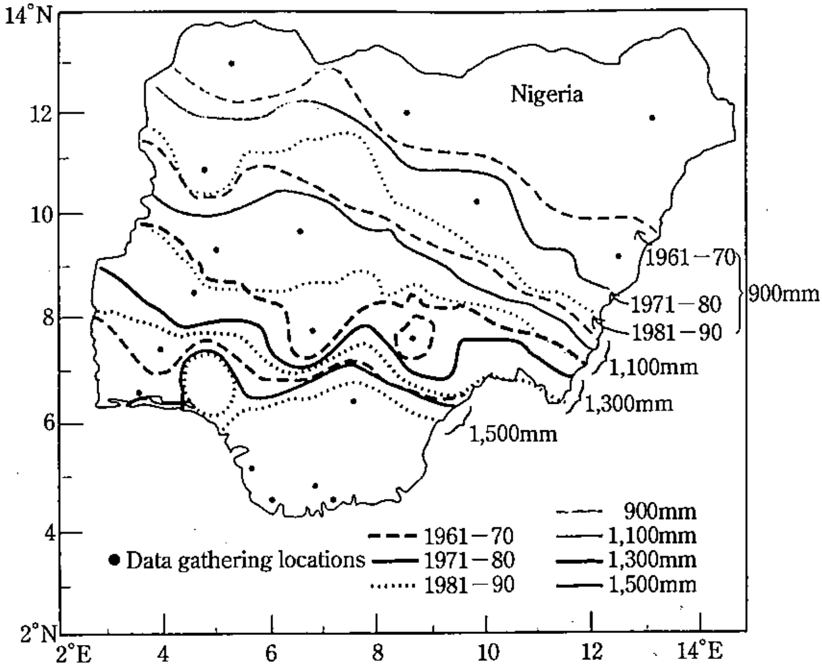


Fig. 1-14 Southward movement of isohyets: expanding desertification (IITA, 1992)

Table 1-12 Tendency of closed-canopy forest areas in the 1900-1984 period
(Kumazaki, 1990 ; Mather, 1990 ; World Resource Institute, 1990, 1998-2000)

(%)

Year	Ratio of closed-canopy forest area to land area				
	Tailand	Ghana	Nigeria	Cote d'Ivoire	Liberia
Original coverage	100	66	45	75	99.6
1900				50	
1920s	75	41	-	46	67
1930s	70	20	-	-	-
1950s	69	18	-	37	57
1960s	58	10	?(23)	34	-
1970s	43(48)	9(38)	?(19)	22	26
1980	25(35)	?(37)	?(18)	8	21
1984	18(30)	?(36)	6(16)	5(22)	-
1995/1996	22.8(22.8)	8.6(39.7)	11(15.1)	10(17.2)+2	44(46.8)
Aforested area by 1990(million ha)	0.53	0.053	0.15	0.063	0.006

Notes : Figures in parentheses are those including open canopy forests, too.

Table 1-5, the area of sterile land with no biological production, which was produced by desertification or urbanization, increased by about three million hectares respectively in Côte d'Ivoire and Nigeria in the 25 years from 1974 to 1999. In 1999, Nigeria has only 14 million hectares of forests and woodland compared with 28.2 million hectares of farmland. Côte d'Ivoire has only 5.5 million hectares of forests and woodland compared with 3 million hectares of farmland (Because it is hard to define forests and conduct forest surveys precisely, the FAO survey for Table 1-5 and the survey for Table 1-12 do not agree with each other). The forest destruction of Côte d'Ivoire was very severe during the last 25 years. About 7 million hectares of forest were lost. Rapid increase of upland rice cultivation was one of the major reasons.

The total cereal production of rice, maize, sorghum, millet and cassava (cassava is regarded as an equivalent to one-fifth that of cereal) were 2.9 million tons for Côte d'Ivoire and 34.1 million tons for Nigeria in 1999. Supposing per capita grain consumption is 300kg a year allowing for possible losses, Nigeria needs about 32.7 million tons of grain output. Côte d'Ivoire needs 4.4 million tons of grain output in 1999. This means in recent years Nigerian food production has recovered considerably as shown in Tables 1-1~1-5 ; however, Côte d'Ivoire is in a very critical situation now. Since both countries no longer have any spare forest in which to increase crop production by expanding farmland and if they take no proper action, the countries farmlands are in danger of severe degradation. Now it is very clear that the anticipated population expansion in this region can be supported only by the significant increase of cereal yields.

While deforestation in West Africa has the above-mentioned history, Thailand in tropical Asia experienced, as Table 1-12 shows, a rapid decrease in forests in the 1970s and afterwards, especially in the period of high economic growth. The country achieved economic development at the sacrifice of its own ecological environment. In West Africa, the case of *Côte d'Ivoire*, which used to be a French colony, may resemble that of Thailand to some extent. However Côte d'Ivoire is a major crop importer (mainly rice) while Thailand is the major rice exporter. But in almost all West African countries, deforestation was only to the advantage of their colonial rulers, while *Thailand*, because of not suffering from colonization, could use her natural forest resources for her own development.

The situation is similar in other countries in West Africa other than those shown in Table 1-12. Since the area estimation of various forests are difficult, the data should contain considerable errors, especially before 1984. Probably the area estimation on 1995/96 by the World Resource Institutes will be the best at the moment. As evident from Table 1-5, the average ratio of forests in West Africa is only 11%. Liberia has the highest figure of 47% in 1998, followed by Ghana with 39% (including bush-type forests). Countries in this region have only a few tropical forests to be conserved. In this sense, the situation is basically different from that of Brazil, Indonesia, and some other countries where the need is emphasized to protect existing tropical rain forests. Needless to say, Nigeria, Côte d'Ivoire, and other West African nations must conserve a few remaining forests in their land (as evident from Table 1-5, the decreasing rate of decrease in forests in this region is the highest among the three major tropical zones). But in addition to considering strategies for protecting their existing forests, they have also to establish positive afforestation plans to restore lost forests.

The *afforestation areas* in tropical African nations are generally very small as shown in Table 1-5. According to Table 1-5, the total planted areas in Nigeria and Benin, where afforestation was more actively carried out, were only 150,000 and 120,000 hectares respectively by 1990. Annual afforestation will be not more than 50,000 hectares. On the other hand, in Asia, China has ambitious plans about as much as 4.80 million hectares of annual afforestation and Indonesia and Vietnam have 200,000 hectares each. This is not adequate but it is far more than in African countries. Although China decreased the forest to 22% of his total land, the total area of afforestation reached 32 million hectares (about 24% of total forest) by 1990. Neither sustainable afforestation nor forest restoration projects is possible without any support of food production, and in this respect, the difference between Asia that has a firm agricultural basis and a strong economic power and tropical Africa that is suffering from an agricultural crisis is evident in afforestation areas, too. For example, in Thailand in tropical Asia, the afforestation area is larger than the deforestation area in recent years. As shown in Table 1-12, total the area of afforestation was 0.53 million hectares of Thailand even in 1990 ; all the West African countries in Table 1-12 except for Nigeria have almost no evidence of afforestation.

4. Directions of *restoration of degraded farmland* and development of *sustainable farming systems* in West Africa

4-1. *Traditional farming systems* in West Africa (okigbo 1990)

(1) *Shifting cultivation and nomadic herding*

Shifting cultivation is a sustainable farming system as far as it is possible to lay land fallow until its soil fertility is sufficiently restored. But if population density exceeds 10 persons/km^2, it becomes unsustainable though it depends on soil fertility. Nomadic herding is sustainable, too, as far as the raising density of animals is within the carrying capacity of the soil to produce grassland. But in addition to decreasing precipitation in recent years, those foreign assistance projects that do not take account of this carrying capacity of grassland have led to one-sided improvements in livestock raising services, such as providing water and better hygienic conditions, which has resulted in a shrinkage of herding areas. Moreover, the borders drawn according to the old regimes of the colonial years, ignoring ecological and natural conditions, are limiting the range of herding activities in this region. These factors are working in combination, thus causing excessive animal densities beyond the sustainable carrying capacity of grassland and *overgrazing* in increasing places. As shown in Table 1-8, in Africa, overgrazing is by far the most important cause of farmland degradation out of all the factors concerned. It accounts for 50% or 240 million hectares of the total area of human-induced farmland degradation (490 million hectares) in Africa. In the entire world, including Africa, overgrazing is the major cause of desertification.

(2) *Bush fallowing or land rotation*

Bush fallowing is now the most widely used farming system in West Africa. Mainly because of the too high population density and the cultivation of peanut, cacao, coffee, rubber, oil palm and other plantation crops for export, the population pressure on land becomes heavier and the fallow period is shortened. As a result, it becomes impossible to restore forests, and agriculture turns into bush fallowing or *rudimentary sedentary agriculture*. The planting of the next crop is now carried out before soil fertility has been completely restored. Therefore, this method is not sustainable. As already discussed, in West Africa, deforestation rapidly occurred and the formation of derived savanna and alang alang (*Imperata cylindrica*) grasslands. Thus the cultivation of cassava is increasing because it can be grown even in degraded land and does not need much labor (conversely, it is hard to use any soil conservation-type farming system for this crop). The widespread introduction of IITA-bred high-yielding cassava varieties is also contributing to the increased planting of this crop. But *expansion in cassava* cultivation seems to have some problems both in terms of farmland degradation and quality of human food supply. The ratio of cassava consumed as a staple food by people, particularly poor farmers, is higher in West Africa than in tropical Asia and other parts of Africa. It appears to raise the question of nutrition that people continuously eat large quantities of cassava having an extremely low protein content (only one-eighth that of rice, maize and sorghum). It is probably a grave problem that the *Consultative Group on International Agricultural Research (CGIAR)* has reinforced the strategy of encouraging small farmers in Africa to increase cassava production.

According to the result of the reforestation experiment by the *Forest*

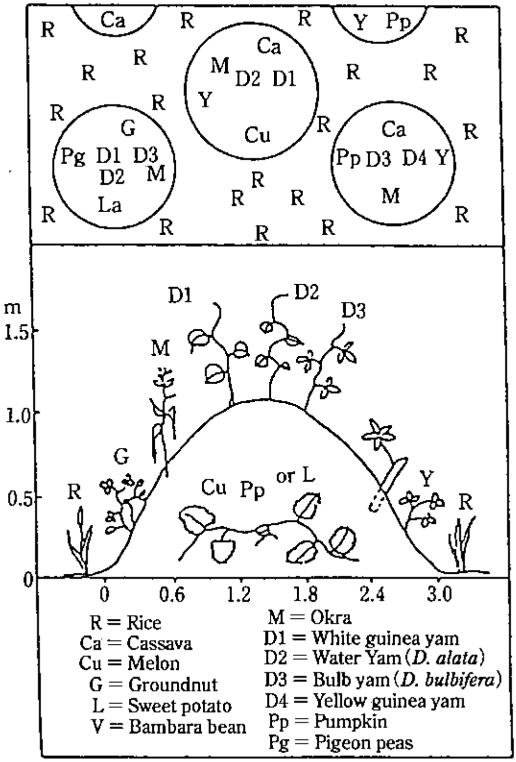


Fig. 1-15 Microscale-mixed cropping on a mound
(Okugbo, 1978, p.18)

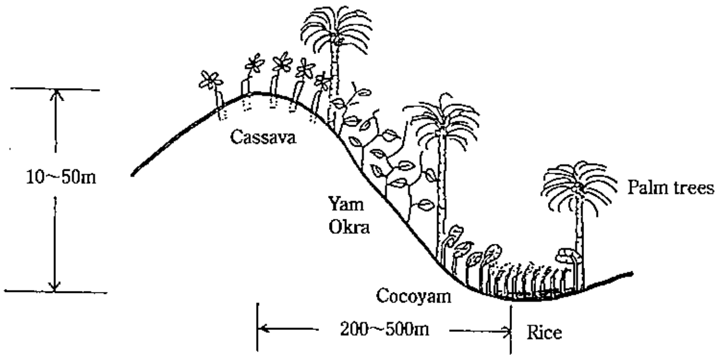


Fig. 1-16 Macroscale-mixed cropping using topo-sequence, Bende area, Nigeria

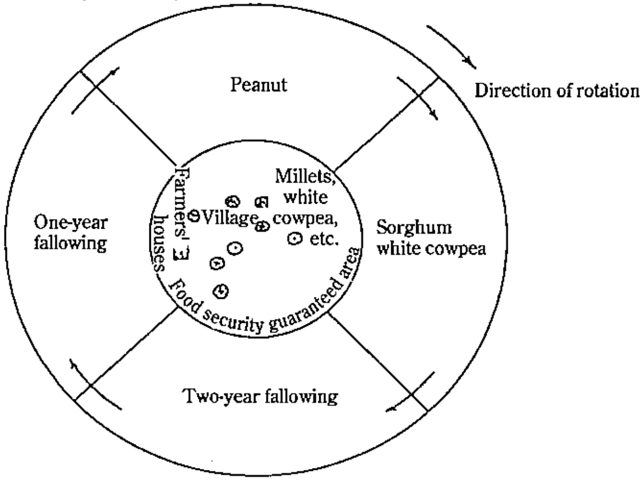
Research Institute of Nigeria (FRIN) at Olokemeji located about 40km southwest of Ibadan, derived *savanna* was restored only to youth-stage tropical forests with diameters at breast height (DBH) of 20-30cm. The highest tree was 20-30m after a fallow of about 60 years from 1929 to 1990. This seems to suggest that a fallow of 20-30 years is not long enough for reforestation. The severe dry season from December to March when no rains may weaken the capacity to restore forests despite an annual precipitation of 1,500mm.

(3) *Intensive subsistence agriculture*

Intensive subsistence agriculture is observed in the Hausa areas in northern Nigeria and in the Ibo areas in the southeastern parts of the country. This is a fairly intensive and sustainable farming system (Okigbo 1990). Its characteristic is that a form of agroforestry can be observed, emerging from traditional compound agriculture. For example, (1) this is a rational mixed cropping system developed in the extreme ; (2) it positively uses the nutrient cycle, such as animal dung, plant and crop residues ; (3) it adopts an agroforestry system and soil-improving trees and other trees for various purposes are planted together with crops ; and (4) it is combined with animal raising, too, forming a agro-silvo-pastoral system.

Fig. 1-15 shows an example of *microscale-mixed cropping on a mound* (Okigbo, 1978) and Fig. 1-16, one of *macroscale-mixed cropping using the toposequence*. Fig. 1-17 shows the crop rotation system and an *agro-silvo-pastoral system* based on *Acacia albida* (*Faidherbia albida*) in a semi-arid area in Senegal (Durprie and de Leener, 1983 ; Katsumata, 1990).

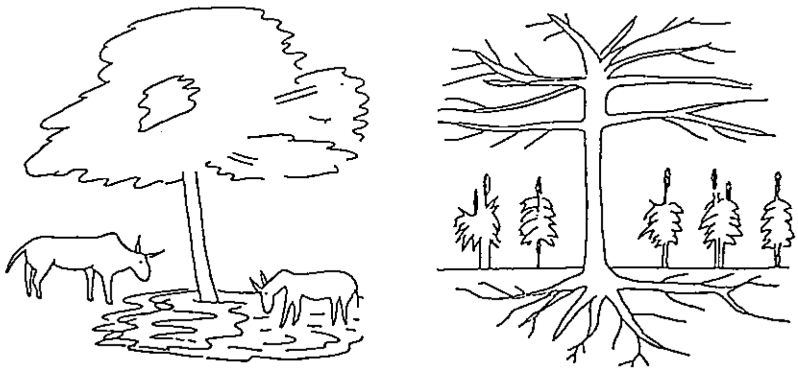
Serer's crop rotation system



Source: Based on Durprie Z, H., and de Leener, O., Agriculture tropicale en millien paysan african, Paris, 1983, p.67.

Usefulness of *Acacia albida* (*Faidherbia albida*)

Dry season | Rainy season



*Acacia has leaves in the dry season when the supply of grass is smaller and animals can eat its leaves and seeds

*Animal dung help the soil increase its fertility.

*Acacia has no leaves in the rainy season and so does not form any shades on the cultivated land.

*Because of leguminous species its dead leaves make the soil fertile

Fig. 1-17 Serer's farming system and effective use of multipurpose tree species in central and western Senegal (Durprie and Leener 1983, Makoto Katsumata, 1990)

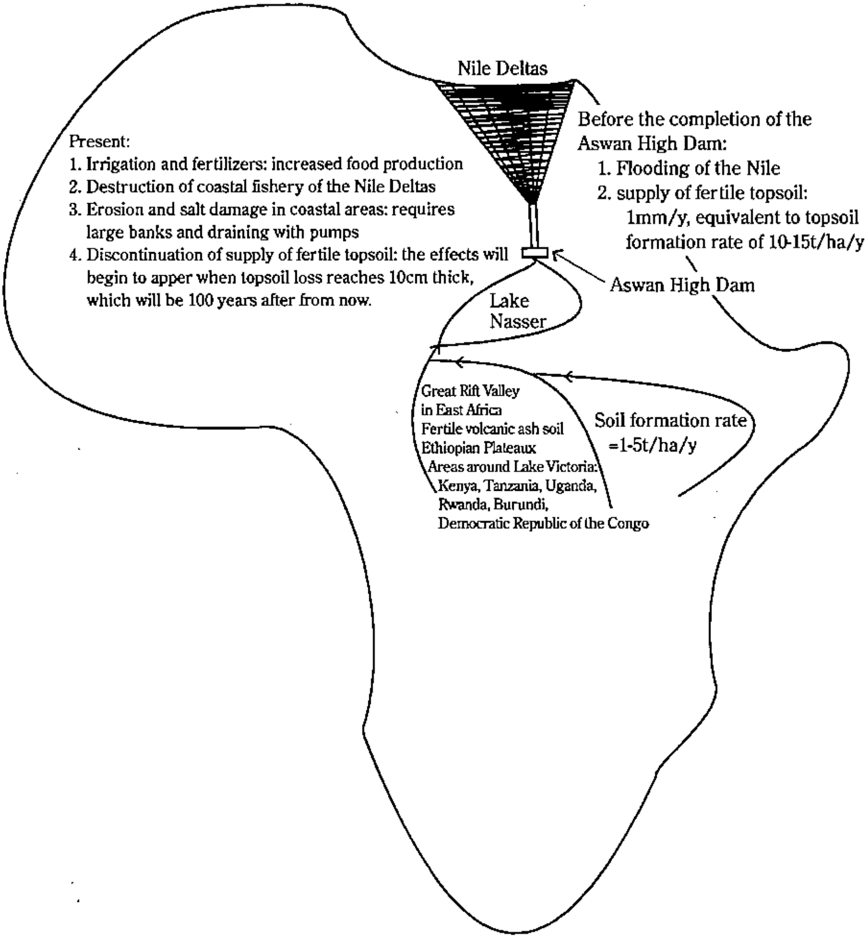


Fig. 1-18 Crises of the sustainablility of the Nile Deltas after the completion of the Aswan High Dam

(4) *Flood plain agriculture*

Upland farming is the main agricultural system in tropical Africa and so farming in lowlands has not been widely developed. But farmers in the basins of the Niger river and the Nile have continued sustainable flood plain agriculture. In the areas where ancient kingdoms prospered, such as the inland deltas in Mali and the Hausa areas in northern Nigeria, Sudanese and Egyptian people used the fertile soil brought by periodical yearly floods to carry out intensive and very sustainable agriculture. The *Nile deltas* before the completion of the *Aswan High Dam* were typical of the areas where this farming system was used.

But since many dams were constructed on other rivers, including the Niger river, too, there have been no periodical floods recently as in the past, throwing traditional flood plain agriculture into a crisis about *long-term sustainability*.

Fig. 1-18 is a rough sketch of the pedological crisis of the sustainability of the Nile deltas after the completion of the Aswan High Dam. During the four decades after the dam's completion in 1957, food production remarkably increased, thanks to expanded irrigation networks, but negative effects came to appear gradually. The most serious problems at present are *salt damage* resulting from rising groundwater levels, *erosion of coastal areas* and damage to coastal fishery (Stanley and Warne, 1993). To cope with these problems, the construction of large-scale concrete dykes in the coastal area and the adjustment of groundwater levels with pumps have been proposed. But what should not be overlooked is the impact of the discontinuation of supply of fertile topsoil (UNEP 1997) caused by the Aswan High Dam. The quantity of soil supplied to the Nile deltas before the dam's completion, which occurred mostly when the Nile flooded, is estimated at about 1mm depth per year (Stanley and Warne, 1993). In terms of *soil formation rate*, this is as high as 10-15t/ha/y (bulk density is supposed to be 1-1.5g/cc). Since fertile soil derived from volcanic ash in the *Great Rift Valley* in eastern Africa is extensively distributed in the upstream parts of the Nile, the Nile deltas had doubly benefited, that is, from the high rate of soil formation in the Great Rift Valley areas and from the fertile soil supplied by the Nile river. This flooding of the Nile that carried fertile eroded soil had developed the delta, allowed fishers to continue fishing and prevented salt damage. Above all, it was *geological fertilization* since it had renewed and revived the topsoil each year. It was the basis of long sustained ancient *Egyptian civilization*. Forty years have passed since this geological fertilization disappeared. In a usual case, if 5cm or more of the topsoil is lost (which is equivalent to a soil erosion of about 500t/ha), agricultural productivity begins to be affected. It is considered that the soil in the Nile delta is affected only very slowly by top soil loss (fertile alluvial soil ; it may be more fertile than in the case of Soil b of Fig. 1-7). So let's suppose here that a top soil loss of 10-15 cm is the level at which agricultural productivity begins to be affected. According to this assumption, it will be 100 to 150 years after the dam's completion that the impact of interrupted geological fertilization and the suspended supply of fertile topsoil starts to affect agricultural productivity. This means that such a situation will occur about 100 years from now. While 100 years seems like the very distant future, 100 years is a much shorter than the 5,000-year Egyptian civilization. Soil fertility is considered to be steadily decreasing. Now is the time to establish the method and system for precise monitoring of long-term changes in the soil, such as soil degradation. Also needed is the construction of a new irrigation system that will allow geological fertilization—the earth's activity for maintaining soil fertility—to continue, in addition to improving existing irrigation and drainage facilities.

4-2. Present situations of research and development (R&D) on sustainable farming systems in tropical Africa

(1) *Improvement in shifting cultivation and fallowing system*

If population density is less than 10 persons/km², then shifting cultivation is sustainable system in terms of both ecology and socioeconomy. However, since its carrying capacity is limited, there have been few R&D efforts that suppose this system would be used continuously. But if its purpose is defined as forest conservation, the system cared possibly be improved, as follows. (Ruthenberg, 1980):

1) Shifting cultivation with planted fallow vegetation:

This is the system in which shifting cultivation is continued while during the fallow, *Leucaena, pigeon peas*, and other leguminous crops and trees contributing to soil conservation and improved soil fertility are planted instead of the farmer depending on natural fallowing. Human power is used for reforestation rather than relying on natural reforestation. In this case, the problem is where the funds for planted fallow should be raised.

2) Shifting systems in forestry reserves (*Taungya system*):

Forest developers in several areas (India, Burma, Indonesia, East Africa) successfully combine shifting cultivation with planned reforestation. They allow control the cultivation of food crops in the forest reserves by a limited number of shifting cultivators. The period of time needed before an afforested area generates profits is much longer than the fallow of traditional shifting cultivation (10 to 20 years). Even in the case of acacia and pine, fast growing species, 20 to 30 years are needed, while teak and mahogany require as long as 50 to 80 years. This reduces the population-carrying *capacity* further. Thus, this system is not sustainable for more densely populated areas that are inhabited by shifting cultivators.

3) The *"Couloir" system* :

This is a controlled shifting cultivation system. In this system, fallow land is placed alternately in belts along contour lines for soil conservation purposes. Shifting cultivation is carried out in the area between *shelterbelts (sheltered forests in belts)*. Between 1950 and 1970, this system had been imposed by the colonial government in the Yangambi district in the mid-northern part of the DRC. In those days, 200,000 farmers practiced the couloir system in about two million hectares of land (population density : 10 persons/km^2). But after the country became independent, the system was destroyed. The main reasons for its collapse were the disappearance of the compelling force of the colonial government and the destruction of cooperative organizations. But another cause is probably that the soil in this area was unable to support its population density of 10 persons/km^2 though measures were taken to protect it.

(2) R&D on sustainable upland farming systems

1) Zero- or reduced tillage :

In the 1960s and afterwards, this farming method was rapidly introduced in Western countries in the temperate zones to prevent soil erosion and maintain fertility and vegetative covers by conserving soil structures. Studies for applying this technology to the tropics were positively conducted from 1970 to around 1985 mainly at IITA (International Institute for Tropical Agriculture) based in Ibadan, Nigeria. It was found that this method could check soil erosion and bring relatively high sustainable productivity in the tropics, also. The results of these studies have been published in many reports (Lal, 1985, 1986 ; Lal et al., 1986 ; Lal, 1988 ; Lal and Stewart, 1990, 1992). But this system has a fatal defect : since the soil is not plowed, it requires large quantities of herbicide. In the tropics, the most important aspect of farm work is weeding. It is clear that the method developed for the temperate and almost semi-arid climate of the West where weeds pose not so serious a problem cannot be used directly without modification in the wet tropical zone. This system is highly dependent on herbicides and so is considered not to be sustainable in wet and moist tropical Africa.

2) Mulching and cover crops :

Mulching is the method of covering the soil surface with organic substances to check soil erosion, hold water in the soil, and maintain soil fertility. Leguminous plants are used as covering materials. From the standpoint of soil conservation,

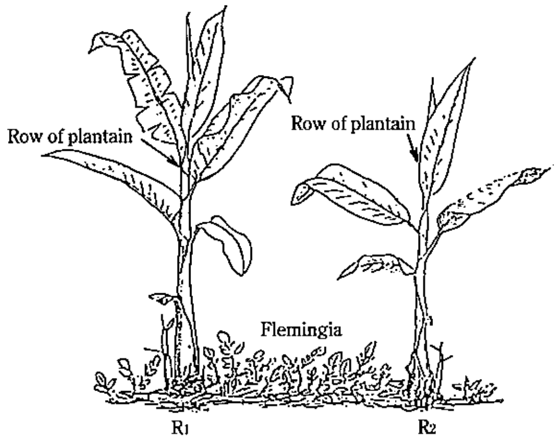


Fig. 1-19 Living mulch of *Flamingia congesta* between rows R1 and R2 of plantain (*Musa paradisiaca*: MS). The Flemigia mulch supplies nitrogen to the plantain, minimizes stand decline of plantain, and ensures higher stable yield.

live mulching (cover cropping) is better because it covers the soil surface throughout the year or for the necessary period in the year depending on the conditions. Covering the soil surface with leguminous plants, such as *Psophocarpus palustris* and *Centrosema*, is effective for soil conservation and the maintenance of fertility and also raises the yield. This mulching is easy to apply to tree crops, plantain, etc. Fig. 1-19 is shows live mulching in a plantain farm (Okigbo, 1990). But many problems have to be solved this can be used for rice, maize, sorghum, and other cereal crops as well as for cassava because the delicate competition between plants must be controlled. Thus live mulching has not yet been an established method for these crops.

3) Intercropping :

In multiple cropping, sequential cropping, and intercropping, farmers grow two or more crops in sequence or at the same time on the same field in a year. mixed intercropping, row intercropping, strip intercropping, and relay intercropping are promising because herbivores are deterred, nitrogen is more efficiently utilized, evaporation is reduced, among of other mechanisms (Vandermeer 1989). IITA recently found that the infestation of *Striga hermonthica* was reduced by intercropping with soybean and/or cowpea and maize (IITA 1998).

4) Alley cropping :

According to Dr. B.T. Kang of IITA who has conducted most of the R&D

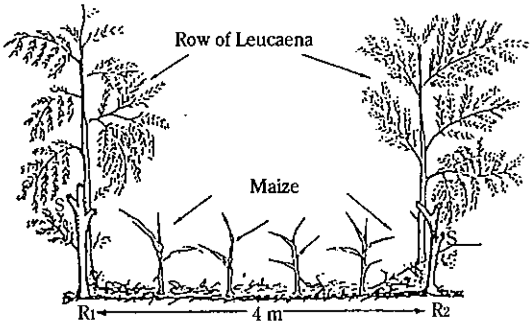


Fig. 1-20 Alley cropping with the maize crop grown between rows R1 and R2 of *Leucaena* planted at 4 meters apart. The *Leucaena* is pruned periodically to mere stumps (S), and the pruning (PR) is applied as mulch to the maize crop.

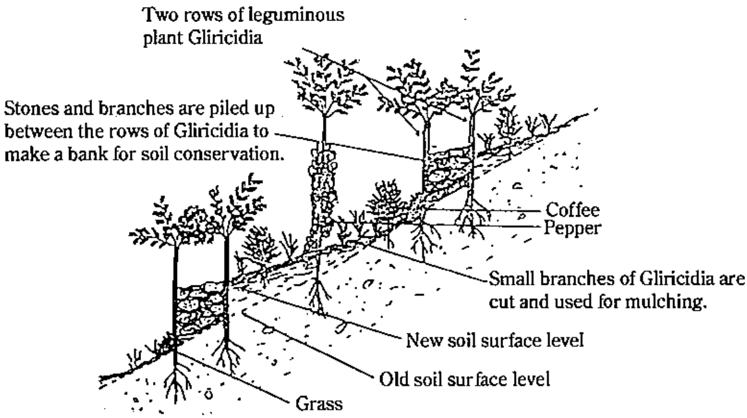


Fig. 1-21 Soil conservation effects of alley cropping
(Tato, K. and Hurni, H. ed., "Soil Conservation for Survival," American Society of Soil and Water Conservation, 1992, pp.79-194)

activities on this system, alley cropping is the method directly developed from the traditional technique of farmers in the Ibo area in Nigeria, though it is based on the traditional agroforestry method in Indonesia where Dr. Kang was born. Alley cropping has a number of advantages. As shown in Fig. 1-20, a crop such as maize, cassava, and upland rice is grown in the alley between the rows of trees planted at intervals of 4 to 6m along the contour lines. The trees planted are leguminous or other useful species. If they grow favorably, after three to four years, the trees along the alleys fix as much as 60kg of nitrogen per hectare per year. From time to time, the branches and leaves of the trees are cut off and used as mulch materials or animal fodder. They may be used as fuelwood, too.

Fig. 1-21 shows sloping agricultural land technology (SALT) by which alley cropping is introduced onto a slope. Banks are built with stones and other materials to prevent soil erosion and to make terraces by the natural process with the aim of achieving soil protection and the maintenance of soil fertility (Tato and Hurni, 1992).

Studies on alley cropping or alley farming were started at IITA around the mid-1970s. In the 1980s, applied studies began, too, on farmers fields (Kang and Reynolds, 1989 ; IITA, 1990). As a result of these efforts, alley farming came to be regarded as the most promising sustainable farming system for Africa and other tropical regions. With the strong support of the US Agency for International Development (USAID), the World Bank and other organizations, activities for publicizing and spreading this method have been continued since 1986. While these activities have succeeded in providing researchers in countries around the world with training on its basic technology and having them understand its usefulness, they have not reached the stage where farmers introduce the system on their own. At present, it is confirmed that unless the soil is not acid, leguminous trees such as *Leucaena leucocephala* and *Gliricidia speium* are suitable as species planted as rows of trees. But it is a future problem to find and validate tree species applicable to acid Ultisols with poor fertility levels in rainy areas (IITA, 1988).

According to recent IITA Annual Reports (IITA, 1990 ; IITA, 1992), further investigation on the techniques of alley farming is needed since the rows of trees and the crop compete for nutrients, light, etc., and the rows of trees are not always easily established in all climatic zones or soil types. Also what types of trees, *Leucaena*, *Gliricidia*, and other species, are suited in the long run from the standpoint of sustainability ? For example, where *Leucaena* was used, the effects of alley cropping were clearly obtained for maize, whose main areas of cultivation are the Guinea savanna zones (neutral Alfisols) with a precipitation of 1,000-1,500mm, whereas the yield of cassava, which is mainly grown in tropical forest areas (acid Ultisols), decreased. Cotton suffered a lower yield, too, and the effects of alley cropping were not clear for rice and cowpea.

Since trees have a long growth period, it needs much time to evaluate their effects on crops. Thus many more years will be necessary before agroforestry is established on the basis of adequately long-term experimental data. In this field, the International Center for Research in Agroforestry (ICRAF), a Nairobi-based CGIAR organization that has strengthened its activities since 1991, is achieving remarkable success in recent years (e.g., Sinclair, 1995).

The most important problem of alley cropping now is how to encourage farmers to introduce it into their farms. Though the results of experiments at research institutes are very good and a considerably large organization was created and has worked on the system's widespread use, there have been only a few instances so far where farmers successfully adopted it in their own farming system (IITA, 1992).

But Asian farmers have a long history of the use of trees for agriculture. For example, Ae *et al*. (1990, 1991) investigated the sustainable agricultural system of mixed cropping of pigeon pea/chickpea and sorghum/millets that farmers in India's semi-arid areas have continued for several thousand years. The researchers discovered that pigeon pea and chickpea make iron phosphate in Alfisols available with the specific chelate compounds, such as Piscidic acid (p-hydroxybenzyl tartaric acid), that they secrete from their roots. Studies on the effective use of tree crops and on the scientific meaning of mixed cropping have just been started recently and are expected to produce more new discoveries in the future (Nair et al 1995, Kang and Shannon 2001).

Upland areas in Africa do not have many forests. Thus, one possible method is to plant rows of trees as an intermediate stage of afforestation and then to develop them into forests, ultimately achieving reforestation. But it is basically more important to establish a farming system that can produce sufficient food without destroying existing forests or rather that can to expand the forests. From the viewpoint of increased food production and environmental conservation by intensive and sustainable farming systems, agriculture on lowlands discussed below is the important frontier in West Africa.

(3) R&D on sustainable lowland farming systems

Excluding its traditional flood plain farming system, agriculture in Africa is almost all limited to the uplands. In addition, the Western countries that colonized this continent had neither the tradition of lowland use nor the technology. Because of this, few investigations and R&D have been carried out on lowland agriculture in Africa except in some limited areas.

The huge scale of the pioneer project on lowland agriculture was the demonstration and technology transfer of sawah based rice farming held in Africa by the experts from Taiwan during the 1960s and 1970s (Hsieh 2001). The Taiwanese expert team worked in grass root style with their emphasis on people's participation and training. This project was regarded as successful in Burkina Faso and Côte d'Ivoire (Buddenhagen and Persley, 1978). But later reports from IITA and WARDA concluded it was a failure (Izac, et al., 1990). Major reason for these contradict evaluation was related to the sudden discontinuation of the activities of Taiwan team because of the change in diplomacy from Taiwan to China in the mid 1970s and afterward.

The recent scientific study on lowland agriculture was the Wetland Utilization Project(1982-1987), a joint study by a Dutch team and IITA. This study revealed that lowland agriculture in tropical Africa, especially in inland valleys, had great potential. A very important inventory of lowlands was made that described the situation of farming systems, etc., in addition to climate, topography, and soil (Windmeijer and Andriesse, 1993). Regrettably, however, it was unable to assess the possibility of sawah based rice cultivation in lowlands. This is probably the limited view of European researchers. Therefore,the study provides us with very useful information on the present situation but cannot find "what should be done," that is, the direction of future sustainable development.

The areas of various types of lowlands in West Africa are estimated at as follows (Windmeijer and Andriesse, 1993) :

1) Large lowlands (including deltas, coastal lowlands and, Boliland*) : 4.20-8.50 million hectares
2) Flood plains : 12-25 million hectares
3) Inland valleys** : 21-51 million hectares

* Boliland is the type of lowlands typically observed in Sierra Leone ; it is an inland valley having latively large size (several hundred hectares or more) and characterized by relatively clayey soil.

** Inland valleys can further be divided into those in the upstream section, stream flow valley, and those more downstream up to flood plains in the midstream section, river overflow valley. The area of the former is estimated at about 11-28 million hectares and that of the latter, at 10-23 million hectares (see Fig. 2-13 in chapter 2).

According to the West Africa Rice Development Association (WARDA, 1992), the area of lowland rice cultivation in inland valleys in the whole of West Africa was 630,000 hectares and the area of irrigated sawah fields was only 160, 000 hectares in 1989. In general, in inland valleys, rice is cultivated continuously with upland rice in uplands topologically adjacent, upland/inland valley continuum. The combined cultivated area of the two rice types was only about 2.40 million hectares (Table 1-13). Since the total area expanded from 3.1 million

Table 1-13 Distribution of main rice cultivation ecosystems in West Africa in 1989 (WARDA 1992)

(1000ha, %)

Rice cultivation ecosystem	Area	Percentage
Upland/Inland Valley Continuum		
Upland rice	1,800	58
Lowland rice	630	20
Irrigated rice	160	5.0
Sahelian rice	180	5.8
Mangrove swamp rice	210	6.7
Deep water and Floating rice	140	4.5
Total	3,120	100

Notes: Total rice area was 4670×10^3 ha in 1999, of which upland and lowland rice area were estimated to 80-90%. The area of the other rice cultivation ecosystems were not changed significantly last 10 years.

hectares in 1989 to 4.7 million hectares in 1999 (Table 1-4), and although the detailed figures are not reported, the combined cultivated area in the upland/inland valley continuum of the watershed might reach close to 4 million hectares in 1999. Because the average planted area of rice per household is about 1 ha or less, this means that about four million farming families cultivate their rice fields in inland valleys. This is an important fact. The number was 3 million in 1989. The fact that so many rice growers exist and their numbers are rapidly increasing is very significant both in the management of watersheds and in the development of sawah based rice agriculture.

5. Restoration strategies for West African land: ecotechnology approaches for sustainable development of sawah and afforestation in inlands valley watershed

5-1. Potential of inland valleys for the development of sawah-based agriculture

As noted above, inland valleys have the highest potential both in area and in the number of rice growers. Flood plains have also great potential since they have relatively fertile soils. Irrigation with pumps is carried out in the Senegal river, the Niger river, etc. But if several hundred hectares or more of sawah fields are irrigated with middle- to large-sized pumps, West African countries have to rely on foreign assistance for everything, including the development and maintenance of sawah fields, especially the maintenance and renewal of pumps, and so this poses the problem of sustainability. Since 12.3 to 24.8 million hectares of flood plains are distributed in the whole of West Africa, the development of sawah fields will be possible in about a half of them or in about 9 million hectares of land if the above-mentioned problems are solved.

The formation of large deltas is not very naticeable not only in West Africa but in the whole of tropical Africa as well. Deltas are observed only in the Niger, the Senegal and a few other rivers. In coastal lowlands, about 210,000ha of rice cultivation areas, are found in ecologically adaptable mangrove zones (Table 1-13). They have a long history going back more than 100 years, and the potential of development in these areas is estimated at one million hectares (WARDA, 1988, 1989). If deltas are included, the combined potential will be four to eight million hectares. But to develop sawah systems in these areas, more advanced technology will be required and greater investment than in flood plain development and to maintain these fields, technology for sophisticated sawah systems must be spread among most of the rice farmers. Because none of these conditions exist in present West Africa, the development of coastal lowlands has only a low priority (Wakatsuki, 1990a). The short-to-medium term priority of development is inland valleys, flood plains and delta/mangrove zones in descending order.

Occupying the largest part of the lowlands in West Africa, inland valleys are the lower parts of various sizes of watersheds and that are prevalent in tropical West Africa form great peneplains with gentle slopes. They are relatively narrow, ranging from tens to several hundreds of meters wide, and their area is from a few to several hundreds hectares. The slope is gentle from 0-3%. In most cases, the base line flow rate of runoffs in the rainy season is 1t/sec or less. In case of heavy flooding, water discharge reaches 5-10t/sec. The base line flow rate increases to about 10t/sec near flood plains in the midstream section. Inland valleys of this kind are distributed all over West Africa. The cultivated rice species originating in Africa (*Oryza glaberrima*) was long grown throughout this region. But at present Asian rice (*Oryza sativa*) occupies almost of the cultivated area ; 10% or less areas is cultivated with this African rice.

In inland valleys, rural communities can construct dams, dig canals and develop sawah fields themselves without any need of large-scale engineering works. Therefore, they can perform maintenance work, too, on their own. Technical assistance projects may be needed at the initial stage but if adequate education and training are provided, farmers will be able to develop and maintain sawah systems themselves (Chapter 6). Actually the history of rice cultivation in Asia shows that these kinds of inland valleys were the first places where the shifting cultivation of upland rice and rainfed hydromorphic rice, i.e., the upland-inland valley continuum (WARDA 1995), evolved into sawah based rice cultivation (Watabe, 1987 ; Watabe *et al.*, 1987 Sato 1996, 1999).

It is unknown what percentage of the 21-51 million hectares (median : 35 million hectares ; Windmeijer and Andriesse, 1993) of inland valleys in the whole of West Africa can be developed into sawah fields. According to an estimate based on the results of the on-farm experiments by the author's group conducted in Bida in central Nigeria and in the neighborhood of Makeni in central Sierra Leone, one-fifth to one-third of the total area of lowlands may be turned into irrigated sawah fields (IITA 1988, Wakatsuki 1995a, b, c). Here we use the average figure of one-fourth (25%). Thus the potential areas of sawah fields in the whole of West Africa can be estimated at about nine million hectares.

5-2. The concept of geological fertilization and the carrying capacity of a global region

How large population can the earth and the African continent support? The world population rose above the 6 billion mark in 2000 and is expected to reach a steady level of about 10 billion by about 2050 (UN Population Fund, 1992). Some estimates say that the earth cares ultimately support 50 to 100 billion people, but its sustainable supporting capacity is believed to be around 10 billion (Fukui, 1994, Cohen, 1995). But if the level of energy consumption needed for the living standards and industrialization that Westerners, especially in the US, now have is applied to all other peoples on the earth, some people think that, the present population of 6 billion already exceeds the global carrying capacity. Apart from the final confirmation of the earth's limitations, what we should do is to reconsider the Western lifestyle that consumes too much energy and other natural resources and to design a sustainable food production system for supplying food to the global population of 10 billion in about 50 years from now (Fukui, 1994). In designing such a food production system, the promotion of sawah based rice cultivation in the tropics other than in Asia, especially in tropical Africa, will be an important strategy—this is one of the conclusions of this book.

Setting aside the problem of the earth's environmental capacity, we will here focus our discussion on the capacity of each region of the world, especially tropical Africa, to support its population, Africa, especially sub-Saharan tropical Africa, is now in a general environmental and agricultural crisis and at the

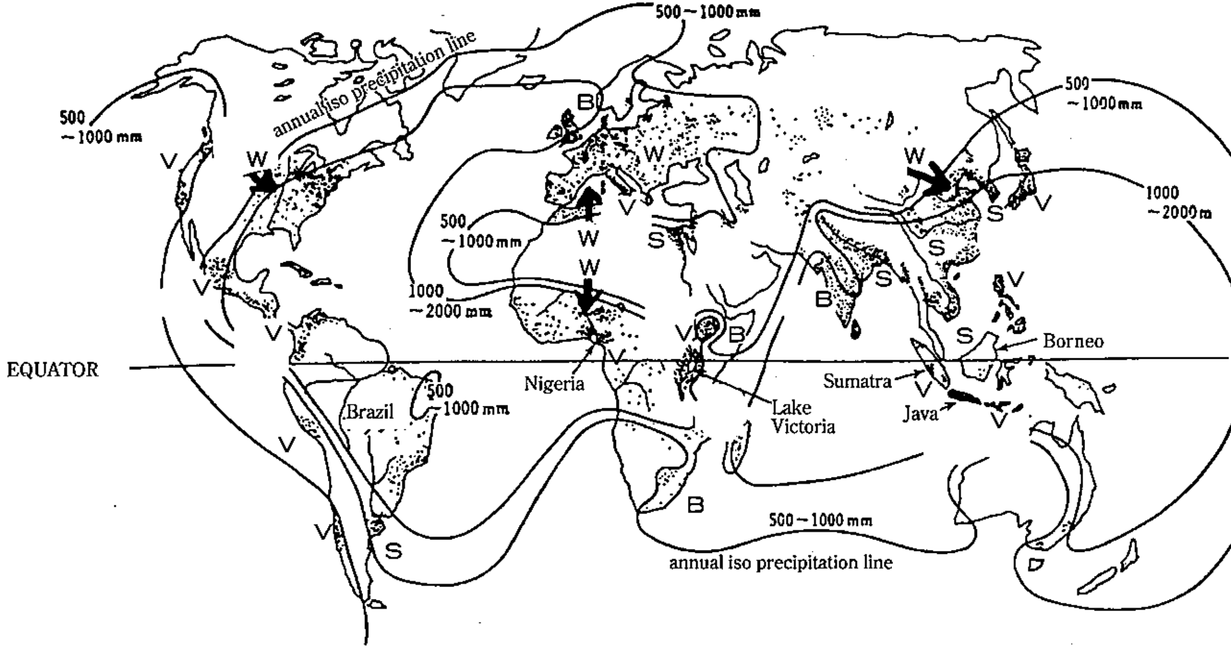


Fig. 1-22 People and soil: macroscopic global environment where people live?
Fertile soil: geological fertilization by winds, water and volcanic activities

Notes: 1) Black spots show densely populated areas and lines are isohyets.
2) Four geological fertilization processes
W: loess deposition by wind, S: sediments by river, V: volcanic ash and B: dynamic balance between soil formation and erosion on base rich parent material

same time in the midst of a population explosion. Its population is about 500 million and is expected to exceed 2 billion by 2050. Africa is the region where we can feel it is a real possibility that global environmental issues will directly threaten the survival of humanity and bring catastrophe to all life on the earth. Conversely, if we can successfully cope with the global environmental problems facing sub-Saharan Africa, our future will be safe for the time being.

In what kind of environment do we live? What are the factors that determine the geographical distribution of population? What decides a region's population-supporting capacity? While we can understand that socioeconomic factors play important roles in the concentration of population in cities, what are the causes of the wide gaps observed in the distribution of population in suburban areas, which are the basis of formation of towns and big cities, as shown in Fig. 1-22 (Wakatsuki, 1985, 1994a). In this figure, the areas with concentrations of black spots are densely populated. As evident from the figure, precipitation (or water supply from rivers) is an important factor affecting population density. Very densely populated areas exist only in those districts with a yearly precipitation of 500-1,000mm or more in the temperate zone where there is less evapotranspiration and in those with area rainfall of 1,000-2,000mm per year in the tropics where evapotranspiration is greater. However, even in the tropics blessed with rainfall, population density differs greatly from area to area. As Fig. 1-22 shows, the population density of tropical Asia is much higher than that of tropical Africa and the America as a whole, but the density differs considerably according to areas. For example, the population density reaches 500 persons/km^2 or more in the deltas of the Ganges and other big rivers, on islands with many volcanic activities, such as Java and Bali, and on basaltic lava plateaux, including the Indian subcontinent. By contrast, Borneo has a very low density of about 10 persons/km^2.

A more detailed distribution of population density and precipitation in tropical Africa is shown in Fig. 1-23 (Wakatsuki and Miwa, 1994). The numbers 1 to 16 in this figure are the locations where soil fertility was analysed and the results of the analyses are summarized in Table 1-14.

In tropical Africa, population density is low in the Congo Basin but is several hundred persons or more per km^2 in the Ethiopian Plateaux, volcanic ash soil areas in East Africa around Lake Victoria, Hausa areas in northern Nigeria, and Yoruba and Ibo areas in southern Nigeria. Let's examine the situations at the locations where soil sampling was conducted. Fertile soils high in exchangeable calcium and having a high *effective cation exchange capacity*

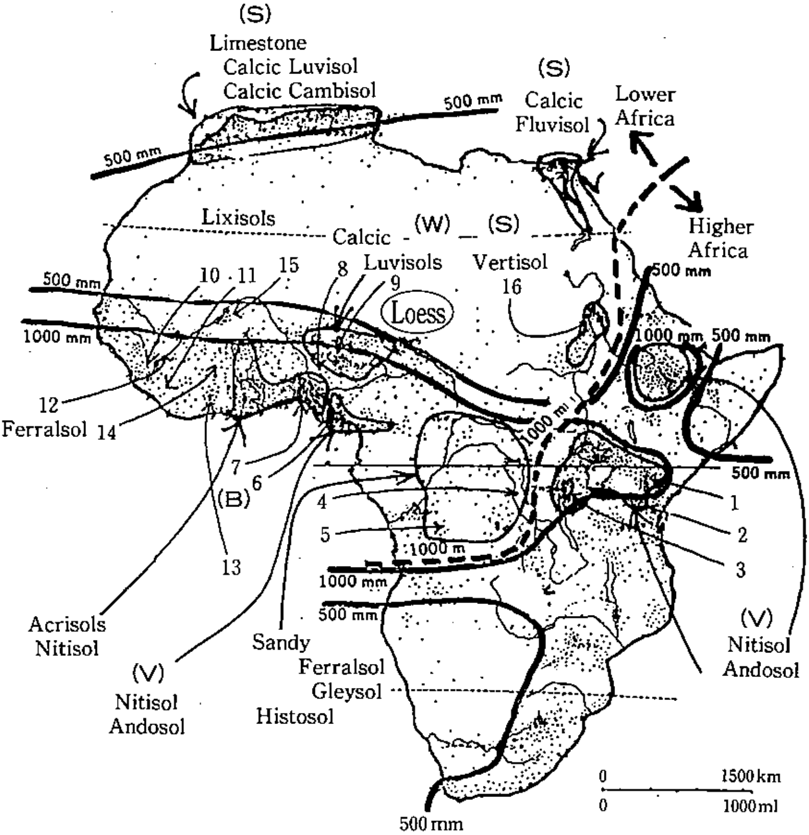


Fig. 1-23 Distribution of population density and geological fertilization/fertile soil in the African Continent

Notes: 1) Black spots show densely populated areas and lines are isohyets.
2) (S): action of water, (V): volcanic activities; (W): action of winds, (B): dynamic balance

(eCEC) are distributed in densely populated areas: Nyaga, Kenya(No.1); Arusha, Tanzania (No.2); Goma, DRC (No.3); Bende (No.6), Ibadan(No.7) and Zaria (No.9), Nigeria; and Khartoum, Sudan (No.16). On the other hand, soil fertility is low in the areas with low population density: Kindu (No.4) and Kikwit (No.5), DRC; Bida, Nigeria (No.8); Makeni, Sierra Leone (No.10); Gbarnga, Liberia (No.11); and Banfora, Burkina Faso (No.14).

In tropical America, population is sparse in the vast lowlands of the Amazon but dense in Mexico, Peru, and other areas where the Maya and Inca civilizations prospered. These densely populated areas are all blessed with

Table 1-14 Distribution of fertile soil and population density

Location	Exchange able Ca	Acidity	eCEC	Population density*
1 Nyaga	7.9	0.1	12.7	High
2 Arusha	17.2	0.1	22.7	High
3 Goma	26.0	0.1	32.9	High
4 Kindu	0.2	2.0	2.7	Low
5 Kikwit	0.3	1.0	1.8	Low
6 Bende**	23.1	0.4	28.6	High
7 Ibadan**	7.0	0.2	9.9	Low
8 Bida	1.0	0.7	2.1	Low
9 Zaria**	7.0	0.2	9.5	High
Harmattan dust**	23.8	0	35.3	-
10 Makeni	0.9	1.3	2.7	Low
11 Gbarnga	0.7	1.9	3.5	Low
12 Kissidougou	3.2	1.5	6.1	Medium
13 Bouake	2.8	1.0	5.6	Medium
14 Banfora	1.5	0.5	3.4	Low
15 Mopti	5.4	1.9	12.4	Medium
16 Khartum**	43.9	0	70.0	Medium?
Average of sawah fields in Japan***	9.3	-	13.3	High
Average of sawah fields in tropical Asia	10.9	-	17.9	High

Notes: 1)*Population density: High > 200 per km² > medium > 40 per km² > low.
2)**Kosaki and Juo, 1984; Morberg *et al.*, 1991 a. b.
3)***Kawaguchi & Kyuma, 1977.

fertile soil and abundant water resources. Water resources are determined by the distribution of precipitation and topography. The distribution of fertile soil is dependent on geological fertilization, the earth's activity. "Geological fertilization" is here defined as the earth's function of supplying new parent materials to rock weathering and soil formation reactions to restore (renew) the soil (Wakatsuki, 1985).

Geological fertilization can be divided into the following four categories as shown in the Fig. 1-22:

① S: Action of water (soil erosion, transportation, and alluvium formation by rivers): Floods occur from intervals of several years to several decades and form fertile lowland soils (Entisols, Inceptisols). In tropical Asia, the formation of deltas is noticeable because of the existence of the Himalayas and the huge monsoon of the Pacific Ocean. Asia's lowland sawah soils are the product of this natural fertilization and of human activities. In Africa, the Nile delta is a typical example. It also benefits from the volcanic ash soils distributed in the

Ethiopian high land and the Great Rift valleys around Lake Victoria in the Nile's upper reaches. The action of water is the reason for fertile soils in Bende (No.6) and Khartoum (No.16) shown in Fig. 1-23.

② V : Volcanic activities (supply of volcanic ash and basic lava) : Supplied once in period between several hundred and several thousand years, volcanic ash causes catastrophic disasters in the short term but restores soils and forms fertile volcanic soils (Andisol) full of nutrition and vitality. Soil fertility is high on the Ethiopian plateau and in the countries around or near Lake Victoria (Kenya, Uganda, Rwanda, Burundi, and the far eastern parts of the DRC) because volcanic ash and basic lava provide these regions with geological fertilization. Volcanic activities are the reasons that Nyaga (No.1), Arusha (No. 2) and Goma(No.3) have fertile soils.

③ W :Action of winds (supply of loess) : Natural deserts are needed for the formation of fertile soils. Harmattan dust from the Sahara is fertile and rich in bases (See its analytical data in Table 1-14). Northern Nigeria has harmattan winds from the Sahara in December and January in the dry season every year which bring a large quantity of loess. In Lagos, facing the Gulf of Guinea, too, harmattan dust sometimes intercepts sunlight, which temporarily lowers temperatures and makes the weather much cooler. Loess-derived soils are widely distributed in the grain-producing areas of Western countries. The eastern parts of China enjoy the benefit of dust from the Gobi desert, loess plateaux like Huangtu Gaoyuan, etc. Though the quantity is small, aeolian yellow fine sands from China are considered to be helpful in the maintenance of soil fertility in Japan. Dust from deserts also possibly helps to prevent global warming by supplying iron to the ocean, which in turn promotes CO_2 absorption by algae.

④ B : Dynamic balance between rock weathering, soil formation and erosion (soil metabolism or prevention of soil aging) : The Deccan in India is a lava plateau composed of basalt ten or more million years ago. This plateaux provide parent material to the extensive production of fertile Regur soils (Vertisols). But since the maturity period of Vertisols is estimated at within several ten thousand years (Eswaran *et al.*, 1992), it is clear that the Vertisols in the Deccan keep a dynamic balance between soil erosion and soil formation. The dynamic equilibrium is probably the reason that the soils in Ibadan, Nigeria, No.7 location shown in Fig. 1-23, are relatively productive. However, it should be noted that, as discussed later, improper farming activities easily turn the balance between erosion and formation achieved in the natural environment into excessive erosion, soil degradation, and desertification. Conversely, if the rate of erosion is much smaller than that of soil formation, the leaching and exhaustion of soil nutrients take place in the long run, resulting in the formation of intensely weathered senile soils, Oxisols.

Lowland soil formation involves the transportation and sedimentation of eroded upland topsoils by surface run-off and by river water. This process is very important for fertile lowland soils. Small-scale examples are the valley bottom soils as shown in Fig. 1-25. The large-scale examples include the formation of fertile deltas, such as those of the Nile, Ganges, and many Asian rivers. In the sawah based farming system this geological fertilization process can be enhanced. The long-term sustainability of sawah farming can be attributed to this process.

5-3. Restoration theories and hypothes for land and agriculture in tropical Africa

(1) Sawah hypotheses

Will there be ways to overcome the low soil fertility of West African lowland, as discussed in Chapter 2, and break down stagnant agricultural productivity in tropical Africa and realize an intensive and sustainable farming system? The author considers that behind the agricultural and environmental crisis that now faces tropical Africa lies the fact that no intensive, sustainable lowland farming systems, such as sawah based agriculture, have been traditionally developed there (Fig. 1-24). The lowlands in this region are estimated at 38-84 million hectares in total but have mostly been left unused.

Moreover, environment restoration technology or ecotechnology, such as the development and maintenance of sawah systems, which is the key to keeping

1. Lowland farming systems are underdeveloped.
2. The environment formation technology, such as that of the development and maintenance of sawah fields, has not widely spread among farmers, which results in:
   - →Low irrigation efficiency
   - →Ineffective fertilization
   - →Ineffective use of high yielding varieties
   - →Inability to maintain soil fertility
3. Therefore, no"green revolution"is possioble.

Fig.1-24 Sawah hypotheses

the fertility of lowland soil (Kanazawa and Tanaka, 1992), has not been spread among farmers. Irrigation and drainage become ineffective because there is no sawah system technology for water management. Inability to maintain dams and canals well is one reason why it is difficult to have effective irrigation in tropical Africa but a more important cause is probably the inability to develop and manage water in sawah fields. In flooded lowlands where no sawah fields exist, fertilizers cannot show their effectiveness well. Therefore, no effective use of high-yielding varieties is possible.

The sawah system in lowlands is also a method capable of artificially strengthening geological fertilization. In lowlands, no soil fertility can be maintained without sawah fields; water flows in occasional floods inevitably degrade soil quality. It is clear that the natural conditions of tropical Africa, are one reason for the low soil fertility of inland valleys in this region (see Chapter 2, subsection 3. Distribution and types of lowland soils in West Africa). But another cause of soil degradation will be the farming system peculiar to this area, that has continued for many years (Wakatsuki, 1990b) the cultivation of lowland rice without using sawah systems.

What are the reasons for the continued high productivity in lowland sawah fields, then? Biological, chemical, and physical mechanisms that maintain the

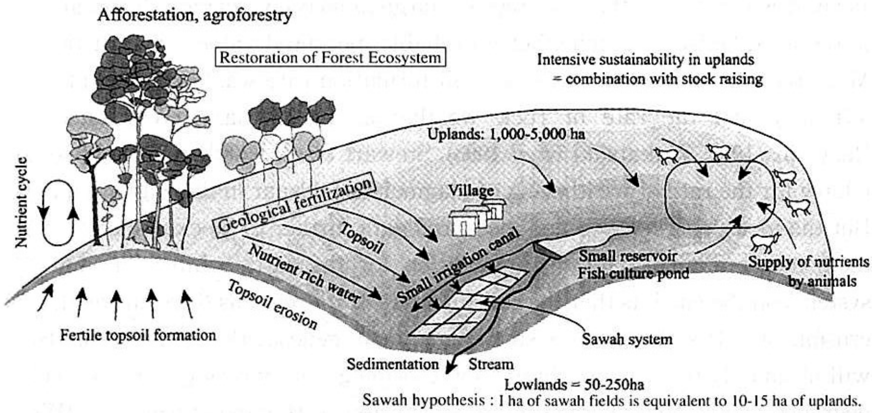


Fig. 1-25 Watershed Agroforestry by the Integration of Forestry and Sawah in a unit Watershed. Fertile topsoil formation in forest ecosystem and sedimentation of the eroded topsoil in lowland Sawah are the Geological Fetilization Process. The geological fetilization and well known biophysico-chemical processes under the submerged irrigated Sawah enhance the intensive sustainable productivity of Sawah system. As the results one hectare of Sawah has sustainable productivity equivalent to 10-15 ha of upland fields (Sawah hypotheses).

fertility of soils in sawah fields are not repeated here because there is a classic work on this subject (Kawaguchi, ed., "Soil Science of Sawah Fields" (in Japanese), 1977). Through these processes Sawah systems itself can fix nitrogen 20-200kg N per ha per year biologically, increase phosphate availability and supply other important minerals from irigation water. Here the author visually presents the role of sawah fields in the lowlands on the basis of the topographical relations between uplands in the watershed and lowlands and the movement of water and eroded topsoils (Fig. 1-25). The processes described in the Fig. 1-25 are explained in details in the following subsection (3).

(2) Basic pedological conditions for the sustainability of the global ecosystem

The water cycling in the watershed works to weather rocks, form soil, and maintain vegetation. The weathering process of rocks enables plants to absorb nutrients. The yearly volume of rock weathering and soil formation is a basic condition for allowing plants to take up nutrients and keep their primary productivity. But no reliable cases of measurement are available of the rates of rock weathering and the soil formation, and therefore of the yearly rate of nutrient release. This is because there is no established measurement method. The reported value for the tropics has a wide range of 0.1-100t/ha/y (Buol *et al.*, 1990). It is considered that the figure is large in fertile volcanic ash soil and low in the aged Oxisol soil zone, but no reliable measured values exist at present. More recently, the earth's average soil formation rate was estimated at about 0.7t/ha/y and the rate of rock weathering at 0.8t/ha/y (Wakatsuki and Rasyidin., 1992, Wakatsuki *et al* 1993). Stewart *et al.* (2001) reported 0.01 to 2 t/ha/y for the rate of weathering of plagioclase feldspar in the Hawaiian lavas. But the measuring method and measured data further to be examined to make them more reliable. The basic condition for the sustainability of land ecosystems on the earth is that the soil formation rate remains the same as the soil erosion rate. If soil erosion is smaller than soil genesis, the aged soil of Oxisol will ultimately be formed, while if soil erosion grows excessive, the soil will be degraded. The global average soil erosion rate is estimated at 0.9t/ha/y (World Resource Institute, 1990). Compared with the earth's average rate of soil formation referred to above, this figure seems to suggest soil degradation in the entire earth. But the above figures may contain some errors, and so a more detailed quantitative assessment is a future subject.

The recognition that the balance between soil formation and erosion is important is not a generally accepted idea. Comparison between the world's

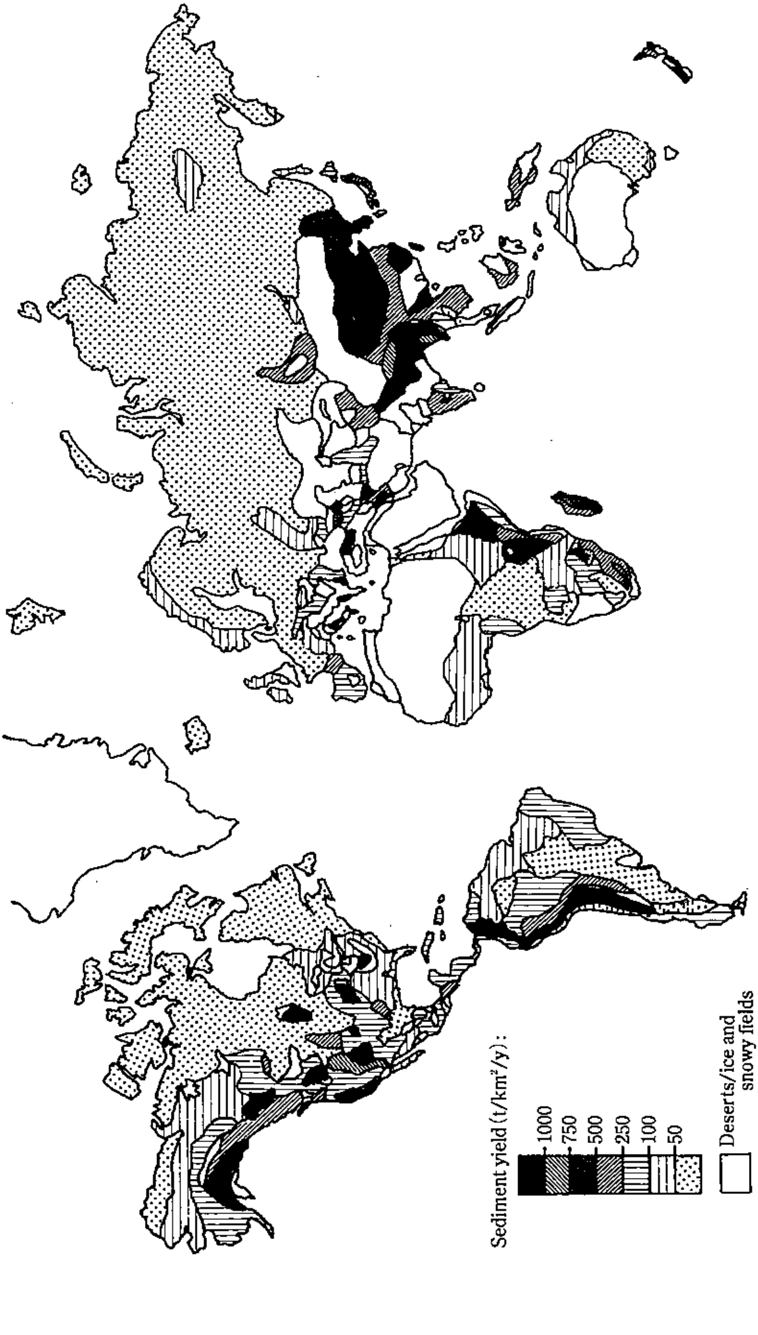


Fig. 1-26 Yearly soil erosion (t/km^2/y) in the world (Walling, 1983; quotation in Lal 1988, "Soil Erosion Research Method")

yearly soil erosion shown in Fig. 1-26, the soil distribution in the tropics in Fig. 1-10, and the population distribution in the world in Fig. 1-22 clearly shows the problems of the popular belief now that soil erosion is always absolutely bad thing. Worldwide, as evident from Fig. 1-26, the areas with less soil erosion are observed in the Congo basin and the Amazon lowlands where the senile soil of Oxisol is distributed. By contrast, soil erosion is very high in the volcanic zones and in the basins of large Asian rivers where geological fertilization is active and so is soil genesis. Since these areas are densely populated, they may also be regarded as the regions where there is most human induced soil degradation. But a better point of view is that these areas have relatively high rates of soil erosion just because they have the most active rates of soil formation in the world, thus fertile soil is being formed there on this balance of soil erosion and formation. True, soil erosion is the most important factor of soil degradation but it has another aspect, that is, the function of soil metabolism, renewal, and restoration, too. Neither the formation of lowland soil nor of sawah field soil is possible without soil erosion. The reassessment of soil erosion from this standpoint will become an important research subject in the future.

(3) *Sawah system* in the *watershed ecosystem*

As shown in Fig. 1-25, the soil formed in the uplands and the nutrients released in the soil weathering process in the uplands are accumulated in the lowlands. If a sawah system is developed in the lowlands, it is possible to store and use effectively this nutrient-rich water and fertile topsoil. This is the basis of the ecological environment for the long-term sustainability of high productivity in sawah systems for several hundred to one thousand years or more. But though a relatively large amount of data exists on the importance of irrigation water, few quantitative data are available for the conditions of the soil that moves together with the water and piles up at the lowland. Because of this, a great deal of supposition is needed for discussions on this subject at present. This is the field that should be given high priority in future studies for the evaluation of the ecological sustainability of a watershed.

Let's suppose 1t/ha/y is the soil formation rate in the uplands which account for 95% of the total area in the case of the watershed shown in Figure 1-25. Since the soil genesis and erosion rates should be evenly balanced in a stable watershed ecosystem, the topsoil formed in the upland (95% of the area) and the nutrients discharged in this pedogenic process are concentrated in the lowlands (5% of the area). Therefore, the soil formation rate in the lowlands is equivalent to 20t/ha/y. Though all of them cannot be used in lowland sawah fields, sawah systems will still be the best choice to make effective use of the fertile soil and nutrient-rich water from the uplands. In short, the sawah system in lowlands is the one capable of using effectively the benefits produced by the huge stock of uplands. It is the farming system that can artificially strengthen 1) and 4) of geological fertilization processes (see subsection of 5-2 of this chapter). As seen from Fig. 1-25, if it is combined with lowland sawah systems, forest ecosystems where trees send out roots deep into the ground and help to form topsoil further reinforce the topsoil formation, water holding function, and sustainable productivity of the whole watershed. The combination like this of forests and lowland sawah systems in the watershed is a kind of traditional agroforestry that has attracted attention recently. We may name this watershed agroforestry. It is an excellent ecotechnology (ecological engineering technology) for sustainable production that Japanese and Asian traditional agriculture has developed. It is a restoration technology for the degraded environment of watershed, by the combination of forests and sawah systems. The purpose of this study is to consider ways to restore degraded lowlands and uplands in West Africa by the use of this environmental technology.

Fig. 1-25 aims to show the situation in the savanna zone in West Africa but it is not entirely wrong to consider that it describes the relations between upland areas and lowlands in Japan. Let us suppose that the average soil formation rate in the watersheds in Japan is about 3t/ha/y (the rate is estimated at about 1t/ha/y in granite areas, 5t/ha/y in basic volcanic rock areas; Wakatsuki *et al.*, 1993). Soil formation and erosion are balanced with each other in a mature ecosystem. In Japan, lowlands have been well developed and the topsoil formed in uplands (about 85% of the area) and the nutrient-rich water released in the pedogenic process are supplied to lowlands (15% of the area). Thus the rate of soil formation in lowlands is 5.7 times as high as the average, that is, 17t/ha/y. Supposing the bulk density of lowland soil to be 1.0g/cc and the sedimentation rate to be 50%, the annual average rate of soil formation (sedimentation) is 0.9mm, which means that 90cm of lowland soil is sedimented in 1,000 years. While there are no data that directly support these values quantitatively at present, indirect data are available from the results of archaeological surveys that have been conducted in many districts in Japan. An examination of the results of all the excavations and soil profile surveys on various old archaeological sawah remains from the Yayoi (tenth to third Century BC), Kofun (third to sixth Century AD) and Heian (eighth to twelfth Century AD) up to modern days

(Nouko-Bunka-Kenkyu-Shinkou-Kai, 1988) shows that the sedimentation rate of lowland soil on sawah fields was 70-200cm/1,000 years. This supports the estimated figure for a 1,000-year period mentioned above.

As already noted, high hopes are placed on agroforestry in tropical Africa. While agroforestry will be effective in using the action of trees to form topsoil and control excessive soil erosion, it has no mechanism equal to the fertility maintaining geological fertilization action of lowland sawah fields. But promoting agroforestry in uplands will lead to promoting the action of forests to form topsoil and if agroforestry is combined with a lowland sawah system, it will reinforce the sustainable productivity of the entire watershed.

As Fig. 1-25 shows, another method for realizing the intensive sustainability of uplands is the combination of agriculture and stock raising. In this case, animals (cattle) play the role in accumulating nutrients. It is the method by which animal wastes are concentrated in the soil while conserving the soil in the especially favorable areas in uplands. But unlike water, it is impossible to raise very much the efficiency of the accumulation of the nutrients absorbed by grassland vegetation in uplands. Moreover, because large grasslands are needed rather than forests, this system is apt to result in the destruction of the watershed environment. Stock raising can also be combined with lowland sawah fields. In this respect, too, it is evident that sawah systems are advantageous.

To present quantitative data on the intensive sustainability of soil fertility from the viewpoint shown in Fig. 1-25 is a subject for the future. It will be important to study not merely the circulation quantity of nitrogen, phosphorus, potassium, and other individual nutrient elements but also the dynamic state of the soil as a whole. The following comparisons are possible though they are too rough and only on a qualitative level. The possible yield of upland rice by shifting cultivation in West Africa is about 1t/ha or less in paddy base and that of rice cultivation in lowland sawah fields is about 2.5t/ha without fertilization (Wakatsuki, 1991). In upland rice cultivation, the land should be fallowed after two crops or so to wait for the restoration of fertility of the topsoil. In shifting cultivation, fallowing for ten years or more is needed after two harvests to secure sustainable production. In lowland rice growing in sawah fields, continued planting is possible for the reasons already stated. The ratio of sustainable productivity of sawah fields to upland fields can be calculated by multiplying (ratio of yield) by (ratio of continued planting). A simple calculation using the above figures $((2.5/1)\times(10/2))$ results in 12.5. This means that sawah fields have sustainable productivity 12.5 times as high as that of upland rice fields. Agriculture in the lowlands is much more advantageous than in the upland.

5-4. Conceptual frameworks for ecotechnology approaches for the restoration of degraded watersheds in West Africa (Wakatsuki 2000, Wakatsuki *et al.* 2001)

(1) The Sawah hypothesis and the Green Revolution

1) Sawah hypothesis : Why has the Green Revolution not yet occurred in West Africa in spite of its success in Asia in the 1960s? The Green Revolution laid the foundation for the rapidly growing economies of Asia today. The layouts of groups of sawahs in the watershed were adapted to the local topography for efficient irrigation and drainage. The main cause of the present agricultural and environmental crises in West Africa is the general under development of low-land agriculture. Environmentally creative technology, such as sawah farming in lowlands, is not traditionally practiced in sub-Saharan Africa. Sawah is the prerequisite for realizing the Green Revolution as well as for preserving and even restoring ecological environments. Irrigation and drainage without sawah farming technologies have proved inefficient or even dangerous because of accelerating erosion. Thus, the development of irrigation has been slow. In the absence of water control, fertilizers cannot be used efficiently. Consequently, the high yielding varieties are useless and soil fertility cannot be sustained. Hence, the Green Revolution cannot take place.

2) Sawah and Irrigation : Another frequent source of misunderstanding in West Africa is the term "irrigated rice". In Asia, the meaning of this term is clear, as the sawah is prepared first by farmers before completing the government-assisted irrigation system. However, there are many irrigation systems without proper sawah preparation in West Africa. In the past, research on water control in inland valleys concentrated on irrigation and drainage systems, such as the central-drain system, the interceptor-canal system, the head-bund system, and head-dyke system. The contour-bund system is somewhat similar to the sawah in terms of bunding and leveling, it may be more difficult for local farmers to construct and manage than the sawah system. It may be difficult for local farmers to share land and irrigation water fairly by using the contour bund system which may be more suitable for large-scale irrigated rice farming, such as that in the United States and Australia.

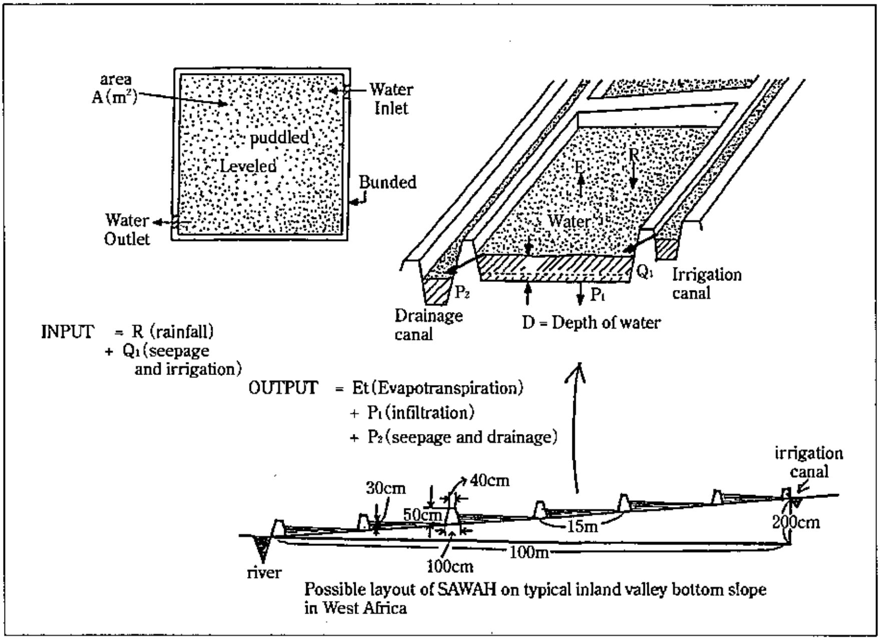


Fig. 1-27 What is sawah? Sawah is a leveled, bunded and puddle rice field with inlets and outlets to control water

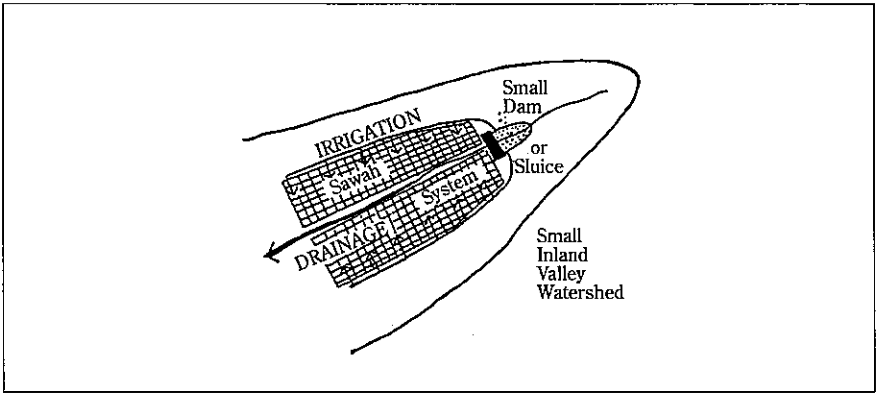


Fig. 1-28 Sawah and irrigation/drainage facilities for the control of water in a watershed. Dam, sluice and irrigation canals can effective for water control only in combination with sawah. Irrigation/drainage without sawah will accelerate erosion and drought.

Generally speaking, the construction cost of sawah is far higher than that of irrigation facilities in terms of labor and amount of soil moved. Out of the total cost, 50-70% should be allocated for sawah construction and 30-50% for irrigation and drainage. Therefore in order to achieve sustainable development, farmers need to participate actively in the construction of Sawah systems. The key element is the sawah. In the sustainable irrigation systems in inland valleys, the sawah technology should be extended to the farmers first (Fig1-27 and Fig 1-28). Although the work sharing should be flexible, the construction and management for the irrigation facilities are assigned to the government or related community, whereas those for the Sawah fields are assigned to participat farmers.

(2) Geological fertilization theory for the integration of a watershed

As already explained in subsection 5-2 in this chapter, geological fertilization processes are reinforced by the introduction of the sawah system in inland valley bottom of a watershed. Since the sustainable productivity of sawahs is more than 10 times that of upland rice fields, if a sawah system is combined with forestry, it will be an excellent ecotechnology for sustainable food production and the same time conserve or even restore the degraded watershed.

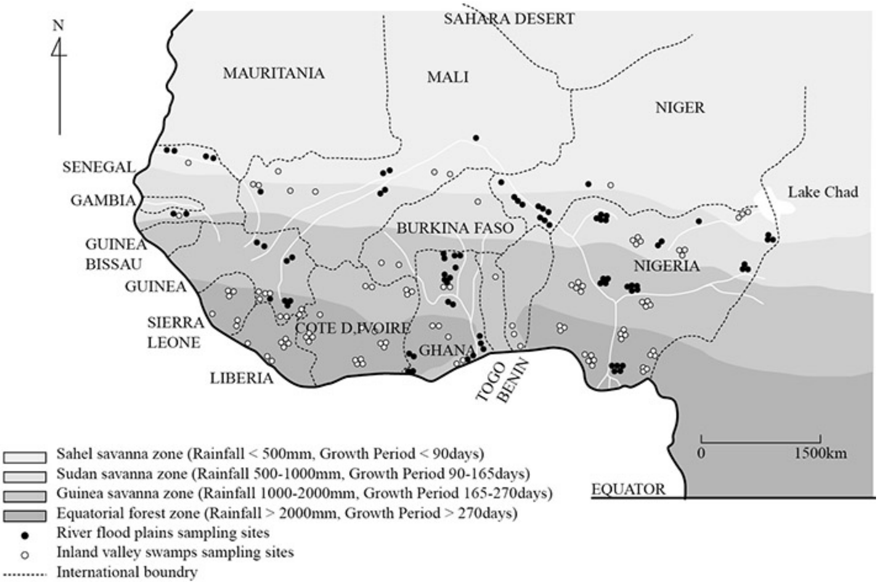


Fig. 1-29 West Africa map showing selected lowland soil sampling sites (Buri *et al.*, 2000)

Table 1-15 Means values of fertility properties of inland valleys (IVS) and flood-plains (FLP) of West Africa in comparison with lowland topsoils of tropical Asia and Japan

Location	Total C (%)	Total N (%)	Available P (ppm)	Exchangeable Cation(Cmol/kg)				Sand (%)	Silt (%)	Clay (%)	CEC/Clay
				Ca	K	Mg	eCEC				
IVS	1.3	0.11	8.7	1.89	0.25	0.88	4.20	60	23	17	25
FLP	1.1	0.10	7.3	5.61	0.49	2.69	10.31	48	23	29	36
T.Asia*	1.4	0.13	18	10.4	0.40	5.5	17.8	34	28	38	47
Japan	3.3	0.29	57	9.3	0.40	2.8	12.9	49	30	21	61

*Kwaguchi and kyuma, 1977.
Source: Hirose and Wakatsuki, 1997.

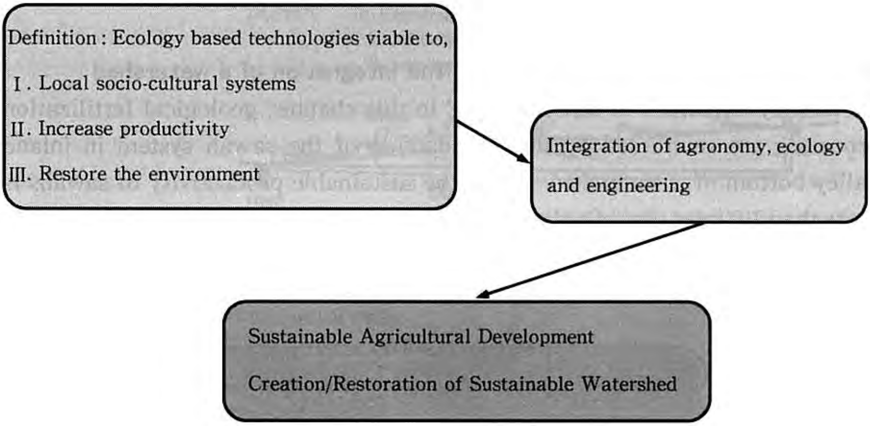


Fig. 1-30 Key concept 3 : Ecotechnology

As shown in Fig.1-29, Wakatsuki made extensive lowland soils survey during 1986-1990 (Wakatsuki *et al* 1988, Buri *et al* 2001). Issaka (1996a, b, 1997) and Buri (1996, 1999) showed the general fertility and geographical distribution of soils of inland valleys and flood plains in West Africa (Chapter 2). The general fertility was compared to those of tropical Asia (Kawaguchi and Kyuma, 1977) and tropical America (Tanaka *et al*., 1986). The results were summarized in Table 1-15. The total carbon and nitrogen content were low for West Africa and tropical Asia. The mean values of available phosphorus (Bray No.2) suggest that the phosphorus status of West Africa is very low throughout the region. Base status such as exchangeable calcium and potassium and effective cation exchange capacity were particularly low. The study revealed that the soils of inland valleys of West Africa are characteristically low in the majority of plant nutrients. In addition, as Buri *et al.* showed (2000), some micronutrients, such as sulfur and zinc also, are generally very low and about 60-80 % of lowland soils, both in inland valleys and flood plains, are at a deficient level, as shown in Fig. 2-30 in Chapter 2. For effective and sustainable crop production, new farming systems that are both soil restoring and enriching must be developed. As discussed above, the sawah-based farming system with small-scale irrigation schemes is one of the most promising systems that can be adopted in Africa.

(3) Sawah and forestry ecotechnology development

1) Definition of ecotechnology

The focus of research activities is to develop suitable ecological engineering technologies (ecotechnologies) for integrated watershed/rural development through increasing sustainable productivity and at the same time improving the total water cycling in a given watershed. Ecotechnologies should be adaptive to indigenous farming systems and rural village society. In Chapter 6 we described the results of our long-term on-farm trials in both the Guinea savanna zone of Nigeria, near Bida, and forest transition zone of Ghana, near Kumasi. In Ghana, various areas of benchmark watersheds, from 100 to 10000 ha, located 40-50km northwest from Kumasi, have been selected for a basic agroecological survey and on-farm trials.

The term, ecological engineering technology (ecotechnology), is defined here as a ecology-based sustainable farming technology compatible with local sociocultural systems to increase farming productivity and to improve the environment. Local farmers should be able to use the ecotechnology developed in the project to control water and to conserve water and soil. Leveling, bunding, and construction the of canal and head dyke are example of such eco-technologies, which can be an extension of agronomic practices using locally available tools and materials. Forestry technology, such as nursery preparation and the management, contour shelter-belt, planting of multi-purpose useful trees, regeneration of the forest to conserve water and soil, and to establish carbon sequestration against global warming are examples of the eco-technology. The ecotechnology will be the key technology to attract the active participation of local farmers' for the improvement of the basic agricultural infrastructure, such as irrigation and soil conservation measures. Ecotechnology will be able to integrate agronomy and agricultural engineering as well as the ecological sciences and various other forms of enigneering (Fig. 1-30).

2) Regeneration of Africa and the earth through the sawah and the forest-based ecotechnology in twenty first century

In the tropical environment and ecology, (only ?) sawah-based farming systems have fully proved their long-term intensive sustainability. Since sustainable productivity of 1 ha of sawah is equivalent to more than 10 ha of upland fields, development of 1 ha of sawah opens the field for afforestation in the degraded uplands in Africa. The total potential area for new sawah development in Africa is estimated at 20 million ha. Thus if we can develop 20 million ha of sawah in the next 50-100 years, we can open up on afforestation area of 200 million ha. If we can plant trees in 200 million ha with a net primary productivity of 2.5-5 ton-C/ha/year, the forest can fixed half to one billion ton, of carbon dioxide annually in next 50-100 years. This is roughly enough to reduce 5-10% of the present global carbon emission. Thus sawah systems can help not only to increase food for Africa but also make this contribution from Africa towards reducing global warming.

(4) Participatory approach for ecotechnology research, development and extension

1) Field work and ecotechnology research and development : field work should come first.

Farmers' fields and forest are our place where major research activities for ecotechnology development and extension are done. This is an important characteristics of our study project in West Africa. Although the results of experimental fields and laboratory work at the research institutes will be applied, field work should come the first and confirmation on the field is the most important evaluation criterion.

2) Participatory approach and the ecotechnology development and extension : Ecotechnology comes the first, then the participatory approach.

Various ecotechnologies for water management will be researched and developed in collaboration with farmers, based on the local ecological and socio-economic conditions, designed, constructed or practiced with the farmers' participation, and tested from ecological and socio-economic viewpoints. In our study project, researchers should propose the various possible ecotechnological options to farmers. This is especially necessary for our two main target fields, sawah-based ecotechnology in the lowland and forestry-based ecotechnology in the upland. Field ecotechnology development comes first, then the participatory approach. Farmers' participation is essential at the various stages of the research, development, design, construction and practice, testing and evaluation. Therefore the farmers who participate in this project are not only beneficiaries but also partners. At the same, time the farmers who participate will be trained on the job, OJT, for further extension.

(5) Ecotechnology approach for the sustainable sawah development in inland valley bottom in West Africa.

Irrigated sawah systems were introduced into West Africa by the experts from Taiwan during the period 1962 to 1975. In whole of West Africa irrigated sawahs occupy only 5% of total rice fields. However, it is now very difficult to build new irrigation projects because of the high cost of irrigation and its apparent low net return.

As shown in Table 1-16, a large-scale irrigation project, such as Tono irrigation in Ghana and the Lower Anambra irrigation project in Nigeria, is very costly. Although the total sales of produce are between US$ 1,000-2,000 per ha, the running cost including large items of machinery such as tractors is very high. Due to the high construction cost, the economic return has been negligible or rather negative for a long period of time (20-30 years). Therefore in such big schemes, foreign aid is a prerequisite to the development of the system. Long-term support is necessary for maintenance and rehabilitation. Since farmers in such project areas are mainly new settlers, project ownership and participation are normally at a low level. This makes maintenance costly and technology transfer/adoption a long process. Cases in point are the Tono irrigation project in Ghana, the lower Anambra in Nigeria, and the Office du Niger in Mali. There, target technology transfer never included the engineering aspects for irrigated sawah development. Environmental impact was also high. Although existing large irrigation systems can be viewed as model irrigation schemes, their sustainable development is now impossible.

Owing to various problems outlined in large schemes as described above, the development of small irrigation schemes is considered more suitable at present. However, with the present small irrigation schemes, the cost of construction is comparable to that of large schemes since their development depends mainly on engineering work by outside experts. Therefore the project ownership still belongs to the government (the engineers) rather than to the farmers. The characteristics of the target technologies are similar to those of the big schemes. However, because the scheme is small, technology transfer, i.

Table 1-16 Comparison of past large scale, present small scale, traditional system and ecotechnology based sustainable irrigation development in Ghana

	Large Scale Development	Small Scale Development	Ecotechnology Approach to Sawah Development	Traditional System
Development cost per hectare	20,000-30,000 US$ per hectare	20,000-30,000 US$ per hectare	3,000-4,000 US$ per hectare	20-30 US$ per hectare
Economic returns of rice and vegetable etc	1,000-2,000 US$ per hectare	1,000-2,000 US$ per hectare	1,000-2,000 US$ per hectare	100-300 US$ per hectare
Possible income (Economic Returns)	Negative	Negative	1,000 US$/ha	100-200 US$/ha
Maintenance cost for the system	High	Medium	Low	Zero
Running cost including machinary	Medium to High (300-500 /ha)	Medium to High (300-500 US$/ha)	Medium(200-300 US$/ha)	Low(10-20 US$/ha)
Farmers participation	Low	Medium	High	High
Type of famers	New migrants	Old/New migrants and indigenous	Old migrants and indigenous	Old migrants and indigenous
Project ownership	Government	Government/ Farmer	Farmer	Farmer
Type of Technology	High input rice based agronomy including machinery	High input rice based agronomy including machinery	Sawah Ecotechnology and medium input rice based agronomy including small machinery	Low input
Adoption of Technology	Long, Difficult	Short, relatively easy	Medium to short, needs intensive demonstration and On the Job Training (OJT)programme	Little technology transfer
Sustainable development	Low	Low	High	Medium
Environmental effect	High	Medium	Low	Medium to high

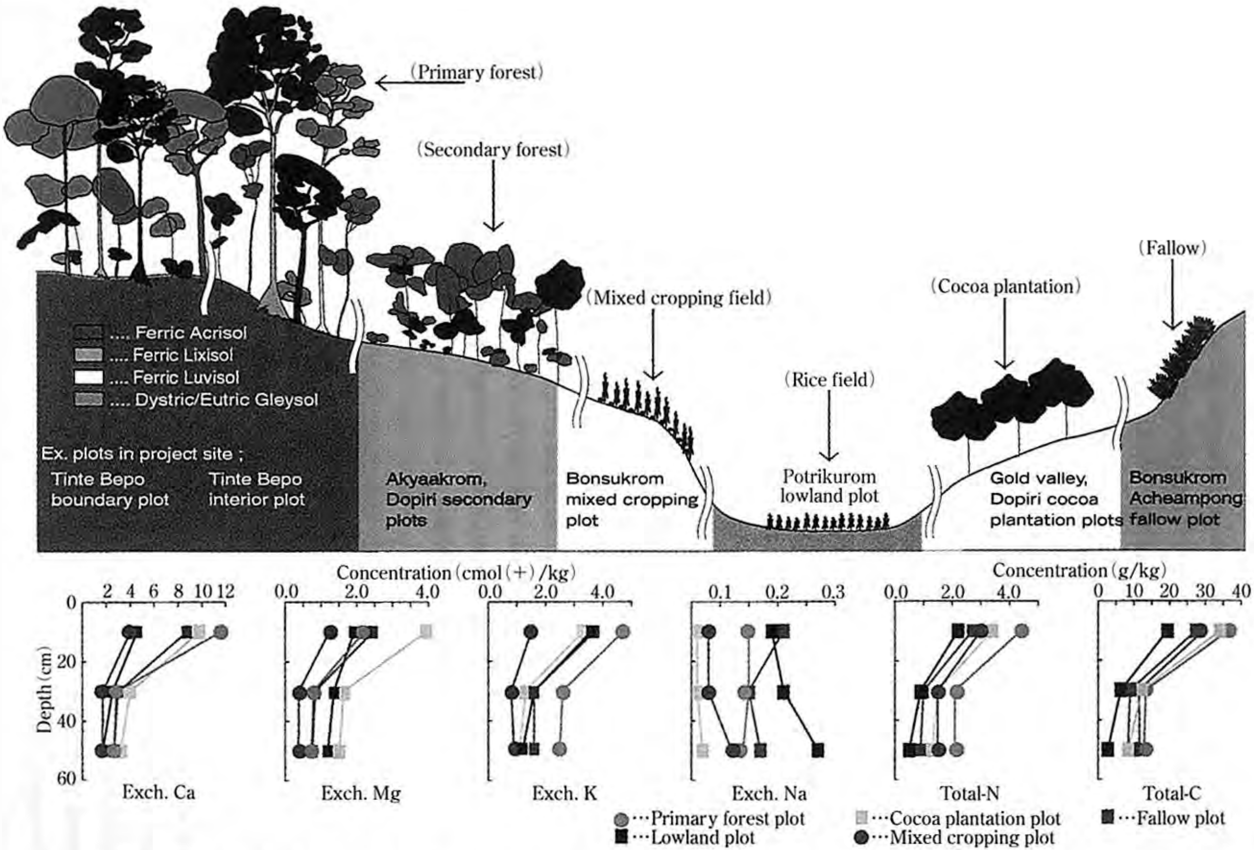


Fig. 1-31 Typical soil type, land use (vegetation) and topography in project area described in chapter 6 with profiles of soil nutrients, semi-deciduous tropical forest zone, Ashanti, Ghana.

e., high/medium input of irrigated rice-based agronomy including machinery, will be relatively easy. The sustainable development of the present small schemes, however, is questionable, because of the very high initial construction cost. The production level of rice farmers could not compensate for the expense.

There is an upsurge in the use of inland valleys for rice production. This is as a result of the rapid increase in domestic consumption. However, the sustainability of further development is rather questionable, because of very low yields (0.5 -1.0 t/ha), low economic returns, and relatively strong environmental impact. Low yields necessitate a larger area for cultivation, which in turn leads to the utilization of a bigger area of forest. The absence of bunding and leveling in the traditional systems accelerates soil erosion, even in the valley bottom. Soil deterioration even in lowland under present farming systems is clearly seen in comparison with the primary forest as shown in Fig. 1-31 in the Ashanti region of Ghana (for details, see Chapter 6). Although the presence of soil degradation is not so clear between the forest and cocoa plantations, both upland mixed farming and lowland rice farming under traditional system shows considerably lower soil fertility than that of primary forests.

As described in Chapter 6, based on the various participatory on-farm experiments and evaluations on various sawah ecotechnologies, the author's group could propose the following new ecotechnology and loan-based sustainable small-scale sawah development for the integrated watershed management of inland valleys in Ghana and West Africa. Although the proposal is in draft, the draft can be improved and consolidated through continuous field practice and dialogue with participating farmers.

1) Possible funding for sawah development to make the ecotechnology approaches sustainable in West Africa

1, Call for sawah group formation of about 10 farmers

2, $6,000 loan for one group : breakdown

$4,000 for power tiller

$500 for tools for development and rice cultivation

$5,00 for small pump

$1,000 for annual running costs including fuel, spare parts, fertilizer, sand bags and pesticides

3, Provision of free technical advice, on the job training and education. Institutional backstopping is necessary to facilitate such technical advice, training, and education. The development of sawah system for rice cultivation by sawah

group without external assistanece.
4, 1 ha of sawah development per year; 5 ha per five years during the five years without any loan repayment. During 6-11 years, loan payment with 5% interest (Note : in the case of African bank loan, no interest is necessary to pay). Total payment will be $7,050 and annual mean payment will be $1,175.
5, 1st year income will be $1,350, assuming a rice sale of $ 1100 from 3.5t/ha and dry season vegetable of $200.
6, 2-5th year : total sales will be $2.600-6,500 and running cost, $600- $1000 annually.
7, 6th year : yield will increase to 4.5t/ha, vegetable production will also increase. Then total sales will be $7,300 per group. The net income will be $5125 after paying mean annual loan, $1,175 and depositing the necessary annual running cost, $1,000. Mean annual income per each farmer will be $500 (current income about $250).
8, Continue to produce more sawah up to about 10 ha. Then annual income will be $1,000.
9, During the project period, plots of multipurpose tree species and other useful trees are enlarged. Fishponds are constructed and tilapia, catfish, etc. are cultured there.

2) Participant Farmers' Response to the sawah approach by March 2001
All participant farmers showed a strong interest in joining the proposed project in order to increase their income and job opportunities. None of the farmers, however, has used loans in the past. Many farmers (54%), responded that the amount of the loan, $6,000, is too high, compared to their present mean annual income of about $250. With regards to the construction work, although the majority of farmers (90%), said that they would be able to continue work if a small amount of support, such as food, (1000cedi =0.3dollars per day), was available, they strongly prefered the payment of the labor cost during the sawah construction work especially in the first year.

Farmers thought that if other farmers knew about the sawah activities, they would be attracted by the proposed project. The number of farmers who have an interest in the sawah in rapidly increasing. Farmers who have experienced upland rice cultivation will easily confirm the superiority of sawah rice farming. This proposal is more fascinating in addition because of the loan for power tiller and pumps. Although they have to pay back the loan, they can own all the equipments in future. This proposal makes possible what was thought impossible. It also seems to open before them a life of higher purchasing power very different from the present one of rural insufficiency. They though the proposal will be a gateway to solving the present extremely poor conditions of village life.

However, the breakdown of the power tiller will be a severe problem. Some special measures should put in place to cater for machinery troubles and abnormally low yields. To develop 1 ha per year by one group will need very hard work. They were worried about fluctuations in the price of rice and whether it was possible to find enough labor, even after full operation for five years. Since sawah is quite a new technology for the farmers, they felt that technical advice alone might not be enough. More systematic training or on the Job training will be necessary. The income is very satisfactory, but we have to consider the harshness of the work.

3) Application of the Ecotechnology approaches for sustainable sawah development in inland valleys in West Africa

West African government, have plan to develop of sawah systems in various parts of inland valley bottoms in West Africa with reasonable loan from African Development Bank (AFDB). According to the estimation of African Development Bank, sustainable scheme of the loan for the sawah development will be 5000ha development per $20 million ($4,000 per ha of irrigated sawah). The ecotechnology approaches will be one possible option to examine. Since one major investment is buying a small power tiller to develop sawah, extension of small machinary should integrate the ecotechnology approach. Since the essence of the ecotechnology approaches are training and education in the field, we have to develop newtypes of technical cooperation in a scheme of international cooperation organizations, such as Japan International Cooperation Agency (JICA), to integrate (1) institutional backstopping to facilitate the training and education for sawah development in the field, (2) integrated technical cooperation in agronomy, engineering, and environment, (3) KR-2 donation, such as fatilizers, madinary and pesticides, for sustainable agricultural developments, (4) loan based projects of Japan Bank for International Cooperation (JBIC), AfDB, and/or World bank, and (5) enhancement of Asian African collaboration for sawah development and supplying the best power tillers from Thailand (or China or India)

(Toshiyuki Wakatsuki)

Chapter 2

Ecological Environment of West Africa

1. Climatic characteristics

1-1. Climatic features

(1) Climatic zones

West Africa is characterized by relatively regular changes in climatic types according to latitude. From low-latitude to high-latitude regions, the climatic zones can be divided into 1) equatorial forest zone, 2) Guinea savanna or sub-humid tropical zone, 3) Sudan savanna zone, 4) Sahelian zone and 5) desert or Sahara zone (Fig. 2-1) (Oosterbaan et al., 1987).

In addition to these, there is 6) highland zone which includes the Jos Plateau and the Fouta-Djallon Plateau. Thus, this region has six climatic zones in all. Two air masses are closely associated with the climate in this region: the equatorial maritime air mass represented by the humid southwest monsoons, and the tropical continental air mass typified by the dry and dusty northeast trades or harmattans. The area where these two air masses join is known as the Intertropical Convergence Zone (ITCZ) and moves from north to south according to which of the air masses is prevalent. The ITCZ rarely reaches the coast. Since it rains only on the southern side of the ITCZ, some coastal areas have rain almost all the year round. In January, the ITCZ stays around latitude 9° N and so all the areas except coastal zones are affected by hot and dry northeast winds. In August, the ITCZ lies roughly at latitude 20° N and the whole region is under the influence of wet southwest and west winds.

The distribution of mean annual rainfall is shown in Fig. 2-2, and that of

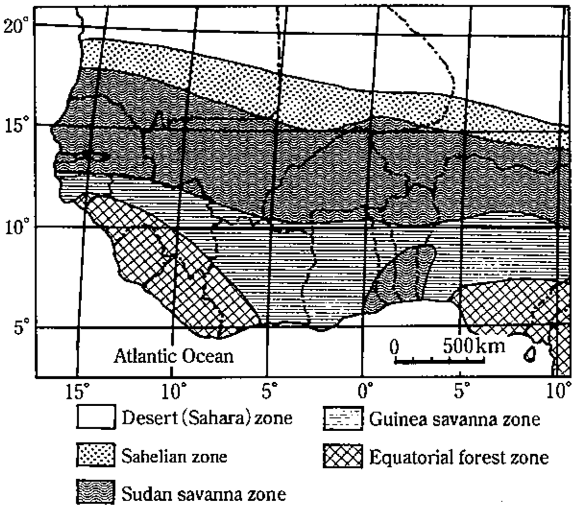


Fig.2-1 Climatic zones in West Africa

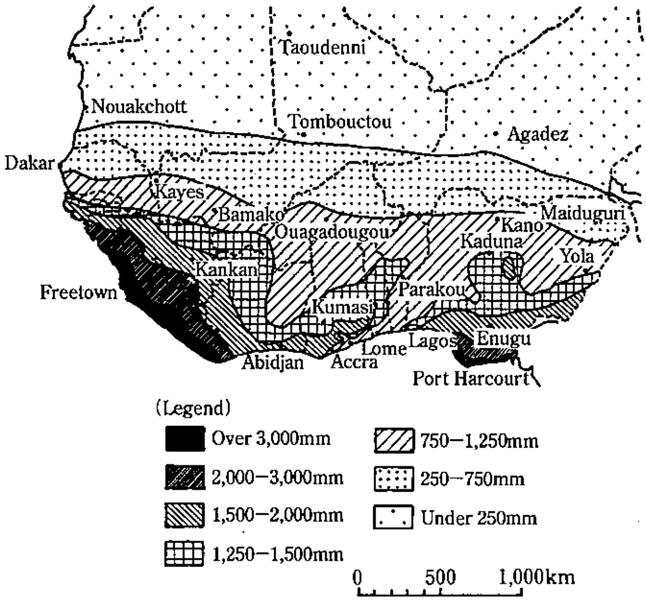


Fig.2-2 Distribution of mean annual rainfalls (Udo, 1978)

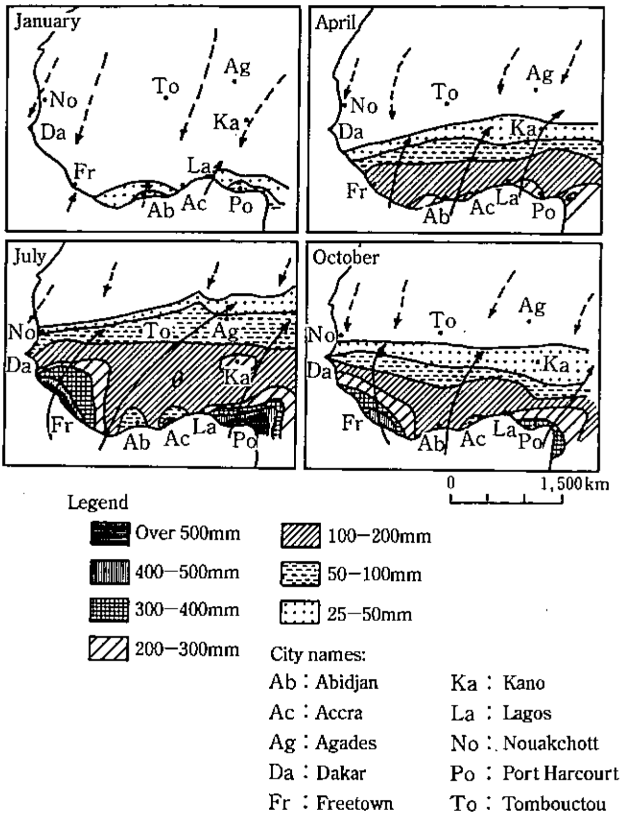


Fig.2-3 Distribution of rainfalls in each season (Udo, 1978)

rainfall in each season in Fig. 2-3 (Udo, 1978). Fig. 2-4 shows changes in rainfall and temperature according to latitude (Grove, 1978). Table 2-1 shows temperature and rainfall at some locations (Udo, 1978 ; Tokyo Astronomical Observatory, 1988).

(2) Rainfall

The characteristics of rainfall in this region can be summarized as follows :

1) The coastal areas excluding the Accra dry belt have the highest rainfall. Sierra Leone, Liberia, the Niger Delta and other areas along the coast have more than 3,000 mm of rain a year, while the areas at latitude 15° N have only about 500 mm. In general, there is less rainfall more inland districts. As the latitude increases by degree (about 110 km), the annual rainfall decreases by about 200 mm.

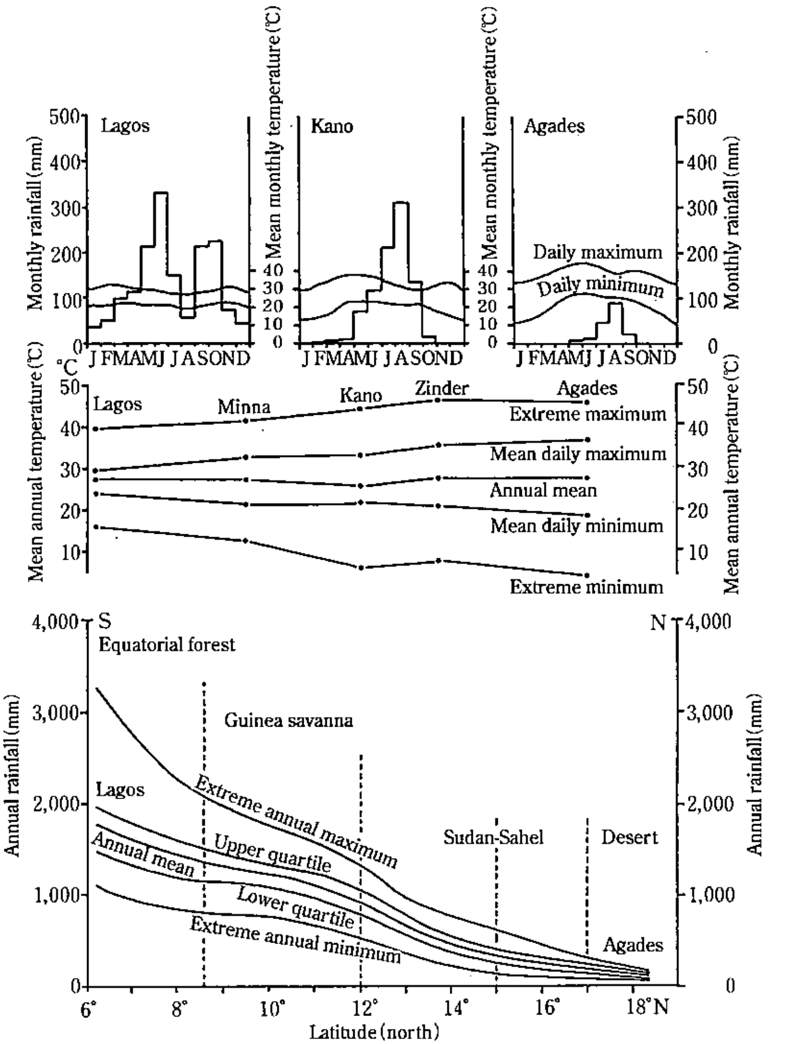


Fig.2-4 Changes in rainfalls and temperatures according to latitude (Grove, 1978)

2) Orographic rainfall can be observed on the Jos Plateau, the Togo Plateau and other inland areas. In Debunscha at the foot of Mt. Cameroon, an annual rainfall of 10,000 mm was recorded.

3) The areas around Accra have little rainfall and are known as the Accra dry belt but the districts just north of this belt have heavy rain. The dry belt exists because : a) the coastline is parallel to the direction of the moist winds ; and b) the Benguella cold current and the Guinea warm current join off the coast,

Table 2-1 Temperatures and rainfalls in West Africa

Upper rows: mean daily maximum temperature(°C); middle rows: mean daily minimum temperature(°C); lower rows: rainfall (mm)

Observation site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Climatic type
Conakry Altitude: 4.9m 9°31′N 13°45′W	21	32	32	32	32	31	28	28	29	30	31	31	31	Monsoon
	23	23	24	24	24	24	23	23	23	23	24	24	23.5	
	2.5	2.5	10	22.5	155	550	1,278	1,038	673	367	120	10	4,228.5	
Warri Altitude: 6m 5°31′N 5°44′E	31	33	33	33	31	30	28	28	29	30	32	32	31	Equatroial forest
	22	22	23	23	23	22	22	23	22	22	22	22	23	
	32.5	52.5	132.5	225	270	372.5	385	295	427.5	317.5	110	35	2,655	
Bouake Altitude: 338m 7°41′N 5°02′W	33	34	35	35	33	31	29	29	30	31	32	33	32	Forest savanna transition
	21	22	22	22	22	21	21	21	21	21	21	21	22	
	10	37.5	102.5	145	132.5	150	80	115	205	130	37.5	25	1,170	
Tamale Altitude: 194m 9°42′N 0°59′W	36	38	38	37	34	32	31	30	31	33	35	34	34	Guinea savanna
	18	21	23	23	23	22	22	21	21	22	21	21	22	
	2.5	7.5	55	80	117.5	137.5	137.5	202.5	222.5	92.5	17.5	5	1,077.5	
Jos Altitude: 1,289m 9°52′N 8°54′E	28	30	31	32	29	27	24	24	26	28	28	28	28	Highland
	14	15	18	19	18	17	17	17	17	17	21	14	17	
	2.5	2.5	27.5	85	200	222.5	325	287.5	210	40	2.5	2.5	1,407.5	
Dakar Altitude: 32m 14°39′N 17°25′W	28	28	28	27	28	31	31	31	31	31	31	28	29	Snegal coastal
	18	18	18	18	20	23	25	24	25	24	23	20	22	
	0	0	0	0	0	30	87.5	260	142.5	42.5	5	0	567.5	
Kano Altitude: 472m 12°02′N 8°32′E	30	32	36	38	37	35	31	29	31	34	34	31	33	Sudan savanna
	13	16	19	22	24	23	22	21	21	20	17	14	19	
	0	0	2.5	7.5	67.5	112.5	200	310	127.5	12.5	0	0	840	
Kayes Altitude: 56m 14°24′N 11°26′W	35	38	41	44	43	40	34	32	33	35	38	34	37	Sahel
	17	19	22	25	28	26	24	23	23	23	18	18	18	
	2.5	0	0	0	25	95	157.5	237.5	185	42.5	0	0	745	
Nouakchott Altitude: 20m 18°06′N 15°59′W	29	31	32	32	34	33	32	32	34	33	32	28	32	Coastal desert
	14	15	17	18	21	23	24	24	24	22	18	13	19	
	0	2.5	2.5	0	2.5	2.5	10	100	22.5	10	2.5	2.5	157.5	
Agades Altitude: 520m 16°59′N 7°58′E	28	32	38	42	44	44	41	39	41	41	34	32	38	Desert
	10	12	16	21	25	24	23	23	23	20	15	12	18	
	0	0	0	0	5	7.5	50	92.5	17.5	0	0	0	172.5	

lifting cold seawater upward and cooling the winds blowing above. Because of this, fogs are formed in the coastal areas instead of bringing rains.
4) The rainy season is shorter in more inland areas. Southern areas with thick forests have about seven months with a rainfall of 100 mm or more, while northern inland areas have less than three months with 100 mm or more rainfall. In southern areas, the rainy season starts around March and ends in October, but in northern areas it begins in May and ends in September.
5) In southern areas, the peak of rainfall is observed twice, in June and in October. In western and northern areas, the peak is observed only once a year in September.
6) The annual variation of rainfall is very high. It is especially high in northern areas where the coefficient of variation reaches 50%.

Temperatures have the following features (Udo, 1978):
1) Temperatures are high throughout the year and there are few seasonal variations in all of the observation sites. In southern areas, the mean daily temperature is about 27°C except in the rainy season when it is a little lower.
2) In coastal districts in Mauritania, Senegal and Gambia, the mean daily temperature in the dry season tends to be lower than that in the rainy season. This lower temperature in the dry season is the result of the cooling effect of the Canary cold current and sea breezes blowing across the cold current.
3) Except in highlands like the Jos Plateau, the temperature is higher inland. The diurnal range of temperatures is also wider in more inland districts.
4) The mean daily temperature in January is lower in northern areas. For example, the mean daily temperature in January is 27°C in Tamale and 21°C in Tombouctou. By contrast, the temperature in July is higher in northern regions; it is 26.5°C in Tamale and 31°C in Tombouctou.

1-2. Climate and agricultural potential

One of the methods for assessing Africa's climatic environment as a resource for agriculture and natural vegetation is the climate classification method proposed by the Food and Agriculture Organization of the United Nations (FAO). This method divides Africa into six climatic zones according to the length of growth period (LGP) and is effective in considering agricultural development and greening. Here LGP is defined by the number of days in a year when temperatures and water conditions are suitable for crop growth (FAO, 1986).

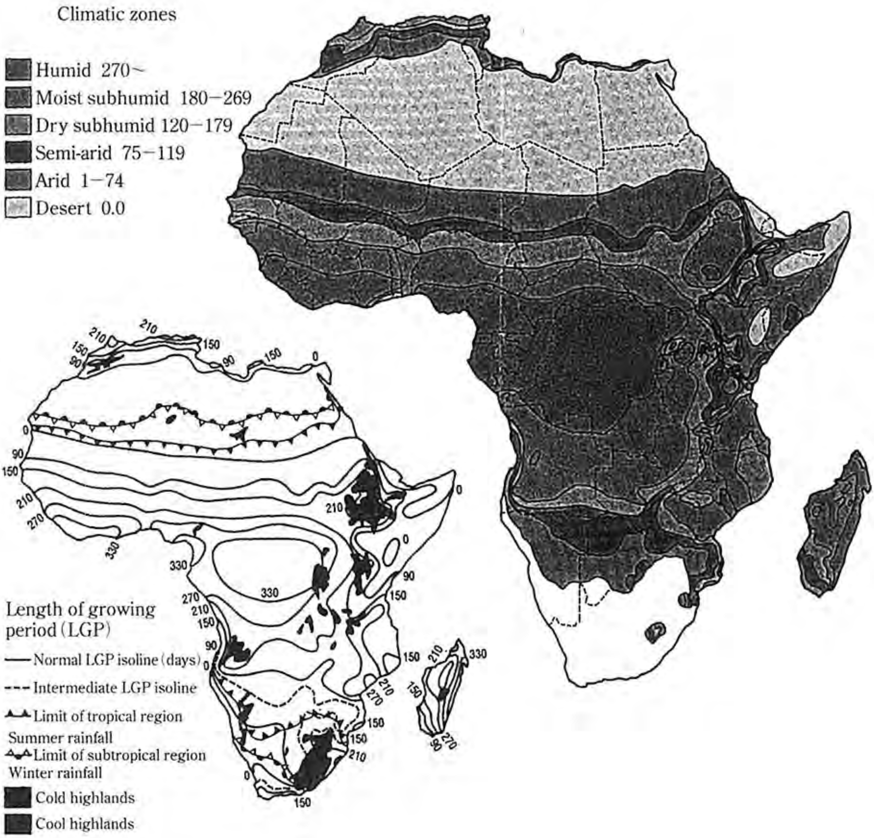


Fig.2-5 Agricultural climatic zones in Africa (FAO, 1986)

Fig. 2-5 shows the African continent classified into the six main agricultural climatic zones (FAO, 1986), but the boundaries of the zones shown are not fixed. In a year of drought, they move in parallel and the zones with shorter LGP become prevalent. In particular, these climatic zones are apt to collapse and droughts are liable to occur in arid areas in northern Africa and Sahel-Sudan areas. In general, the regions with an annual rainfall of less than 600 mm have very high yearly changes in rainfall and a high drought incidence.

Table 2-2 lists the features of each of the agricultural climatic zones (FAO, 1986). It shows the relationship between climatic zones and such factors as rainfall, vegetation and land use.

The climatic features and agricultural potential of West Africa, including Mauritania and Chad, can be summed up as follows :

Table 2-2 Characteristics of climate,

Climatic zone	Length of growing period (days)	moisture availability	Area (×10⁶ha) (%)	Climate(rain fall) (mm/y)	Natural vegetation
Desert (Saharan)	0	Deficit	822(29.1)	Less than 100mm annual rainfall	Very occasional dwarf desert thorn scrub with some perennial grasses.
Arid (Shararo-Sahelian)	1-74	Deficit	488(17.1)	Single short variable rainy season: long dry season (8-9 months in Kalahari: 10 months elsewhere). 100-400mm rainfall.	Sparse scrub with some perennial grasses. Annual grasses become dominant in moister parts of zone. Acacia-Commiphora woodland in East Africa.
Semi-arid (Sudano-Sahelian)	75-119	Deficit	233(8.1)	Single 3-4 month rainy season. Dry season with cool night temperatures, Prior to rains, temperatures increase to 45°C with high humidity. 400-600 mm rainfall.	*Combretacea* tree and shrub grass land. Perennial grasses present but not dominant. *Acacia-Commiphora* woodland in East Africa.
Subhumid (North and South Soudanian ; northern and southern *miombo*)	120-179	Adequate	314(11.0)	Up to 6 months humid. 600-1200mm rainfall	**WestAfrica:** *Parkia-Butyrospermum-Khaya* woodland, tree and shrub grassland, and *Andropogon* grasses. **Central/Southern Africa:** *Brachystegia* and *Julbernadia* woodland (miombo) with tree and shrub grassland. Perennial grasses. **East Africa:** *Combretum-Acacia* woodland.
Moist subhumid (Guinea and Forest transition)	180-269	Adequate	584(20.4)	Up to 8 months humid. Winter rainfall in north is twice as effective as summer rainfall elsewhere. 1200-1500mm rainfall	Forest, Southern Congolian evergreen forest and woodland, and so-called"derived savanna".
Humid (Equatorial Forest)	More than 270	Excess	409(14.3)	Humid virtually throughout the year, often with biomodal pattern. More than 1500mm rainfall	Tropical rainforest.

source: FAO, Atlas of African agriculture, 1986.

vegetation and land use

Land use	Specific problems
Hunters and gatherers. Nomadic pastoralists (camels and goats: no cattle) on opportunistic basis on southern edge of Sahara and near boreholes in Kalahari. Sedentary agricultural irrigators around oases. No rainfed agricultural and no potential for same.	
Extensive grazing of sheep, goats and camels by nomadic pastoralists, plus zebu cattle in moister parts of zone. Some millet and sorghum cultivated in depressions in moister areas.	Increasing animal populations have resulted in overgrazing, which combined with the effects of cultivation and the pressure on woody vegetation for fuelwood and fodder-all exacerbated by drought-have led to extensive land degradation and desertification.
Meeting zone of nomadic pastoralists and cultivators. The direct region in which rainfed cultivation is attempted. Main crops millet and sorghum, with short-cycle cowpea, phaseolus beans and groundnuts, Maize cultivation now being attempted in cooler parts of the zone in East and southern Africa.	One of the most critical areas in Africa. Potential for rainfed agriculture is low due to nutrient shortages (nitrogen and phosphorus) and extreme variation in the annual rainfall. Cultivation expands in good years, only to be followed by crop failure, degradation and desert encroachment in drought years. Low night temperatures in dry season limit desease but also place constraints on winter season cropping.
Zone of arable crop production, traditionally used by nomadic pastoralists (zebu cattle, goats and sheep) in dry seasons and drought years. Many pastoralists now partially settled: major influx of nomad occurs in wet season. Tsetse used to limit access to some areas, but this problem largely removed through increasing destruction of fly habitat. Main crops millet, sorghum, maize and groundnuts; also cassava and cowpeas, cotton, sweet potatoes, tobacco, rainfed rice, soya, mango and cashew nuts. Grazing of zebu and Taurine cattle, sheep and goats. Fodder crops and sown pastures possible (e.g. *Stylo*).	Declining yields and land degradation result from considerable pressure on the available land resource and consequent disruption of traditional cultivation patterns. Fuelwood deficit or acute scarcity is widespread.
A transition zone for agriculture, Generally too wet for seasonal arable crops and too dry for tree and shrub crops. Maize and cassava grown extensively in tropical zone. Also yams, banana, pineapples, suger cane and rice. Wheat and barley are grown in the winter rainfall zone and in the East African highlands.	Severe tsetse infestation limits the exploitation of livestock potential.
Tree crops-oil palm, rubber, cacoa; shifting cultivation based on root crops (yams, cassava, etc.) Also some sorghum and maize, bananas, pineapples, suger cane and rice. Few livestock; mainly Taurine cattle, sheep and goats, and poultry. Tropical hardwoods are a valuable resource where forests remain.	Biomodal rainfall distribution may cause problems with cereal cultivation.

1) Fifty-two percent (380 million ha) is either desert or arid areas (LGP : 74 days or less), these areas are not suited to rain-fed crop production at all. The only safe land use here is grazing in large areas.
2) Nine percent (60 million ha) is in the semi-arid zone where water availability is limited and changeable. In these areas, grazing and the cultivation of mainly millet and sorghum are carried out. Since these regions have extremely large variations in rainfall and infertile soil, their potential for rain-fed agriculture is low.
3) Thirty percent (220 million ha) is in the subhumid zone and suitable for the rain-fed cultivation of millet, sorghum, maize and other staple food crops.
4) Ten percent (70 million ha) is in the humid zone where water supply is excessive.

(Yoshinobu Kitamura)

2. Topography, geology, vegetation and soils in West Africa

2-1. Topography and geology

As evident from topographic map (Fig. 2-6) and geological map (Fig. 2-7) (Udo, 1978 ; Unesco, 1975), peneplains at or below 600m above sea level and a basement complex, West African craton of 1 - 3.5 billion years, are prevalent in sub-Saharan West Africa. Mountainous areas with an altitude of over 600m are find in the Mambila Mountains in the border area with Cameroon in eastern Nigeria, the Jos Plateau in central Nigeria and the Guinea Plateau in the source region of the Niger River. The Sahara also has relatively high altitudes ; it forms tablelands 300 - 600 m above sea level and includes the Adrar des Iforhas and Agadez Mountains. In these mountains, acid and basaltic volcanic rocks that cover basement and sedimentary rocks are also observed. Apart from Mt. Cameroon (4,100 m), adjacent to the Mambila Mountains, no active volcanoes exist in this region.

The topographic map (Fig. 2-6) shows that coastal areas are lowlands below 300 m, central belt zones are relatively high at 300-600 m and the areas north of them are again lowlands less than 300m. This roughly agrees with the distribution of climatic zones : the coastal areas agree with the equatorial forest zone, the central belt, with the Guinea savanna zone and the northern lowlands, with the Sudan savanna zone. The Guinea savanna zone in the central highland belt has relatively low soil fertility because it does not benefit much from geological

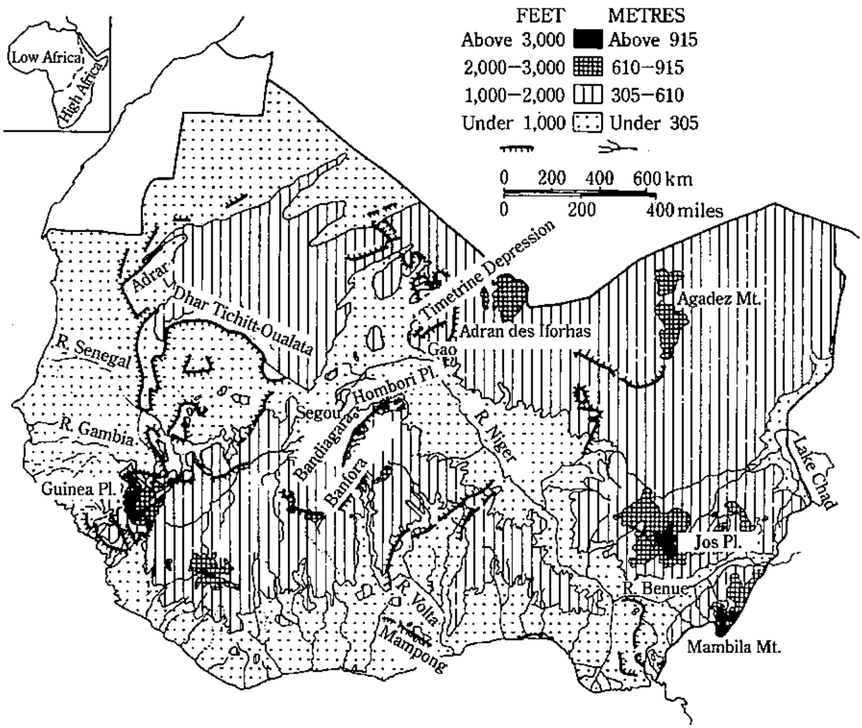


Fig.2-6 Relief and drainage of West Africa (Udo, 1978)

fertilization and its topographical factors are not favorable.

In the Sudan savanna zone, which is a lowland area between the central belt area and the Sahara tablelands, a variety of deposits and eolian deposits, such as loess (Harmattan dust), are widely distributed, covering its basement complex. It is considered that these deposits formed relatively fertile soils and supported the agricultural base of ancient kingdoms in West Africa. The Hausa districts in present northern Nigeria, which support intensive agriculture and have high population centers, such as Sokoto, Kano and Zaria, agree with the areas where this loess is distributed. Zaria and Kano are in the zone 300-600m above sea level and the Jos Plateau serves as a partition for helping loess deposition in these areas. In addition, these districts are in a good location for sedimentation of the fertile soils rich in bases carried by winds from the areas around Lake Chad.

Deltas are formed on the River Niger and at the mouth of the Senegal River. The River Niger forms a huge inland delta of about three million hectares in its middle basins from Segou to Gao in Mali.

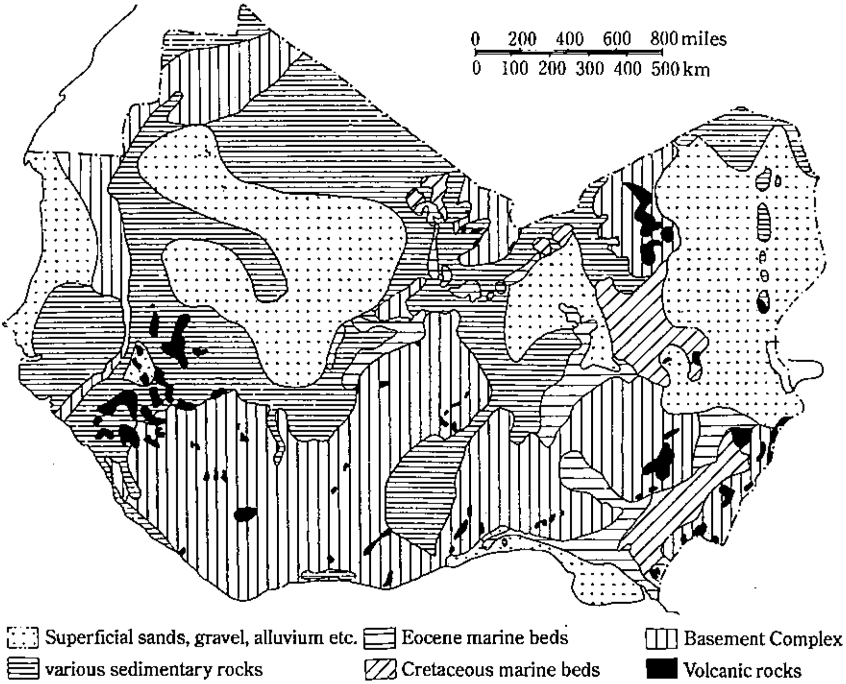


Fig.2-7 Simplified geological map of West Africa (Udo, 1978)

2-2. Distribution of vegetation

The distribution of vegetation in West Africa is shown in Fig. 2-8. As Table 1-5 shows, the area of forests in this region is about 82 million ha, but only 14 million ha of these forests are tropical rain forests having closed canopies according to an estimate at the end of 1985. Nigeria has the largest area of closed-canopy forests, about 4.5 million ha. Therefore, the tropical rain forests shown in Fig. 2-8 are mostly nonexistent and have been turned into either farmland or what is called "derived savannas." Côte d'Ivoire has the second largest area of closed-canopy forests, with three million ha. According to Fig. 2-8, the country's southern half was almost all covered with tropical rain forests. This means that the country once had an estimated 16 million ha of these forests, a half of its total area of 32 million ha, but they decreased to less than one-fifth. Other major areas of tropical rain forests are Guinea with 1.9 million ha, Liberia with 1.8 million ha, Ghana with 1.6 million ha, Sierra Leone with 0.7 million ha and Togo with 0.29 million ha.

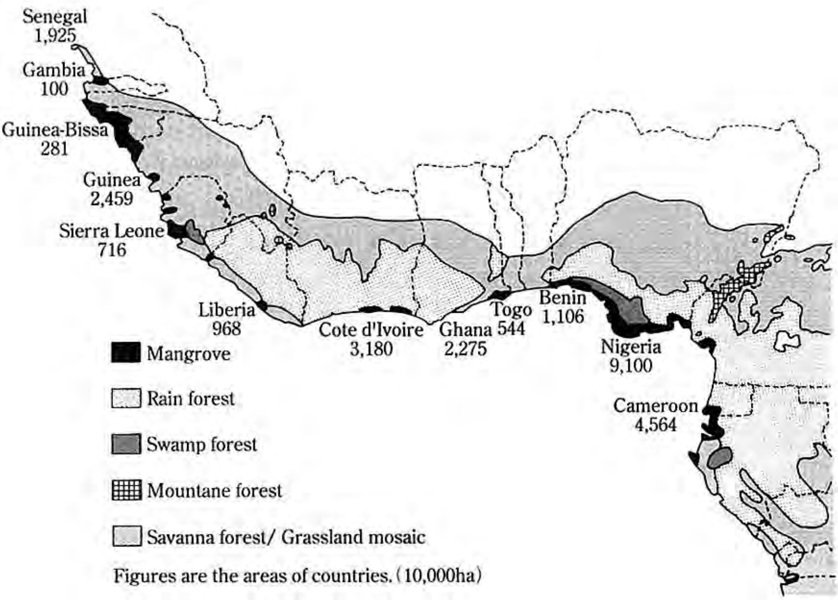


Fig.2-8 Vegetation distribution in West Africa, modified according to the UNESCO/AETFAT/UNSO Vegetaion Map of Africa (White, 1993; Martin, 1991)

The area of coastal mangroves and swamp forests is about three million ha in West Africa, half of which exists in the Niger Deltas in Nigeria and the rest is mainly distributed in the regions from Senegal to Sierra Leone. Mangrove zones are important for fisheries. West Africa has about 200,000 ha of unique mangrove rice producing areas where rice is grown by natural tidal irrigation using the phenomenon that at high tide the seawater pushes up fresh water to the field in the rainy season. This type of rice cultivation started several hundred years ago after the introduction of Asian rice by Western people. WARDA has long operated an experimental station of mangrove rice cultivation in Rokupr, Sierra Leone.

Mountain forests are distributed in the Guinea Plateau and in the Mambila Plateau adjacent to the Cameroon highlands and their total area is less than 100,000 ha. In the Mambila Plateau, Nigeria, forests have been cut down and tea has been grown. Soil erosion is severe because overgrazing by Fulbe nomads has destroyed the mountain forests, turning them into grasslands (see Fig. 2-9).

Most of West Africa's vegetation (over 80%) has been turned into savannas, that is, sparse woodland or grasslands.

Fig. 2-9, the vegetation map of Nigeria (Barbour, 1982), shows more clearly

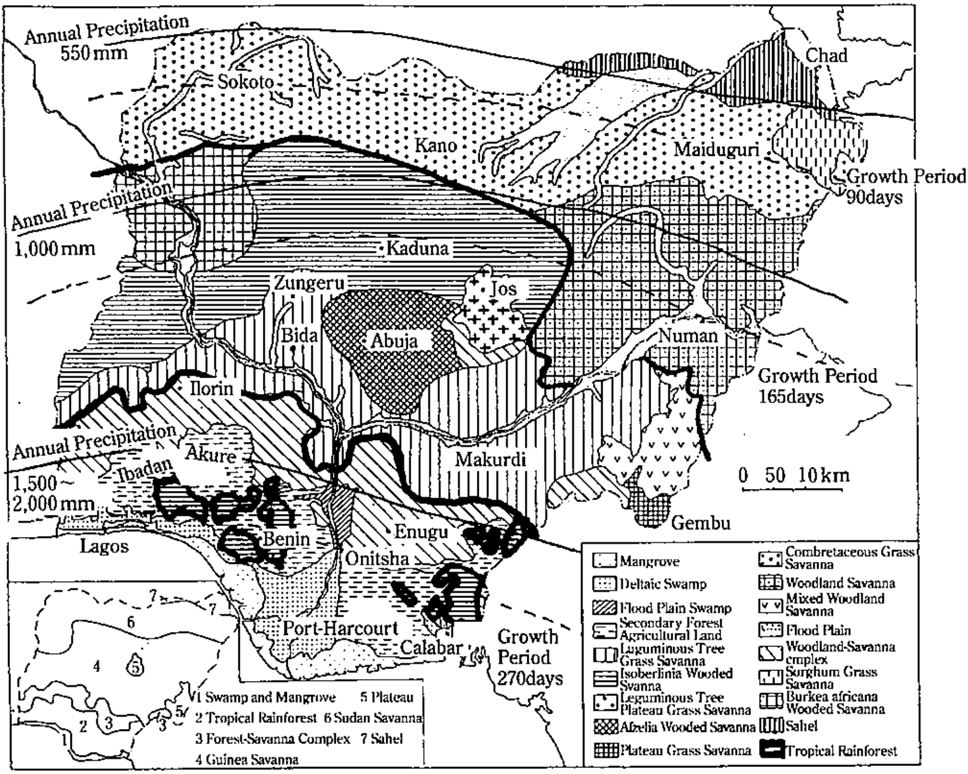


Fig.2-9 Nigerian vegetation map (Barbourn, 1982)

how closed-canopy primary forests, such as tropical forests, have been lost. Large forest areas that remain are only coastal mangrove forests and swamp forests in the deltas, but since oil producing districts exist in these mangrove and swamp forests, deforestation is taking place in these areas too. The forced eviction of residents from these districts, which deprives fishermen of their means of livelihood, uses of state power in an attempt to protect oil capitalists, and long continued political instability are also accelerating forest destruction.

There is little left of the tropical rain forests that used to cover large areas from Ibadan to Benin, Enugu and Calabar. Only a few remain in some protected areas. Like mangrove forests and swamp forests in the deltas, these protected forests are rapidly disappearing by illegal cutting. The regions south of the lowest line drawn in Fig. 2-9 are the equatorial forest zones having rainfalls of 1,500-2,000 mm or more and a growth period of 270 days or more. These zones roughly correspond with the mixed areas of secondary forests and derived savannas in the figure. Tropical forests remain in these equatorial forest zones, but according to a field survey the author's group conducted in 1990, no closed-canopy tropical forests remained north of the Benin-Onitsha line. It is supposed that more than half of the tropical forests shown in Fig. 2-9 have disappeared. As noted, in forests southern Nigeria have been lost and turned into farmland or savannas. On the other hand, the Sahel zone in northern Nigeria has been moving south (see Chapter 1, Fig. 1-14). In Nigeria, the transition of forests to savannas, savannas to grasslands and grasslands to deserts is taking place at the same time.

North of the equatorial forest zone lies the savanna zone. Having the largest area in Nigeria and West Africa, savanna vegetation is classified into four types. Savanna woodlands have many trees and bushes, canopies and bushes being continuous, and are almost all composed of natural vegetation. In tree savannas, trees and bushes grow sparsely. In shrub savannas, no tall trees are seen and only bushes and grasslands exist. In grass savannas, there are a few low bush-like trees. These four types are subdivided into smaller groups according to tree and grass species.

Except the derived savannas observed in the Jos and Mambila (or Gembu) plateaus, the distribution of grass savannas roughly coincides with the border between the Guinea savanna, i.e., wet savanna and the northern Sudan savanna, dry savanna, zone, which is located along the 1,000 mm isohyet and the line of the 165-days growth period. The areas having an annual rainfall of 550 mm or less and a growth period of 90 days or less are called the Sahel zone, the front line of desertification.

2-3. Soil distribution

Fig. 2-10 shows the distribution of main soils in West Africa (FAO/Unesco, 1974,1990). The soil distribution in this region has the following three characteristics. First of all, the features of zonal soil distribution are clear. From the coast of the Gulf of Guinea to the Sahara, main soil types are distributed in belts according to gradual decrease in precipitation and correspond well to the distribution of vegetation zones. Second, even in the same zonal division, the strong effects of parent materials can be observed. Third, different types of soil appear even in the same zonal division and parent material division because the moisture environment and the sedimentation and erosion conditions change by the influence of topography. In other words, the catena or toposequence can be

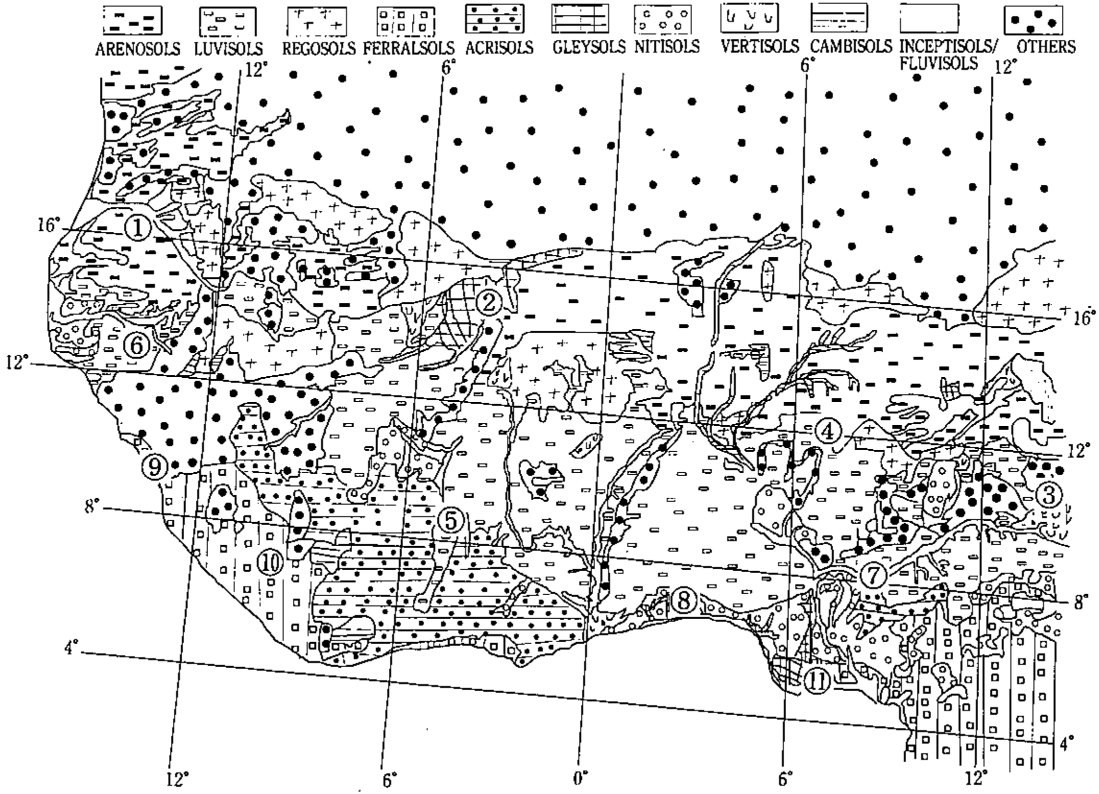


Fig.2-10 Distribution of main soils in West Africa (FAO Soil Map of West Africa, FAO/Unesco, 1974, 1990)
General physico-chemical characteristics of the Numbered sites ①~⑪ are shown in the Table 2-3.

observed clearly. The characteristics of soil distribution in West Africa are outlined below for each of the region's main climatic zones from the Sahel zone with the least rainfall to the equatorial forest zone having heavy rain.

1)Sahel zone

In the Sahel zone with an annual rainfall of 500 mm or less, Arenosols (Psamments, Udipsamments, Quartzipsamments; the soil names in parentheses are based on the U.S. Soil Taxonomy (Soil Survey Staff, 1975, 1994, 1999); hereinafter the same) and Regosols (Orthents, Psamments) have a wide distribution. These soil types in the uplands are sandy or gravelly and poor in nutrients, containing little organic matter, organic nitrogen and phosphorus. Although there is little possibility of using these soil types for agriculture except nomadic grazing, some sandy soils with relatively deep rooting zones in the lowlands where soil moisture is available, can grow millet and sorghum.

Fluvisols and Gleysols (Fluvents, Aquents or Aquepts) are distributed in the flood plains along the Senegal and Niger rivers and around Lake Chad and in the lowland areas along rivers, such as inland deltas, while Vertisols are also observed in some lowlands areas around Lake Chad. Small differences in altitude within several meters exist in the inland deltas in Mali and in the flood plains along the Niger and Senegal rivers, and Vertisols are locally but widely distributed in the low parts of these areas, providing an important agricultural base. In these soil types, millet and sorghum are also cultivated. In the districts where water is naturally supplied, African rice is grown. Irrigated farmland, each plot having a scale of 10-20 ha, is managed by villages with small-sized floating pumps, and rice, vegetables and other crops are intensively planted in the basins of the Senegal river. This type of small-scale irrigated system is considered to be a relatively sustainable one. On the other hand, large dams were constructed in the Niger and Senegal rivers and large-scale irrigation projects using huge pumps were completed or attempted in Lake Chad. These large-scale irrigation projects aim to increase the output of rice, wheat and barley, cotton, sugarcane and other crops. However, great doubt has been cast on these large projects from the viewpoint of sustainability. In particular, in Lake Chad, the large-scale South Chad Irrigation Project with a target irrigated area of 50,000 ha was carried out on the Nigerian side. But the lowered water level of the lake made it impossible to pump water from the central diversion weir, bringing to naught the ambitious plan to develop 50,000 ha of farmland and wasting the development fund of over US$ one billion of oil money of Nigeria.

Table2-3 General physical and chemical properties of representative soils distributed in each agro-ecological climatic zone

(soil sampling sites are shown in Fig. 2-10)

Climatic zone	Depth (cm)	pH (H_2O)	Organic Carbon (%)	Total Nitrogen (%)	Available phosphorous Bray 1 (mg/kg)	Exchangeable ion (cmol(+)/kg)						Sand (%)	Slit (%)	Clay (%)	Gravel (%)
						Ca	Mg	K	Na	Exchange acidity	eCEC				
Sahel zone															
No.1	0-25	7.4	0.18	0.023	-	1.52	0.50	0.06	0.09	tr	2.16	94	1	5	0
Cambic	50-70	7.2	0.08	0.011	-	1.21	0.40	0.04	0.1	tr	1.75	94	2	4	0
Arenosol	100	7.5	-	0.011	-	1.28	0.50	0.04	0.27	tr	2.09	93	3	4	0
(Snegal)	175	-	-	0.007	-	0.78	0.74	0.06	0.25	-	1.83	93	3	4	0
No.2	0-10	5.0	1.07	0.110	0.9	5.43	3.46	0.85	0.48	1.87	12.42	9	18	73	0
Futric	10-25	4.1	0.51	0.052	2.1	5.73	3.80	0.42	0.5	2.23	13.05	5	8	87	0
Gleysol	40-55	4.8	0.86	0.094	0.9	8.35	3.09	0.65	0.53	1.48	14.5	9	14	77	0
(Mali)	55-70	4.2	0.20	0.050	0.7	5.48	3.46	0.38	0.48	2.60	12.81	0	9	91	0
Sudan savanna zone															
No.3	0-10	7.7	0.94	-	4.6	31.1	10.9	1.1	-	tr	43.56	15	26	59	0
Futric	10-35	7.9	0.69	-	1.8	30.8	19.8	0.75	-	tr	43.14	19	24	57	0
Vertisol	35-100	8.5	0.67	-	1.8	27.2	12.1	1.2	-	tr	43.25	19	27	54	0
(Cameroon)	100-140	8.5	0.74	-	2.1	27.2	14.0	1.6	-	tr	48.07	13	26	61	0
No.4	0-22	6.8	1.92	-	7.4	9.2	1.4	0.51	-	0.2	11.3	56	27	17	-
Haplic	22-55	6.5	0.44	-	0.9	4.6	1.8	0.40	-	0.1	6.9	13	35	42	-
Luvisol	55-105	6.5	0.29	-	0.9	4.0	1.5	0.34	-	0.1	5.9	39	24	38	-
(Nigeria)	110-160	6.4	0.20	-	0.4	3.1	1.4	0.19	-	0.1	4.6	46	31	24	-
Guinea svanna zone															
No.5	0-20	6.5	1.19	0.79	-	3.3	1.1	0.22	0.03	-	4.7	79	8	13	5
Plinthic	20-45	6.1	-	-	-	3.0	0.7	0.30	0.06	-	4.1	51	10	39	7
Luvisol	45-90	5.1	-	-	-	3.1	0.6	0.25	0.06	-	4	43	11	46	39
(Cote d'Ivoire)	>90														

No.6	0-6	6.5	0.07	0.07	-	2.25	1.05	0.15	0.05	-	3.5	85	5	10	14
Ferric	6-13	5.6	0.68	0.05	-	1.70	0.65	0.10	0.05	-	2.5	85	5	10	12
Luvisol	15-25	5.6	0.38	0.03	-	1.70	1.05	0.05	tr	-	2.8	70	6	24	11
(Senegal)	40-60	6.2	0.33	0.03	-	2.10	1.50	0.05	tr	-	3.7	55	6	39	11
	90-110	6.3	0.29	0.03	-	1.30	2.30	0.05	0.05	-	3.7	45	6	49	11
	130-150	6.3	0.20	0.03	-	1.70	1.85	0.05	tr	-	3.6	48	7	45	12
No.7	0-20	6.4	2.06	0.124	22.2	3.52	2.48	0.35	0.23	0.31	6.90	40	46	14	-
Eutric	20-40	5.7	1.10	0.067	2.0	2.02	1.55	0.20	0.23	0.41	4.42	4	44	52	-
Fluvisol	40-60	5.5	0.94	0.037	1.5	9.55	1.83	0.76	0.23	0.56	12.99	16	48	36	-
(Nigeria)	60-80	5.6	0.91	0.033	1.2	4.03	2.25	0.39	0.21	0.47	7.36	16	48	36	-
	80-100	5.7	0.83	0.021	1.8	3.80	1.56	0.40	0.21	0.36	6.34	30	30	20	-
Equatorial forest zone	0-20	6.4	2.06	-	3.0	7.4	1.6	1.21	-	0.2	9.5	18	24	58	-
No.8	20-30	6.3	1.05	-	1.2	4.6	1.0	0.05	-	0.1	5.8	13	16	71	-
Futric	30-55	6.4	0.44	-	2.5	3.2	0.73	0.03	-	0.1	4.0	14	21	65	-
Nitisol	55-95	6.3	0.32	-	3	3.0	0.59	0.03	-	0.2	3.7	10	22	67	-
(Nigeria)	95-130	6.2	0.33	-	3	2.3	0.94	0.03	-	0.1	3	8	20	72	-
No.9	0-10	4.7	1.24	-	3	3.2	6.2	0.7	24.7	40.8	17.5	62	26	12	-
Thionic	10-20	3.2	1.94	-	2	4.0	6.3	0.5	21.7	20.9	27.1	17	32	51	-
Fluvisol	20-80	2.8	1.94	-	5	2.7	2.3	0.4	37.6	23.2	33.7	16	25	59	-
(Guinea)	80-120	2.7	2.06	-	4	3.7	9.0	0.1	33.4	28.1	33.7	8	40	52	-
No.10	10-40	4.5	1.74	0.138	4	0.50	0.08	0.11	0.05	2.82	3.56	65	13	22	-
Xanthic	40-100	4.5	0.81	0.100	1.2	0.40	0.07	0.17	0.05	3.34	4.04	49	13	38	-
Ferralsol	100-180	4.1	0.45	0.063	1.5	0.20	0.07	0.1	0.04	2.54	2.95	39	17	44	-
(Liberia)	180-300	4.1	0.32	0.050	2.0	0.10	0.05	0.09	0.04	2.98	3.26	43	17	40	-
No.11	0-13	4.6	4.56		4.5	23.10	4.42	0.41	0.11	0.55	28.59	18	33	49	-
Eutric	13-35	5.5	2.13	-	2.2	26.30	4.82	0.33	0.10	0.14	31.69	14	35	51	-
Nitisol	35-65	5.7	0.58	-	1.2	24.40	4.50	0.31	0.09	2.15	31.45	14	35	51	-
(Nigeria)	65-100	5.4	0.36	-	0.9	24.60	4.67	0.33	0.10	1.16	30.86	14	35	51	-

Source: Nos, 1, 5, 6, 9: FAO/Unesco(1974); Nos.2, 7: Wakatsuki, unpublished data;Nos.3, 4, 8,: Moberg *et al.*, (1991);No.10: Kosaki, unpublished data, No.11: Kosaki and Juo (1984)

Table 2-3 shows the general physical and chemical properties of Arenosols and Gleysols, the representative soil types. The sampling sites are shown in Fig. 2-10. Arenosol's sand content is 90% or more and its effective cation exchange capacity (eCEC) is as small as 2 or so. By contrast, Gleysols have a high clay content and a relatively high level of eCEC and exchangeable cations, indicating that these are relatively fertile soils.

2)Sudan savanna zone

The northern half of this zone is mostly composed of Arenosols (Luvic, Cambic) and Regosols that continue from the Sahel zone. But the Senegal and Niger rivers and their tributaries as well as the rivers flowing into Lake Chad have eroded these sandy soils and have deposited fertile lowland soils (Fluvisols, Gleysols). Vertisol's distribution is considerably wider than in the Sahel zone. It is mainly seen in Burkina Faso and the areas around Lake Chad. In Burkina Faso, Planosols are also observed together with Vertisols.

In the south of the Sudan savanna, Luvisols (= Alfisols) are the main soil type. In Mali, Luvisols are the principal soils in its entire Sudan savanna zone. In the areas where basement rocks are parent materials, Luvisols having Chronic, Orthic, Ferric and Plinthic nature have come to be formed and weathering intensity is great. The distribution of Ferric and Plinthic Luvisols is the highest. These soil types are considered to have been formed by the long-term weathering of basement rocks under a humid climate. Because of this, clay is kaolinitic and the soil has a small CEC and low activity, making it sensitive to erosion. As shown in Fig. 2-10, since Luvisols in this zone are distributed in semi-arid areas with an annual rainfall of 1,250 mm or less, they have a high base-saturation percentage and are classified as Alfisols in the U.S. Soil Taxonomy (Soil Survey Staff, 1994) system.

The relatively high soil fertility in the Sudan savanna zone in comparison with the Sahel and Guinea savanna zones is observed. This is probably because the soils in this zone are formed from the parent materials of various deposits with relatively young geological ages (Fig. 2-7). While the Sahel zone is situated in the upper basin where it is subjected to wind erosion by harmattan winds in the dry season, the Sudan savanna zone is in the lower basin where the eolian dust, harmattan dust, is deposited as loess. The Hausa area in northern Nigeria that has thick layers of loess where has been an important farming district thanks to the relatively fertile loess. The dust brought each year by the harmattan wind in the dry season plays an important role in maintaining soil fertility in this area. But if the fertile soils derived from eolian deposits are lost by soil erosion, extremely low nutrient exhausted lateritic, iron stone, or quartz sandy parent materials are exposed on the surface of the soil. Such iron stone land surfaces, typical of soil degradation, are also common in this region.

Relatively fertile deposit-derived Nitisols are also observed in the coastal part of southern Senegal and the north of the Benue River in eastern Nigeria, providing these areas with an important farming resource.

In the regions from the Sudan savanna to Sahel zones, groundnut, cotton and other cash crops have been extensively cultivated since the colonial days and have been the means to earn foreign exchange. However, cultivation of these cash crops on the relatively fertile soils in large areas of West Africa brought about the stagnation of basic food production in this region. Such plantations were important causes of destruction of soil and other farming resources as well as the environment. This is because the food crops were cultivated in more marginal areas. This is an indirect cause of human induced desertification in this region that is now posing a grave problem.

3) Guinea savanna zone

This zone forms a central highland belt zone in West Africa. With low population densities (Fig. 1-3), its importance in agriculture has not been very high except in some areas. Though this zone is more blessed with rains than the Sudan savanna zone, harmattan is relatively weak and the level of geological fertilization by loess is not very high. The soil formed by the strong weathering of basement rocks has a wide area of distribution. Because of this, soil fertility in the Guinea savanna zone is not so high except in some districts. As seen from the data of the physical and chemical properties of representative soils in each agro-ecological zone in Table 2-3, the soil fertility in this zone is generally lower than the Sudan savanna and equatorial forest zones.

The soil types most widely distributed are Ferric and Plinthic Luvisols, which are observed in southern Senegal, Mali, southern Burkina Faso, Ghana, Togo, Benin, Nigeria and northern Cameroon. The southern border of these soil types roughly corresponds with the isohyet of 1,250 mm a year.

In the southern Guinea savanna zone with more rainfall, acid Ferric Acrisols are distributed. These soils are chiefly seen in Guinea and Côte d'Ivoire. Because forests have been lost and soil erosion is serious, the soils are composed of coarse granules of iron stone and a thin top soil layer and have low productivity in most cases. In some parts of southern Guinea savanna zone in Cameroon and the Central African Republic, Ferralsols are distributed as an extension of the equatorial forest zone.

Fertile Fluvisols are observed in the flood plains of the Niger, Volta and Benue rivers but because of difficult water control, these soils have not been used effectively for agriculture. However, rice is grown in Guinea and in the flood plains of the Niger River in Nigeria mostly by rain fed condition. In some parts, there are irrigation schemes using medium and large-scale pumps. In the upper basins of the Volta River in Ghana and in those of the Benue River in Nigeria and Cameroon, Vertisols are also distributed in flood plains. Ghana's eastern coast and Togo's and Benin's coastal areas belong to the savanna climate with an annual rainfall of 1,250 mm and Vertisols are observed in some depression parts.

4) Equatorial forest zone

What is worthy of mention is that despite heavy rainfall of 2,000 mm, southern Nigeria with a high population density has no distribution of Ferralsols (Orthic, Xanthic) but relatively fertile Nitisols, Acrisols and Luvisols. In particular, in the Ibo area on the left bank of the Niger Delta in southeastern Nigeria (see Fig. 1-2 and 1-3) that has a very high population density, the soils are fertile Eutric Nitisols. The soil shown in No.11 of Table 2-3 is that sampled in an inland valley in this area and has an abnormally high fertility for a soil in the equatorial forest zone. The clay mineral of this soil is chiefly composed of smectite. Volcanoes exist in the border region with Cameroon. The soil is derived from the shale which is the weathered material of this basic volcanic ejecta which settled and consolidated on the seabed.

The Niger Delta is now not very important as an area for agricultural purposes. It is Nigeria's oil producing area and is little regarded as a district for farm development. Another reason is that it is no easy task to establish a water management system for such a huge delta area. The main soils in the delta are Gleysols and Thionic Fluvisols which are also distributed in mangrove areas. These soil types are also observed in the coastal areas from Senegal to Sierra Leone.

Ferralsols, a soil type found in the equatorial forest zone, have a wide distribution in Sierra Leone and Liberia and these Ferralsol areas are mainly used as rubber and oil palm was the first to be plantations. Since oil palm is domesticated areas there is a wide and diverse distribution in local farmers' fields, apart from the plantations. However since production technology is underdeveloped, major world production of the palm oil comes from Southeast Asia, such as Malaysia and Indonesia. Acrisols are extensively distributed in the equatorial forest zone in Côte d'Ivoire, Guinea and Ghana and Nitisols are observed in the coastal areas of Benin and Nigeria. These soils are acidic but relatively fertile. These areas have become the producing districts of cocoa, coffee, kola nut, oil palm and other cash crops. (Toshiyuki Wakatsuki)

3. Distribution and characteristics of lowland soils in West Africa

3-1. Distribution and characteristics of lowlands in tropical Africa

Fig. 2-11 shows the distribution of major lowlands in Africa (Van Dam and van Diepen, 1982). These lowlands are mostly inland basins. Except in the Nile Delta, Africa's large lowlands are not used for intensive farming activities. Chemically fertile Vertisols and alluvial soils are widely distributed in the upper basins of the Nile around Khartoum and in the Sudd Swamps, Sudan, in the lowlands around Lake Chad and in the inland deltas in Mali. However, these areas are semi-arid and not blessed with water supply and so except for the

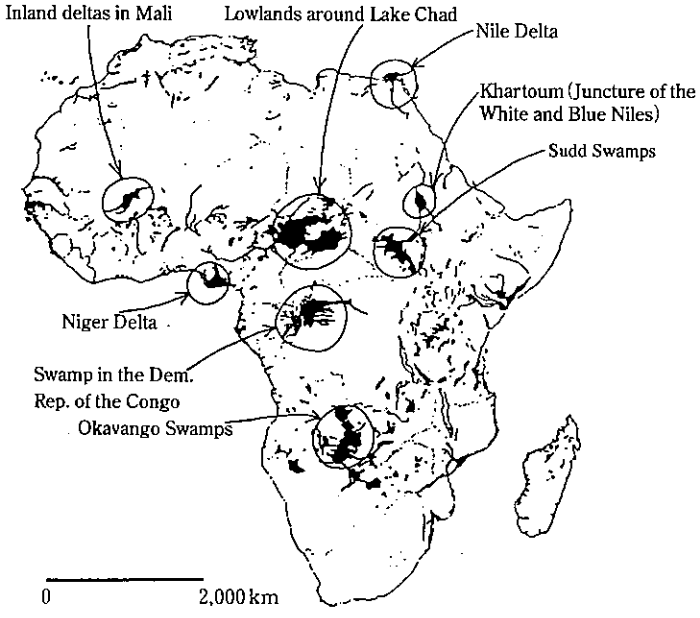


Fig.2-11 Distribution of major lowlands in Africa (Van Dam & von Diepen, 1982)

Table2-4 Disribution of lowlands in tropical Africa
(Hekstra & Andrisse, 1983)

Classification	Area (million ha)	Precentage (%)
Coastal swamps	16.5	7
Inland basins	107.5	45
Flood plains	30.0	12
Inland valleys	85.0	36

lowlands in Sudan along the Nile their use as farmland is limited unless large-scale irrigation succeeds. The drying of the Sahel zone in recent years makes it more difficult to develop irrigated farming in large inland basins in tropical Africa. On the other hand, although swamps in the Dem. Rep. of the Congo have ample water supplies, their soil is an extremely nutrient poor alluvial one composed mainly of quartz sand and has been little used for farming. These marshes should rather be conserved as areas of valuable tropical rain forests for the global environment. Not much information is available concerning the Okavango Swamps but sandy Regosols are a widely distributed here. These swamps are not sites for agricultural development but to be reserved for wild animals and protected.

Fig. 2-11 shows some flood plains as thin lines along the Nile and the Niger. But no inland valleys in the source of rivers are shown in this figure. According to Hekstra & Andriesse (1983), inland basins in tropical Africa total about 110 million hectares and inland valleys about 85 million hectares, together accounting for about 80% of the area's lowlands (Table 2-4). The properties of the main soil types are outlined below according to the classification shown in Table 2-4.

3-2. Vertisols in inland basins

1)Physical and chemical characteristics

As shown in the No.3 soil in Table 2-3 and the data in Table 2-5, Vertisols are heavy clay and rich in base with large eCEC and thus have high chemical fertility. The soil around Mopti in an inland delta in Mali shown in Table 2-5 is not a Vertisol but a Eutric Gleysol which is shown for comparison. If these soils are dried, montmorillonite, the main constituent of their clay minerals, shrinks, causing large cracks. As a result, water leakages from the banks of reservoirs and irrigation canals and from the boundary ridges as well as subsoils of sawah

Table2-5 General physical and chemical properties of Vertisols and Eutric Gleysols

	Depth (cm)	pH (H_2O)	Organic carbon (%)	Total nitrogen (%)	Exchange cation (cmol(+)/kg)						Sand (%)	Slit (%)	Clay (%)	eCEC/ clay (cmol(+)/ kg)
					Ca	Mg	K	Na	Aci-dity	eCEC				
Areas around	0-18	6.1	0.43	0.050	17.92	8.30	0.91	0.95	0.32	28.4	27	12	61	47
Lake Chad*	38-57	7.1	0.43	0.030	19.76	7.61	0.96	1.79	0.68	30.8	18	16	67	46
Sudan**	0-18	7.5	0.68	0.034	26.4	19.2	0.70	tr	tr	46.3	39	7	54	86
	18-60	7.5	0.48	0.022	23.7	18.1	0.70	0.1	tr	42.6	36	10	54	79
Inland deltas	0-10	5	1.07	0.110	5.43	3.46	0.33	0.85	3.54	13.6	9	18	73	19
in Mali	25-55	4.8	0.86	0.094	8.35	3.09	0.40	0.65	2.87	15.4	9	14	77	20

Sources: *Oyediran (1990)
**Sudan Soil Survey Administration/FAO (1985) and Abdulla (1985)
***Eutric Gleysol

fields increase. Moreover, these soils turn so hard when dried that they can be plowed only with a pickax. On the other hand, under humid conditions, these soils lose their bearing capacity, making it hard for tractors and other large cultivators to be used on them. Thus these soils have poor physical properties and are one of those problem soils having a narrow range of soil moisture for sufficient tillage operation.

2)Irrigation of Vertisols

In West Africa, Vertisols are mainly distributed in semi-arid regions with an annual rainfall of 800 mm or less. Because of this, these soils require irrigation except in the areas where drought-resistant crops, such as millet, are grown. Since Vertisols are very fertile, it is possible to achieve a high yield of 5-8 t/ha of paddy rice on them once irrigation is properly provided and managed. If sustainable irrigation is available, a high yield can also be obtained for wheat, maize, sorghum, cotton and other crops. But in the irrigation of Vertisols, care should be taken of the matters described below.

3)Problems of chemical properties

Vertisols have large eCEC and are black, but as shown in Table 2-5, their organic matter content is low. Therefore, nitrogen and often phosphorus as well as other fertilizers should be additionally applied to these soils. If upland crops, rather than rice, are grown by irrigation, care is needed to prevent these soils from salinization. Fig. 2-12 and Table 2-6 are not showing West Africa, but a project site constructed by the technical cooperation of the Japan International Cooperation Agency, JICA, in the State of Kilimanjaro, Tanzania, the Kiliman-

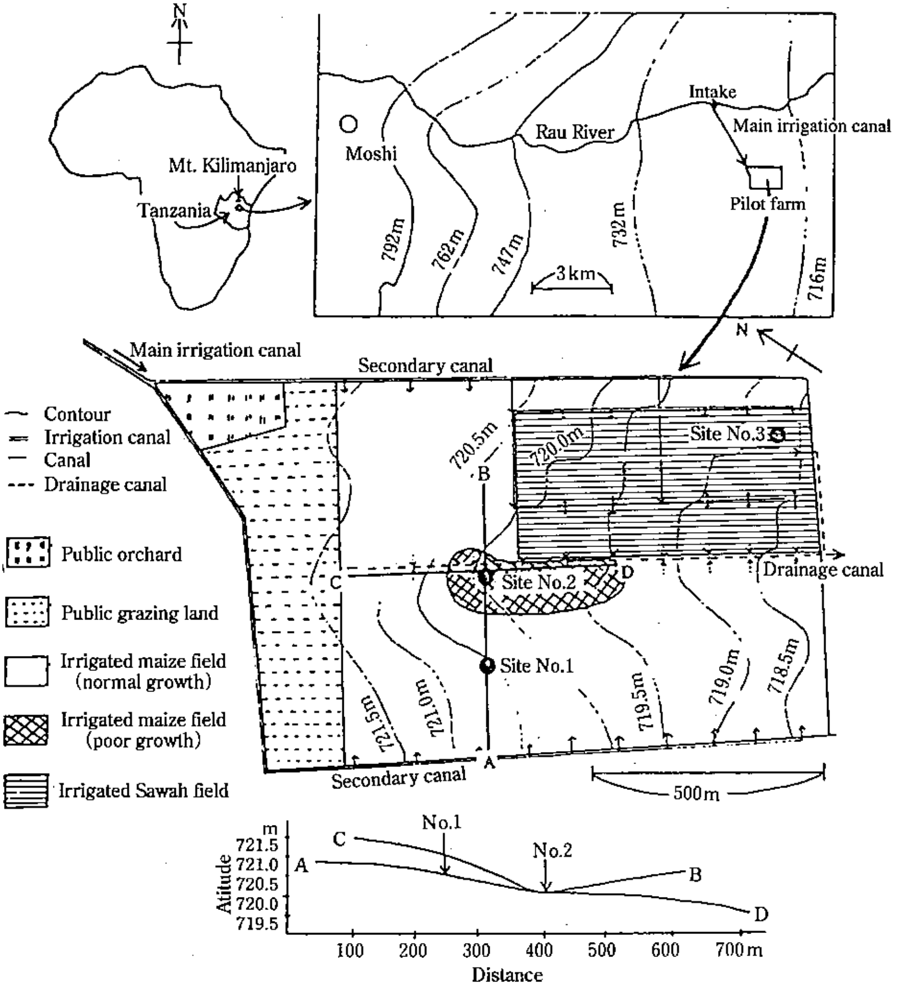


Fig.2-12 Pilot farm at the Kilimanjaro Agricultural Development Center (KADC) Tanzania.

jaro Agricultural Development Center (KADC). The data show the results of the soil analyses of the poorly drained plot where growth obstacles of maize were serious and the well-drained plot where no problems arose after four years of continuous cultivation of maize (the survey was conducted in August 1985: Wakatsuki and Mizota, 1992). The topographical features of vertic soil zones are flat as a whole but actually have small differences in altitude from tens of centimeters to several meters. Since the soils have very low water permeability, poor drainage occurs even in tiny depressions. As shown in the table, sodium, magnesium and other salts accumulate in these areas within five years.

Table2-6 General physical and chemical properties of the soil at Sites No.1, 2 and 3 at the Kilimanjaro Agricultural Development Ceter (KADC) pilot farm, Tanzania

Site	Depth (cm)	Soil texture	Color moist	Total (g/kg)		pH (H_2O)	pH (KCl)	1 M ammonium acetate extractable cations (cmol(+)/kg)					Available phosphorus (g/kg)
				C	N			Ca	Mg	K	Na	Sum	
No.1	0-1	SiC	5YR2/4	35	3	7.0	6.1	12.5	6.6	3.3	0.2	22.6	1.13
	1-10	SiC	5YR2/4	10	1	6.5	6.0	11.2	5.6	3.5	0.1	20.4	1.22
	10-20	SiC	5YR3/3	9	1	6.8	5.9	10.8	6.2	2.0	0.2	19.2	0.98
	40-50	SiC	5YR3/3	5	0.5	6.5	5.3	9.7	4.7	2.3	0.3	17.0	1.16
	90-100	SiC	5YR3/3	5	0.5	6.5	5.5	10.5	4.6	1.9	0.4	17.4	1.41
No.2	0-1	SiC	5YR2/4	-	-	6.1	6.1	78.8	61.8	7.8	205.8	354.2	0.97
	1-10	SiC	5YR2/4	-	-	6.4	6.3	29.9	26.5	6.8	6.5	69.7	1.41
	10-20	SiC	5YR3/3	-	-	6.1	5.1	8.6	6.0	2.5	4.7	21.8	0.86
	40-50	SiC	5YR3/3	-	-	6.8	5.4	6.6	6.0	2.0	4.1	18.7	0.61
	90-100	SiC	5YR3/3	-	-	8.5	7.0	9.2	8.2	2.2	6.9	26.5	1.05
No.3	0-1	SiC	5YR3/3	-	-	6.6	6.6	14.6	8.0	2.0	0.6	25.2	0.21
	1-10	SiC	5YR2/3	-	-	7.3	6.8	14.2	6.0	3.2	0.4	23.8	1.19
	10-20	SiC	5YR2/4	-	-	7.6	6.9	14.7	5.1	4.1	0.3	24.2	1.43
	40-50	SiC	5YR2/4	-	-	7.5	6.8	15.8	2.8	3.1	0.3	22.0	0.94
	70-80	SiC	5YR2/4	-	-	7.6	6.6	15.9	2.6	4.0	0.3	22.8	1.15

Source: Wakatsuki & Mizota (1992)

On the other hand, sawah fields are hard to be salinized as evident from the table. This is because salts are washed away while the fields are kept flooded. This suggests that continuous sawah agriculture by irrigation is possible even in a semi-arid area. If enough irrigation water to make up for large evapotranspiration in a dry area is provided to sawah fields and is then efficiently drained, the storage of salts in the surface soil can be prevented. If it is impossible to get sufficient irrigation water, a rotation system in which sawah agriculture is performed once in several years may be introduced. In the salt-injured sites at KADC mentioned above, the problem of salt injuries was later settled by turning the sites into sawah fields. To realize continuous irrigated rice production in this area, it is a precondition that enough water resources to wash salts away are available. But since the area has only limited water resources, its potential for development of irrigated sawah fields is not high.

Vertisol's tillage-related physical properties, i.e., cracks and hard soil, may be managed by the following method. The surface soil should be plowed after the fields have been drained and rice has been harvested to cut off the capillary water routes from the subsoil and to prevent the soil from being dried and cracked. This is an effective way to check soil hardsetting caused by excessive drying.

4)Low-temperature injuries to rice

In the Vertisol areas in tropical Africa where rice can be grown by irrigation, both in the Sahel zone and in the highlands of an altitude higher than 800m in East Africa, low-temperature injuries pose problems in some cases depending on the rice cultivation period. In Niamey, N'Djamena, Tombouctou and other places in the Sahel zone, the average temperature in December and January is 21.8～24.8°C due to the harmattan that carries dust from the Sahara. But sometimes the maximum temperature goes down to 25°C or less and the night-time temperature, to 10°C or less. If these low temperatures occur at the booting or heading stage, rice becomes sterile. Sensitive to cold weather, Indica varieties are apt to be injured by low temperatures. Thus there is a need of breeding cold-resistant varieties and of taking some preventive steps, such as changing the planting period and improving nurseries. While the high temperature resistance of African rice (O. glaberrima) is well known, almost no studies have been conducted about its cold tolerance. Since this rice was turned into a cultivated species in the Sahel zone, it may have the genetic characteristics both of high-temperature and cold resistance. (Toshiyuki Wakatsuki)

3-3. Poor soils in inland valleys and more fertile soils in flood plains

(1) Inland valleys

While highlands prevail in East Africa, peneplains are prevalent in West Africa. Inland valleys are found in the lower parts of watersheds of gently rolling peneplains. They have low altitudes of only tens of meters and several hundred meters but form the watersheds of river sources. Fig. 2-13 shows schematic location of the two categories of inland valleys and flood plains (Savvides, 1981). The principal water sources of inland valleys are rains, surface runoff from the watershed and seepage water. The course of a stream is not clear in the uppermost parts of the water source but becomes more distinct as the stream goes to lower basins and then forms valleys with features of flood plains along it.

Inland valleys have different names according to the region. They are known as basfond or marigot in Francophone countries and as fadama in the Hausa area in northern Nigeria, Chad, etc. They are named inland valley (swamp) in the Anglophone area and dambo, mbuga, etc. in the Bantu area in

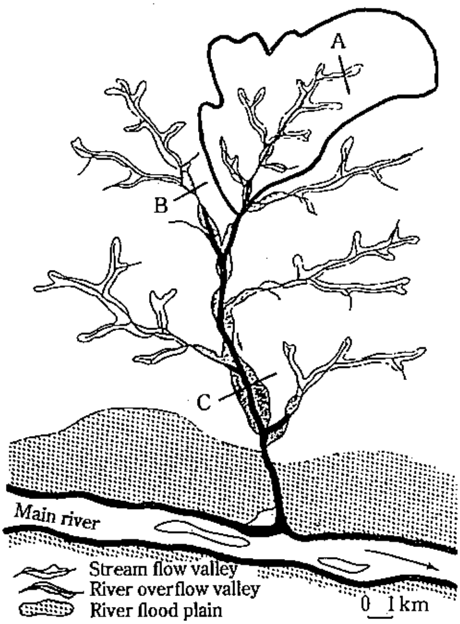


Fig.2-13 Schematic location of the two categories of inland valleys and river flood plains (Savvides, 1981)

Note: See Fig.6-1 for the schematic cross sections at Sites A, B and C.

southeast Africa. Inland valleys in tropical Africa total about 85 million hectares (Table 2-4), most of them found in West and Central Africa (about 65 million hectares). It is estimated that southeast Africa has about 20 million hectares of inland valleys. There are Takishima's general remarks (1992) about the ecology and potential of development of dambo in southeast Africa. Shimada, Kodamaya, and Hanzawa (1993, 2000) conducted interesting long-term studies on land use and rural communities and their economy in this area. The total area is, however, much smaller than in West Africa and most of the inland valleys in southeast Africa are found in the highland. The potential area for rice is therefore limited, so discussions below will focus on West and Central Africa.

(2) Soil fertility of inland valleys and flood plains in West Africa

During 1986 to 1998, the authors conducted various survey trips on the rice-based farming systems both in flood plains and inland valleys. Lowland soils were also collected from most West African countries, including Senegal, Guinea, Sierra Leone, Liberia, Côte d'Ivoire, Mali, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, Cameroon and the Dem. Rep. of the Congo (Fig. 1-29, Fig. 2-14, 2-15). In these studies soil fertility characteristics were evaluated and their fertility was compared with that of soils in tropical Asia and Japan (Wakatsuki, 1988; Wakatsuki et al., 1988, 1989; Issaka et al., 1996a, b, c, 1997; Buri et al., 1996a, b, 1999, 2000). Table 2-7 shows the general physical and chemical properties of the surface soil samples taken from flood plains and inland valleys in each agro-ecological climatic zone of West Africa as compared with the data of surface soil in various lowland rice fields in southeast Asia and in Japan (Kawaguchi & Kyuma, 1977).

Though the number of sampling sites was not determined according to the distribution of lowlands, it roughly corresponds to the estimated lowland distribution in the whole of West Africa, which is 38.6 to 84 million hectares (Windmeijer and Andriesse, 1993). For the inland valleys whose distribution is estimated at 21 to 51 million hectares (median: 36 million ha), soil samples were taken at 185 sites, and for an estimated area of flood plains of 12.3 to 24.8 million hectares (median: 19 million ha), samples were collected at 62 sites. Almost no sampling was conducted in coastal lowlands and deltas, which are estimated at 4.7 to 8.2 million hectares (median: 6 million ha). This is because, as already noted, the priority of lowland development for agricultural purposes is first given to inland valleys, then to flood plains and finally to coastal lowlands and deltas. To assess the fertility of lowland soil in West Africa, there is a need of increasing the number of samples from coastal lowlands and flood plains in future. But since this study is focused on inland valleys and aims at evaluating the fertility of inland valley soils, the numbers of sampling sites mentioned above will be sufficient.

The number of samples for each climatic zone given in Table 2-7 shows the characteristics of lowland distribution in West Africa. Inland valleys exist mainly in the Guinea savanna and equatorial forest zones. On the other hand, flood plains using rice cultivation at the moment are distributed mostly in the Sudan savanna and Sahel zones. Coastal lowlands and deltas and inland basins, which were not sampled in this study, are observed chiefly in the equatorial forest zone and the Sahel zone, respectively.

From this table it can be known that chemical fertility is higher in the soil of the Sudan savanna and Sahel zones where rainfall is lower and less leaching occurs. Soil in flood plains is generally more fertile than that in inland valleys except in inland valleys having base-rich parent materials, such as the Ibo and Yoruba areas in southern Nigeria. Inland valleys are widely distributed.

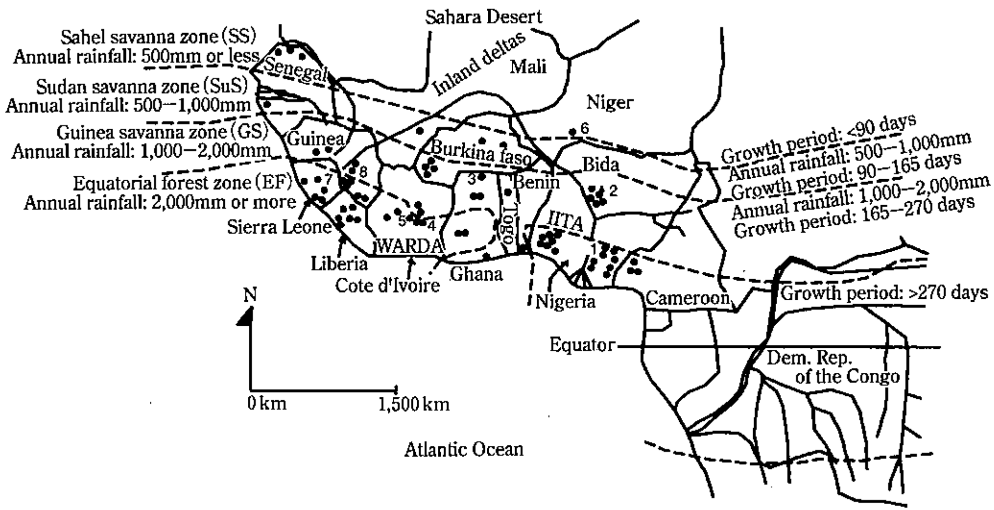


Fig.2-14 Main sampling sites of rice growing soil in inland valleys
(samples taken from a total of 185 sites)

The eco-environmental features of the numbered locations in the figure were as follows:
1. Abakaliki: traditional inland valley rice growing area; 2. Bida: traditional inland valley and flood plain rice area; 3. Tono irrigation project (Tono ICOUR) undertaken by ODA from Britain and South Korea; 4. Bouake: WARDA's headquarters and field exist in the Mbe Valley; 5. Daloa and Katiola: by ODA from the World Bank, Taiwan, etc. SODERIZ (Societe du Organise D'developpement de la Riziculture) developed sawah fileds; 6. Brinin Konni: African rice was partly grown in a small depression; 7. Makeni: traditional inland valley rice growing area; 8. Gueckedou: traditional inland valley rice growing area.

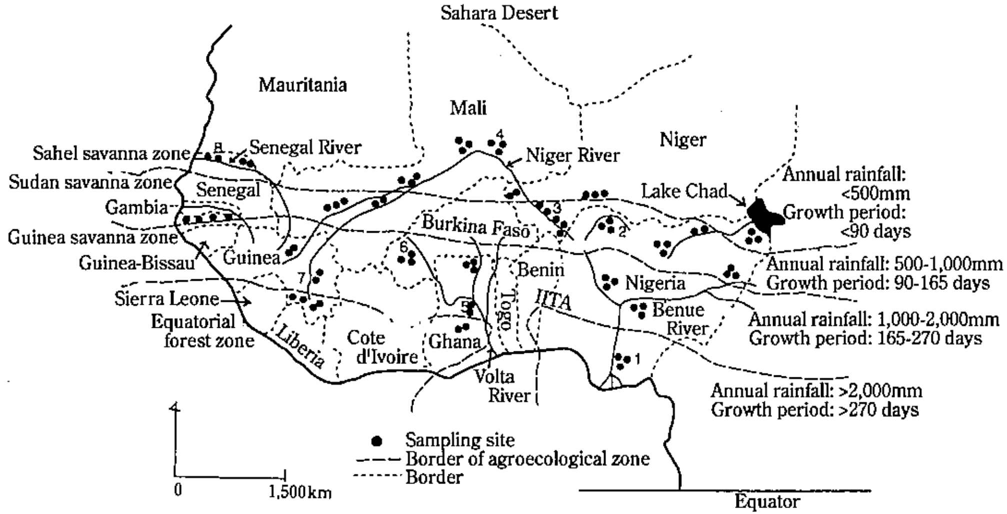


Fig.2-15 Sampling sites of flood plain soil (samples taken from a total of 62 sites)

1. Large-scale irrigated sawah fields developed by an ODA from Japan (about 4,000 ha), lower Anombra project; 2. Sokoto:African rice growing area by traditional flood plain farming system; 3. Niamey area: irrigated sawah fields with pumps; 4. Gao area: cultivation of deep water Asian and African rice observed; 5. Aframso: small-scale sawah fields in small flood plains; 6. vallee du Kou (Kou valley): irrigated sawah fields developed by an ODA from Taiwan and Holland; 7. Baro flood plains: upland rice type non-sawah fields and mechanized rice cultivation by an ODA from France; 8. Saint-Louis: small-scale irrigated sawah fields with small floating pumps and vegetable fields.

Table2-7 Physical and chemical properties of surface soils (0-15 cm) in inland valleys and flood plains

	Climatic zone	pH	Organic Carbon (%)	Total Nitrogen (%)	C/N ratio	Available phosphorous Bray No.2 (ppm)	Exchangeable ion (cmol(+)/kg)						eCEC/ clay	Sand (%)	Silt (%)	Clay (%)
							Ca	Mg	K	Na	Exchange acidity	eCEC				
Flood plain	Equatorial forest zone (n=7)	5.7	1.44	0.086	16.7	9.8	4.11	1.47	0.17	0.35	0.93	7.03	21	30	37	33
	Guinea savanna zone (n=19)	5.5	1.63	0.133	12.3	8.0	3.92	1.93	0.47	0.75	0.73	7.80	31	47	28	25
	Sudan/Sahel zone (n=36)	5.5	0.76	0.082	9.3	7.3	6.79	3.32	0.57	0.86	0.76	12.30	41	52	18	30
	Total, WestAfrica (n=62)	5.4	1.10	0.098	11.2	7.7	5.61	2.69	0.49	0.77	0.75	10.31	36	48	23	29
Inland valley	Equatorial forest zone (n=79)	5.3	2.04	0.166	12.3	11.8 (5.3)*	2.28	1.24	0.27	0.26	1.57	5.72	29	60	20	20
	Guinea savanna zone (n=98)	5.3	0.73	0.070	10.4	6.5 (2.9)*	1.33	0.51	0.20	0.11	0.51	2.66	18	61	24	15
	Sudan/Sahel zone (n=8)	6.0	0.59	0.066	8.9	6.0 (2.7)*	4.80	1.86	0.60	0.47	0.20	8.00	53	56	29	15
	Total, West Africa (n=185)	5.3	1.28	0.111	11.5	8.7 (3.9)*	1.89	0.88	0.25	0.19	1.00	4.20	25	60	23	17
Lowland rice field in tropical Asia** (n=410)		6.0	1.41	0.130	10.8	17.6	10.4	5.5	0.40	1.50	-	17.8	47	34	28	38
Lowland rice field in Japan** (n=155)		5.4	3.33	0.290	11.5	57.3	9.3	2.8	0.40	0.40	-	12.9	61	49	30	21

Note: *Bray No.1 method, (Issaka *et al.* 1996 a)
**Kawaguchi and Kyuma (1977)

Although the distribution is highest in the coastal equatorial forest zone, followed by subhumid Guinea savannas, there are some in inland semi-arid Sudan savannas and even part of the Sahel zone. Though located at the uppermost basin, inland valleys are topographically the low parts of the watershed and the slope of their bottom is mostly about 1%. Because of this, they are where soil substances flowed down from the uplands by erosion and accumulated and deposited. Thus it may be considered that the soil fertility of the watershed is entirely reflected in inland valleys.

As evident from Table 2-7, the soils in inland valleys in West Africa are generally very poor in nutrients. The average exchangeable Ca, Mg and K, eCEC and clay content and available phosphorus of these soils are all considerably lower than those of southeast Asia and Japan. Its fertility is among the lowest worldwide. The principal reason is that the soils in this region are characterized by very coarse particles and low fertility is probably a natural environmental factor caused by the weathering of old rocks for many years. But other important reasons will be deforestation and subsequent soil-exploiting farming activities in upland areas and also the fact that no soil-conserving farming systems, such as sawah agriculture, have been developed in lowlands.

Table 2-7 also shows the result of comparison between West Africa's present rice fields and those of Japan and southeast Asia. Some of the inland valleys in West Africa have fertile soils even in the equatorial forest zone, like the Ibo area in southeastern Nigeria (see also No.11 soil in Table 2-3). But in general, the soils in the Guinea savanna and equatorial forest zones, where many inland valleys are distributed, are not only acid and poor in organic matter but also have low clay content and coarse particles. Thus their eCEC is very small and their content of exchangeable bases, especially calcium and potassium, is very low. The soils of inland valleys in Sudan savannas and northward are relatively fertile but are not widely distributed, and their moisture content is insufficient in most cases.

Flood plain soils are considerably more fertile than inland valley soils. Their clay content is on a similar level to that of southeast Asia, but their eCEC (effective CEC) and exchangeable base content are lower. Their clay activity (eCEC/clay) is also lower than that of southeast Asia and Japan. Clay activity is especially low in the equatorial forest and Guinea savanna zones, suggesting the different degrees of weathering by rain according to zone. It is also clear from the table that the clay minerals of soils in Japan have an especially high activity. Seen from the composition of bases, the flood plain soils in the equatorial forest zone and the inland valley soils in both equatorial forest and Guinean savanna zones have low available potassium content. There is a report of a case where iron toxicity symptom, a problem in West Africa, was eased by the application of potassium sulfate (Yamauchi, 1989) and it is supposed that potassium deficiency causes this problem in some cases. In addition, as Yamaguchi (1999) and Buri et al. (2000) showed, extensive sulfur deficiency may also exaggerate the symptom of the iron toxicity. The soils of flood plains in the equatorial forest zone have a high concentration of organic carbon but low nitrogen content, resulting in a rather high C/N ratio of 16.7, which suggests that the decomposition of organic matters is hindered.

The soils in the Sudan savanna and Sahel zones have a similar fertility to those in southeast Asia and Japan, but their content of organic matter and nitrogen is lower, showing a feature of soil in dried areas. As already discussed, the factor that restricts the use of soils in these zones for agriculture is the quantity of available water sources rather than the soil's chemical fertility.

What should be emphasized about chemical fertility is generally low phosphorus fertility. As shown in Table 2-7, the content of available phosphorus (Bray No. 2) is half that of southeast Asia and less than one-sixth of that in Japan. Since it affects the nitrogen fixation capacity of the sawah field ecosystem, too, phosphorus fertility is a very important factor.

Table 2-8 compares the results of total elemental analysis of surface soils of inland valleys in West Africa and those of sawah field soils in tropical Asia, tropical America and Japan. It shows more clearly the characteristic of inland valley soils in West Africa that the content of bases and phosphorus is very low. It is evident that this soil is close to Oxisols (highly weathered and degraded

Table2-8 Comparison of the chemical composition of inland valleys in West Africa and that in tropical Asia, Japan and tropical America

Region	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	P_2O_5	MnO_2	TiO_2	Na_2O
Equatorial forest zone	79	4.5	14.9	0.29	0.37	0.29	0.088	0.052	0.63	0.25
Guinea savanna zone	86	3.3	8.2	0.47	0.39	0.43	0.079	0.063	0.55	0.35
Total, West Africa	81	3.9	12.0	0.36	0.38	0.38	0.083	0.057	0.59	0.30
Japan*	72	6.0	16.3	1.86	0.75	2.14	0.22	0.13	0.88	-
Tropical Asia*	72	5.9	16.3	1.42	0.92	1.83	0.13	0.12	1.14	-
Tropical America**	77	5.2	14.9	0.27	0.37	0.43	0.053	0.027	1.40	-

Note: -: No measurement made * Kawaguchi and Kyuma (1977) ** Tanaka et al. (1984, 1986).

soils in the tropics) and Ultisols (base-leached and highly weathered soils) in tropical America. But these soils in tropical Africa have slightly higher total phosphorus levels than Oxisols and Ultisols in tropical America. This indicates that if inland valleys are developed into sawah fields and rice grown in flooded sawah soils, it may be possible to increase their phosphorus availability. Although the absolute amounts of phosphorus are still very low, this is another factor that suggests the advantage of developing more sawah fields in this region.

Using the data of the soil samples of inland valleys as shown in Fig. 2-14, their physical and chemical properties by depth will be examined for each climatic zone in more detail (Issaka, 1997).

1)Acidity :

The average values of pH (H_2O) and exchange acidity by climatic zone and by depth are shown in Fig. 2-16 and 2-17 (Issaka, 1997). The soils in the equatorial forest zone up to 60 cm deep have a low pH and high exchange acidity, suggesting that leaching occurred by heavy rain. No clear changes due to depth are observed in the soils in the Guinea savanna zone and northward.

2)Carbon and nitrogen :

Figures 2-18 and 2-19 show the results of analysis of total carbon and nitrogen. In the equatorial forest zone, the average total carbon is 1.7%, the average total

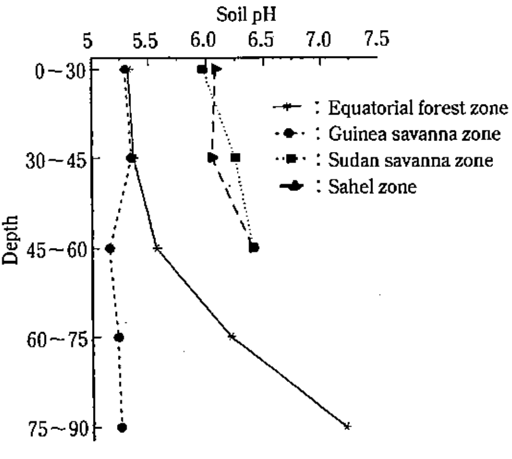


Fig.2-16 Distribution of mean soil pH by depth of inland valleys in the four climatic zones

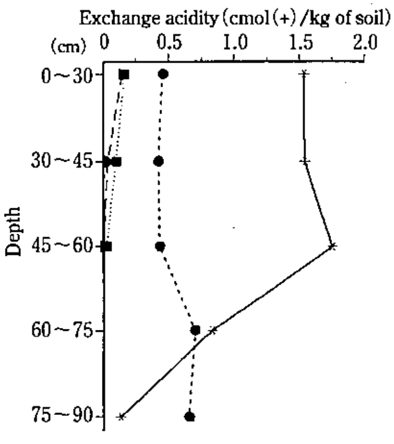


Fig.2-17 Distribution of mean total acidity of soils by depth of inland valleys in the four climatic zones

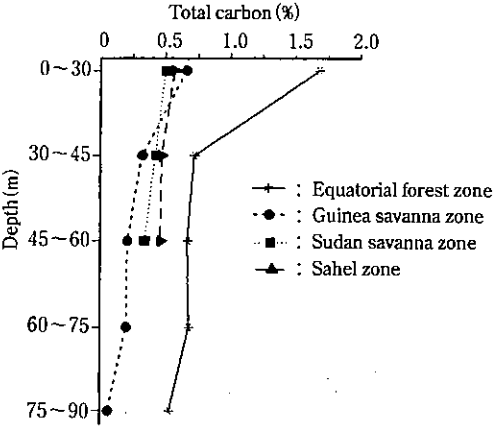


Fig.2-18 Distribution of mean total carbon by depth in the four climatic zones

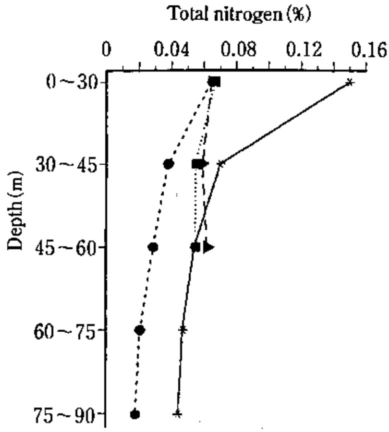


Fig.2-19 Distribution of mean total nitrogen by depth in the four climatic zones

nitrogen, 0.15% and the C/N ratio, 11. Both carbon and nitrogen are reduced by half in the soil layers 30 cm or deeper. In the Guinea savanna zone, the figures are 0.66%, 0.065% and 10, respectively. The content of carbon and nitrogen gradually decreases in deeper soil layers. As a result, the subsoils in the Guinea savanna zone have the lowest carbon and nitrogen content of the four climatic zones.

3)Available phosphorus :

As shown in Fig. 2-20, the concentration of available phosphorus measured by the Bray No.1 method is very low in all of the four climatic zones. It is especially low in all the soil layers in the Sudan savanna and Guinea savanna zones. The surface soils in the equatorial forest zone have a relatively high value of 5 ppm because some of the soils in the Ibo area in southeastern Nigeria (Nitisols) derived from shale or other sedimentary rocks have a specifically high concentration of phosphorus, which helps raise the entire level. Except this type of soil, the available phosphorus concentration of the soils in the equatorial forest zone is low and so is the phosphorus fertility of inland valley soils in West Africa, which is a limiting factor in farming production in this region.

4)Clay content :

Table 2-9 summarizes the clay content in the four climatic zones, the factor that determines cation exchange capacity (CEC), an important indicator of soil

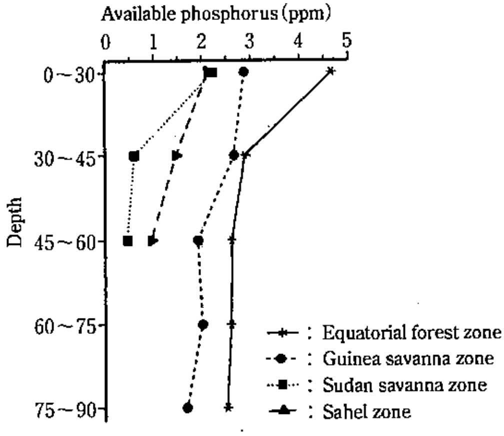


Fig.2-20 Distribution of mean available phosphorus (Bray No.1) by depth in the four climatic zones

fertility. While the clay content is low on the whole, it is noteworthy that the content is very low in all the soil layers in the Guinea savanna zone, the central belt area, roughly a half of that in the other climatic zones. This is the principal reason for low soil fertility in this zone. The clay content in the Sudan savanna and equatorial forest zones is 20% or so in all the layers. In the Sahel zone, the surface soils in lowlands contains about 20% of clay but the clay content of the soils in deeper layers is fairly high. The reason for the low clay content of the surface soils may be that clay particles in the surface soils were lost by both wind erosion during the dry season and water erosion during the short rainy season.

Table2-9 Comparison of average clay contents in the four climatic zones (%)

Climatic zones	Depth (cm)			
	0-30	30-45	45-60	60-75
Equatorial forest zone	19	19	21	25
Guinea savanna zone	11	14	10	15
Sudan savanna zone	19	21	19	
Sahel zone	20	32	40	

Table2-10 Average values of exchangeable cations in the four climatic zones

Depth (cm)	Climatic zone	Cation (cmol(+)/kg)					
		Ca	Mg	K	Na	Mn	Total acidity
0-30	E. F.	2.51	1.15	0.245	0.293	0.079	1.533
	G. S.	1.31	0.49	0.186	0.108	0.065	0.458
	Su. S.	4.99	1.98	0.494	0.444	0.030	0.163
	S. S.	5.29	1.98	0.584	0.428	0.072	0.146
30-45	E. F.	1.89	1.00	0.187	0.300	0.060	1.541
	G. S.	1.27	0.56	0.130	0.116	0.048	0.426
	Su. S	7.96	2.74	0.346	0.366	0.035	0.100
	S. S.	7.72	4.05	0.461	0.381	0.066	0.035
45-60	E. F.	2.04	1.22	0.212	0.461	0.042	1.753
	G. S.	0.99	0.54	0.151	0.109	0.063	0.433
	Su. S.	6.70	2.12	0.246	0.551	0.035	0.023
	S. S.	9.20	4.71	0.536	0.348	0.051	0.000
60-75	E. F.	3.31	1.94	0.207	1.326	0.082	0.832
	G. S.	1.34	1.03	0.154	0.170	0.053	0.703
75-90	E. F.	3.08	2.78	0.124	2.384	0.016	0.133
	G. S.	0.96	0.57	0.145	0.050	0.021	0.658

Note: E. F.: equatorial forest zone: G. S.: Guinea savanna zone; Su. S.: Sudan savanna zone; S: shael zone

Table2-11 Total base, eCEC and base-saturation percentage in the four climatic zones

	Climatic zones	Depth (cm)				
		0-30	30-45	45-60	60-75	75-90
Total base (cmol(+) /kg)	E. F.	4.28	3.44	3.98	6.87	8.38
	G. S.	2.16	2.13	1.85	2.75	1.75
	Su. S.	7.94	11.45	9.65		
	S. S.	8.51	12.67	14.85		
eCEC (cmol(+) /kg)	E. F.	5.81	4.98	5.73	7.70	8.52
	G. S.	2.62	2.56	2.28	3.45	2.40
	Su. S.	8.10	11.55	9.67		
	S. S.	8.67	12.71	14.85		
Base-saturation percentage (%)	E. F.	74.0	69.0	70.0	89.0	98.0
	G. S.	82.0	83.0	81.0	80.0	73.0
	Su. S.	98.0	99.1	99.8		
	S. S.	98.2	99.7	100		

Note: Same as Table 2-10.

5)Exchangeable cations and eCEC :

The average values of exchangeable cations are shown in Table 2-10 and those of eCEC and base-saturation percentage, in Table 2-11. The contents of exchangeable cations, especially calcium and potassium, are very low in the equatorial forest and Guinea savanna zones in all the soil layers. But because the eCEC is also on low levels, the base-saturation percentage (B.S.P.) is higher than 50%.

6)Summary of soil fertility in the four climatic zones :

The most important problem in the equatorial forest zone is low base contents. The nitrogen content and phosphorus fertility are not high either. Since this zone has the richest water supply and its soil fertility is higher than that of the Guinea savanna zone, it is the climatic zone that should be given top priority in future sawah field development. The Guinea savanna zone has the lowest in all the soil fertility indicators. It has been a main climatic zone for inland valley rice cultivation in West Africa because it has a moderate water supply and is topographically easier to be developed as a rice producing area than the equatorial forest zone. But to prevent soil erosion and raise soil fertility, this zone should establish a rice cultivation system based on sawah systems as soon as possible. The Sudan savanna and Sahel zones have high levels of bases. In these zones the management of the phosphorus and nitrogen fertility is important.

(3) Geographic distribution of soil fertility in inland valleys and flood plains

1)Geographic distribution of the fertility of surface soil (0-15 cm) in inland valleys : Fig. 2-21 shows the distribution of effective cation exchange capacity (eCEC). The Guinea savanna zone, the central belt area, generally has minimum values. The areas having the most rainfalls in Sierra Leone and Liberia have small eCEC values, too, reflecting the highly weathered nature of their soil. The eCEC levels are relatively high in the soils in northern parts of the equatorial forest zone in Nigeria, Ghana, Cote d'Ivoire, Guinea, etc., the forest-savanna transition zone extending to the Guinea savanna zone, the Sudan savanna zone north of the Guinea savanna zone and the Sahel. The distribution pattern of exchangeable calcium in Fig. 2-22 and that of exchangeable potassium in Fig. 2-23 resemble each other. The Sudan-Sahel zone where leaching less occurs and there are more loess-derived deposits and the succession zone where moderate rainfall causes moderate soil formation and erosion and geological fertilization

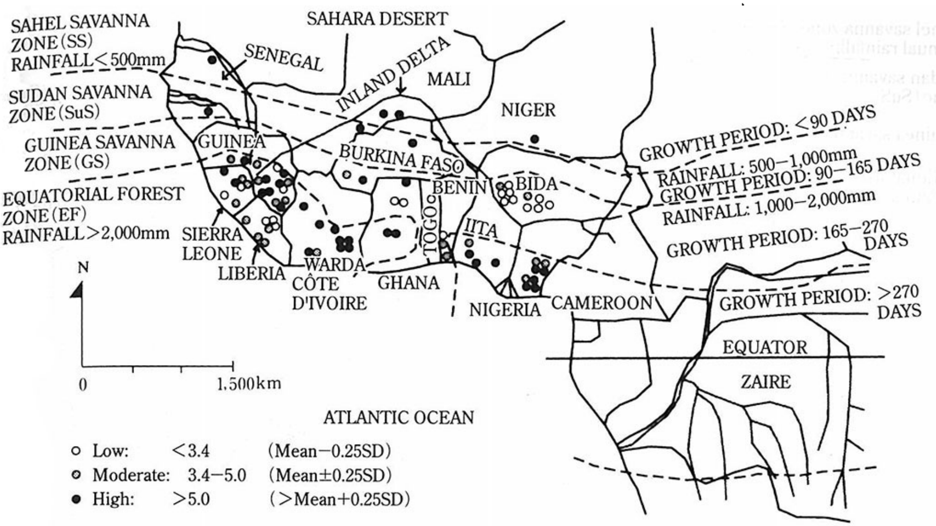


Fig.2-21 Geographical distribution of soil fertility in surface soil (0-15 cm) in inland valleys: effective cation exchange capacity (eCEC, cmol(+)/kg)

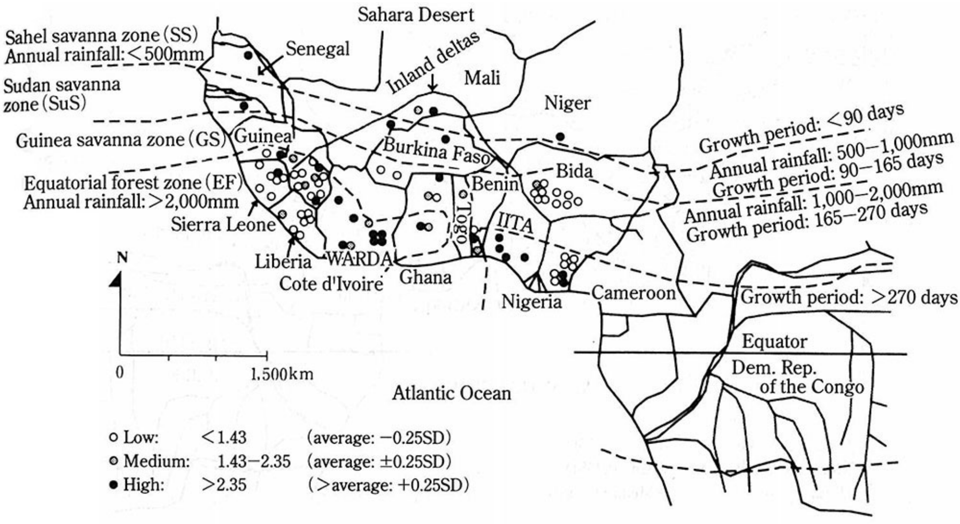


Fig.2-22 Geographical distribution of exchangeable calcium in surface soil (0-15 cm) in inland valleys (cmol(+)/kg)

is balanced (see Chapter 1), are relatively fertile. However, in addition to climate, parent materials have important effects on the base conditions of soil and they are not distributed zonally but scattered. This is considered to be the effects of the basic and neutral parent materials that penetrated into acid basement rocks. While the levels of exchangeable potassium are low in general,

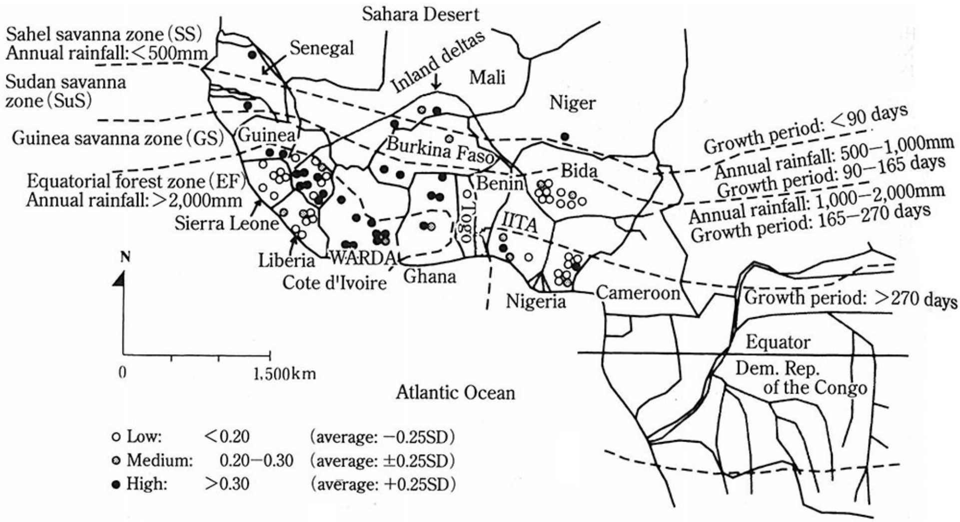


Fig.2-23 Geographical distribution of exchangeable potassium in surface soil (0-15cm) in inland valleys (cmol (+) /kg)

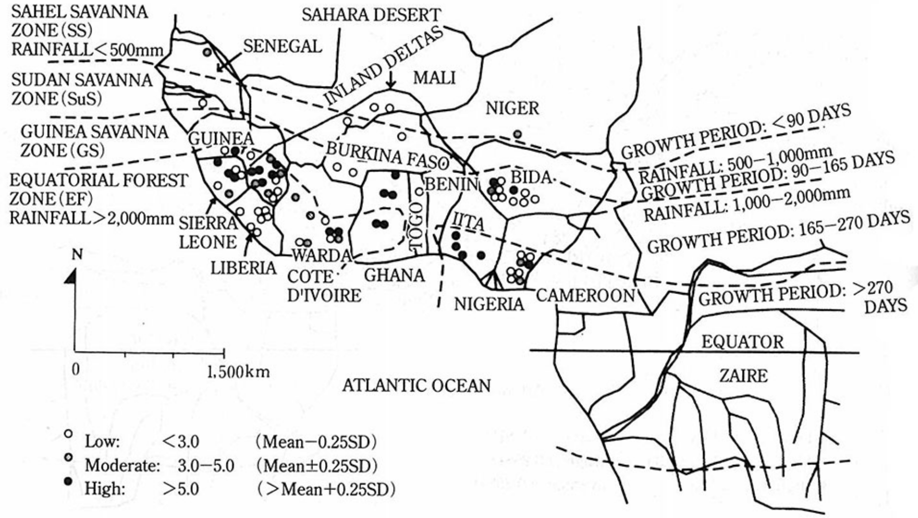


Fig.2-24 Geographical distribution of available phosphorous (Bray No. 1 method) in surface soil (0-15 cm) in inland valleys (mg/kg)

there exist, as seen from Fig. 2-23, some sizable areas in Burkina Faso, Guinea, Cote d'Ivoire and Ghana where the problem of low levels of this element does not seems to be very serious.

As already noted, the level of available phosphorus is very low on the whole and Fig. 2-24 indicates that the distribution of low-level areas is wide. The level

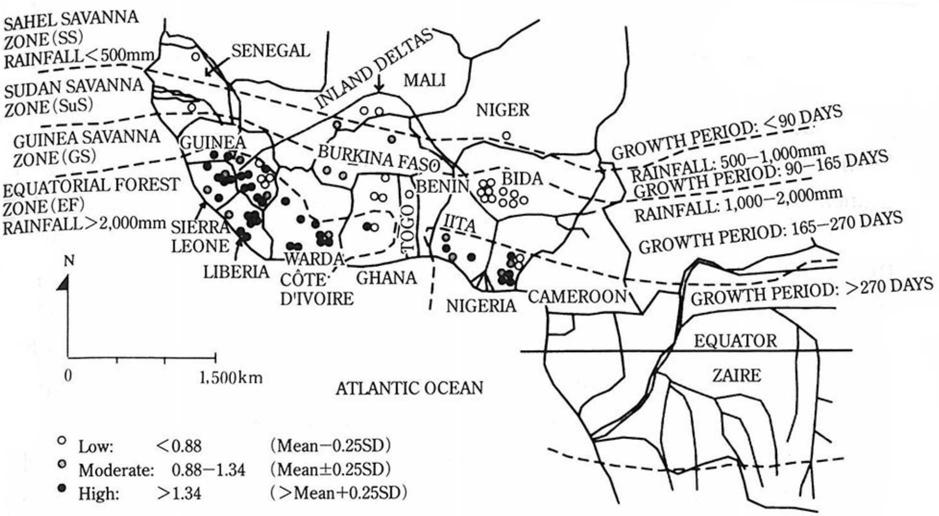


Fig.2-25 Geographical distribution of total nitrogen in surface soil (0-15 cm) in inland valleys (mg/kg)

is low both in the most rainy and driest areas and relatively high in some parts of Sierra Leone, Guinea, Cote d'Ivoire, Ghana and Nigeria. This is probably because of the effects of parent materials.

As shown in Fig. 2-25, the geographical distribution of total nitrogen corresponds to climatic zones. The distribution of organic carbon resembles that of total nitrogen. The level of total nitrogen is high in the equatorial forest zone and low in the Guinea savanna and Sudan savanna-Sahel zones.

2)Geographical distribution of the fertility of surface soil (0-15 cm) in flood plains: As shown in Table 2-4, the area of flood plains in tropical Africa is estimated at about 30 million hectares. Countless flood plains exist along rivers of all sizes and their width ranges from over 10 km to 1 km or less. Just like in the temperate zones, the distribution of soil in flood plains differs according to the type of topography, that is, whether it is a natural levee, back swamp or area in a transition to upland. In general, sandy deposits become the parent materials of soils in a natural levee and fine-textured deposits, in a back swamp.

The properties of alluvial soils in flood plains are basically the same as those of alluvial soils observed in Japan except soils in arid areas. According to the Japanese soil classification, Brown Lowland, Gray Lowland and Gley Lowland soils are distributed in these flood plains. These soil types come under the categories of Gleysols and Fluvisols used by FAO/Unesco and those of

Fluvents, Tropaquents, Tropaquepts, Tropaquults, etc. adopted by the U.S. Soil Taxonomy. Vertisols are observed in the semi-arid Sudan savanna and Sahel zones.

In addition to the properties of inland valley soils, Table 2-7 shows the fertility of flood plain soils in the humid equatorial forest zone, subhumid Guinea savanna zone and semi-arid Sudan savanna and Sahel zones. The levels of CEC and base saturation percentage are higher in areas with higher aridity. By contrast, those of exchange acidity and organic matter content are higher in the humid equatorial forest zone. As evident from this table, flood plain soils in tropical Africa are relatively fertile. Therefore, the flood plain areas where it is possible to realize sustainable flood control by dams and irrigation with pumps, etc., could be developed into highly productive farmland.

The geographical distribution of pH, organic carbon, total nitrogen and available phosphorus is shown in Fig. 2-26, and that of effective cation exchange capacity (eCEC), exchangeable potassium, exchangeable magnesium and exchangeable sodium, in Fig. 2-27. The basic pattern of distribution resembles that in inland valleys. But while the transportation, sedimentation and flooding actions of rivers have extensive effects, the influences of climate and geological parent materials are not very great. The values of pH are relatively low in the equatorial forest zone and in the Niger basin where there is much rain. The distribution of soils with higher pH in the Sahel and Sudan savanna zones can be understood as a common feature of arid areas. The reason that acid soils are observed in these zones is possibly that there occur phenomena like the ferrolysis (Brinkman, 1979) of clay resulting from changes in ferrous iron and ferric ion caused by repeated flooding and drainage. Organic carbon and nitrogen have high levels in Nigeria, Guinea and southern Senegal. The levels of available phosphorus are low on the whole but are relatively high in Burkina Faso, Ghana and southern Guinea. Soils with an extremely low level of exchangeable potassium, one of the important available bases, are observed in Nigeria, Ghana and southern Guinea. The other exchangeable bases have higher levels than in inland valleys. In particular, exchangeable calcium and magnesium have high values in Vertisols in the Benue basin and in the areas along Lake Chad. In Senegal, the content of not merely these bases but also exchangeable sodium is high and so some measures to prevent salinization will be necessary.

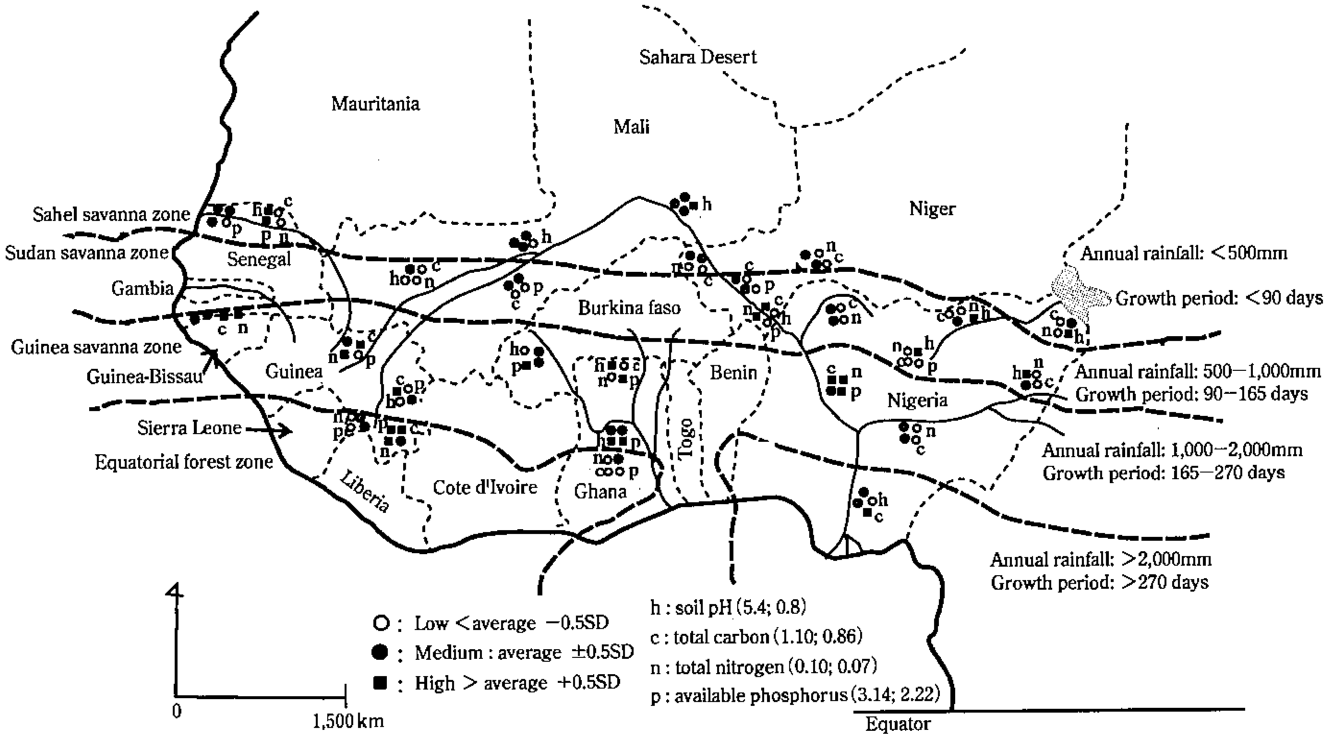


Fig.2-26 Geographical distribution of pH, organic carbon, total nitrogen and available phosphorus (Bray No. 1 method) in surface soil (0-15 cm) in flood plains
(Average values and standard deviations (SD) are as follows: pH: 5.4, 0.8; organic carbon: 1.10, 0.86%; total nitrogen: 0.10, 0.07%; available phosphorns: 3.14, 2.22 mg/kg)

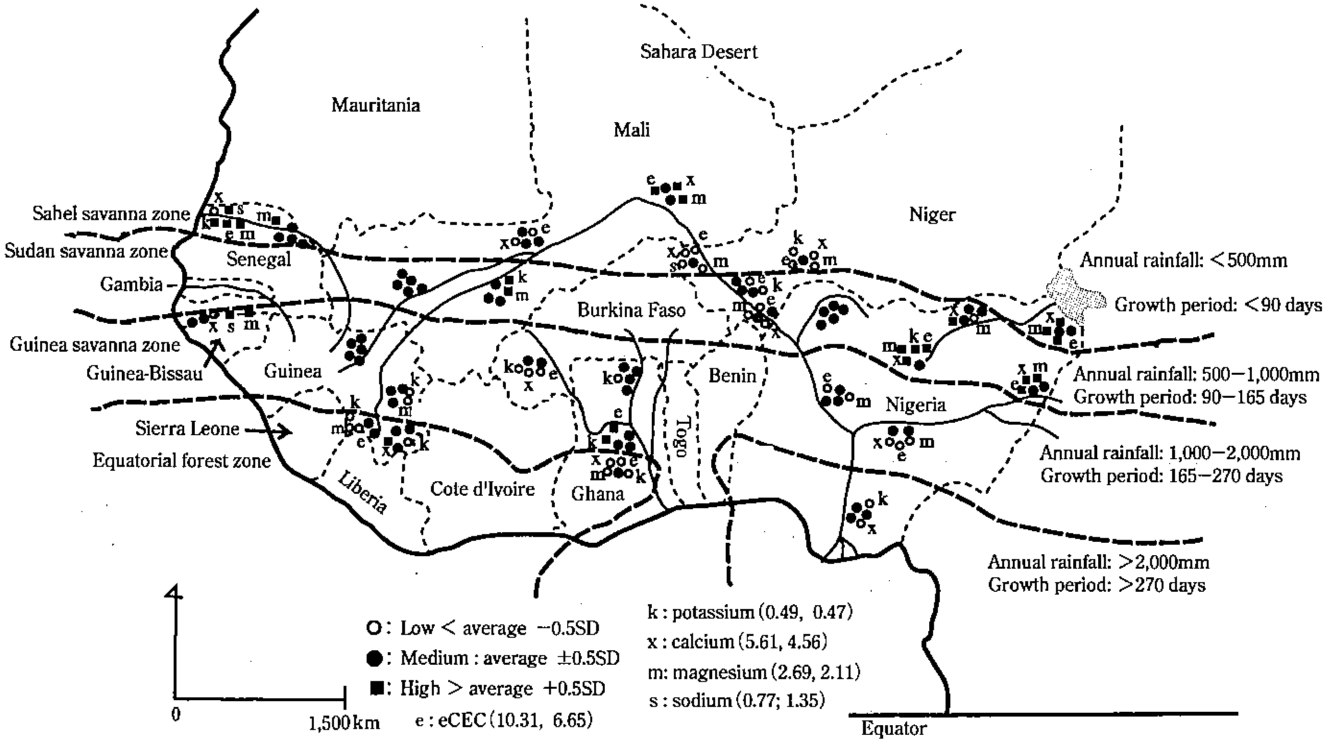


Fig.2-27 Geographical distribution of exchangeable Ca, effective cation exchange capacity (eCEC), exchangeable K, exchangeable Mg and exchangeable Na in surface soil (0-15 cm) in flood plains

(Average values and standard deviations are as follows: eCEC: 10.31, 6.56; exchangeable Ca: 5.61, 4.56; exchangeable K: 0.49, 0.47; exchangeable Mg: 2.69, 2.11; exchangeable Na: 0.77, 1.35) (cmol(+)/kg)

(4)Toposequence of inland valley soils

Fig. 2-28 shows the example of an inland valley in the equatorial forest zone around Makeni city in central Sierra Leone (Smaling et al., 1985a). The typical toposequence in this area is Oxisols/Ultisols in flat uplands, Ultisols on slopes and Inceptisols in valley bottoms. Annual rainfall in this area is over 3,000 mm. Since rains fall like squalls and their intensity is high, their eroding capacity is great. Coupled with the fact that no farming system for sustainable lowland use, such as soil-conserving sawah agriculture, has been established, this area has very poor-nutrient sandy soil in valley bottoms, especially in the topsoils. As Table 2-12 shows, the eCEC of the topsoils in valley bottoms is 1-5 cmol(+)/kg but more than 65% of this is exchange acidity and bases are 1 cmol(+)/kg or less in many cases. This table also shows the CEC values measured by the classical standard method (1N ammonium acetate, pH=7), which are commonly twice to three times as high as those of eCEC. But because no conditions of such high salt concentration and high pH values exist in actual soils in the area, the measured values of eCEC, exchangeable bases and acidity are better as the criteria for soil fertility evaluation.

In this area with high rainfall, the soils in fringes with slopes of 5-12%, a little steep for peneplain topography, and upland soils have lost topsoils by erosion and even indurated plinthite layers and basement rocks are exposed. Ironstone concretions are also observed just below the soil surface, suggesting

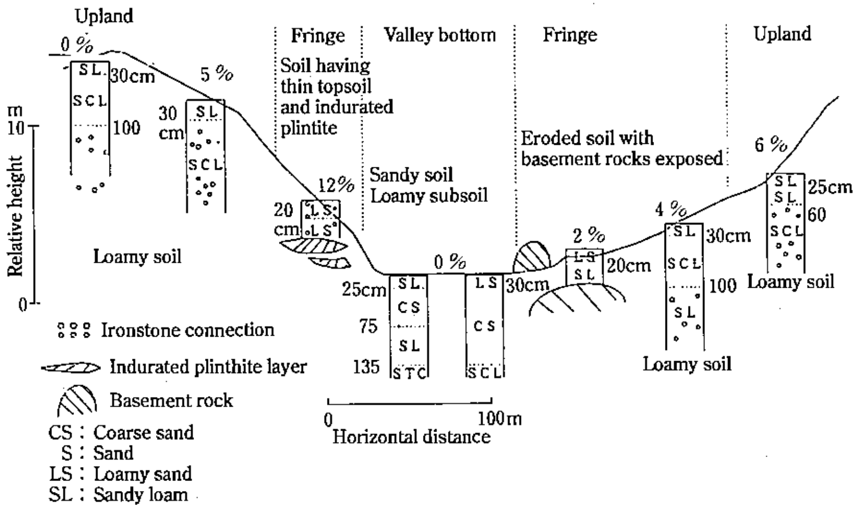


Fig.2-28 Example of toposequence of an inland valley around Makeni, Sierra Leone
(Smaling, *et al.*, 1985a, some changes made)

Table2-12 Toposequence-based differences in chemical properties of acid granite soils in Sierra Leone in the equatorial forest zone (Smaling *et al.*, 1985a)

Chemical property	Depth (cm)	Upland	Fringe	Valley bottom
pH H_2O	0-20	5.5	5.2	5.0
(1 : 2.5)	20-40	5.1	5.3	5.1
pH KCl	0-20	4.2	4.0	4.2
(1 : 2.5)	20-40	4.1	4.1	4.4
Org. C	0-20	1.5-4.0	1.0-2.5	1.5-9.0
(%)	20-40	0.5-2.0	0.5-1.5	<0.5
CEC pH=7	0-20	4-11	4-7	15-17
cmol(+)/kg	20-40	4-8	3-6	<13
eCEC	0-20	2.0-3.0	1.9-2.5	1.0-5.0
cmol(+)/kg	20-40	1.5-3.0	1.0-3.0	0.5-1.5
Base sat.	0-20	5-50	5-20	5-10
(%)	20-40	4-15	3-6	n.d.
Ex. Acid.	0-20	10-90	30-90	<65
(% of eCEC)	20-40	>60	>85	>65
Total nitrogen	0-20	0.1-0.3	0.1	0.2-0.4
(%)	20-40	n.d.	n.d.	n.d.
P-Bray 1	0-20	1-4	2-4	3-4
(ppm P)	20-40	0-1	0.5-1	0-4
Total phosphorus	0-20	45-60	35-50	40-100
(ppm P)	20-40	35-50	35-45	10-50
S-available	0-20	8-35	9-15	3-8
(ppm SO_4)	20-40	n.d.	n.d.	n.d.
Total iron	0-20	1-1.8	0.3-0.8	0.1-0.4
(%)	20-40	n.d.	n.d.	n.d.

Note : n.d.: not determined

that heavy soil erosion has occurred.

Fig. 2-29 is the example of an inland valley near Bida city in central Nigeria (Smaling et al., 1985a). This area belongs to the Guinea savanna zone and has an annual rainfall of 1,200 mm. Because the parent material is sandstone dating back to the Mesozoic age, the soils are very sandy in general. Table 2-13 shows the physical and chemical properties of the fringe and valley bottom soils where rice is grown (Wakatsuki 1988). The soils in sloping fringes are sandy and poor in nutrients with low levels of CEC and exchangeable bases, suggesting heavy erosion. On the other hand, the topsoils (0-20 cm) in the valley bottom have a clay content of 10% or more and are relatively fertile. But below such topsoils lie a layer of sandy soil. In general, in the areas where land is used excessively,

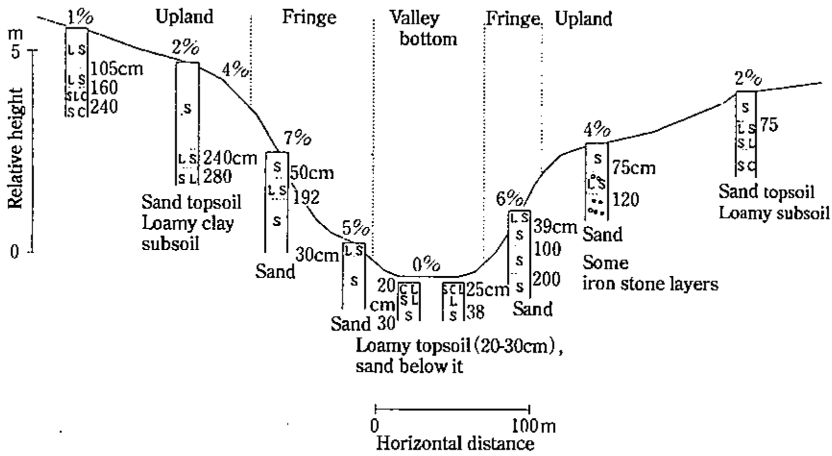


Fig.2-29 Example of toposequence of inland valley around Bida City, central Nigeria (Smaling, *et al.*, 1985b, some changes made)

even this relatively rich surface clay layer in the valley bottom has been lost, too. The districts where the surface clay layer has been lost are left uncultivated and lie barren because it is no longer possible to continue farming activities there. Subsoils of upland soils, Alfisols (Oyediran 1990), however contain clay.

(5) Sulfur and zinc deficiency and the other micronutrients in the soils of inland valleys and flood plains

The frequency distribution of various available micronutrients of lowland soils in West Africa(Fig. 2-14 and 2-15) are shown in Fig. 2-30 (Buri et al. 2000). The frequency distribution of available sulfate in topsoils showed that almost 100% of both flood plains and inland valleys are below the soil critical levels of 5-20 mg S per kg soil required for the normal growth of both flooded rice and upland crops as proposed by Wang (1976). Available sulfur of topsoil correlated positively and significantly with organic carbon, r=0.874 and 0.690, available P, r=0.873 and 0.939, and eCEC, r=0.612 and 0.859, for the soils of inland valley and flood plains, respectively.

Fig. 2-30 showed the frequency distribution of topsoil available Zn. The distribution was similar for both flood plains and inland valley swamps with about 70% of West Africa lowland showing available Zn levels below the soil critical level of 0.83 mg Zn per kg of soil necessary for rice cultivation proposed by Randhawa and Takkar (1978). The distribution of topsoil available Zn was similar to that of available sulfur within the lowlands. Available Zn also

Table2-13 General physical and chemical properties by depth of fringe and valley bottom soils based on the toposequence in Bida (Wakatsuki, 1988)

Physical and chemical property	Depth (cm)	Fringe area		Valley bottom area	
		1	2	1	2
Clay content (%)	0-5	6	8	20	21
	10-20	5	8	21	21
	20-30	6	9	24	10
	40-50	5	6	6	8
Sand content (%)	0-5	87	77	73	55
	10-20	84	80	63	57
	20-30	88	78	63	81
	40-50	91	89	91	77
eCEC (cmol(+)/kg)	0-5	1.3	1.6	3.1	3.8
	10-20	0.9	1.3	3.5	3.8
	20-30	0.8	0.6	4.4	1.7
	40-50	0.6	0.9	0.8	0.8
Exchange-able Ca (cmol(+)/kg)	0-5	0.81	0.86	1.65	1.87
	10-20	0.37	0.64	1.11	1.50
	20-30	0.43	0.56	0.83	0.58
	40-50	0.36	0.48	0.33	0.36
Exchange-able K (cmol(+)/kg)	0-5	0.10	0.07	0.11	0.11
	10-20	0.04	0.05	0.09	0.08
	20-30	0.04	0.03	0.07	0.04
	40-50	0.03	0.03	0.04	0.03
Organic C (%)	0-5	0.29	0.54	1.54	1.37
	10-20	0.11	0.41	1.17	1.00
	20-30	0.05	0.30	1.13	0.29
	40-50	0.06	0.08	0.23	0.25
Total N (%)	0-5	0.012	0.032	0.129	0.112
	10-20	0.011	0.027	0.087	0.087
	20-30	0.023	0.022	0.087	0.023
	40-50	0.037	0.029	0.017	0.011

correlated significantly and positively with total organic carbon, r =0.867 and 0.800, and available P, r=0.690 and 0.850, but negatively with eCEC, r =-0.675 and -0.544 for both river flood plains and inland valley swamps, respectively.

Soils of the West African lowlands were observed to be very deficient in available sulfate sulfur and available Zn. Available Fe, Mn, Cu and Ni were at moderate levels, except soil solution Fe that tended to show toxic levels in isolated areas.

The relative deficiency in soil sulfate sulfur and other micronutrient supply within West African lowlands was in the order $S \geq Zn \gg Cu = Ni = Mn = Fe$.

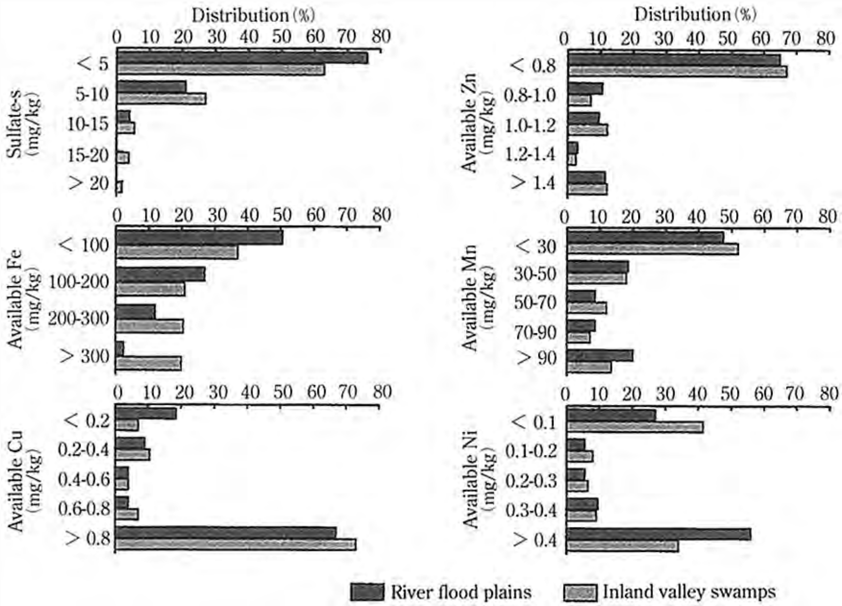


Fig.2-30 Frequency distribution of topsoil (0-15 cm) available micronutrients within West Africa lowlands (Buri *et al.*, 2000)

Fertilizer usage within the region is still very low and in most instances where attempts are made to supplement crop nutrient requirement with artificial fertilizers, much attention is focused on the macro-nutrients, particularly N, to the detriment of the essential micro-nutrients. This tendency coupled with unfavorable farm management practices is leading to the rapid depletion of some nutrients, especially S and Zn. In order to stabilize and/or increase the very low levels of available Zn and S, there is the need for farmers to adopt practices that allow/encourage both organic matter recycling and accumulation. Favorable future solutions will be to encourage the production and use of Zn containing ammonium sulfate instead of urea which is the major fertilizer presently used in West Africa.

(6) Relationship between the configuration, geology and climate of inland valleys and their soil fertility

The configuration of inland valleys is greatly affected not only by geological features but also by rainfall. As shown in Fig. 2-31, the cross section of an inland valley can be described by wavelength and amplitude. In the coastal equatorial forest zone with high rainfall, inland valleys have a wavelength (interval) of

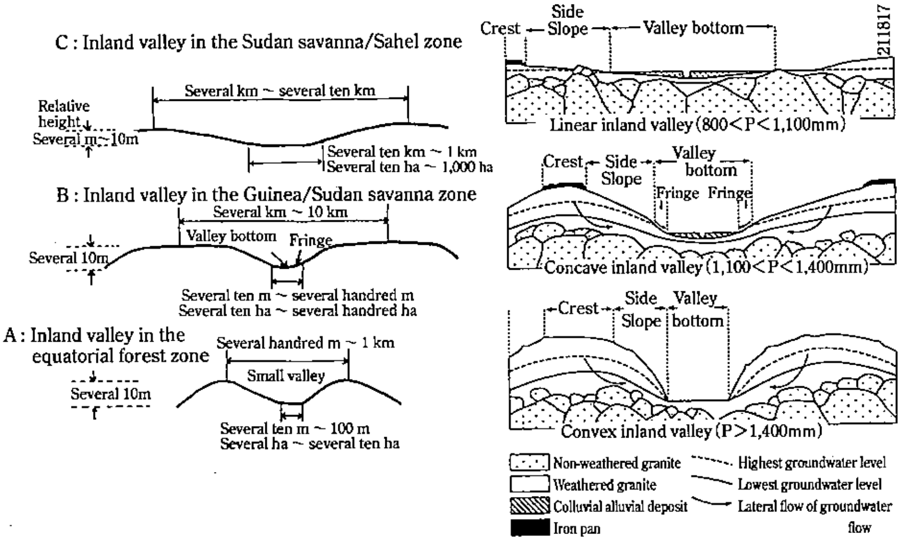


Fig.2-31 Relations between the configuration of inland valleys and climate
(Figures at right are based on Raunet, 1985) (See Fig.2-13 and Fig.6-1)

several hundred meters and relative height of tens of meters. The area of an inland valley in this zone is usually only several hectares to tens of hectares, though it differs according to how the areas along the river are measured. In the Guinea savanna and Sudan savanna zones with less rain, the distributed area of inland valleys is smaller than that of the uplands ; the wavelength is several kilometers and terrace-like wide ridges make up most parts of the watershed. The width of valleys is a little wider, ranging from tens of meters to several hundred meters. In the arid Sudan savanna and Sahel zones, valleys are wider, making it hard to distinguish inland valleys from inland basins.

3-4. Acid sulfate soils in coastal swamps

According to Table 2-4, the total area of coastal swamps in tropical Africa is about 16.5 million hectares. While these swamps have only a limited use for agriculture, they are treasure houses of fish, making them important fishing bases. Coastal swamps are grouped into three categories : sand dunes formed by tides ; brackish-water mangrove and salt-affected swamp zone ; and fresh-water swamp zones.

Main soil types in coastal swamps are Thionic Fluvisols (acid sulfate soils under the mangrove forests in brackish-water swamps), Gleysols under the fresh-water swamps, and sands on dunes (Arenosols, Regosols).

At present, rice cultivation in the mangrove zone is the only case of agricultural land use. This rice production makes use of the action of tides with high specific gravity that pushes up fresh water to rice fields. It was started more than 100 years ago when Asian rice was introduced into this area. The area of mangrove zones totals about one million hectares only in West Africa, of which about 210,000 ha are now used for rice cultivation (WARDA, 1989). Major producing districts exist in Guinea-Bissau, Guinea and Sierra Leone.

(Toshiyuki Wakatsuki, Roland Nuhu Issaka, and Mohamed Moro Buri)

3-5. Characteristics of clay minerals

Kawaguchi and Kyuma (1977) classified 410 sawah soils collected in tropical Asia into ten types based on the relative ratios of the three clay minerals (7A, 10A, 14A) as shown in Fig. 2-32. Fig. 2-33 compares the clay mineral composition of the 87 lowland soil samples collected in each climatic zone in four countries in West Africa (Nigeria, Cameroon, Liberia and Sierra Leone) with that of tropical Asia. Figures in the two triangles are percentages. As evident from these figures, in tropical Asia, Types 14-7 and 7-14 are predominating and followed by other types, i.e, 7, 7-10-14, 14, 7-10, 14-10 and 10-7. By contrast, in West Africa, Type 7 accounts for more than a half and over 60% of the rest is Type 7-14, and few soils are composed mainly of 10A and 14A minerals. Fig. 2-33 supports what has so far been stated: West Africa has a wide distribution of

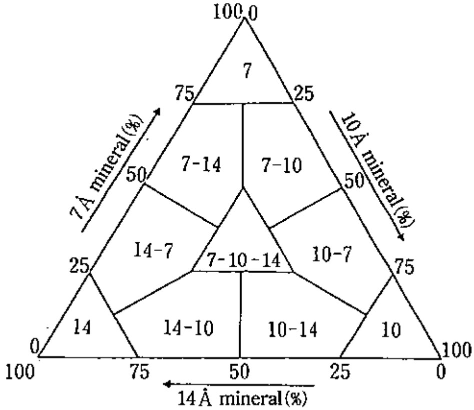


Fig.2-32 Soil classification by clay mineral contents
(Kawaguchi and Kyuma, 1977)

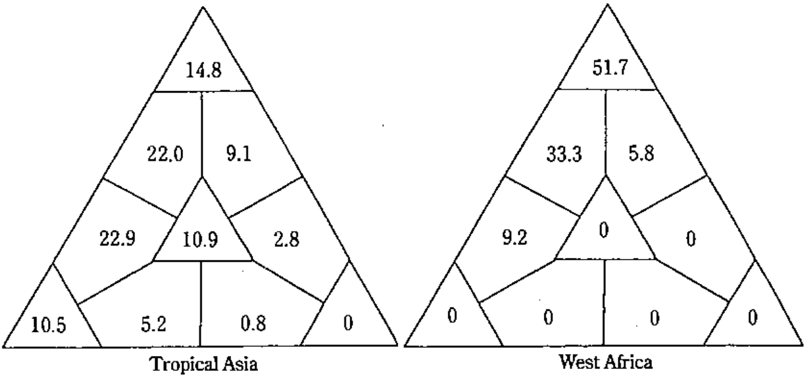


Fig.2-33 Comparison of sawah soil in tropical Asia and lowland soils in West Africa by clay mineral contents (Kawaguchi and Kyuma, 1977) (Figures show the content of clay minerals in percentage)

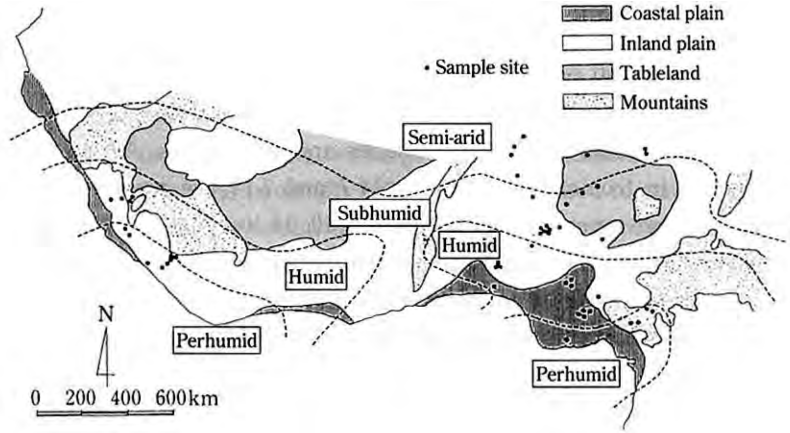


Fig.2-34 Agricultural ecology types classified by climate and topography

soils characterized by low nutrient holding, and supplying capacity, an advanced stage of weathering, and low fertility.

Fig. 2-34 is the map showing agro -ecological zones with the locations where the 87 soil specimens were collected and whose clay mineral compositions were analyzed. Fig. 2-35 shows the relationship between climatic zones and clay minerals. These two figures indicate that the samples from perhumid areas with no clear dry season in the equatorial forest zone belong to Type 7 and those from the Sudan savanna zone (semi-arid zone) to Type 7-14. But the number of samples from humid areas in the equatorial forest zone and subhumid areas in the Guinea savanna zone, which are located between the above-mentioned two

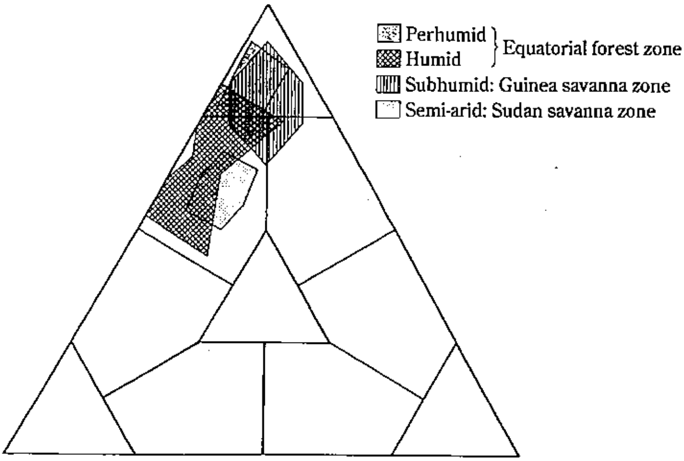


Fig.2-35 Climatic zones and soil clay mineral contents

regions, are too limited to show significant changes in clay mineral composition in the zones from humid to arid. This is partly because parent materials affect clay mineral composition rather than climate for those samples. One example is the soil No. 11 in Table 2-3, which is formed on shale containing high amounts of 14A minerals originally derived from volcanic materials widely covering southeastern Nigeria to Cameroon. It should be noted that the above mentioned relationship between climatic zones and clay mineral composition reflects the uniqueness of samples including those strongly affected by their nature of parent material as soil No. 11. A more comprehensive analysis must be done including additional 185 samples for inland valleys and 62 for flood plains to be characterized. (Takashi Kosaki)

4. Characteristics of the hydrologic environment (Kitamura, 1994)

4-1. Hydrologic geography

West Africa is a vast low tableland and differs from other parts of the African continent characterized by narrow coastal plains, narrow continental shelves, many tablelands and underdeveloped rivers. This region can be classified into three main topographical types : lowlands less than 1,000 feet (305m) above the sea level; inland plains 1,000 feet or more above the sea level ; and tablelands (see Fig. 2-6).

Lowlands are distributed along the coast, in Chad and in the Niger inland deltas. Coastal lowlands are not flat but have many undulations and are generally very small except those extending to inland areas by 160-240 km. These are observed in Senegal, Gambia, Cote d'Ivoire, southeastern Nigeria, etc. Of these, the wetlands with thick mangrove and other forests are commonly known as mangrove swamps. Mangrove swamps are observed in the coasts of Senegal, Gambia, Guinea-Bissau, Guinea, Sierra Leone, Nigeria, etc. and their total area in West Africa is estimated to be about one million hectares. About a century ago, farmers began to cultivate these swamps and grow rice. The two main inland lowlands in the Chad basins and in the Niger inland deltas form inland drainage basins. These basins have remarkably uniform topographical features and suffer large-scale flooding in the rainy season.

The border areas of coastal plains and higher inland plains have sharp slopes where rivers flow down as rapid streams or falls. While these plains have eroded surfaces and usually have undulations, they are relatively open and their topographical features are simple. They have been developed on basement rocks and clearly belong to a different type from newer plains formed on deposited layers: they are much subjected to wind erosion as well as water erosion. In these plains isolated hills with very steep slopes known as inselbergs are found here and there. Gully erosion is also seen in some parts of the plains.

The main highlands in West Africa include the Jos and Adamawa plateau (1,200-1,300 m above sea level), the Fouta Djallon Plateau and Guinea Highlands (750-920 m), the Biu Plateau (700 m) and the Sikasso Plateau (450 m). They form the sources of many main rivers.

One characteristic of West African rivers is can be pointed out that many of them expanded their basins by the capture of other rivers (Udo, 1978). The rivers that flow straight to the sea, such as Bandama, Volta and Okpara, extended their river sources to inland areas by capturing the rivers flowing slowly inland. This phenomenon is due to the fact that the watersheds in this region have relatively low altitudes and the River Niger may be a typical case of this. Formerly, the River Niger had flown into a large lake around the present inland delta, but later, it was captured by the Lower River Niger somewhere near Tombouctou and flowed directly into the sea. Other examples include the capture of the Enyong Creek by the Imo River, of the Black Volta by the Volta and of the Upper Gongola (which used to flow into Lake Chad) by the Benue. River capture occurs even now as part of the topography formation process, which is accelerated if artificial activities, such as projects that change the existing topography, take place. There is a possibility that the Logone, which flows into Lake Chad, will be captured by the Upper Benue. This lake receives about three-fourths of its water from the Logone and Shari rivers, and if this river capture does occur, the lake will certainly lose much of its water resources. As noted, river capture in West Africa istopographically the phenomenon of robbing inland arid areas of water resources and riparian countries should recognize this fact and take careful steps to cope with this problem.

4-2. Outline of water resources

Table 2-14 shows the average annual water balances of main regions of the world (Biswas, 1974 ; Baumgartner, 1975 ; USSR National Committee for IHD, 1974 ; L'vovich, 1974). According to the averages of water balances of the three estimates, the average precipitation of all land areas except the Antarctic is 825 mm. Of this, 527 mm is lost by evapotranspiration and the remaining 298 mm is runoff. In other words, about 64% of precipitation is the quantity of evapotranspiration and 36%, that of runoff.

In Africa, precipitation is 707 mm, much smaller than the world average, and as much as 81% of this is lost by evapotranspiration, runoff being only 19% (135 mm). Africa's runoff per unit area is about one-fifth that of South America and half that of other regions. In addition, the direct runoff is 65% (88 mm) of this total runoff and the groundwater runoff is only 35% (47 mm). Therefore, it

Table 2-14 Average annual water balances by continent

Continent	Depth of water (continent-wide average (mm))											
	Baumgartner			USSR IHD			L'vovich			Average of the three		
	P	E	R	P	E	R	P	E	R	P	E	R
Africa	696	582	114	740	587	153	686	547	139	707	572	135
Asia	696	420	276	740	416	324	726	433	293	721	423	298
Europe	657	375	282	790	507	283	734	415	319	727	432	295
North America	645	403	242	756	418	338	670	383	287	690	401	289
South America	1,564	946	618	1,595	910	685	1,648	1,065	583	1,602	974	629
Australia	803	534	269	791	511	280	736	510	226	776	518	258
Average of six continents	800	522	278	859	530	329	813	526	287	825	527	298
Antarctica	169	28	141	165	0	165	?	?	?	167	14	153
Average of seven continents	743	475	268	796	482	314	756	482	274	763	475	288
Oceans	1,066	1,177	-111	1,269	1,399	-130	1,141	1,255	-114	1,158	1,277	-119
All the earth	973	973	0	1,130	1,130	0	1,030	1,030	0	1,044	1,044	0

Note : ? : not known ; P : precipitation ; E : evaportranspiration ; R : runoff.

Table 2-15 Water balances of main river basins in Africa

(Balek, 1983)

River	Catchment area (km²)	Rain-fall (mm)	Runoff (mm)	Evapotran-spiration (mm)	Specific discharge (l/s/km²)	Discharge (m³/s)	Runoff ratio
Congo	3,607,450	1,561	337	1,224	10.7	38,800	0.22
White Nile	1,435,000	710	16	694	0.5	793	0.02
Blue Nile	324,530	1,082	158	924	5.0	1,727	0.15
Nile	2,881,000	506	28	478	0.9	2,590	0.06
Niger	1,091,000	1,250	202	1,048	6.4	7,000	0.16
Zambezi*	1,236,580	759	30	729	1.0	1,237	0.11

Note: At the Victoria Falls

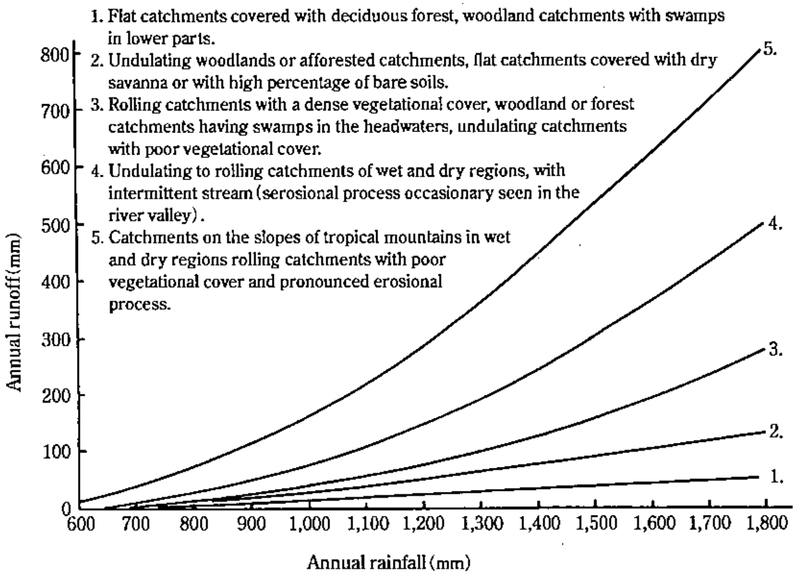


Fig.2-36 Rainfall-runoff relationship of African rivers by ecosystem

can be said that Africa is in a much severer hydrological environment than other regions.

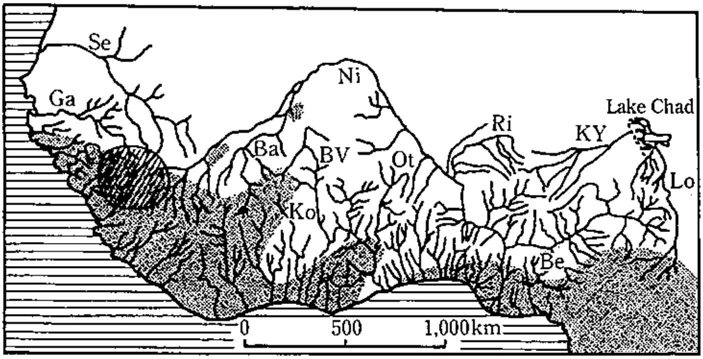
Table 2-15 shows the water balances of main rivers in Africa (Balek, 1983). The basin of the River Congo has the highest runoff ratio (0.22) and specific discharge (10.7ℓ/s/ km²), and this is because the basin is not affected by an arid climate. On the other hand, in the basins of the Nile and Zambezi affected by deserts, the figures are lower : the runoff ratio is 0.06 and 0.11 and the specific discharge, 0.9ℓ/s/km² and 1.0ℓ/s/km², respectively. In particular, the Nile is greatly affected by evapotranspiration and percolation losses in vast Sudd swamps in the While Nile basins. The Niger partly runs along the southern edge of the Sahara but has a relatively high runoff ratio (0.16) and specific discharge ($6.4\ell/s/km^2$) because the runoff in the upper basins is large and the Benue, a tributary abundant in water resources, joins in the lower basin. Fig. 2-36 summarizes the rainfall-runoff relationship of African rivers by ecosystem (Balek, 1977).

4-3. Runoff characteristics

As shown in Fig. 2-37 (Ledger, 1969), rivers in West Africa can be roughly divided into two groups : the River Niger system, the largest in this region, and a group of rivers of all sizes that directly flow into the Atlantic Ocean or the Gulf of Guinea, such as the Senegal and Volta rivers.

(1) River Niger basin

The River Niger is an international one. It has its source in Fouta Djallon, the mountainous area in Guinea 800m above sea level, located 250 km from the



(Legend)

Ni : Niger	Ot : Oti
Be : Benue	KY : Komadougou Yobe
Ba : Bani	Lo : Logone
Ri : Rima	Shaded parts are those areas where groundwater runoff occurs throughout the dry season.
Se : Senegal	
Ga : Gambia	
Ko : Komoe	
BV : Black Volta	Fouta Djallon plateau: headwaters runoff major rivers in West Africa.

Fig.2-37 Main rivers in West Africa (Ledger, 1969)

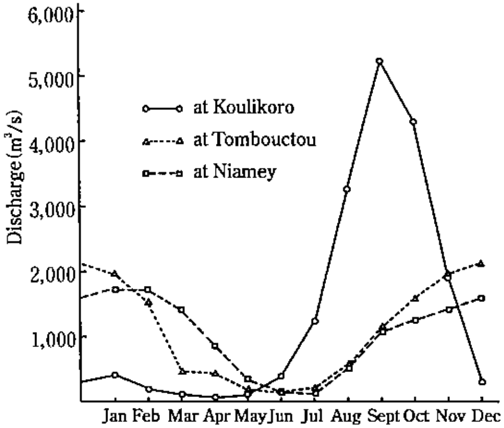


Fig.2-38 Flow conditions in the upper and middle basins of the Niger River
(Ledger, 1969; Balek, 1983)

Atlantic coast, and runs through Mali and Niger and flows into the Gulf of Guinea in Nigeria. Its length is 4,160 km, its catchment area, 1,091,000 km^2 and its runoff, 220 billion m^3/y ($7{,}000 m^3/s$) (Balek, 1983). It main characteristics are a very gradual slope of 1/10,000 and the fact that it has vast floodplains in inland delta areas totaling 2,500,000 ha. Because of the effects of these two factors, river water takes a very long time to reach the lower basin and the forms of runoff are very complicated.

The flow conditions of the Niger from the upper to lower basins can be summarized as follows :

1) Upper basin to inland deltas : At Koulikoro, the floods during the rainy season mostly flow down from the headwater mountains during the months of June to November (Fig. 2-38)(Ledger, 1969 ; Balek, 1983). The peak comes in September, when the peak flood discharge reaches 8,000-10,000 m3/s in some cases. The basin from Segou to downstream Tombouctou is inland delta areas ; since the river's conveyance capacity is small, river water overflows and is stored in floodplains. Since this stored water begins to return to the main course of the river as the discharge from the headwaters decreases, the peak flow comes in December and January at Tombouctou (Fig. 2-38). As a result, the dry season starts in September in this area but the river's discharge continues increasing for four months after that and the low flow season ends in three to four months. This means that 85% of the total runoff at Tombouctou is discharged during the dry season, and this runoff is a valuable water resource in this season. While the water storage capacity of the vast floodplains has a great advantage, it should

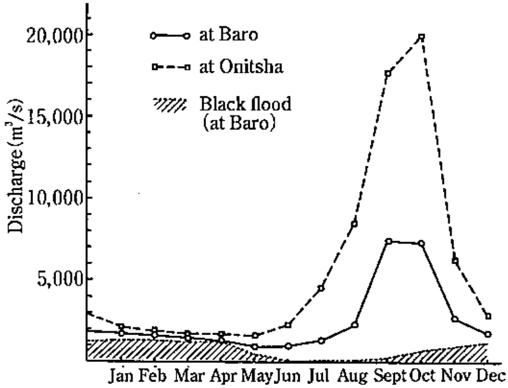


Fig.2-39 Flow conditions in the lower basin of the Niger River
(Ledger, 1969)

also be remembered that during the storage process, a large quantity of water is lost by evapotranspiration and percolation. Water loss in these inland deltas is estimated to be as much as 50% (Ledger, 1969).

2) Middle and lower basins : In the section between Tombouctou and Niamey, only wadies join the Niger. Because of this, the flow conditions in Niamey are similar to those in Tombouctou except the fact that the peak flow comes about one month later (Fig. 2-38)(Ledger, 1969). In the section from Niamey to Baro, the Alibori River and other tributaries flow into the Niger one after another. Since the flood season of these tributaries is June to October, the peak flood of the Niger mainstream roughly coincides with this season (Fig. 2-39). The discharge in the dry season is considerable because the flood from the upper basin known as the black flood reaches in this season (the hatched parts in Fig. 2-39) (Ledger, 1969). Another flood flow originating from the runoff from the downstream sections of Niamey is named the white flood (Japanese Institute of Irrigation and Drainage (JIID), 1985). Because the huge lake formed behind the Kainji Dam regulates the discharge in this section, the flow conditions in the lower basins change greatly. Then the Benue River joins the Niger and forms vast deltas and finally reaches the Gulf of Guinea. The flow conditions at Boro, 200 km upstream from the confluence of the Benue, and at Onitsha located in between the confluence and the delta are shown in Fig. 2-39.

(2) Senegal river basin

The source of the River Senegal is the River Bafing that starts from the Fouta Djallon Plateau in Guinea about 850m above sea level and has relatively high

Table 2-16 Distribution of the Senegal River's monthly runoff at Bakel

(catchment area : 232,700km²)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual average	Ratio of dry season run-off to annual runoff (%)
Run off (m^3/s)	129	77	46	22	11	122	569	2,351	3,429	1,710	560	230	774	30
Percentage (%)	1.4	0.8	0.5	0.2	0.1	1.3	6.1	25.4	37.0	18.5	6.1	2.5		

rainfall. The Bafing describes an arc as it runs north and joins the Bakoye River in western Mali, turning into the Senegal. From the confluence of the two rivers the flow is slower. In the lower basins where the river runs along the Senegal-Mauritania border, its average riverbed slope is as gradual as several centimeters per kilometer and vast floodplains are formed. The backward flow of seawater is remarkable in the lower basins. During the ordinary flow period, seawater intrusions of as much as about 500 km along the river are observed and seasonal brackish water swamps are formed in the areas up to about 250 km from the river mouth.

The Senegal river has a total length of 1,630 km, a catchment area of 441, 000 km2 and an annual total runoff of 23.2 billion m3. This runoff is small for the catchment area and the specific discharge is only 1.7ℓ/s/km2. This is

Table 2-17 Flow conditions of large rivers in

River	Observation site	Area of basin (km^2)	First dry season month	Jan	Feb	Mar	Apr
Black Volta	Kouri	20,000	Oct	23	12.9	9.6	8.9
Black Volta	Boromo	58,000	Oct	40	24	13.2	10.1
Bani	Douna	101,600	Sept	177	105	69	43
Bani	Sofara	129,400	Sept	405	177	100	59
Niger	Mopti	281,600	Sept	1,031	416	190	109
Niger	Dire	330,000	Sept	2,057	1,556	979	450
Niger	Niamey	unknown	Sept	1,736	1,725	1,419	868
Niger	Baro	unknown	Nov	1,710	1,600	1,485	1,280
Niger	Onitsha	unknown	Nov	2,140	1,850	1,715	1,650
Logone	Lai	60,320	Oct	120	87	65	63
Logone	Bongor	73,700	Oct	145	88	62	55
Logone	Logone Birni	76,000	Oct	217	127	85	69

because the northern basins have low rainfall and the average annual runoff ratio is as low as 10%. Moreover, the Senegal river has great seasonal changes in runoff and the ratio of the month with the minimum runoff (May) to that with the maximum runoff (September) is as large as 1 to 310. Table 2-16 shows the distribution of the river's monthly runoff at Bakel (Ledger, 1969).

(3) Other river systems

The rivers in West Africa except the Niger and Senegal mostly run roughly at right angles to the coastline and flow directly into the Atlantic or the Gulf of Guinea. Their basins exist in the three climatic zones of equatorial forest, Guinea savanna and Sudan savanna. In these basins, there is relatively high rainfall and much runoff in the rainy season but rainfall is low and runoff decreases substantially in the dry season in most cases. Runoff from rivers in the dry season depends on groundwater runoff, which is determined by the size and groundwater storage capacity of the basin and by the quantity of rainfall in the rainy season.

1) Basins of small rivers: In the basins of tributaries and other small rivers before they join the mainstream, runoff rapidly decreases when the rainy season ends and the dry season begins. This is because the soils distributed in these areas have a small infiltration rate and the evaporation loss in the dry season is heavy. The basins of tributaries and other small rivers where groundwater

the southern parts of West Africa (Ledger, 1969)

Average monthly runoff (m^3/s)								Average annual runoff (m^3/s)	Ratio of dry season runoff to annual runoff (%)
May	Jun	Jul	Aug	Sept	Oct	Nov	Dec		
9.4	11.8	18.3	47	90	125	122	63	45	50
11.4	19.7	34	79	113	93	75	64	48	51
31	45	187	1,250	2,535	2,546	1,261	433	726	55
38	50	174	828	1,326	1,538	1,405	938	586	62
82	170	689	1,774	2,585	2,814	2,687	2,027	1,219	65
152	87	282	866	1,498	1,899	2,161	2,299	1,189	85
347	130	124	516	1,067	1,254	1,412	1,588	1,011	90
900	1,000	1,280	2,285	7,420	7,300	2,710	1,800	2,525	35
1,600	2,280	4,550	8,425	17,720	20,000	6,300	2,860	7,000	22
91	164	487	1,102	1,992	1,647	566	197	551	42
79	155	443	1,036	1,713	1,750	741	263	547	49
99	178	383	604	756	868	878	552	403	58

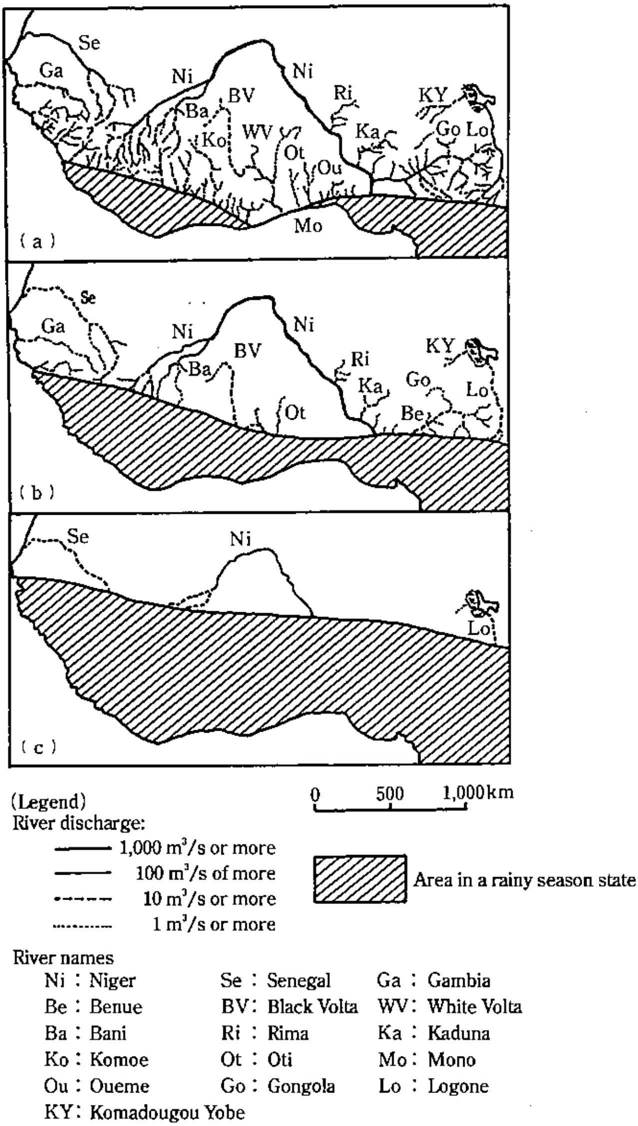


Fig.2-40 Flow conditions of West African rivers in the fourth (a), sixth (b) and eighth (c) month after the dry season starts

runoff occurs throughout the dry season are shown in Fig. 2-37 (Ledger, 1969). According to this figure, these areas are observed in Sierra Leone, most parts of Guinea, Liberia, southern and western Côte d'Ivoire, southwestern Ghana, southern Nigeria and central and southern Cameroon. But no dry season runoff takes place in central and eastern Côte d'Ivoire, southeastern Ghana, southern Togo, southern Benin, etc. because there is not enough surplus water to perform aquifer charging despite a long rainy season.

2) Basins of large rivers: The flow conditions of large rivers in the southern parts of West Africa in the dry season are very similar to the discharge of the small rivers that flow into these large rivers. However, unlike small rivers, large rivers need much more time for the shift from flood runoff in the rainy season to low water runoff in the dry season and so their period of low water runoff begins later and is shorter than that of small rivers. Table 2-17 shows the flow conditions of large rivers in the southern parts of West Africa (Ledger, 1969). In these rivers, the ratio of runoff in the dry season to the annual runoff is about 15-20%. With relatively large floodplains, the Black Volta River has the capacity to extend the high water period by one to two months, delay the passage of the peak flow by roughly the same period and increase the base flow considerably. In the case of the Black Volta, 50% of the total runoff occurs in the dry season.

Fig. 2-40 shows the flow conditions of the main West African rivers in the fourth (a), sixth (b) and eighth month (c) after the dry season starts (Ledger, 1969). This figure clearly indicates how important the River Niger is compared with other rivers. (Yoshinobu Kitamura)

5. Characteristics of the water use environment
(Kitamura, 1994)

5-1. International water treaties

Africa has 60 international rivers. Of these, 13 rivers run through four countries or more. About 40% of the African continent is made up of the basins of these international rivers. West Africa especially has many international rivers.

The early treaties on international rivers in Africa were concerned with navigation and borders, but recent treaties have generally been centered on economic development. Partly because the river runoff in the African continent is less than that in other continents, African countries are apprehensive about

Table2-18 International river basins in Africa (Wolf *et al.*,1999)

Basin name[1]	Riparian countries	Area of basin (km^2)
1 Medjerda	Tunisia, Algeria	23,100
2 Tafna	Algeria, Morocco	9,500
3 Oued Bon Naima	Morocco, Algeria,	510
4 Guir	Algeria, Morocco	79,100
5 Daoura	Morocco, Algeria	34,600
6 Dra	Morocco, Algeria	54,900
7 Atul	Mauritania, Western Sahara	10,400
8 Senegal	Mauritania, Mali, Senegal, Guinea	437,000
9 Gambia	Senegal, Guinea, Gambia	70,000
10 Geba (Kayanga)	Guinea-Bissau, Senegal, Guinea	12,800
11 Corubal	Guinea, Guinea-Bissau	24,100
12 Great Scarcies (Kolenta)	Guinea, Sierra Leone	11,400
13 Little Scarcies	Sierra Leone, Guinea	19,300
14 Moa	Sierra Leone, Guinea, Liberia	22,600
15 Mana-Morro	Liberia, Sierra Leone	6,900
16 Loffa	Liberia, Guinea	11,400
17 St. Paul	Liberia, Guinea	21,200
18 St. John	Liberia, Guinea, Cote d'Ivoire	15,600
19 Cestos	Liberia, Cote d'Ivoire, Guinea	15,000
20 Cavally	Cote d'Ivoire, Liberia, Guinea	30,600
21 Sassandra	Cote d'Ivoire, Guinea	68,200
22 Komoe	Cote d'Ivoire, Burkina Faso, Ghana, Mali	78,500
23 Bia	Ghana, Cote d'Ivoire	11,900
24 Tano	Ghana, Cote d'Ivoire	14,300
25 Volta	Burkina Faso, Ghana, Togo, Mali, Benin, Cote d'Ivoire	414,000
26 Mono	Togo, Benin	23,400
27 Oueme	Benin, Nigeria, Togo	59,500
28 Niger	Nigeria, Mali, Niger, Algeria, Guinea, Cameroon, Burkina Faso, Benin, Cote d'Ivoire, Chad, Sierra Leone	2,117,700
29 Cross	Nigeria, Cameroon	52,800
30 Akpa Yafi	Cameroon, Nigeria	4,900
31 Lake Chad	Chad, Niger, Central Africa R[2], Nigeria, Algeria, Sudan, Cmeroon, Libya	2,394,200
32 Ntem	Cameroon, Gabon, Epuatorial Guinea	35,000
33 Benito	Equatorial Guinea, Gabon	12,600
34 Utamboni	Gabon, Equatorial Guinea	7,700
35 Mbe	Gabon, Equatorial Guinea	7,000
36 Ogooue	Gabon, Congo (R)[3], Cameroon, Equatorial Guinea	223,400
37 Nyanga	Gabon, Congo (R)[3]	12,400
38 Chiloango	Congo (D)[4], Angola, Congo (R)[3]	11,700

39 Congo/Zaire	Congo (D)[4], Central Africa R[2], Angola, Congo (R)[3], Zambia, Tanzania, Cameroon, Burundi, Rwanda, Gabon, Malawi	3,699,100
40 Kunene	Angola, Namibia	110,300
41 Etosha-Cuvelai	Namibia, Angola	167,600
42 Okavango	Botswana, Namibia, Angola, Zimbabwe	708,600
43 Orange	South Africa, Namibia, Botswana, Lesotho	947,700
44 Maputo	South Africa, Swaziland, Mozambipue	31,300
45 Umbeluzi	Swaziland, Mozambique, South Africa	5,400
46 Incomati	Souh Africa, Mozambique, Swaziland	46,200
47 Limpopo	South Africa, Mozambique, Botswana, Zimbabwe	415,500
48 Sabi (Save)	Zimbabwe, Mozambique	116,100
49 Buzi	Mozambique, Zimbabwe	27,900
50 Zambezi	Zambia, Angola, Zimbabwe, Mozambique, Malawi, Tanzania, Botswana, Namibia, Congo (D)[4]	1,388,200
51 Ruvuma	Mozambique, Tanzania, Malawi	152,200
52 Umba	Tanzania, Kenya	8,200
53 Lake Natron	Tanzania, Kenya	55,600
54 Lake Turkana	Ethiopia, Kenya, Uganda, Sudan	207,600
55 Lotagipi Swamp	Kenya, Sudan, Ethiopia, Uganda	38,900
56 Juba-Shibeli	Ethiopia, Somalia, Kenya	805,100
57 Awash	Ethiopia, Djibouti, Somalia	155,300
58 Gash	Eritrea, Sudan, Ethiopia	31,700
59 Braka	Eritrea, Sudan	66,600
60 Nile	Sudan, Ethiopia, Egypt, Uganda, Tanzania, Kenya, Congo(D)[4], Rwanda, Burundi, Eritrea	3,038,100
Total		18,682,410

Notes: 1) River basins are shown in counterclockwise order staring from the northernmost river of Africa, i. e. River Medjerda, Tunisia.
2) Central African R.: Central African Republic
3) Congo(R): Republic of the Congo (Brazzaville)
4) Congo(D): Democratic Republic of the Congo (Kinshasa)

the issue of how to distribute the water sources of international rivers. The obstacle that the riparian countries face in concluding a treaty is lack of runoff data. It is thus important to collect and exchange hydrological and climatic data prior to the negotiation of a treaty. Table 2-18 summarizes the information on main international river basins in Africa (Wolf et al., 1999).

The first international treaty regarding African rivers was the declaration by the Berlin Committee in 1885 on navigation on the Congo and Niger rivers.

A treaty on the management of the Nile was signed in 1929 between Britain and Egypt. A similar treaty concerning technical cooperation in the development of the Nile basin was concluded in 1959 between Sudan and Egypt. The Senegal Valley Development Plan was announced in 1969 by the four riparian countries and the committee created for the plan examined and established the comprehensive development policies of the entire Senegal basin. For the Niger basin, the first treaty was signed in 1963 but was abolished by the new treaty in 1964, which declared multipurpose water use. The Lake Chad Basin Commission was established by the special treaty in 1964.

International water treaties are signed on the basis of mutual understanding of the interests of the riparian countries. Thus these treaties promote further development of water resources and also help increase activities for such development, including surveys, fund raising and exchange of hydrological information. In many cases, plans on international rivers for which an international water treaty was signed are implemented by the cooperation of the UN organizations at the preparatory and initial stages.

5-2. Water treaties for main rivers

(1) River Niger

The River Niger is a valuable water source for West Africa's inland arid areas. Since its basins extend over 10 countries and has a population of about 100 million, its water resources development should be carried out harmoniously by the riparian countries. Because of this, in October 1963, the nine riparian countries* jointly laid down an international law concerning inland navigation on the Niger and economic cooperation among the countries in the Niger basin (commonly known as the Act of Niamey). Then in 1964, a treaty concerning the creation of the Niger River Commission (NRC) was concluded. The NRC was reorganized as the Niger Basin Authority (NBA) in November 1980.

The NBA's basic purpose is to promote and coordinate surveys and plans concerning the development of the Niger basin. Its recent activities are mostly for 1) coordination of the development plans and policies of riparian countries, 2) preparation of river basin plans, 3) promotion, formulation and implementation of plans for common interests of riparian countries, and 4) implementation of the Hydroniger Project. The Hydroniger Project aims at promoting the collection and processing of data by a satellite transmission system that will have 65 observation sites. But these activities have not always been effectively carried out because funds are insufficient and because the NBA has so many member countries that it often established vague goals instead of effective ones. At present, the NBA is requested by donor organizations, etc. to review its objectives, structure, constitution, programs, etc. (World Bank, 1994).

* Nine riparian countries: Guinea, Mali, Niger, Nigeria, Côte d'Ivoire, Burkina Faso, Benin, Cameroon and Chad (Algeria did not join).

(2) Senegal River

The Senegal River is an international river that runs through Guinea, Mali, Mauritania and Senegal. For the latter three countries where most of the land was insufficient rainfall, the areas along this river are especially valuable farming belts and water resource development activities have been carried out for many years in these areas. Comprehensive development activities in the Senegal basin were started by the foundation of the Organisation des Etats Riverains du Senegal (OERS)(Senegal River Riparian States Organization) in 1968. Then in 1972, the Organisation pour la Mise en Valeur du Fleuve Senegal (OMVS; Senegal River Development Organization) was created, establishing the basis of promotion of development plans (Framji et al., 1983). Member states are Mali, Mauritania and Senegal.

OMVS is said to be an organization whose member states probably have the strongest recognition of themselves as a community of co-riparian states of all of the several riparian organizations in Africa (World Bank, 1994). Especially noteworthy is the fact that the organization succeeded in implementing and completing two large-scale multipurpose dam projects, that is, the Manantali and Diama Dam projects. The former constructed a concrete dam (total storage capacity: 11.1 billion m^3) on the Bafin River, a tributary of the Senegal, at Manantali for the purpose of electric power generation, irrigation and flood control. The latter built a fill dam (total storage capacity: 1 billion m^3) in the Diama delta 30 km upstream of Saint-Louis to irrigate the basin and prevent seawater intrusions. It is estimated that by combining these two projects, 303,500 ha of land could ultimately be irrigated. The donors for the two projects include the European Development Fund (EDF), African Development Bank (AfDB), Islam Development Bank (IDB), France and the US. But though the dams were completed, the irrigation development activities by the riparian countries have been delayed considerably and the primary benefits of these dams have not been derived. The OMVS is now shifting its activities from construction work to maintenance.

5-3. Outline of water resource and irrigation development

The introduction of irrigation is an important factor for reforming African agriculture. Its importance will increase in the future together with the introduction of new farming techniques and new organization forms and the resettlement of farmers. One of the serious problems facing many areas in Africa is insufficient and unstable rainfall. The most effective solution to this question is the use of river water. However, this method is generally a costly alternative and does not always succeed in terms of investment effects. Needless to say, irrigation has been used extensively in Egypt for several centuries. This has recently been extended to the upper basins in the Sudan. In particular, the Gezira Scheme is probably a relatively successful case. However, the irrigation plan in the Niger inland deltas, which was started in 1932 and continued after World War II, failed to meet expectations (O'Conner, 1981).

Cultivated land in Africa in 1998 was 201.96 million ha (FAO, 2000) or only 6.7% of the total land area. Moreover, rain-fed agriculture is carried out in almost all of the cultivated area. As shown in Table 2-19, the irrigated area has increased by about 1.5% per annum on average since 1988. As of 1998, the irrigated land was 12.52 million ha and the percentage of this land was only 6.2% (FAO, 2000). Of these irrigated areas, about two-thirds are equipped with modern irrigation facilities and one-third adopts small-scale traditional methods of water use dependent on floodplains and swamps. What is noteworthy is that about 63% of the irrigated land of 12.52 million ha is concentrated in four countries: Egypt (26%), Sudan (16%), South Africa (11%) and Morocco (10%) (FAO, 2000).

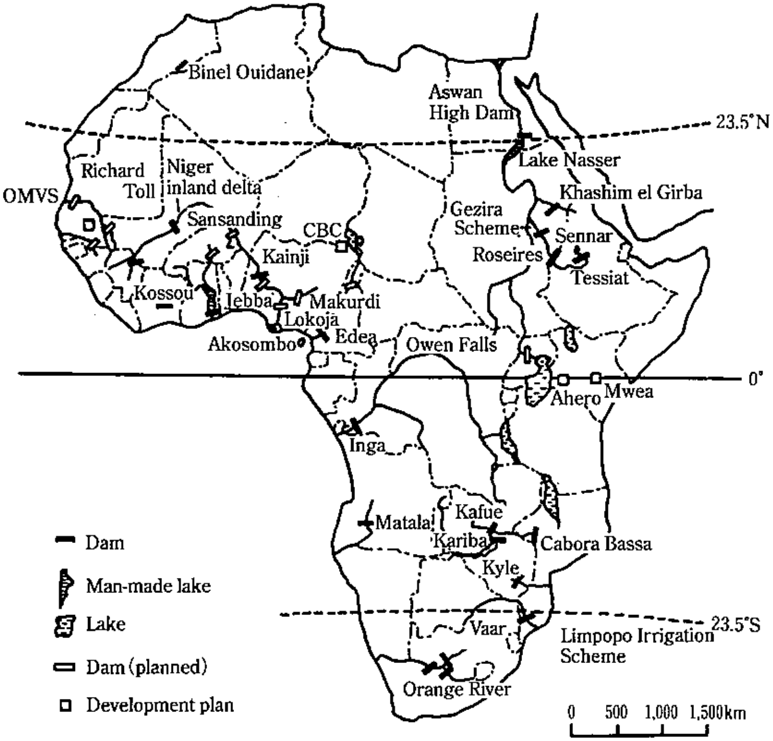
Though West African countries have only a short history of water resource development, they have a relatively high potential in this field because they are blessed with water resources. But past development activities gave higher priority to hydroelectric power generation than to irrigation. For example, the Volta River Project created Lake Volta (storage capacity: 148 billion m^3) by constructing the Akosombo Dam but hydroelectric power generation was its main purpose, and irrigation was only a secondary one. Because of this, the irrigation plan for the Accra Plain (60,000 ha) is laid as pumping irrigation by the water from the Akosombo Dam rather than as gravity irrigation by taking water directly from Lake Volta. In Côte d'Ivoire, too, water resource development activities have placed greater emphasis on power generation.

Farmlands in West Africa mostly depend on rainwater and the ratio of modern irrigated lands is very low. Main irrigation methods are tidal irrigation in tidal reaches like mangrove swamps and deltas, controlled flooding in floodplains and recession farming in depressions. According to the statistics in 1998

Table2-19 Change of Irrigated area in Africa

Country	Irrigated area (1,000ha)					Percentage of irrigated area (%)			
	1983	1988	1993	1998 Area	1998 %	1983	1988	1993	1998
Africa	9,917	10,817	12,318	12,520	100.0	5.5	5.7	6.3	6.2
(Northern Africa)	2,122	2,260	2,668	2,701	21.6	9.4	9.6	10.7	10.7
(Lower Nile)	4,278	4,527	5,192	5,250	41.9	28.2	29.1	29.0	26.0
Egypt	2,478	2,581	3,246	3,300		100.0	100.0	100.0	100.0
Sudan	1,800	1,946	1,946	1,950		14.2	15.0	13.1	11.5
(West Africa)	669	758	843	854	6.8	1.1	1.2	1.3	1.2
Benin	6	6	10	12		0.4	0.4	0.6	0.6
Bukina Faso	12	16	24	25		0.4	0.4	0.7	0.7
Chad	14	16	18	20		0.4	0.5	0.5	0.6
Cote d'Ivoire	50	60	73	73		1.1	1.0	1.1	1.0
Gambia	1	1	2	2		0.5	0.5	1.2	1.0
Ghana	7	8	10	11		0.2	0.2	0.2	0.2
Guinea	90	90	93	95		7.7	7.5	6.7	6.4
Guinea-Bissau	17	17	17	17		5.5	5.1	5.0	4.9
Liberia	2	2	3	3		0.5	0.5	0.8	0.8
Mali	95	110	135	138		4.6	5.3	4.4	3.0
Mauritania	49	49	49	49		17.9	13.4	11.1	9.8
Niger	30	55	66	66		0.8	1.5	1.7	1.3
Nigeria	200	200	233	233		0.7	0.6	0.7	0.8
Senegal	62	90	71	71		2.6	3.8	3.0	3.1
Sierra Leone	25	28	29	29		4.8	5.2	5.4	5.4
Togo	7	7	7	7		0.3	0.3	0.3	0.3
Other Islands	2	3	3	3		4.8	6.8	6.7	6.7
(Eastern Africa)	648	735	850	857	6.8	1.8	1.9	2.3	2.4
Ethiopia	162	162	190	190		1.2	1.2	1.6	1.8
Kenya	40	49	67	67		0.9	1.1	1.5	1.5
Mozambique	80	100	107	107		2.5	3.1	3.2	3.2
Somalia	150	180	200	200		14.8	17.3	19.2	18.8
Tanzania	124	144	150	155		3.0	3.3	3.3	3.3
(Madagascar & island)	778	926	1,116	1,122	9.0	23.8	27.6	33.0	33.2
Madagascar	755	900	1,087	1,090		25.1	29.2	35.0	35.1
(Central Africa)	124	132	141	145	1.2	0.6	0.6	0.7	0.7
(Southern Africa)	1,298	1,479	1,508	1,591	12.7	5.8	6.3	6.0	6.1
South Africa	1,128	1,290	1,270	1,350		8.6	9.4	8.4	8.6
Swaziland	60	62	67	69		42.6	32.6	38.1	38.3
Zimbabwe	80	90	117	117		2.9	3.1	3.7	3.5

Source: FAO Statistical Databases, 2000.



OMVS : Organisation pour la Mise en Valeur de Fleuve Senegal
(River Senegal Development Organization)
CBC : Lake Chad Basin Commission
Mwea : Mwea Tabere Irrigation Scheme

Fig.2-41 Large-scale water reasource development projects in Africa (UNEP, 1981) Bin el Ouidane

(FAO, 2000), the percentage of irrigated areas in West African countries is as low as 1.2% on average. Therefore, in this region, water resources development activities for irrigation should be promoted more positively. Considering cost-benefit ratios and management and operation work required, it is desirable that priority will be given to relatively small-scale irrigation projects, instead of large ones.

Fig. 2-41 shows large-scale water resource development projects in Africa (UNEP, 1981).

5-4. Outline of irrigated rice development

As shown in Table 2-20, the area of rice cultivation in Africa totals to about 7. 84 million ha or 3.9% of all the cultivated land. Of this, 1.83 million ha are irrigated rice fields, a little less than 15% of the continent's total irrigated lands, and the ratio of irrigated fields is 23%. About 80% (approx. 1.50 million ha) of the continent's irrigated rice field exist in three countries: Egypt (36%), Madagascar (27%) and Nigeria (16%). Irrigated rice fields in West Africa are about 570,000 ha (31% of Africa's total) and more than a half of them are concentrated in Nigeria. Table 2-21 shows the effects of irrigation on rice production in Africa using data for 1986 (Dat, 1986). According to this table, 58% of Africa's total rice production is produced from irrigated fields that account for only 30% of its total rice fields. The yield is only about 1.0t/ha in non-irrigated fields but 3.3t/ha, more than three times, in irrigated ones. No reliable data are available about the area and output of rice double cropping but it is supposed that this cropping system is introduced in most large-scale irrigated fields. It is also considered that in the irrigated fields where no rice double cropping is carried out, the double cropping is practiced using maize, tomato, legumes, etc. as off-season crops.

In Africa, the importance of rice has rapidly increased during the past decades. Fig. 2-42 summarizes the trend of rice production in the last 25 years in the whole of Africa and in West Africa using FAO statistics (FAO, 2000) (in paddy equivalent; to convert paddy weight into milled rice equivalent, multiply the weight by 0.667; the weight of rice is always shown in paddy equivalent values below). The situation of paddy rice production in the last 25 years can be roughly divided into two periods according to their character. The first decade was the period when rice production failed to meet the rapidly increasing demand, resulting in a substantial increase in rice imports. On the other hand, during the subsequent 15-year period, rice output achieved a rapid increase but rice consumption also continued to rise and so rice imports have continued growing to satisfy demand. This situation is likely to last for some time and when production can meet demand is dependent on the progress of farming technology and on the development of the infrastructure for irrigated rice in the years ahead.

During the decade from 1974 to 1984, Africa's rice imports grew by 3.4 times while its rice output showed only a small increase of 18%. This is because African consumers changed their preference in food from traditional foods to

Table2-20 Rice cultivation in Africa

Country[1]	Rice cultivated area (ha)			Production[2] (t)	Yield[2] (t/ha)
	Total area harvested[2]	Irrigated rice field[3]	% of irrigated rice field[4]		
Africa total	7,842,483	1,834,393	23.4	17,602,129	2.245
Algeria	200	200	100**	300	1.500
Angola	20,000	-	-**	16,000	0.800
Benin (W)	17,079	8,000	46.8**	35,587	2.084
Burkina Faso(W)	45,904	7,800	17*	88,998	1.939
Burundi	18,000	13,000	72.2**	58,630	3.257
Cameroon	16,000	16,000	100*	65,000	4.063
Central African Rep.	14,000	0	0**	21,000	1.500
Chad (W)	76,400	4,600	6*	100,200	1.132
Comoros	14,000	0	0**	17,000	1.214
Congo (Dem. Rep)	500,000	2,500	0.5*	350,000	0.700
Congo (Rep.)	350	0	0**	300	0.857
Cote d'Ivoire (W)	750,000	36,800	4.9*	1,161,518	1.549
Egypt	655,082	655,082	100*	5,816,181	8.879
Gabon	400	0	0**	800	2.000
Gambia (W)	15,786	1,120	7.1*	28,873	1.829
Ghana (W)	130,000	16,250	12.5*	209,750	1.614
Guinea (W)	500,000	32,000	6.4*	750,000	1.500
Guinea-Bissau (W)	70,000	0	0*	130,000	1.857
Kenya	17,000	17,000	100*	40,000	2.353
Liberia (W)	162,500	0	0*	210,100	1,293
Madagascar	1,227,000	493,000	40.2*	2,637,000	2,149
Malawi	45,000	12,600	28**	93,000	2,067
Mali (W)	330,375	89,500	27.1*	589,048	1,783
Mauritania (W)	23,000	23,000	100*	101,918	4,431
Morocco	7,166	7,166	100**	35,140	4,904
Mozambique	182,000	21,100	11.6*	200,000	1.099
Niger (W)	35,000	16,350	46.7*	73,000	2.086
Nigeria (W)	2,050,000	299,000	14.6*	3,397,000	1.657
Rwanda	4,919	3,000	61**	8,919	1.813
Reunion	40	40	100**	80	2.000
Senegal (W)	95,884	35,300	36.8*	239,786	2.501
Sierra Leone (W)	213,054	0	0*	247,235	1.160
Somalia	900	900	100**	1,000	1.111
South Africa	1,300	1,300	100**	2,900	2.231
Sudan	3,500	0	0**	2,000	0.571
Swaziland	15	15	100**	105	7.000
Tanzania	473,909	20,850	4.4*	676,000	1.426
Togo (W)	42,400	720	1.7*	86,663	2.044
Uganda	68,000	0	0**	96,000	1.412
Zambia	16,120	0	0**	14,698	0.912
Zimbabwe	200	200	100**	400	2.000
West Africa subtotal	4,557,382	570,440	12.5	7,449,676	1.635

Notes: 1)(W): West African countries
2) Total area harvested in 1999, Source: FAO Statistical Databases, 2000
3) Calculated using % of irrigated rice field[4]
4) *% of irrigated rice field in 1955, Source: FAO Rice Information, 2000
**% of irrigated rice field, Estimated

Table2-21 Effects of irrigation on rice production in Africa (Dat, 1986)

Area	Total output (1,000t)	Output in irrigated fields[f] (1,000t)	Ratio of output in irrigation fields to total output (%)
Mediterranean coast and North Africa	2,406	2,406	100
Sudan climate Sahel climate[a)]	425	276	65
Humid/subhumid West Africa[b)]	2,749	263	10
Humid Central Africa[c)]	320	35	11
Subhumid, highlands of East Africa[d)]	2,217	1,787	84
Subhumid/Semi-arid South Africa[e)]	538	159	30
Total	8,565	4,926	58

Source: FAO, 1986.
Notes: a) Excluding Cape Verde and Chad.
b) Excluding Guinea-Bissau.
c) Excluding Equatorial Guinea,and Sao Tome and Principe.
d) Excluding Comoros and Seychelles.
e) Excluding Namibia
f) The ratio of irrigated rice fields to the total rice fields in 1986 was 30%.

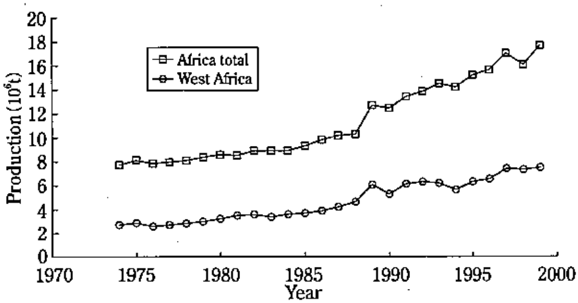


Fig.2-42 Rice production in Africa

rice and their rice consumption increased rapidly. Also, rice cultivation relied highly on rainwater and so its yield did not rise as quickly. In this period African countries put much energy into developing irrigation facilities that could realize rice double cropping in an attempt to settle the problem of rice shortage. However, these efforts to expand irrigated areas did not lead to greater output. This was because most African farmers were not very experienced in irrigated rice growing and because rice double cropping was faced with a lot of technical, socioeconomic and managerial problems.

By contrast, growth in rice production in the last 15 years has been remarkable. According to Fig. 2-42, Africa's rice output doubled in the 1984-1999 period

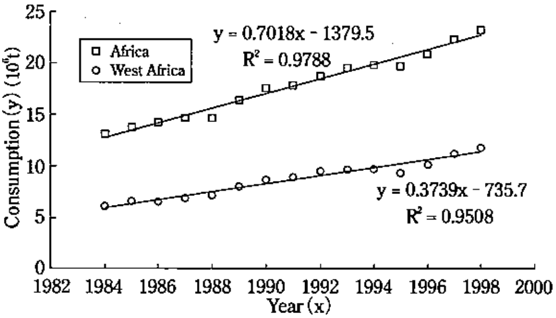


Fig.2-43 Rice consumption in Africa (paddy equivalent)

from 8.95 million tons to 17.602 million tons. This means that the production increased by 0.58 million tons a year on average or at an average annual rate of 4.6%. This substantial growth in output is because the area of irrigated rice was expanded by 1.54 times (at 2.9% a year on average) and yield increased 1.28 times (at 1.6%) from 1.76t/ha to 2.25t/ha.

In West Africa, rice production more than doubled from 3.69 million to 7.45 million tons. During these 15 years, it continued rising by 0.260 million tons a year or at an average annual growth rate of 5.0%. Behind this lay the fact that the area of rice fields increased 1.70 times (at 3.6% a year on average) and the yield, 1.22 times (at 1.3%). In West Africa, rice fields have been expanded, but increases in the yield have been less compared with the entire continent. The level of yield in this region is as low as 1.64t/ha or only 73% as much as that in the whole of Africa (2.25t/ha). The probable reason that West Africa has a lower yield is that its percentage of irrigated areas is only 12.5% or about a half that of Africa's average (23.4%).

Fig. 2-43 shows the trend of rice consumption for the whole of Africa and in West Africa using FAO statistics (FAO, 2000). The consumption of rice was calculated by subtracting exports from the sum of output and imports and then adding loss of stock to the remainder. Rice consumption is still on an upward trend and has risen by 0.7 million tons a year on average in the past 15 years. In West Africa, it is increasing by an annual average of 0.37 million tons. Rice consumption is especially large in this region, accounting for about a half that of the whole of Africa in the recent five-year average. Per capita paddy consumption is 50 kg/person (30 kg/person milled rice) in West Africa, much higher than Africa's average of 30 kg/person (20 kg/person in milled rice).

The deficiency of rice in the African continent is on the increasing annually. The average shortage in the past five years is 5.5 million tons, of which 3.75

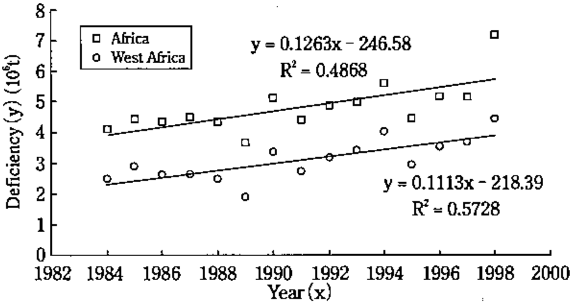


Fig.2-44 Rice deficiency in Africa (paddy equivalent)

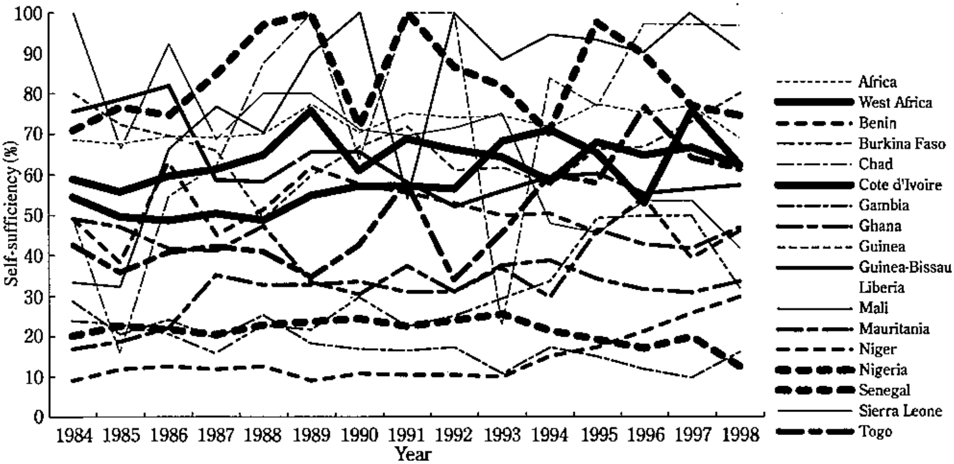


Fig.2-45 Self-sufficiency of rice in West Africa

million tons or more than two-thirds represents the deficiency in West Africa. Fig. 2-44 shows the trend of rice shortage in the whole of Africa and West Africa in the past 15 years. The deficiency is increasing by about 0.13 million tons a year in Africa, of which 0.11 million tons is an increased shortage in West Africa. In other words, in the African countries out side West Africa, the quantity of rice deficiency seems to be on similar levels and the future of rice supply-demand is brighter. But in West Africa, rice output will need to be increased further and it is hoped that greater effort will be made to expand irrigated rice field and improve farming techniques.

Fig. 2-45 shows the trend of rice self-sufficiency ratios for Africa, West Africa and West African countries in the 1984-1998 period. For the entire continent, the ratio was 68% in 1984 and gradually increased to a five-year average of 74% for 1994 to 1998. The figure for West Africa was 59% in 1984 and rose to 64% on average for the same period, also indicating an upward trend. However, great yearly changes in self-sufficiency ratios indicate that this region has a weak irrigation infrastructure and its rice growing tends to be easily affected by weather conditions.

It is argued that irrigated rice field development in Africa has three types (Budeenhagen and Perslet, 1978):

1) Large-scale irrigation. This is the method by which farmers settle in highly productive land to develop farmland and is modeled after the Gezira Project in Sudan. Examples include the project in the Niger basin in Mali, several schemes in the Senegal basin, the plan for the areas around Lake Alaotra in Madagascar, the Tana River Development Project in Kenya and the Rufiji Delta Development Project in Tanzania.

2) Rice cultivation in rain-fed paddy field. In the 1950s and 1960s, West African countries provided farmers with plowing services on contract with large machines to develop rain-fed paddy fields. Projects belonging to this category include the Boli Project in inland valleys in Sierra Leone known as boli land, the development project in northern Nigeria and the Faranah Project in Guinea.

3) Small-scale irrigation. This is a small-scale irrigated rice production project in a land area of 10-20 ha and has particularly successful in Côte d'Ivoire. This method was devised by Taiwanese experts by closely keeping in touch with local farmers and is a reinforced and intensive version of irrigated rice cultivation. In large-scale irrigation schemes, there is the tendency that problems for achieving higher yield in the field are neglected. This attitude mostly ends in additional costs and time for securing the planned yield. Small irrigation plans have corrected this defect of large projects to a considerable extent.

In the Niger basin, the basic rice cultivation method is the traditional floating rice culture using flood water, which has been carried out in major beds of the river (JIID, 1985). Cultivated land equipped with modern irrigation facilities exist only in the major beds in this river or in the lower basins of dam projects on tributaries. The areas having highly developed irrigation infrastructure are usually under government management.

5-5. Present situation of water resource and irrigation development of West African countries

(1) Guinea

Blessed with much rainfall and having as many as 25 rivers, Guinea has a high

Table2-22 Freshwater resources and present utilization in West Africa

Country	Renewable surface water resources(1)		Internal renewable water resources(2)		Annual water withdrawals						
	Total (km³)	Per-capita (m³)	Total (km³)	Per-capita (m³)	Total (km³)	% of (1)	Per-capita (m³)	Year	Sector-wise withdrawals (%) Domestic	Industrial	Agriculture
Benin	25.8	4,386	10.3	1,751	0.15	0.6	28	1994	23	10	67
Burkina Faso	17.5	1,535	17.5	1,535	0.38	2.2	39	1992	19	0	81
Chad	43.0	6,238	15.0	2,176	0.18	0.4	34	1987	16	2	82
Cote d'Ivoire	77.7	5,334	76.7	5,265	0.71	0.9	67	1987	22	11	67
Gambia	8.0	6,701	3.0	2,513	0.02	0.3	29	1982	7	2	91
Ghana	53.2	2,822	30.3	1,607	0.30	0.6	35	1970	35	13	52
Guinea	226.0	29,454	226.0	29,454	0.74	0.3	142	1987	10	3	87
Guinea-Bissau	27.0	23,809	16.0	14,109	0.02	0.1	17	1991	60	4	36
Liberia	232.0	84,425	200.0	72,780	0.13	0.1	54	1987	27	13	60
Mali	100.0	8,452	60.0	5,071	1.36	1.4	162	1987	2	1	97
Mauritania	11.4	4,646	0.4	163	1.63	14.3	923	1985	6	2	92
Niger	32.5	3,213	3.5	346	0.50	1.5	69	1988	16	2	82
Nigeria	280.0	2,300	221.0	1,815	3.63	1.3	41	1987	31	15	54
Senegal	39.4	4,377	26.4	2,933	1.36	3.5	202	1987	5	3	92
Sierra Leone	160.0	34,957	160.0	34,957	0.37	0.2	98	1987	7	4	89
Togo	12.0	2,707	11.5	2,594	0.09	0.8	28	1987	62	13	25

Source: World Resources Institute, 1999.
Note: 1) Renewable surface water resources include river inflow from other countries.
2) Internal renewable water resources refer to the average annual flow of rivers and recharge of groundwater generated from endogenous precipitation.

potential for water resource development. Table 2-22 shows the situation of water resources of West African countries and from this figure Guinea can be regarded as a country rich in water resources. The Fouta Djallon Plateau forms the source of many river, including the representative rivers of this region, the Niger, Senegal and Gambia, and is known as the water tower of West Africa. Therefore, the area is very important for the conservation of West Africa's water resources. But due to the frequent occurrence of drought, the population density of this plateau is increasing, resulting in deforestation, excessive cultivation and overgrazing, which is in turn reducing the water storage capacity of the area. If this situation continues, the plateau will fall into ruin and this will seriously affect West Africa's main rivers. It will naturally accelerate desertification in the Sahel and Sudan savanna zones. Concerned about this problem, the Organization of African Unity (OAU) announced its support for comprehensive conservation and management of this basin. The Guinean government has also started activities for protecting and reviving the basin, such as afforestation, with the cooperation of the UN Food and Agriculture Organization (FAO), etc. This area has a population of about one million and comprehensive measures are needed to protect it as the site both for the lives of these people and for water conservation. Residents in the area have understood the importance of this plan, too, and a system of cooperation is being built up. The planting of shrub species is planned because they can provide feed for animals in the dry season.

Water resource development activities in Guinea have been mainly for hydroelectric power generation and those for irrigation have just started. The irrigated area is estimated at about 95,000 ha or only 6.4% of the cultivated area(Table 2-19). It is hoped that irrigation development will be carried out making use of abundant water resources, mainly in the Niger system.

In mangrove swamps on the Atlantic coast, tidal irrigation has been adopted using the rise and fall of the tides. In inland swamps, crops are planted using natural flooding in the rainy season. The self-sufficiency ratio of rice has recently risen and reached 80% in 1998 (Fig. 2-45).

(2) Mali

Rainfall in Mali is 1,400 mm in southern areas but is lower in northern parts (200 mm or less). Corresponding to this distribution of rainfall, the country's climatic zones change from the Guinea savanna zone to the Sudan savanna zone, the Sahel and desert from south to north. Its main rivers are the Niger and Senegal and Mali's agricultural development depends on how to exploit these two river systems.

In particular, the Niger forms vast inland deltas between Segou and Tombouctou, where irrigation activities have been carried out since 1932 for cotton, rice, and sugarcane. This is known as the Niger River Project or Inland Niger Delta Project and is the largest irrigation plan now implemented in Mali. The main facility is the 2.8 km-long Sansanding Barrage that was constructed in 1948 near Markana. This barrage raises the upstream water level by 4.3 m and directs water to canals on the left bank, including the Sahel and Macina Canals, thereby irrigating nearly 100,000 ha of land. The irrigation facilities in this district are managed by the Office du Niger. The most important crop is rice and cotton and sugarcane are also grown. At first, it was estimated that the inland deltas would have irrigation potential for about one million ha but it will be very hard to exploit this potential fully. Other irrigation facilities include the Sotuba Dam completed in 1929 near Bamako, the capital, and the Selingue Dam constructed on the Sankarani River, a tributary in an upper basin. These dams have made it possible to secure more stable water resources.

Other high potential irrigation projects are the Segou Rice Development Project (35,000 ha), Mopti Rice Development Project (18,000 ha) and Baguineda Development Project (3,300 ha). All of these projects benefitted from increased discharge during the low-flow season following the completion of the Selingue Dam and will realize expansion in irrigated land and double cropping. Mali's rice self-sufficiency ratio has exceeded 90% and its attainment of complete self sufficiency is in sight (Fig. 2-45). This is because the long stagnated rice yield in the project area of the Office du Niger has increased dramatically recent 10 years (Wakatsuki 1999).

Mali's irrigated area is estimated at about 140,000 ha or 3.0% of the cultivated area in 1998 (FAO, 2000). The following types of irrigation exist in Mali (Framji, Garg and Luthra, 1983) : large-scale irrigation, controlled submersion and recession irrigation observed in the Niger basin ; small-pump irrigation in the Senegal basin around Kayes ; spate irrigation using small dams in the Dogon Plateau ; and small-scale irrigation of rice fields in the rainy season in natural depressions known as bas-fonds. It is estimated that the country could achieve further irrigation development and improvement of 500,000 ha using the water resources of the Senegal and Niger and its tributary Bani River.

(3) Niger

Rainfall in Niger is 850 mm in southern parts but nearly zero in northern districts. The climatic zones change from the Sudan savanna zone to the Sahel and then to desert from south to north, and desert areas make up two-thirds of the total land area. As shown in Table 2-22, Niger's annual internal renewable water resources are 3.5 km^3 and its per capita water resources are as scarce as 346 m^3. On the other hand, the annual river inflow from other countries by the Niger that runs to the southeast in southwestern parts is as much as 29 km^3 (2,867 m^3 per capita) (Table 2-22) and very important. The country's economic development cannot be realized without the water resources of the Niger and its future problem will be water resources development in cooperation with other riparian countries through the Niger Basin Authority (NBA).

Since river terraces develop in the Niger basin, water use is limited to small areas along the river, where intensive irrigation projects for using river water are in progress. In this basin, the Irrigation Agriculture Development Authority (ONAHA) played a central role and completed 24 projects (total area : 5,035 ha) by 1983. These projects are equipped with pumping facilities and rice double cropping can be carried out in the fields developed. The goal of the project is to develop 1,000 ha of these fields a year (JIID, 1985). Niger's rice self-sufficiency ratio has fluctuated between 40% and 50% (Fig. 2-45) and it should increase its rice output further. This country's irrigated area is estimated at about 66,000 ha or only 1.3% of the cultivated area (Table 2-19).

In the northeastern parts of Niger, rain-fed agriculture is generally carried out. In particular, water harvesting is introduced to agriculture in the valleys where runoff water is apt to concentrate. In the Keita Valley in mid-southern Niger, soil erosion and land degradation became serious due to rapid population growth and resultant excessive deforestation. The Niger government started comprehensive regional development activities with aid from FAO, etc. and is positively promoting the greening of this valley. The basis of the greening project is water harvesting technology. By this method the desert areas with sand dunes and rocks have been turned into areas where trees and crops can grow. The method of irrigating valley bottoms by water spreading through weirs constructed on wadis is also employed and seems to be relatively effective.

(4) Nigeria

Rainfall in Nigeria is about 1,500-3,000 mm in southern areas and about 600 mm in northern parts. The evapotranspiration has a similar distribution pattern to that of rainfall ; it is 1,400 mm the southern borders and 635 mm on the northern border. Nigeria's total average rainfall is 1,400 mm, of which about 1,067 mm is lost by evapotranspiration and the remaining 330 mm becomes surface and subsurface runoff. The climatic zones change from the equatorial forest zone to the Guinea savanna and Sudan savanna zones from south to north. While this country is relatively blessed with rain, its problem is how to secure adequate water in the dry season since rain falls much more in the rainy season. Its main rivers are the Niger and its tributary the Benue. As Table 2-22 shows, the country's renewable surface water resources are as much as 280 km^3 (per capita water resources : 2,300 m^3) including inflow from other countries. Nigeria has continued irrigation projects for the purpose of using this river water but these projects are still few in number. Thus considering its rainfall and river discharge, the country has a fairly high potential for irrigation development. Its irrigated area is estimated at 233,000 ha in 1998, the largest in West Africa, but the percentage of irrigated area is as low as 0.8% (Table 2-19).

A representative water resource development project in Nigeria is the construction of the Kainji Dam on the Niger in 1969. This dam which rises to a height of 66 m, is a multipurpose dam having the function of flood control and irrigation though its main purpose is power generation. The 12 generators supply a total of 960 megawatts of electricity. The dam provides irrigation water to large sugarcane plantations in Bacita, a little downstream district from Jebba. In the Sokoto-Rima River Basin, the power produced from this dam is used for pump irrigation. In addition, in the man-made lake created by the dam construction (1,300 km^2), an inland water fishery was started and has achieved a yearly catch of 10,000 tons. Another dam was constructed in Jebba and increased the power generation and irrigation water supply capacity.

In Nigeria, many floodplains are formed along the Niger, Sokoto-Rima, Yobe and Benue Rivers. These floodplains are also known as fadama land in Hausa and have a high irrigation potential. In these areas, it is possible to carry out controlled submersion in the flood season, and lifting from tubewells and direct pumping from rivers in the dry season. It is estimated that the country has about 1.8 million ha of irrigable floodplains (Mijindadi, Umar and Tyem, 1993). Nigeria is the largest rice producer in West Africa and once achieved complete rice self-sufficiency. But the self-sufficiency ratio has been declining recently for several consecutive years and was 75% in 1998 (Fig. 2-45).

(5) Senegal

Senegal is mostly in the Sudan savanna zone except a few districts in the southern part belonging to the Guinea savanna zone. Its annual rainfall ranges from 1,500 mm in Ziguinchor in the south to 330 mm in Podor in the north.

Several irrigation projects are now in the planning stage in Senegal, mostly in the Senegal basin. Already completed schemes in this basin include the Richard Toll Irrigation Project well known as a successful case of rice cultivation. Also known as the Delta Irrigation Project, this project constructed the Richard Toll Barrage on the Taoue River, a tributary of the Senegal flowing into Lake Guiers, and built banks around the flatland of 5,600 ha on the downstream side of the confluence of the two rivers. A 100-km irrigation canal was also constructed to irrigate the flatland. A long drainage canal and pumping system were also built. In the flood season (June to August), the gates of the barrage are opened to store flood waters in Lake Guiers and when the flood begins to recede, the gates are shut to prevent stored water from flowing into the Senegal. The stored water is pumped up and used for irrigation in the

Richard Toll Scheme. In the dry season, seawater goes upstream in the Senegal but by shutting the Richard Toll Barrage, it is possible to prevent this seawater from flowing into the Taoue River and Lake Guiers. In this district, not only rice but also sugarcane are cultivated.

In the delta area on the downstream side of the Richard Toll Scheme, agricultural development activities are now promoted by the polder method but there are problems of saline soils and poor drainage. In the Senegal basin on the upstream side of the scheme, the traditional growing of sorghum, rice, sweet potato, maize, tomato and legumes is carried out by recession irrigation and controlled submersion. In recession irrigation, cropping is carried out immediately after the flood has receded from October to January from the alluvial land of several tens of thousands of hectares. This system became inapplicable because floods no longer occurred after the Manantali Dam was completed in the upstream section. But because farmers wanted to continue this system, recession irrigation is now continued by discharging water from the dam in the flood season to cause artificial floods. But this irrigation system is destined to disappear in this area sooner or later (FAO 1986 b).

The Gambia River basin is another important basin for irrigation projects together with the Senegal basin. This river is an international river, having its sources in Guinea and Senegal and running westward through central Gambia into the Atlantic. Its catchment area is 75,000 km^2 and its average annual discharge at Goulombo is 9.5 billion m^3 (300m^3/s). For the development of the Gambia basin, the riparian countries created the Organisation pour la Mise en Valeur du Fleuve Gambia (OMVG : Gambia River Development Organization).

Senegal's irrigated area is estimated at 71,000 ha or about 3.1% of the cultivated area in 1998 (Table 2-19). Rice and sugarcane are the main crops of irrigated farming. Rice is grown mostly in the Casamance River basin in southern Senegal and in the Senegal basin. But the country's rice self-sufficiency ratio is low, below 20% (Fig. 2-45). The main irrigation problems facing Senegal are the backward flow of seawater in the rivers and the accumulation of salts in soils.

(6) Ghana

While almost all parts of Ghana belong to the Guinea savanna zone, the northern areas and the southeast coastal plains including Accra, the capital, are in the Sudan savanna zone. The country's annual rainfall ranges from 600 mm (in the north) to 2,200 mm (in southwestern parts) and tends to be high in the south and low in northern districts. The dry coastal area is known as the Accra dry zone with a yearly rainfall of about 800 mm.

Ghana has surface water resources enough to meet the need of future economic plans and its average annual renewable surface water resources are estimated at 53.2 billion m^3 (Table 2-22). The largest river is the Volta, which has an average annual discharge of 37 billion m^3 (historic maximum : 96.2 billion m^3 ; historic minimum : 12.3 billion m^3) and an average runoff of 8.7%. In particular, the basin of the Oti River, a tributary, is only 18% of the Volta's total catchment area but its runoff makes up as much as 30-40% of all. Ghana's irrigation water consumption was 162 million m^3 in 1970 but increased to 349 million m^3 in 1980. The figure for 2000 had expected to be about 1.78 billion m^3 (Framji et al., 1983).

Ghana's representative water resource development project is the Volta River Project. The main facility constructed by this project is the Akosombo Dam with a dam height of 134m completed in 1966. This dam mainly aims at power generation ; six generators, each with a capacity of 150 megawatts, produce a total of 800 megawatts of electricity. This electricity is not merely consumed at home but is exported to neighboring Togo and Benin. In the areas around Lake Volta that is as large as 8,000 km^2, water pumped up from the lake is used for irrigation. In the dry season when the lake's water level falls, a variety of food crops are grown in the wet lake shores emerging on the water surface. This growing method is known as drawn-down farming and these crops are shipped in the period of short supply at higher prices. Inland water fishing in Lake Volta brings an annual catch of 40,000 tons and is a valuable alternative source of protein food for Ghana facing the problem of tsetse fly.

In the 40-km downstream section of the Akosombo Dam stands the Kpong Dam. Storing the water discharged from the Akosombo Dam for power generation, this dam produces 140 megawatts of power and supplies water to irrigate sugar cane and rice in the Accra Plain. The total irrigated area will ultimately reach 8,000 ha.

On the Black Volta River in the upstream section of Lake Volta the Bui Gorge Dam was constructed, which supplies irrigation water to the Black Volta Valley.

The Akosombo Dam has a problem : its watersheds mostly belong to the Sudan savanna zone and the water stored in the dam has tended to decrease recently because of drought in the watersheds, resulting in less power generation. In addition, the 7,000 km of shallow waters along the Lake Volta shore provide Bulinus, an aquatic snail that serves as the transmitting vector of bilharziasis, with good habitats; as a result, schistosomiasis is prevalent and controlling this snail has become an urgent problem.

Irrigation has only a short history in Ghana; modern irrigation projects were started with small-scale irrigation schemes in northern savanna areas in 1953. It has been reported that in the south, water is pumped up from the Volta River to irrigate several schemes including the Lower Volta Irrigation Project under sugarcane(3,240 ha). In northern areas, there are two types of irrigation projects. One of them is gravity irrigation by many dams and examples include the Vea, Pasam and Tono projects. The other is the above-mentioned irrigation schemes in the areas around Lake Volta in which irrigation water is pumped up from Lake Volta. In 1988, Ghana's irrigated area was 8,000 ha or 0.2% of cultivated area and the figures for 1998 were estimated at 11,000 ha and 0.2%, respectively (Table 2-19). The country's rice self-sufficiency ratio was only 45% in 1998 (Fig. 2-45) and it is hoped that rice growing will be more encouraged in the future. A future task is to promote the dissemination of basic knowledge of irrigated farming among farmers.

(7) Côte d'Ivoire

The southeastern parts of Côte d'Ivoire belong to the equatorial forest zone and all the other areas, to the Guinea savanna zone. Because of this, the country is blessed with ample water resources. Its renewable surface water resources are 77.7 km^3 and its per capita water resources are as much as 5,334m^3 (Table 2-22). In addition, 99% of these resources are runoff at home, allowing the country to carry out water resource development on its own without being affected by other countries.

The main rivers are the Bandama (that has the largest basin), Komoe, Sassandra and Cavally rivers, all of which run southward and flow into the Gulf of Guinea. The high water season at the middle and lower reaches of these rivers is September and October when the summer rainy season ends; their average annual runoff is 13.0 km^3, 7.7 km^3, 9.6 km^3 and 2.5 km^3, respectively (UNESCO, 1969). Since the development of these water resource lays stress on power generation, water resources development for irrigation purposes should be promoted more in the future. The country began to introduce irrigation as recently as the 1970s, and its irrigated area in 1989 was only 62,000 ha (sugarcane, 33,000 ha; rice, 20,000 ha, fruit trees, 5,000 ha; vegetables, 4,000 ha) or less than 1% of the cultivated area (Boka and Bakan, 1989). The figures for 1998 were an irrigated area of 73,000 ha and 1.0% of cultivated area (Table 2-19).

Irrigated sugarcane cultivation is a state-level project. To eliminate regional gaps, it is promoted in the central and northern parts of the country, and is carried out and managed by the government corporation. Two irrigation methods--sprinkler irrigation and center pivot irrigation systems--have been introduced. Employment opportunities at the sugarcane farms provide local residents with large incomes (Boka and Bakan, 1989).

Irrigated rice production, which was initiated through the technical cooperation by the Taiwan team (Hsieh 2001), is observed mainly in valley bottom alluvial plains in the river basins in the south and lowlands known as bas-fonds using water from small rivers. In some cases, small dams are also used. This rice growing is as small in scale as 10-15 ha or so and is relatively inexpensive except dam construction cost. There is a great possibility of rice cultivation by water control in the lowlands and it is estimated that up to 40,000 ha of new irrigated fields could be developed by 2000. At present, the average paddy yield of irrigated sawah is 3.5t/ha, a satisfactory level for a short history of irrigation. Rain-fed rice cropping is adopted chiefly for upland rice, which is extensively observed in western and northwestern Côte d'Ivoire. Studies on the supply of irrigation water to rain-fed fields continue and a relatively high yield (about 3t/ha) seems to be realized by this method (Boka and Bakan, 1989). The harvested area of rice increased from 286,000 ha in 1970 to 461,000 ha in 1980, and in the 1980s and after, rice production development projects were promoted mainly in the upper and middle basins of the Bandama River and in the basin of the Bou River, a tributary of the Bandama (JIID, 1985). As a result, the rice harvested area reached 750,000 ha in 1999 (FAO, 2000). But the self-sufficiency ratio in recent years is still 65% or so and its yearly fluctuations are great (Fig. 2-45). Therefore, the country should continue to improve its rice growing infrastructure to attain higher self-sufficiency ratios.

Irrigation for fruit trees is carried out by the private sector mainly for pineapple and banana and no government subsidies are provided. In general, fruit tree irrigation is introduced only supplementally but the drip irrigation of banana by a private enterprise has produced satisfactory results (Boka and Bakan, 1989).

Côte d'Ivoire is a pure vegetable importer and so makes efforts to encourage domestic vegetable growing. It introduces irrigation for vegetable cultivation and has a special mechanism for assisting vegetable growers in the selection, cultivation and sale of vegetables. The largest vegetable producing area exists in the north where 1,800 ha of land has so far been developed. The tomatoes harvested there are supplied to the factory to make concentrated tomato juice. Since the supply of tomato is less than the factory's capacity, there is a need to increase tomato production: thus tomato cultivation by small farmers' groups in farmland around the factory and irrigated tomato production in the lower basins of dams are carried out. Farrow irrigation and sprinkler irrigation are the main methods applied to vegetable growing. In other areas, vegetable farms are being developed for the production of vegetables for consumers. Irrigation networks are maintained by farmers' organizations (Boka and Bakan, 1989).

(8) Liberia

Liberia is entirely in the equatorial forest zone and has an annual rainfall of 2,000 mm or more. Therefore, this country's river discharge is large and rivers never dry up even in the dry season though there are large gaps in discharge between the rainy and dry seasons. Its renewable surface water resources are 232.0 km^3 and its per capita water resources are as much as 84,425 m^3 (Table 2-22). Development projects have mainly been large-scale ones but have not always been very successful due to financial and other reasons. Medium- and small-scale development plans have recently been revalued but these are not making rapid progress, either, because of political unrest.

The development of the River Mano that runs along the border between Liberia and Sierra Leone was started in 1975 by an aid from the EC. This project aimed at both power generation and irrigation, and the two riparian countries formed the Mano River Union (MRU) together with Guinea in 1973 for this development scheme (JIID, 1985). However, the project has been abandoned owing to MRU's disintegration after the 1989 outbreak of Liberia's civil war, followed by conflict from 1991 in Sierra Leone.

Liberia's irrigated area in 1999 was only 3,000 ha or 0.8% of the cultivated area (Table 2-19). If the country makes good use of its ample water resources, its agricultural production will increase greatly. Its harvested area of rice in 1999 was 163,000 ha, almost all of which are rain-fed upland/lowland continuum fields. Liberia's rice self-sufficiency ratio was 24% in 1994 but rose quickly after that, attaining full self-sufficiency in 1997 and 1998 (Fig. 2-45). In the future, the country should improve rice production infrastructure further for introducing double cropping to realize stable domestic supply and export to neighboring countries. It is considered that the country has many rice growing districts where rice double cropping can be adopted just by introducing simple irrigation systems.

(9) Sierra Leone

Sierra Leone is entirely in the equatorial forest zone and has an annual rainfall of 2,000 mm or more except a few districts in the north where the rainfall is less than 2,000 mm. In this country, many rivers run in parallel southwestward and provide sufficient water resources not merely for farming but also for other purposes. Not many surveys have been conducted on the river discharge and little reliable data on this are available, but an investigation by the World Resources Institute (1999) reveals that the country's renewable surface water resources are 160 km^3 and per capita water resources, as much as 35,000 m^3 (Table 2-22). Sierra Leone was a member country of the MRU to promote economic cooperation with Liberia and Guinea through the exploitation of the River Mano, but significant progress has not been achieved in water resource development yet due to the prolonged civil war.

Though this country is rich in water resources, its agricultural production has substantially decreased owing to the civil war since 1991 and its agricultural sector has collapsed. But recently some encouraging signs of settlement of conflicts are in sight, including the conclusion of a peace agreement, and moves toward economic reconstruction as well as restoring the MRU are expected.

Irrigation has been introduced only on a limited scale and is a future task for the country. In 1998, the irrigated area was 29,000 ha or only 5.4% of the cultivated area (Table 2-19). While the country has a high potential for rice growing, its rice self-sufficiency ratio in the 1994-1998 period was less than 50% on average as shown in Fig. 2-45. Rice has traditionally been planted in the rainy season mainly in upland and inland valley continuum. Rice is also grown in mangrove swamps around estuaries but how to prevent salt injuries due to the backward flow of seawater is a problem to be solved. In the future, the country will need to strengthen its infrastructure to introduce sawah based rice culture and some double cropping in inland lowlands known as boliland as a way to reconstruct its economy.

(10) Burkina Faso

Burkina Faso is almost all in the Sudan savanna zone except some parts in the south that belong to the Guinea savanna zone. The annual rainfall tends to reduce in northern parts : it is 1,100 mm to 1,200 mm in the south but only 360 mm in the north. In addition, this country's yearly rainfall has recently been decreasing. For example, its rainfall is lower by about 300 mm in the south and by about 100 mm in the north as compared with that of 1970 and before. The country's renewable surface water resources are 17.5 km^3 and per capita water resources, 1,535m^3, the lowest in West Africa (Table 2-22).

Burkina Faso's agricultural production suffered heavy damage due to severe droughts which in the early 1970s and 1980s. Because of this, the government strongly realized the need of irrigation development and is making great efforts in this field. The government operated irrigation projects are mostly small scale. A commonly observed method is to store rain water and runoff by constructing dams on rivers and to feed the water to lower parts and use it for crop cultivation. In swamps or lowlands known as bas-fonds, small banks are built along the contour for each difference in altitude of 15 cm to catch water and supply it from higher to lower parts. If the field in the higher level is filled with water, the excess water overflows into a lower field. In some cases, banks about 70 cm high are built around the project site to prepare for floods. Another pattern is to establish a drainage canal in the center of the project site to provide for an abnormal flood (FAO 1986 b). By this method, it is possible to develop up to several hundred hectares of fields. Considering the fact that the land damaged by floods used to be abandoned, it is especially important to check and examine the capacity of facilities against abnormal rainfall. In Burkina Faso, the catchment area surrounding a project site is restricted to 30 km^2 (FAO 1986 b).

Burkina Faso's irrigated area is as small as 25,000 ha or only 0.7% of the cultivated area (Table 2-19). The country's rice self-sufficiency ratio was less than 30% in 1993 and before and then gradually rose, reaching 50% in the 1995-1997 period. But it again fell to nearly 30% in 1998 (Fig. 2-45). Since the country's rice consumption has recently increased at a yearly rate of 12%, it has striven to breed more productive varieties and to develop irrigated sawah fields in swamps. Burkina Faso farmers are strongly interested in irrigated farming and are highly adaptable for it ; high hopes can be placed on the future progress of irrigation in this country. Taiwanese team has developed about 2600 ha of irrigated sawah systems at Kou valley, Louda and Bagre by the end of 2000 (Hsieh 2001).

5-6. Problems of irrigation development

The problems to be considered in promoting irrigation development in Africa can be summarized as follows:

1) In the light of past economic analyses, priority should be given in Africa to small-scale irrigation projects for rural communities, which are not very costly and can easily be maintained. In addition to small-scale schemes, FAO recommends medium-scale irrigation projects of 100-10,000 acres (40-4,000 ha).

2) From cost-benefit viewpoints, the projects that need small investment and offer high effects should be given priority as much as possible. For example, traditional semi-irrigation observed in the flood plains of large rivers is rather unstable but becomes effective by adding some improvements in many cases. In addition, it is argued that in Africa, irrigated rice and other food crops can be produced in at least 30 million ha of wetlands if simple irrigation or water control is provided (Dat, 1986). The rehabilitation of old existing irrigation systems could achieve great effects with a small amount of investment.

3) There is a need to reinforce the collection and filing of accurate basic hydrological and climatic data. In particular, the data of medium and small rivers suited to the supply of irrigation water will become important in the future. Sufficient care should also be taken to consider long-term climatic changes in planning irrigation projects. Remote-sensing technology should be used more in the future.

4) To offset irrigation development costs, efforts should be made to maximize crop yields. Therefore, from the planning stage, construction and farming should be regarded and studied as inseparable elements. What is especially needed is to ensure farmers' full understanding of irrigation.

5) In arid areas, irrigation is liable to cause salt accumulation and waterlogging. Thus adequate measures against these should be studied at the planning stage. Special care should be taken for the proper location of drainage facilities and for water management.

6) Irrigation development may invite the occurrence of water-borne diseases and endemics diseases. Sufficient preventive steps should be taken. In Egypt, as a result of the construction of the Aswan High Dam and the development of irrigation canals, Schistosome haematobium and Schistosoma mansoni, whose transmitting vectors are aquatic snails, broke out. In West Africa, schistosomiasis occurs in the areas around the Akosombo Dam on Lake Volta in Ghana. In the Volta basin, the occurrence of river blindness (Onchocerniasis), which is transmitted by gnats, has long been observed when farmers reclaimed new land. This disease is finally being prevented by a WHO project.

(Yoshinobu Kitamura)

Table2-23 Average natural abundance of hydrogen and oxygen in the earth's crust

Element	Isotope	Abundance (%)
Hydrogen	H	99.9850
	D	0.0149
Oxygen	^{16}O	99.759
	^{17}O	0.0374
	^{18}O	0.2093

6. Oxygen isotope composition of natural water in West Africa

6-1. Introduction

Water molecules (H_2O) are compounds with a low molecular weight composed of hydrogen and oxygen. Water always exists in the earth's crust and causes various substances to dissolve in it. The quantity of these dissolved solutes is rated as the measure of water quality. On the other hand, it is well known that to pursue the geochemical behavior of water on the earth's surface, it is effective to pay attention to the difference in the mass numbers of hydrogen and oxygen atoms ; which compose water molecules, in addition to the properties of the dissolved constituents. This is because of the particles composing an atom, protons and neutrons in the nucleus have mass but electrons with negative electric charge that turn around the nucleus do not. Table 2-23 shows the average abundance of hydrogen and oxygen in the earth's crust (natural abundance of isotopes).

These isotopes have the same number of protons in the nucleus and so have the chemical properties peculiar to hydrogen and oxygen. However, their physical and chemical properties differ, though slightly, according to the difference in the mass numbers of the nucleus, thus causing differences in behavior between molecules containing different isotopes (e.g., the phenomenon that molecules having different isotopes do not show behavior of equivalent values in evaporation, diffusion and precipitation), that is, isotopic fractionation. This phenomenon is known as an isotope effect. Recently with the progress of sensor and electronic technology, it has become possible to measure precisely even slight isotopic differentiation that occur in natural chemical reaction systems.

The main sources of water on the earth's surface are oceans, especially those in the tropics. The vapor is given solar energy and moves to areas of higher altitudes, where it is cooled and saturated and then falls on the ground as rain, which finally returns to oceans via rivers. This process is known as the geochemical cycle of water on the earth's surface.

According to the previous studies on the temperate zones, the hydrogen-oxygen isotope compositions of rainfall is affected by such factors as latitude, altitude, topography, distance from the coast and rain intensity. The weighted average of the composition of rainfall in an area is ultimately reflected on shallow groundwater and so the composition shows roughly an average value throughout the year.

Supplying irrigation water for at least three months in a row is essential to the cultivation of rice in sawah. It is supposed that in West Africa, except the basins of some large rivers, irrigation water for rice growing is supplied mainly by groundwater. For the study on mechanism of the water cycle using the stable isotopes of hydrogen and oxygen, it will be important to compile the analytical data of natural water samples. However, as far as the author knows, almost no data of the hydrogen-oxygen isotope composition of natural water (river water, shallow groundwater, spring water, rain water, etc.) that cover the broad areas of West Africa have been published.

This section reports the result of investigation of the geographical differences in the oxygen isotope composition of the natural water samples, which were collected during survey trips on the rice growing environment in West Africa during the rainy season from July to August 1993. Similar analyses were also conducted on some water samples collected by Shohei Hirose in the Gadza area, Nigeria, in the dry season in late December 1995.

6-2. Collection of water samples and measurement of their oxygen isotope composition

The samples were collected during the rainy season from late June to August 1993 and in the dry season in late December 1995. Samples were collected in glass vials with a double stopper, the stopper was immediately put in the vials and plastic tapes were used to seal up the vials.

The oxygen isotope composition of these water samples was measured with the continuous-automatic analyzer installed at the Institute for Study of Earth's Interior, Okayama University in Misasa, Tohaku-gun, Tottori Prefecture. After 2 ml of the sample water was put into a glass shaking container together with carbon dioxide gas, the container was shaken for 4 hours at 25°C to cause the sample to reach an isotopic equilibrium. Thereafter, the carbon dioxide phase was purified and introduced into a mass spectrometer to measure the $^{18}O/^{16}O$ ratio. The oxygen isotope composition thus measured as shown as a deviation in permil from the Vienna Standard Mean Seawater (V-SMOW) issued by the International Atomic Energy Agency (IAEA). The measuring accuracy is +0.1 (‰).

6-3. Oxygen isotope composition of natural water in West Africa

The analyzed result of the oxygen isotope composition of representative natural water samples collected in various parts in West Africa is shown in Table 2-24. According to the table, the composition of oxygen isotopes of natural water in

Table2-24 Oxygen isotope composition of natural water in West Africa

sample NO.	sampling site		Country	Town/village	sampling date	Water source	composition of Oxygen isotope	Remarks
	Latitude	Longitude						
1			Nigeria	Ibadan	July.24	Dam	−0.6	IITA Dam
36			Nigeria	Dosso	Aug.2	Well	−5.5	Mach. bored
66			Nigeria	Ibadan	Aug.20	Well	−3.2	Hand dug
69			Nigeria	Ilorin	Aug.22	Well	−3.7	Hand dug
44	13°6′N	1°44′E	Nigeria	Magou	Aug.3	Well	−4.6	Mach. bored
47			Burkina Faso	Tanchari	Aug.5	Dam	−2.2	Agr. Dam
48			Burkina Faso	Fada-N'Gourma	Aug.5	Well	−3.3	Hand dug
51			Burkina Faso	Ouahigouya	Aug.6	Dam	−0.3	Agr. Dam
52			Burkina Faso	Boromo	Aug.7	Dam	−0.9	Agr. Dam
55			Burkina Faso	Bobo Dioulasso	Aug.8	River	−4.4	Running water
56			Burkina Faso	Bobo Dioulasso	Aug.8	Irrig. canal	−2.3	Sawah field
57			Burkina Faso	Donde	Aug.8	Well	−4.8	Mach. bored
58			Cote d'Ivoire	Ferkessedougou	Aug.9	River	−3.0	Sawah field
60			Cote d'Ivoire	Bouake	Aug.10	Dam	+3.6	canal WARDA

Table2-25 Oxygen isotope composition of sampled area

Area	Composition of oxygen isotopes (%)	
	Well water/ river water	Dam water/ irrigation canal water
Central southern Nigeria	−3.7～−3.2	−0.6
Southern Niger	−5.5～−4.6	-
Bunkina Faso	−4.8～−3.3	−3.3～−0.3
Cote d'Ivoire	−3.0	+3.6

this region ranged widely from −5.5 to +3.6 (‰). Compared with, for example, the figures for natural water in a temperate zone like Japan (−12 to −6 ‰), the oxygen isotope composition of the samples taken in West Africa is characterized by an abundance of heavy oxygen (^{18}O). To analyze the factors of such a wide range in the composition observed in these samples, the analyzed result is summarized in Table 2-25 according to sampling site and water source.

For shallow groundwater (well water) and river water, the composition of the samples from central southern Nigeria and Côte d'Ivoire, which are near the Gulf of Guinea considered to be the major source of rain in these areas, is clearly higher than that for southern Niger and Burkina Faso, which are situated in more inland areas. This can be explained as follows: the wet marine air mass derived from the Gulf of Guinea invades land areas, forms cloud particles and advances while bringing rain. In this process, heavy oxygen isotopes are selectively removed as rainfall, resulting in a lack of heavy oxygen in rains in inland areas. The value of the river water sample collected in Burkina Faso (sample No.55 ; −4.4 ‰) is very close to that of the sample from a deep well (machine-bored well) in the country (sample No.57 ; −4.8 ‰). In addition, the tendency is observed that water from hand dug wells (10 m or less deep) in the country is richer in heavy oxygen than water from bored wells (30 m or more deep in general).

In the survey sites, rains mainly fall in the June-August period, the summer season in the northern hemisphere. About nine months excluding these three months are the dry season when it is supposed that there will be much evapotranspiration from the soil surface. This supposition is also supported by the fact that the samples from dams and irrigation canals are richer in heavy oxygen than those from wells (shallow groundwater) in the country. This is important in that it suggests the possibility that whether the source of the surface runoff is cultured directly by groundwater or is the one that has once came out on the soil surface and has then evaporated may be revealed by measuring the oxygen isotope composition.

6-4. Oxygen isotope composition of natural water around the City of Bida in central Nigeria

(1) Outline of the survey area

The area around the City of Bida, Nigeria, is composed of peneplains formed by eroded Cretaceous sand and shale (known as Nupe sandstone). The average

Table2-26 Oxygen isotope composition of the natural water collected around Bida, Nigeria

Sample NO.	Sampling village	Sampling date	Water source	Oxygen isotope composition	Remarks
2	Gadza	July 27	Well	−3.8	Hand dug
3	Gadza	July 27	Small water	−3.2	Experiment Sawah field
4	Boku	July 27	Ponding water	+1.1	Sawah field
5	Doko	July 27	Well	−3.9	Hand dug
6	Emigugu	July 27	Well	−3.7	Hand dug
8	Eminambari	July 28	Well	−3.6	Hand dug
9	Sodangi	July 28	Well	−3.9	Mach. bored
10	Sodangi	July 28	Small river	−3.3	Running water
11	Ndaba	July 29	Well	−3.9	Mach. bored
12	Tsaudu	July 29	Well	−3.8	Mach. bored
13	Ndakpantago	July 29	Well	−4.6	Mach. bored
14	Kagowogi	July 29	Well	−4.3	Mach. bored
15	Zanchita	July 29	Well	−4.0	Mach. bored
16	Gbanguba	July 29	Well	−3.7	Mach. bored
17	Gbanguba	July 29	Well	−4.0	Mach. bored
18	Patitagi	July 29	Well	−3.9	Mach. bored
19	Elagi	July 29	Well	−3.7	Mach. bored
20	Kosotukpa	July 29	Well	−4.0	Mach. bored
21	Sonkpata	July 29	Well	−3.9	Mach. bored
26	Kusotatci	July 30	Well	−3.8	Mach. bored
27	Ndaijingosan	July 30	Well	−4.0	Mach. bored
28	Gusadin	July 30	Well	−4.0	Mach. bored
29	Pichi	July 30	Small river	−4.9	Running water
30	Jima	July 30	Well	−3.6	Hand dug
32	Bida	July 31	Large river	−4.8	Kaduna River
33	Bida	July 31	Small river	−3.5	Gbako River

altitude is about 150 m and a peculiar topography formed by eroded sandstone (Mesa) is observed in the southwestern part of this area. As if to sandwich Bida between them, the Kaduna and Gbako Rivers run from north to south (see Fig 6-4 and 6-5). Main soils distributed in the area are strongly affected by these sedimentary rocks ; sandy Red soil is seen in terraces, while wet Regosol mostly composed of quartz sand is observed in lowlands around small valleys.

In natural conditions, Bida and its environs are not blessed with good-quality water for daily life, and small rivers dry up in dry season. To cope with this problem, modern machine bored wells have been constructed all over this area since 1989 at a fairly high density by technical assistance from Switzerland and Japan. These wells are equipped with hand pumps of the push-up type and the clear and good-quality shallow-layer groundwater pumped up from these wells is used by residents as daily water. In this study, the local office of Tone Boring Co. Ltd. provided us with topographical maps of 1 : 50,000 showing the location of these wells. It was not impossible to print the map for several reasons. We tried to get a map of about 1: 250,000 to indicate the sampling locations both in the survey area and in Japan but failed to do so. Table 2-26 shows the names of the villages where the water samples for this study were collected (If the reader wants to know the sampling sites in more detail, the author are ready to supply him or her with the copy of the map of the related districts).

(2) Analysis and discussion

The oxygen isotope composition of shallow groundwater, river water and water from sawah fields sampled in the areas around Bida is shown in Table 2-26.

The composition of the five shallow groundwater samples from hand dug wells taken in 1993 has a relatively narrow range from -3.9 to -3.6 ‰ (n=5 ; average : -3.7+0.1 ‰). The well water samples collected in 1995 show a similar composition, too (Table 2-27). These wells were bored by local farmers and even the deepest ones are only 10m or so. It has been known that in some areas, hand dug wells dry up in the dry season. By contrast, the shallow groundwater samples from the 14 machine bored wells have the composition between -4.6 and -3.7 ‰ (n=14 ; average : -4.0±0.2 ‰), indicating that they are slightly lighter than the groundwater from the hand dug wells. The part beneath the ground surface is sealed in machine-bored wells and is opened in hand dug ones. The reason that groundwater from hand dug wells is a little richer in heavy oxygen can be explained as the result of some of light oxygen-containing water evaporating from the well top. Of the samples from the machine-bored wells, Sample No.13 was the lightest. The topographical and other natural conditions of location of the No.13 site were examined but no cause that could explain this specificity was identified. The value of the composition of these groundwater samples is roughly between those of the two rivers running southward on the

Table2-27 Oxygen isotope composition of natural water samples collected in Bida, Nigeria

Sampling date	Water source	Oxygen isotope composition	Remarks
Late December	Well	−3.7	Well in central Gadza
〃	〃	−3.8	Southern end of Gadza
〃	〃	−3.7	Floodplain of the Kaduna River
〃	Ponding water	−0.8	Severe iron toxicity of Sawah rice
〃	〃	−1.0	〃

Table2-28 Oxygen isotope composition of rainwater samples collected in Bida

Sampling date	Time	Precipitation	Oxygen isotope composition
Juy 29	22 : 00	About 1mm	−1.1 (%)
	Until 22 : 30	35mm	−6.0
	Until 23 : 00	3mm	−6.3
	Until 24 : 00	10mm	−6.1
August 4	About 20 : 00	No data available	−4.3
August 20	23 : 00-24 : 00	About 150mm	−2.6

eastern and western sides of the area : the Kaduna River (-4.8 ‰) and the Gbako River (-3.5 ‰) with a much less discharge than the Kaduna. It is supposed that the water of the two rivers moves, disperses and mixes the underground storage layers. The water from a small river in Pichi village (sample No.29, -4.9‰) was the lightest of all the samples analyzed. Because this river usually has almost no running water, the sampled water is supposed to be mostly from the heavy rain the previous day (described below).

Strongly affected by evaporation, the ponding water from a irrigated rice producing area in the alluvial lowlands along the Kaduna (sample No.4 ; +1.1 ‰) is much richer in heavy oxygen compared with the groundwater and river water in the neighboring areas. A similar tendency can be observed in the samples of the ponding water that has heavy excess iron damage to irrigated rice, which were collected in late December, 1995 (Table 2-27).

During the survey period in the summer of 1993, some samples of rainwater could be collected preliminarily since the survey area was in the rainy season. Unlike the rain observed in the temperate zones, rain in this area has the characters of tropical rainfall, that is, heavy thunderbolts and high rain intensity per hour. The oxygen isotope composition of the rainwater samples collected in Bida in 1993 is shown in Table 2-28.

From the analysis of these samples, it was supposed that their oxygen isotope composition has a fairly wide range from -6.3 to -1.1 (‰) according to the weather conditions at the time.

6-5. Summary

The composition of oxygen isotopes of the natural water samples collected in various parts of West Africa (Nigeria, Niger, Burkina Faso and Cote d'Ivoire) in July and August 1993 during the survey on the rice cultivation environment was noted. The composition of the shallow groundwater and river water samples taken in such a large region has a relatively narrow range of −4.8 to −3.0 ‰. These values are peculiar to the tropics and clearly show that these samples are heavier than those of the samples collected in the temperate zones like Japan.

The composition of shallow groundwater around Bida, Nigeria, has a range of −4.6 to −3.6 ‰, which suggests the existence of uniform underground storage layers. The composition of the groundwater samples collected in Bida in the dry season of 1995 is similar to that of the rainy season samples and from this it is supposed that groundwater in this area has a definite composition all the year round.

By the strong impact of evaporation in the tropical climate, dam water, irrigation canal water and ponding water are very rich in heavy oxygen. The water affected by evaporation can clearly be distinguished from fresh groundwater by its oxygen isotope composition. It is hoped that a similar water analysis is tested in the sawah-based rice growing environment.

(Chitoshi Mizota)

Chapter 3

Traditional Agriculture and Crop Production

—Case studies in the Guinea Savanna Zone

1. Rice and upland farming in the Nupe community

1-1. Introduction

The total area of wetlands (coastal swamps, inland basins, flood plains and inland valleys) in tropical Africa is as much as 240 million hectares (Hekstra & Andriesse, 1983). From the rice farming area in West Africa estimated by WARDA (1988), it is supposed that only a small part of these wetlands has been used. But inland valleys in West Africa have a good hydrologic environment and a wide distribution and are regarded as the most promising ecosystems for rice cropping for the future.

IITA conducted an on-farm study on rice farming in these inland valleys in West Africa for three years from 1986 (IITA, 1987; Wakatsuki, 1988, 1990a, 1990b; Wakatsuki *et al.*, 1987, 1988). Andriesse & Fresco (1991) and Windmeijer & Andriesse (1993) also reported the results of their studies aiming to express the rice-farming environment of West African swamps by a set of indexes.

On the basis of their study results, Windmeijer & Andriesse (1993) pointed out that the "Green Revolution" of rice and wheat was successful in Asia but would not necessarily be a right solution to the food problems in Africa. As part of the reasons for this, they cited many environmental factors existing in Africa, such as irregular rainfall patterns, as well as social and economic factors. Then they suggested that there was great potential for rice-based agriculture on a rural community level in the inland valleys with a gently rolling topography distributed widely in West Africa. The recent high population pressure of the whole of Africa, including West Africa, and decreasing per capita food supply due to drought have led to a greater attention being given to unused wetlands by many researchers and administrators. However, there have been only a few reports that made concrete proposals for strategies to use inland valley watershed in real situations. Our realisation of this fact lay behind our present study. First of all, we would investigate, from the viewpoint of agroecology and farming techniques, the situation of the farming activities that are actually carried out in West Africa, i.e., rice and upland farming, forestry and livestock farming. Then, based on the result of the investigation, we would develop strategies for reviving the agricultural and forestry ecosystems of inland valley watershed areas. Our final goal was to establish an African-type rice farming technology that would be viable in the region.

We first studied the nature, farming activities and human environment of inland valleys and selected Gadza, a village in Niger State in Nigeria, as our survey site. We decided to conduct fact-finding surveys in this village and Nupe communities around it and then, based on the survey outcome, to examine the traditional rice and upland farming in the area as well as any problems that might arise in establishing improved technology.

1-2. Nature and diversity of inland valleys

(1) Inland valleys

As already stated, many wetlands exist in tropical Africa. These wetlands are classified into coastal swamps, inland basins, flood plains and inland valleys (or inland valley swamps). These wetlands provide many benefits to those who depend on their environment and resources in daily life. These include, for example, rice farming using floods, flood recession cropping and freshwater fishery. Of the four types of wetlands mentioned above, inland valleys have a great potential for rice cropping.

According to Windmeijer & Andriesse (1993), inland valleys "exist in the upper basins of the main river or a tributary." Raunet (1985) divides inland valleys according to the course of the river into those located in the most upstream section (i.e., the headwaters) and in the midstream section (stream flow inland valleys), and those situated in the downstream section (river overflow inland valleys) (see also Chapter 2, 3-3, (1) and Chapter 6, 1-1).

(2) Complex hydrological environment and their elements

Inland valleys have their own scenic elements and water regimes according to their toposequence. According to Andriesse & Fresco (1991), the toposequence changes from uplands, which are at the highest location, to wetlands in the valley bottom, while the water source needed for plant growth is mainly rainwater at the top and in the high and middle parts of slopes and groundwater at the low parts of slopes. In the valley bottom, the source is rainwater, surface runoffs from the watershed area and seepage from underground/spring water as well as overflows from the river. Because of this, the soil on the valley bottom often becomes saturated, not only during the rainy season but after it as well. As noted, the hydrological environment of inland valleys changes according to toposequence, and the groundwater level naturally changes according to precipitation and evapotranspiration, which differ among different climatic zones. The depth and duration of flooded water on the valley bottom are affected by the topography of the inland valley, the length and incline of adjacent slopes, different level permeability of rocks, and the amount of precipitation. On the other hand, the topography of the inland valley is influenced by geological features and rainwater and shows diverse patterns.

(3) Physical and chemical properties of soil and related factors

The soil of inland valleys is strongly affected by toposequential location. According to Wakatsuki (1990a, b), it is known that the soil of inland valleys is generally very poor in nutrition but soil fertility is also greatly influenced by the position in toposequence, too. In the area around Bida in central Nigeria, which is located in the Guinea savanna zone with a yearly precipitation of 1,200mm, the parent material of soil is Nupe sandstone. While the soil in this area is very sandy as a whole, the soil in the high and middle parts of slopes has a low cation exchange capacity (CEC) and a low content of exchangeable Ca and clay, which indicates that the soil has been subjected to heavy erosion. On the other hand, on the valley bottom, the clay content (of the soil layers 0-20cm deep) is 16-21% and both CEC and the content of exchangeable Ca are higher than those on the slopes. In addition, the comparison of the soil fertility in Bouake, Cote d'Ivoire, which belongs to the same agricultural ecosystem (Guinea savanna zone) but has a different type of rocks, and that in Nigeria showed that the former had a higher level of soil fertility than the latter, both in the upper and middle parts of slopes and on the valley bottom.

Generally speaking, the soil fertility of upland areas depends on the correlations among the degree of cropping, weathering and surface erosion. On the slopes and valley bottoms of inland valleys, soil fertility sometimes increases as a result of colluvial action on the upper parts of the slope, but a problem comes up if the colluvial soil is poor in nutrition. The lateral movement of groundwater also causes nutrients to move to the lower parts of uplands, making the state of soil fertility very complex. On the valley bottom, there occurs the colluvial action of surrounding slopes but frequent flooding delays the decomposition of organic substances, resulting in an increase in the CEC of the surface soil. But at the same time flooding delays the mineralization of organic nitrogen and then increases denitrification as a result of soil repeated by becoming dry and wet, thereby lowering the availability of soil nitrogen (Windmeijer & Andriesse, 1993).

What has to be considered in the use of inland valleys is therefore how effective strategies (including the selection of crops) may be applied in such a complicated hydrological and soil environment. To achieve this, we will be able to learn much from the methods local farmers are using.

1-3. Division of cultivated land in inland valleys and its ecology

The ecology of West Africa is divided into the Sahel, Sudan savanna, Guinea savanna and equatorial forest zones according to the regional characteristics of annual precipitation (Figure 2-14). Precipitation is higher and drought stress is smaller in more southern areas. On the other hand, in more southern districts, the diurnal range of temperature is narrower and sunshine hours are shorter. These factors reduce solar radiation and bring about high humidity, often causing crop damage from diseases and insects and having negative effects on agricultural production. Cultivated land in inland valleys in the Guinea savanna zone is divided by toposequence and also by water regimes (seasonality of the rainy and dry seasons, water distribution, groundwater levels, etc.). In uplands in the rainy season, the main activities are the mixed cropping of grain crops for home-consumption and some non-leafy vegetables using shifting cultivation and fallowing. On the slopes in inland valleys with a good hydrological environment, rainfed rice farming and the cultivation of tubers and vegetables are carried out. Rainfed or irrigated rice farming is practiced in valley bottoms and the areas around them. In the dry season, the fields in uplands and in the upper and middle parts of slopes are left to lie fallow, and those in the areas adjacent to valley bottoms are used like the upland farms of cassava, sweet potato and various vegetables.

According to the survey conducted by Shimada *et al.* (1993) in the Kanconco dambo in Zambia, tomato, cucumber, watermelon, pepper and other non-leafy vegetables are grown during the dry season (April to October) and the land is fallowed in the rainy season in the areas around valley bottoms. But unlike situation in West Africa, no rice cultivation is carried out in these areas. In the uplands that are the watershed of the *dambo*, grains and legumes, the staple foods, as well as sunflower, watermelon, etc. are planted in the rainy season. As noted, the use of inland valleys differs from area to area.

1-4. Farming environment and livelihood in Bida and its environs in central Nigeria

Bida and its environs belong to the Guinea savanna zone and have a yearly precipitation of more than 1,000mm. This area is in the dry season for a half of the year (November to April). The Nupe, a farming people, lives here and their means of livelihood differs a little according to ecological division. In uplands, they depend on upland farming during the rainy season, growing sorghum, millets, maize, cowpea and other grain crops, legumes and some vegetables. In lowland watersheds that are the flood plains of small rivers, livelihood depends on rice farming in the rainy season using rainfalls, surface runoffs and seepage from underground water and also on upland farming in the dry season. In the huge flood plains along the Niger, Kaduna and Benue Rivers, the Nupe type of livelihood relying on traditional rice farming in the rainy season and fishery is seen. Nupe communities and their land ownership system are discussed by Misa Masuda in Chapter 4 and so are not mentioned here. It is enough to point out that this ethnic group is still under the traditional governing mechanism being ruled by an Emir. This has effects on their farming in connection with the right to own and use farmland.

During some months of the year, Fulbe, the nomad ethnic group moving in search of grazing land, invade Nupe's farming areas with their animals, sometimes causing damage to cultivated land. Thus the Nupe's farming environment has a close relationship with Fulbe's grazing activities.

1-5. Farming environment of Gadza, the survey site

(1) Outline of Gadza

To study the situation of farming in inland valley watersheds, Gadza was selected as the survey site. This is a village 12km south of Bida, the second largest city in Niger State, central Nigeria. This village is at Lat. 8°59'N and at Long. 6°6' E and is about 150m above sea level (see Fig. 3-3). The annual precipitation in the Bida area is about 1,200 mm and the area's recent highest and lowest precipitations were 1,408 mm in 1975 and 807 mm in 1983. The rainy season is from April to October. Gadza can be described as a typical Nupe village of combined lowland rice and upland farming situated in an inland valley. Fig. 3-1 and 3-2 show the arrangement of houses in the village and cultivated land by a cross sectional schematic drawing and plane figure.

Gadza has communities composed of clusters of houses. According to Masuda (1994), "the village is composed of more than one social organization called *emi*, and each *emi* is a group of nuclear families of three to four generations. Each nuclear family, except young one with no established economic base, forms an independent economic unit." It is impossible, however, to determine whether this *emi* can be regarded as a farming family in the normal sense. Another report (AICAF, 1994) says that Gadza has 24 farming families and a population of about 200 ; the cultivated area of lowland rice is about 2.0ha per family (of which 0.6ha is the area in other villages cultivated by Gadza farmers) and upland fields are about 2.2ha (some of this is the area in other villages cultivated by Gadza farmers and the land is left to lie fallow). It was impossible, too, to judge if these figures could be used as showing the number of farming families.

The village area of Gadza can be described as follows : a narrow road runs through the communities of the village from north to south and upland fields (cultivated and fallowed land) exist in patches along another narrow road

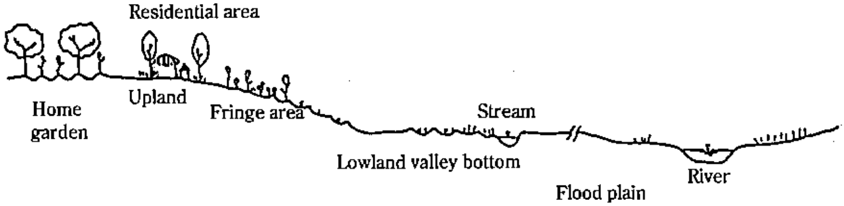


Fig. 3-1 Cross sectional schematic drawing of Gadza in central Nigeria

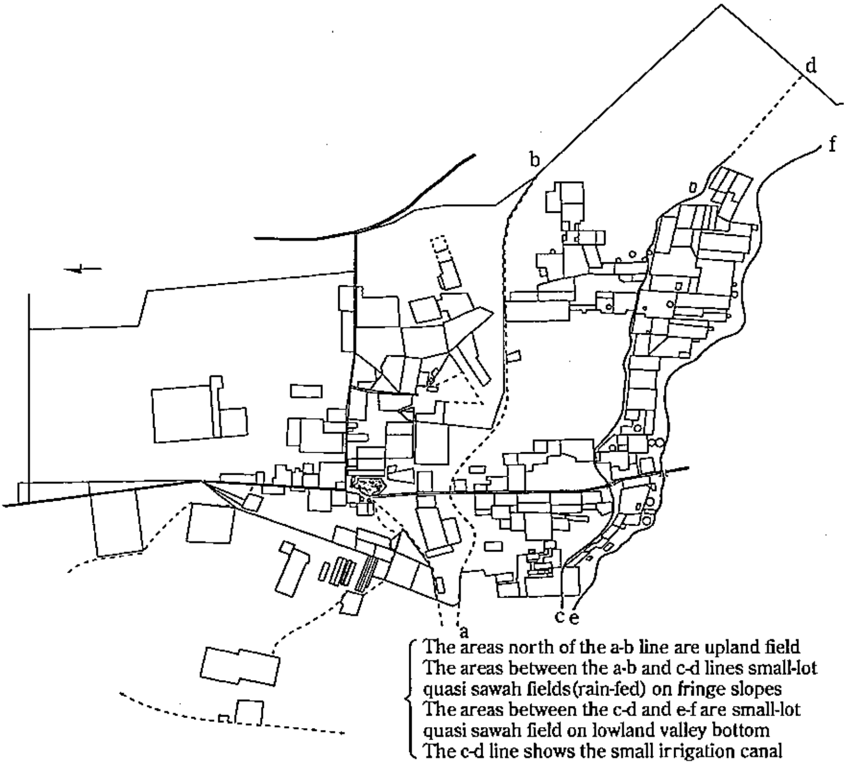


Fig. 3-2 Distribution of upland and sawah fields in Gadza

extending northward and within an east-to-west range of 1.5-1.7km. In the home gardens (locally known as *kpesa*) surrounding each community, useful trees, upland crops and vegetables are grown. The lane heading southward runs along the fringe of an inland valley (incline : 1-3%) and reaches the Emikpata River that is swollen in the rainy season, about 700m away. Along the river meandering to the southeast, a small irrigation canal has been built as if to divide swamps from their fringe areas (Fig. 3-2). The Emikpata River and the canal have gaps of about 20-350m and irrigated small-lot quasi sawah (see 2. Nupe's lowland agricultural systems below) have been developed in these parts. Rain-fed small-lot quasi sawah lie scattered in the fringe areas having a gentle incline (1%) sandwiched between the northern side and the home gardens around communities that are about 300-400m wide.

(2) Gadza's farmland environment

The hydrological and soil environments of different topographical areas in the

Table3-1 Ecological division and hydrological soil environment in the Bida areas in Nigeria

Agroecotype of rice farming	Hydrological environment	Soil environment
Inland flood plain in the middle basin	1.Rainfalls, surface runoffs from watersheds and overflows from rivers 2.The flooding time differs according to the rainfall pattern.	1.Relatively fertile. 2.The value of exchangeable Ca and K is higher than that in the valley bottoms of inland valleys. 3.The content of clay is also higher than that of inland valley soil.
Valley bottom of inland valley	1.Rainfalls, surface runoffs and seepage from underground/spring water. 2.The flooding time differs according to the rainfall pattern. 3.Off-season crops can be grown using remaining water.	1.In general, the clay content is low and so is soil fertility. 2.The parent material is Nupe sandstone and sandy. The surface clay layer has been lost in most cases but there are some parts where the clay layer is retained and the soil is relatively fertile.
Fringe of inland valley	1.Surface runoffs caused by rainfalls and seepage from underground/spring water. 2.Damage from drought occurs in a year of little rain.	1.Sandy poor-nutrition soil having low CEC and low content of exchangeable bases. 2.Heavily eroded, the soil is very sandy.

Gadza district are summarized in Table3-1 based on the report of Wakatsuki (1990a). The natural soil environment of these topographical clearly differs one from another because of topographical differences. The soil of flood plains can be described as relatively fertile because it contains more clay and has higher values of exchangeable Ca and K and CEC. By contrast, the soil of fringe areas has a very low fertility since its sand content is higher and its chemical constituents show lower values. Finally in valley bottom, which are topographically between the flood plains and fring areas, the values are also between the two and the soil fertility differs according to differences in topographical features.

1-6. Traditional farming systems : rice cropping

As already noted, rice field in Gadza can be divided into those in lowlands (including some irrigated small-lot quasi sawah) and rain-fed type in fringes. In 1993, survey for rice farming was carried out in the 53 sites in lowlands and 55 sites in fringes, which are within an east-to-west range of about 1.4km along the Emikpata River.

In the survey site, the rainy season usually begins in April but it is two to three months later before enough water for rice growing can be obtained. In Manbe and Mochita, the villages located in the flood plains of the Niger and

Kaduna Rivers 20km southwest of Gadza where Gadza farmers go to cultivate land on contract, land preparation is carried out in June and afterwards and rice is sown directly just after that. On the other hand, in Gadza situated in an inland valley, land preparation is started in early August, one to two months later than in the flood plains of the large rivers. Land preparation methods, cultivars and other cultivation methods differ according to different cultivation environments ; these can be regarded as adaptation to changing environments.

(1) Land preparation methods

1) Flood plains in the middle basin

In these flood plains, flat wetlands lie as far as the eye can see and rice fields partitioned by relatively wide (30-50cm wide) banks exist in the disorderly fashion. Each of the lots is large (each side is 10-odd meters or more), and because these banks play the role of walk-ways in both the rainy and dry seasons, the rice field have established shaper. Rice farming work begins with the removal of the weeds that grew rank in the field during the dry season. Herbicides such as Roundup and Gramoxon are sometimes applied at this time. After waiting for the soil to expand and be softened by the rain that begins to fall in May to June, farmers use short-haft African hoes called *Zukun* to turn the soil from both sides and make ridges (*Gbaragi*) 35-45cm wide and 12-18cm high in the rice field (Photo 3-1). Local farmers call this method or the state of fields prepared by this method (cultivation environment) *Gbaragi*. Rice is sown directly (*Dzudzochi*) on these ridges. If the ridge is too wide, the clods of earth on its shoulders are broken and rice is sown in two rows, followed by earthing up. In

Photo3-1 Traditional rice farming using ridges in the middle-basin flood plain (*Gbaragi*)

the year when the rainy season comes later than usual, the rice seedlings (*Kpechi*) cultured at the waterside are transplanted (*Shishichi*) in the rice field. The direct sowing on ridges in flood plains has the effect of promoting germination and also reducing damage from a sudden rise in water level.

The rice fields in flood plains have an impermeable layer about 40cm below the ground surface and the rice farming depends on surface runoffs caused by rains in the rainy season. Because of this, the hydrological environment is characterized by quick flooding and quick drying-up and the flooding time and water depth are different from year to year. But in a normal year the water depth reaches 30-50cm. The situation of traditional rice farming in the flood plains is also outlined in Table 3-2.

Ridge culture in rice fields is a rarely seen method, but local farmers say that making ridges by heaping up earth from both sides is advantageous because they do not have to cultivate all of the land and so can save both labor and time.

Table3-2 Ecological division and rice farming in the inland valleys in the Bida area in central Nigeria

Agroecotype of rice farming	Rice farming and off-season cropping			
	Sowing method	Cultivar	Manuring and management	Off-season cropping
Inland flood plain in the middle basin	*Shinkafa dzudzochi* (direct sowing: Sd) *Shinkafa shishichi* (transplanting: Ss)	1.Native species whose plant height reaches 200 cm and whose growth period is about 200 days. 2.They mature by late November regardless of the seeding time (sensitive to day-length) 3.Variety names: Manbefu, Guiana Manbete, etc.	Manuring and weeding 30 and 60 days after sowing: first with a *Zukun*(large hoe) or *Dugbe*(small hoe) and second by manual work; flow irrigation.	Only one cropping in the rainy season
Valley bottom of inland valley	Sd or Ss	1.Native varieties whose plant height is 200cm or less and whose growth period is 135-150days. 2.Variety names: Manbechi (150days), Tomoko (150days), Banbogichi (135days)	Same as above	Mounds are made on which various upland crops are grown together
Fringe of inland valley	Sd	1.Native varieties whose plant height is 150cm or less and whose growth period is short (120days). 2.Variety names: Egwazankpa,Ajiya Kashi, Gyara	Same as above	Impossible because of water shortage; cassava is grown on mounds in rare cases.

Let's look at rice farming in flood plains in more detail. Before seeding, paddy is soaked in water for one to two days and 10 grains or so are sown per hill on average. At the harvesting time, ridges are 74cm wide and spaces between hills are 37cm on average and the planting density is as low as 15 hills or so per $1m^2$. As a result of discussions with farmers, at least 8 to 10 cultivars were identified but it is supposed that they also grow some other cultivars than these. Since these cultivars reach maturity by November or December, they are considered to be sensitive to light. The growth period ranges from 120 to 180 days but is mostly about 150 days (Table 3-2).

The harvest (*Enyako*) in 1994 and 1995 was totally completed in November. The harvesting method is low-level cutting with a sickle (*Lenzhe*) : the plant is cut at a height of 25-35cm above the ground. The bundles of reaped rice are dried on the stubbles and then piled up to form a circle with the ears inside it (Photo 3-2). The piles are about 160-180cm high and this piling-up method can be said to be a defense against damage by the cattle grazed by Fulbe. A strict division of labor exists in harvesting work : while men thresh (*Enyakum*) rice by hand beating it by hand, women then take charge of winnowing work (*Efedan*), separately the chaff from the grain.

Other management work is weeding performed about 30 and 60 days after seeding. Either *Zukun* (large hoe) or *Dugba*(small hoe) is used for weeding, during which the ridge is partly broken. Because of this, ridges are recognizable only barely at the harvesting time. Manure is usually spread but its quantity is not clear because no data on the planted area are available.

In flood plains, rice is cropped once a year. Some farmers in Gadza borrow yam fields in Kpanji, a village in an upland area, and grow yam there. They

Photo3-2 Harvested rice plant piled up in a circle (in a middle-basin flood plain)

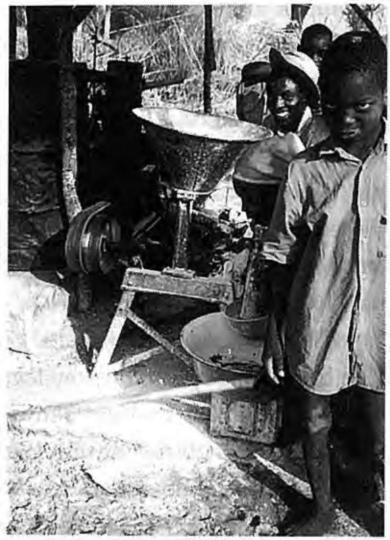


Photo3-3 Sorghum flour mill

plant yam in April and reap it in November and December. In Gadza, too, some farmers take advantage of small differences in land altitude to cultivate egusi melon, yam and sorghum. Most farmers in the village sell about a half of the rice they have harvested and buy sorghum, one of their staple foods. According to them, they like sorghum as much as rice. Their yearly consumption of staple foods is sorghum, rice and yam in order of consumption. There was a sorghum flour mill on the outskirts of the village and during the harvesting time (November to December) we saw many farmers milling their sorghum there (Photo 3-3).

Except farming in their own fields and growing yam in Kpanji in the dry season, Gadza farmers in flood plains do not perform any other agricultural activities and engage in fishing, mainly in the swamps in the flood plains of the Niger and Kaduna Rivers. The fish species they catch are mudfish (*Clarias anguillaris*) and various kinds of catfishes. They sell these fishes on the market day as raw fishes and if they have a good catch, they make smoked fish and store it for future consumption or sell it.

2) Lowland watershed areas

Various land preparation methods are used in the lowlands in Gadza. The traditional rice farming environments prepared by these methods can roughly be classified into seven basic forms (see Fig. 3-4) (Ishida, 1998, Ishida *et al.*, 1996, 1998). *Gbaragi* referred to above is one of the methods. The main methods of land preparation observed in lowland watershed areas are outlined below:

Baragi Method: In lowlands, weeds grow thick even in the dry season. Thus in the swamps where no cropping is carried out in this season, farmers first remove weeds and then burn them or carry them out from the field. Thereafter they do rough plowing and simple leveling of the soil with *Dugba*. The clods of earth that remain in the plowing and leveling work are used to make small banks (5-10cm wide and 10cm high) and thus small-lot quasi-sawah fields (about 3-10m^2) are developed. But since the banks initially built are low and are partly opened, water is always flowing in the fields and no accumulation of soil nutrients can be expected. But later the weeds and clods of earth cut with a hoe during the weeding work are piled up on the banks, resulting in increase in their height. Thus sawah like lots with banks are made though they are small and water flows become stagnant there. Because their banks are moved year after year, these lots cannot be called sawah fields in the proper sense of the term. According to Wakatsuki (1990b), we will call them small-lot quasi-sawah fields (Photo 3-4). This is a flat→flat land preparation method by which the surface of the field or the seeding bed becomes flat and the form of the fields prepared using this method is locally named *Baragi*. But as rice grows, the small banks not entirely closed are built on flat *Baragi* (Photo 3-4, *Togogi naafena*), which are then remade into *Togogi kuru* or totally closed and higher banks.

Ewoga Method : This is the land preparation method used after the harvest of off-season crops (upland crops) grown during the dry season on the bun-shaped mounds built in the rice field. The state of the mounds in the dry season is locally called *Ewoko* and the act of breaking the mounds and preparing flat seeding beds for rice cultivation in the rainy season (*Ewoga*), that is, the mound →flat land preparation method, is named the *Ewoga* Method. *Gbaragi*, the method observed in flood plains, is used here, too. There are also the types of farming as shown in Figure 3-4, which are used for the cultivation of rice or upland crops in the rainy or dry season.

3) Fringes of swamps (*Wada*)

Since rice fields in these areas depend on rainfalls, their water environment is unstable and is damaged by drought in the year of little rain. Even if farmers can

Photo3-4 Rice grown in traditional small-lot quasi-sawah

cultivate rice in the rainy season, they cannot generally grow upland crops in the dry season. But where they have relatively high precipitation in the rainy season and can expect to secure more water for dry season cropping, they make bun-shaped mounds (*Ewoko*) in the rice fields just after they have harvested rice grown in the rainy season to prepare for upland cropping in the dry season. These mounds are 50-60cm high and about 150cm in diameter. They are built at intervals of about 70-80cm. On the top of the mound, five to six stem-cuttings of cassava are planted with their tips exposed above the mound surface. Farmers make mounds of this type when they cannot expect very much from rice farming in the next rainy season. Other types of mounds are *Togogi kuru* and *Togoko kuru* and *Togogi naafena* and *Togoko naafena,* shown in Fig. 3-4. Cassava is usually planted on these mounds, too. But if farmers have plenty of rain in the early rainy season and consider it possible to grow rice with rainwater, they flatten the mounds and make small-lot quasi-sawah fields with low and thin banks. As described, the forms of rice fields observed in swamps differ according to the crops grown before or after rice. They also change according to the growth conditions of rice with the passage of time. In short, farmers change their cultivation forms to cope with changing cultivation environments.

(2) Traditional rice cultivation methods and cultivars in inland valleys and flood plains

In inland valleys, farmers usually develop small-lot quasi-sawah fields but have no habit of soil puddling. After leveling the land or making ridges, they make small holes for sowing with a toe, put several to ten soaked rice seeds into the holes and earth up the holes with the foot. The planting density is as low as 11-12 hills per $1m^2$. Direct sowing is commonly used and seedlings are rarely transplanted. The cultivars are native species with a growth period of 135-150 days and improved varieties (see Fig. 3-6). In the fringes of lowlands, they grow cultivars with a shorter growth period (about 120 days) and a shorter plant heigth. In flood plains, they usually plant the varieties with a growth period of 150 days or more and a greater plant heigth (nearly 200cm), which suggests that farmers select those varieties adaptable to water depth and the time of flooding. The rice they cultivate in Gadza and other villages in flood plains is all Asian rice (*Oryza sativa*), and now they do not grow African rice (*Oryza glaberrima*, local name : *Dzwagwandami*), which they consider a local species. But we sometimes saw by looking more closely some surviving African rice varieties planted together with Asian rice and from this fact we suppose that a switch

Photo3-5 Clay grain storehouse

Photo3-6 Parboiling of paddy

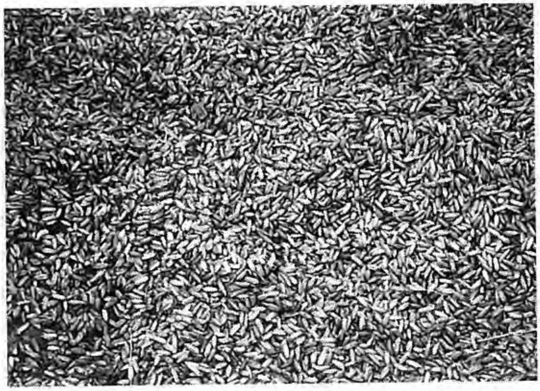


Photo3-7 Drying of parboiled paddy

from African rice to Asian rice occurred relatively recently. The characteristics of some of these cultivars are shown in Table 3-2 ; all have slender-type grains and the yield is 2.0t/ha or less if no manure is spread. As Table 3-2 shows, there are no great differences in manuring (*Taki*) and weeding (*Enunu*) between the three types of environment and manuring is a common practice though the quantity applied small. Weeding work is done about 30 and 60 days after sowing at the same time as manuring. In the first weeding, farmers use short-haft hoes and when ridges are made, weeding is done by cutling off part of the ridges. Because the fields are flooded by the time of the second weeding, they manually remove only large weeds. They do no further management work after that and reap the rice when it has matured (*Enyako*). Harvesting work is carried out by low-level cutting with a sickle (*Lenzhe*), and reaped rice is dried on the stubbles and then is threshed (*Enyakun*) by hand beating method. Part of the rice straw after threshing is left on the rice field and is consumed as roughage by the cattle grazed by Fulbe in the dry season. After being well dried, paddy is stored in a clay storehouse (*Edo*, Photo 3-5). It is parboiled and processed (Photos 3-6, 3-7) and then polished. Part of polished rice is sold.

1-7. Traditional farming systems : upland farming

In Gadza, upland farming is performed by rainy-season cropping in home gardens (*Kpesa*) and uplands (*Kinit*) and by dry-season cropping in swamps (*Fadama*). Upland fields exist in the northern and southeastern parts of the village. The cultivated area of upland fields is estimated at 1.8 ha per farming family if the following are excluded from the total cultivable area : (1) new fallow (*Enufu*), (2) cultivable fallow (*Gonta* ; land let lie fallow for 15 years or more) and (3) land lying fallow almost permanently because it is too far from the communities (*Cikan*). In 1993, Gadza farmers cultivated 64 lots in the village and 18 lots in Machigi. Their upland farming system can be called bush fallow in which the cropland is used for continuously at least 5-6 years or for more than 10 years at most and then left to lie fallow for 5-10 years at or for about ten years for the longest.

(1) Plowing methods of fallow land

When farmers decide to bring fallow land back into cultivation, they choose a particular lot according to the recovery condition of vegetation. The land left fallow for 15 years or more whose fertility has been recovered to a cultivable level is locally known as *Gonta*, but the observation of the vegetation of many *Gonta* shows that there are only a few whose fertility may be considered to have been restored. Bare parts where vegetation has been removed are seen everywhere in these *Gonta*. Because Fulbe grazes their cattle in *Gonta*, they often burn its vegetation in the dry season (this promotes the sprouting of gramineous grass). This inhibits the accumulation of organic matters, thus delaying the revival of vegetation. Moreover, Gadza villagers collect firewood in *Gonta*.

Once they decide on the fallow land for cropping, farmers start plowing it in the early dry season. They do not fell useful tree species, such as sheanut (*Vitallaria paradoxum*), West African locust bean (*Parkia biglobosa*), oil palm (*Elaeis guineensis*) and baobab (*Adansonia digitata*) (Masuda, 1994), but cut small shrubs and undergrowth and burn the land. Then as in the case of the *Gbaragi* Method for rice fields, they pile up soil from both sides with *Zukun* while turning it to make ridges. These ridges are 20-28cm high and 95-125cm wide. This method does not require plowing of all parts of land and also can gather fertile surface soil in the ridges. It can save farmers' working hours by 20-30% compared with the cultivation of the entire field. In addition, these ridges prevent rainwater in the rainy season from flowing away but make it remain and permeate into the soil. In the second year and afterwards, farmers put the stems and leaves of crops and weeds into the space between the ridges and pile up the soil of the ridges used in the previous year on the bottom to make new ridges.

According to the farmers in Gadza, the labor needed for *Gonta* plowing is 400-600m^2 per farmer per day for cutting small shrubs and weeds and for burning, and 300-330m^2 for making ridges. This means that each farmer needs 20-28 days to prepare 1ha of land and part-timers have to be employed during the busy season. Gadza has traditional systems for hiring part-time workers. *Egbe* is one of them, by which part-timers are supplied with meals and drinks and paid some wage (50 naira a day, equivalent to one dollor in 1994). *Dzoro* is a system for reciprocal supply of labor among farmers.

(2) Species of upland crops

Table 3-3 shows the species, cultivation environments and characteristics of upland crops grown in Gadza and its neighboring villages. According to the

Table3-3 Cultivation of crops in Gadza and neighboring villages in Nigeria

Crops	Species	Nupe name	Cultivation environment			Staying period of days in field and Characteristics
			Tree-home garden (*kpesa*)	Upland field (*kinti*)	Inland valley[2] (*Fadama*)	
Sorghum	*Sorghum bicolor*	*eickpan*	+[1]	+++	−	150-210
Pearl millet	*Pennisetum glaucum*	*maji*	++	+++	−	60-180
Maize	*Zea mays*	*kaaba*	++	++	±	80-120
Cowpea	*Vigna unguiculata*	*kapangi ezodzuru*[3]	+	+++	±	60-90
Ground nut	*Archis hypogaea*	*guzha*	−	++	±	100-120
Bambara groundnut	*Vigna subterranea*	*edzu(edzy)*	−	++	−	90-120
Cassava	*Manihot esculenta*	*rogo*	+	+	++	150-200
Sweet potato	*Ipomoea batatas*	*duku*	++	++	+	90-120
Yams[4]	*Dioscorea* spp.	*echi*	+	+	−	180-240
Banana, Plantain	*Musa* spp.	*jaba*(Banana) *jabako*(Plantain)	+	−	±	360 or so
Suger cane[5]	*Saccharum officinarum*	*kpansanako*	−	−	++	360 or so
Egsi melon	*Colocynthis citrullus*	*epingi*	±	++	−	Seeds used in cooking
Okra	*Abelmoschus esculentus*	*kpami*	+	++	+	Fruits used as food and in cooking
Tomato	*Lycopersic esculentum*	*tomato*	±	−	+	Fruits used as food and in cooking
Roselle	*Hibiscus sabdariffa*	*emagi*	+	±	−	Calyxes used as food
Egg plant	*Solanum* sp.	*yengi*	±	−	+	Fruits used as food(eaten raw)
Red pepper	*Capsium annuum*	*yaka*	+	+	+	Fruits used as food and in cooking
Henna	*Lawsonia inermis*	*iali*	±	−	−	Used in dyeing the skin and cloth

Notes: 1)+++ : frequently planted; ++ : a little frequently planted ; + : average ; ± rarely planted

2)Includes the valley bottoms and fringes of inland valleys.

3)There are two local names according to the color of the hilum ; the former's hila are not black and the latter's, black.

4)Mostly white yam(*Dioscorea rotundata*); yellow yam (*D.cayenensis*) and water yam(*D.alata* ; native to Asia) are grown, too.

5)Particularly land lots near the bottoms of inland valleys are designated for sugar cane cropping each year.

Table3-4 Varieties of main cereals grown in Gadza and their characteristics

Crop	Nupe name	Variety	Characteristics		
			Maturity	Grain color	Ear type
Sorghum	*ejikpan*	*masungi*	7monthes	White	Compact
		dandrg	7monthes	Red	Compact
		mazagi	7monthes	White	Sparse
		eyikpan	7monthes	White	Semi-compact
		kunyi	5monthes	Yellowish	Semi-compact
Millet	*maji*	*kpayi*	4-5months	Light gray	
		mayi	70-80days	Reddish brown	
		ejegi	70-80days	?	
		jigbagu	80-90days	?	
Cowpea	*kapangi/ezo*	*kapangi*	60-90days		
		ezodzurn	60-90days		

table, three kinds of cereals are grown but sorghum and millet are more important and have many cultivars (Table 3-4). Cowpea is the most important legume, followed by groundnut and Bambara groundnut. Bambara groundnut is geocarpic and native to West Africa. Local farmers say that this legume is the first-year crop they plant in the land brought under cultivation after fallowing. Tubers include sweet potato and yam. It is rare for cassava to be planted in upland fields in the rainy season. There are several types of yam ; white yam (*Dioscorea rotundata*), yellow yam (*D. cayenensis*) and water yam (*D. alata*), were identified ; white yam (*Echi*), Nupe people's favorite, has the largest planted area. Yam is planted on the mound about 50 cm high made in the field (Photo 3-8) in April when the rainy season begins. Sugar cane is grown in swamps and their fringes. Banana and plantain are cropped in part of home gardens and swamps, though the areas planted to these crops are not so large in Gadza. Egusi melon, okra and red pepper are important as supplementary foods and seasonings. Egusi melon is a kind of small gourd, 15-20cm in diameter. It is grown on the same land as cereals. It is harvested in July and August and 250-290 fruits are reaped per 100m². The fruits are piled up in the field for a week to rots then the seeds are collected and dried. The cotyledon portions of the dried seeds are made into flour, which is used to add flavor and plant protein to soup. Okra is used in a similar way as a material for thickening soup. The typical dish in

Nigeria is the yam just pounded with a pestle (pounded yam) eaten with egusi or okra soup and often a piece of bush meat (meat of grass cutter, a large rodent living in bushes).

Photo3-8 Yam planted on a mound

(3) Cropping systems in upland fields

In upland fields in Gadza, planting two to four different crops in the same lot is a generally used cropping system. These crops are sown in May and June, the early rainy season. According to the surveys conducted in July and August, common methods are the mixed cropping of late-maturing sorghum and pearl millet, which stays for a longer period in the field, and legumes and gourds having a shorter period in the field. The mixed cropping of early-maturing pearl millet and late-maturing sorghum is also seen. According to farmer K, one of the Gadza farmers with whom we conducted hearings had cultivated his fallow land for five years, the combinations of crops he used for mixed planting for these five years were as follows :

1st year : sorghum=bambara groundnut ;
2nd year : sorghum=egusi melon ;
3rd year : late-maturing pearl millet=egusi melon ;
4th year : same as the 3rd year ;
5th year : early-maturing pearl millet=sorghum.

Note : Sorghum are a late-maturing variety in all the cases ; = shows the combinations of crops for mixed cropping.

Mixed cropping entails planting the two different crops on the same ridges either alternately or in different positions. For example, in the case of sorghum and bambara groundnut, bambara groundnut is planted in the center of ridges, while sorghum is planted in positions a little lower than the ridge shoulders. The distance between hills is determined for each crop. It is about 50 cm for bambara groundnut and about 85cm for sorghum. But in the mixed cropping of early-maturing pearl millet and late-maturing sorghum, which are both cereals, they are planted alternately on the center of ridges.

Table3-5 Mixed cropping in Gadza farmer's upland fields

No. of crops for mixed cropping	No. of mixed cropping lots in Gadza	No. of mixed cropping lots in other villages	Total of mixed cropping lots	Ratio to total mixed cropping lots(%)
5	1	0	1	1.2
4	6	3	9	11.0
3	9	3	12	14.6
2	13	9	22	26.8
1	35	3	38	46.3
Total lots	64	18	82	100.0

(Survey in October to December 1993)

Tables 3-5 and 3-6 show the crops and their combinations in the 82 lots of upland fields cultivated by Gadza farmers (including 18 lots in other villages where they cultivated by contract) in the rainy season, October to December 1993. Because the early-ripening crops sown in the early rainy season had already been harvested by these months, these figures do not reflect correct cropping systems, including the order of planting, in upland fields but they clearly suggest that sorghum and pearl millet are the most important crops for mixed cropping.

Photo3-9 Heated-air drying of early-mataring millet reaped in the rainy season

(4) Cultivation management and yield

In Gadza, cultivation work is performed with *Zukun* or *Dugba*. Weeding is done with *Zukun* just as when ridges are made in rice fields. Carried out only two to three times during the cultivation period, this work is performed by the method by which the sloping parts of ridges are cut off. If some of the hills have been lost, the seedlings taken from other hills are planted to supplement them, especially in the case of sorghum. The transplanting of sorghum is a common practice ; there are some cases where this crop is transplanted in the entire lot and in these cases the leaf tips cut from the

Table3-6 Combination of crops for mixed cropping in Gadza

No. of crops for mixed cropping	Combination of crops	No. of lots	No. of combinations
5	Sorghum=late-maturing millet=yam=okra=egusi melon	1	1
4	Sorghum=late-maturing millet=sweet potato=cowpea	1	9
	Sorghum=late-maturing millet=yam=okra	1	
	Sorghum=late-maturing millet=cowpea=red pepper	1	
	Sorghum=late-maturing millet=Bambara groundnut=okra	1	
	Sorghum=late-maturing millet=red pepper=egusi melon	1	
	Sorghum=late-maturing millet=red pepper=okra	1	
	Sorghum=sweet potato=red pepper=okra	1	
	Late-maturing millet=cowpea=Bambara groundnut=groudnut	1	
	Late-maturing millet=sweet potato=red pepper=okra	1	
3	Sorghum=late-maturing millet=cowpea	2	10
	Sorghum=late-maturing millet=egusi melon	1	
	Sorghum=sweet potato=cowpea	1	
	Late-maturing millet=sweet potato=Bambara groundnut	1	
	Late-maturing millet=sweet potato=groundnut	1	
	Late-maturing millet=Bambara groundnut=groundnut	1	
	Late-maturing millet=cowpea=Bambara groundnut	1	
	Late-maturing millet=cowpea=red pepper	2	
	Late-maturing millet=cowpea=okra	1	
	Cassava=okra=roselle	1	
2	Sorghum=late-maturing millet	6	10
	Sorghum=cowpea	1	
	Sorghum=okra	2	
	Sorghum=egusi melon	1	
	Late-maturing millet=cowpea	1	
	Late-maturing millet=sweet potato	6	
	Late-maturing millet=groundnut	2	
	Late-maturing millet=okra	1	
	Late-maturing=egusi melon	1	
	Sweet potato=cowpea	1	
1	Sorghum	18	7
	Late-maturing millet	8	
	Cowpea	6	
	Sweet potato	2	
	Cassava	2	
	Groundnut	1	
	egusi melon	1	
		82	37

(Survey in October to December 1993)

Table3-7 Yield of upland crops and rice according to a survey in Gadza

Crop and Characteristics	Yield (t/ha)	Remarks
Bambara groundnut (early maturing)	2.25 (with Shell)	Grown on land after fallowing
Sorghum (late-maturing)	1.58	First year
Sorghum (late-maturing)	1.25	Fifth year of cultivation
Millet (early-maturing)	0.45	
Millet (late-maturing)	0.68	Seventh year of cultivation
Egusi melon (early-maturing)	0.56 (seed)	
Rice (in the fringe of inland valley)	1.54 (paddy)	Rain-fed cultivation

(Survey in 1993)

seedlings having a plant height of 30-40cm are used as cuttings.

To reap sorghum and pearl millet, farmers use *Dugba* to dig each hill and pull out the entire hill. They put the plants on the field to dry and then cut off the ears and dry them further on the stems and leaves. Early-maturing pearl millet harvested in the rainy season is dried by the heat of fire (Photo 3-9). Threshing (*Enyakun*) is done in a mortar (*Dunchi*) with a pestle (*Etun*) ; this is women's work.

The yield of main crops is shown in Table 3-7. This table suggests that the yield gradually decreases in later years of cultivation.

1-8. Toward the realization of sustainable agriculture in inland valleys in West Africa

In the above sections, we have focused our attention on the upland and rice cultivation in the Guinea savanna zone in the Bida area in central Nigeria and have examined the general situation of the cultivation systems of the four ecological types in the area, classified according to toposequence and hydrology. What has been described is the summarized result of the surveys in Gadza, the village south of Bida that we selected as the survey site. In this section, we will discuss the method of realizing sustainable agriculture in inland valley watersheds in West Africa on the basis of these survey results.

In Gadza both lowland rice and upland crops are cultivated and rice and upland fields are located in different but adjoining topographical areas within the village. The hydrological environment gradually changes from the highest

Table3-8 Characteristics of the cultivation methods of upland crops and rice in Gadza and its neighboring villages

Upland field	Fringe of lowlands	Lowlands
1.Ridges are made directly with an African hoe instead of cultivating the entire field. 2.Mixed cropping of miscellaneous cereal crops, legumes and gourds in the same row. 3.Diverse sorghum and millet varieties are grown. 4.Hill sowing method ; the toe is used to dig seeding holes and the heel is used to earth up ; 5.Transplanting of sorghum. 6.Weeding by cutting part of ridges with a hoe. 7.Manuring is rare.	1.Rain-fed small-lot quasi-sawah rice farming in the rainy season ; 2.Upland crops(cassava,etc) are planted on mounds (in the case where precipitation is low in the rainy season and rice cropping is given up).	1.Rice planted on ridges in flood plans and inland valleys ; 2.No custom of puddling exists ; 3.Small-lot quasi-sawah with no banks(water flows are always seen) ; 4.Direct sowing is perfomed in 90% of rice fields ; 5.Different varieties are grown depending on the hydrological environment ; 6.Direct sowing as in upland farmimg ; 7.Manuring is carriedout in most cases.

part of watersheds to swamps (including flood plains) and the four ecological types all exist within short distances. In each of the four ecological zones, farmers grow the crops and varieties suited to its environment. Their cultivation methods are similar in some cases but different in other cases (Table 3-8). For example, while large sawah like fields with high banks are developed in flood plains, small-lot quasi-sawah fields are common in inland valleys. But ridge making and direct sowing are observed in both areas. Ridging in upland fields for miscellaneous cereal crops is performed in exactly the same method. On the other hand, in traditional paddy rice cultivation, the transplanting of seedlings is carried out only infrequently but this is the method, using large seedlings only, when flooding starts so early in flood plains that there is no time to make ridges. If farmers make small-lot quasi-sawah fields with low banks in swamps in watersheds, they level the mounds they made for off-season cropping in the dry season and immediately sow rice seeds directly on the leveled land. This method obviates the need to wait for flooding before transplanting. In addition, direct seeding helps to reduce the growth period, which will be advantageous because it will relieve water stress in the later rainy season and give adequate time for mound making (this work requires hard labor) after rice is harvested. This sowing method is considered to be the countermeasure West African farmers take to cope with insufficient precipitation and sometimes temporary excess in water supply due to local downpours and changing water supply from year to year. It has already been mentioned that the transplanting of sorghum is practiced in upland fields ; this is the strategy used when farmers do not have adequate time to complete ridging work before the right sowing period, for example, because of a labor shortage. As noted, direct sowing is the main method used both in lowland rice and upland fields and transplanting is adopted as a means to deal with changes in environmental conditions. Thus, we should understand that traditional techniques (farming techniques) have been systematized to make them adaptable to the region's farming environment throughout the year. The seven forms of crop cultivation environments developed by various land preparation methods in lowlands (Fig. 3-4) and their changes with time (Fig. 3-5) can be regarded as established traditional techniques based on farmers' experience.

Farming work in lowland and upland fields is all carried out with *Zukun* or *Degba*, African short-haft hoes. Smaller *Degba* is used for ridging and weeding in rice fields because the soil contains lot of moisture and is heavy. But since the *Degba's* edge has a certain width, some people says that it will damage rice plants and be unable to weed efficiently if the planting width of 25×20cm is adopted that we tried to recommend to local farmers (see Chapter 6).

In the small-lot quasi-sawah fields with low banks that are made by the *Baragi* or *Ewoga* Method, farmers neither perform subsoil compaction and puddling work nor take any measure to prevent water leakage. And at the beginning of its development, water flows are always observed in the small-lot quasi-sawah field. As stated by Wakatsuki (1988), this means that the surface soil flows out of the field together with rich soil nutrients (eroded surface soil and clay) as surface runoffs. But as noted earlier, by the time of weeding, weeds and clods of earth are piled up on the banks, and the outflow of water gradually decreases and finally stops. By contrast, high banks are built in large-lot sawah from the beginning to flood them, and this is effective in checking the entire outflow of soil nutrients. In the rice fields in inland valley, mounds (*ewokogi*) are made in the dry season, on which upland crops are planted. The parent material soil is Nupe sandstone. These mounds can be regarded as a means to reduce the solidification as the soil dries out and also to gather as much of the top soil and its nutrient as possible. In small-lot quasi-sawah fields, collecting earth needed for the development of mounds, mainly from banks, is easier work than in flat large-lot fields, and from this fact we can understand the reason for making small-lot quasi-sawah fields. Making mounds is an advantageous method because they can be leveled after upland crops have been harvested and used to bury weeds in the soil, This helps to circulate organic matters and save labor.

By contrast, building high, fixed banks from the beginning is uneconomical in terms of land use since it becomes impossible to plant dry season crops on them. Gadza farmers consider this a very important problem in connection with land ownership.

Iron toxicity is known to be one of the yield restricting factors in rain-fed lowland rice farming in West Africa (Winslow *et al.*, 1989 ; Yamauchi, 1989, 1992). Yamauchi (1994, in Japanese) gives as the countermeasures against these symptoms, (1) K application, (2) introduction of tolerant varieties, (3) ridge culture (practiced by farmers) and (4) drainage and prevention of ill-drained rice fields.

The Asian-type sawah farming system we propose to introduce includes some elements incompatible with (3) and (4) of the measures mentioned above. In the proposed Asian-type sawah farming system, attempts to prevent water flows from the early stage of sawah development and thus to increase soil fertility are made by building high banks, leveling the land, and flooding the field from the beginning. But in lowland sawah fields in Gadza where potentially low soil fertility results in iron toxicity, this strategy will not show its effects very quickly and will inevitably bring about negative consequences at first. As mentioned later in Chapter 6, 2, in the experiments on the introduction of the Asian-type sawah farming system conducted by Wakatsuki *et al.* at IITA from 1986 to 1988, a yield two to three times higher than the average yield of local farmers was achieved when small power tillers were used to puddle the land and adequate fertilization, weeding and water management were carried out. On the other hand, as stated in 2-1, (4) of the same chapter, when the fields were enlarged and transplanting was introduced without giving farmers any sufficient education and knowledge, the yield of improved varieties used in the experiments for the two years was not higher than that of local varieties grown in small-lot quasi-sawah fields (characterized by ridging, direct seeding and low banks and water flows at the early growth stage). These results suggest more detailed analysis of local techniques is needed. If these techniques are found to be advantageous, the future problem is how to harmonize them with the Asian system.

Nakao (1967) regarded rice as a wetland cereal crop and included it in the category of miscellaneous crop farming. Ohji (1987, 1991, in Japanese) also stated from his investigation in the eastern parts of the Indian subcontinent that seen from farming technology point of view, rice is grown both by irrigation farming and by rain-fed millet farming and that this characteristic shows that

Table3-9 Main crops consumed by Gadza residents by month

Month	Main crops
January-February	Rice and sorghum ; rice consumption is larger in these months because there are many holidays for celebration.
March	Sorghum, cowpea, rice and cassava
April-May	Cassava, cowpea, sweet potato and late-maturing millet
June-July	Cassava, sorghum, cowpea, Bambara groundnut and cocoyam
August-September	Early-maturing millet, cassava and sweet potato
October	Early-maturing millet, cassava and sweet potato
November-December	Sorghum, rice, cowpea, yam and cocoyam

"rice is a member of millets" at least in the areas where the two cropping systems exist side by side with.

Gadza farmers lead a self-sufficient life-style in inland valley watersheds by adapting themselves to different hydrological environments, that range from highlands to lowlands and from the rainy to dry seasons and vice versa, and by depending on the harvest of diverse cereals, legumes, and tubers that they produce throughout the year by selective cultivation of crops and varieties (Table 3-9). This is clear if we observe various types of farm work they perform in upland fields, rice fields (in lowland watersheds and in flood plains in other villages where farmers tenant rice fields) and off-season cropping in the dry season, which are shown in Table 3-10. If, like Nakao and Ohji mentioned above, they regard rice as a kind and member of miscellaneous cereal crops, they will not recognize the need of prepare sawah fields, a fixed special kind of cropland, only for rice. Another problem is the way farmers in Gadza rate rice cropping relative to other crops from economic viewpoints and their food preferences. According to AICAF (1995), the gross profit from rough rice per ha is higher than that from other products except yam but this is the result of calculation based on the statistics of a local agricultural development project. It cannot be used as the data for determining if sawah based rice farming is more profitable because there are no information about the input of production materials and other matters. Gadza farmers recognize the importance of rice (parboiled rice) as a cash crop but it is also true that much trouble is required for processing rice into commercial products. Farmers consume about 30-40% of the rice they produce and just like other miscellaneous cereal crops, they often eat rice just after harvest. Taste for rice differs from person to person and many farmers say they prefer sorghum. Considering these facts, we should see if the Asian-type sawah rice farming, which will be described later, gives farmers enough incentive to induce them to work positively for increased farm production with an

Table3-10 Annual farm work calendar of Gadza farmers

Toposequence	Rainy season							Dry season					
	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Upland field	Land preparation	Sowing of egusi melon and cowpea		Planting of sweet potato			In case of adequate rainfalls, planting of cassava, okra and cowpea					Weed cutting and burning in fallow land	
			Sowing of sorghum, millet and Bambara groundnut	Harvest of cassava, cowpea and okra	Harvest of early-maturing millet	Harvest and processing of cowpea, melon and Bambara groundnut		Harvest of late-maturing sorghum and millet					
			Weeding in the fields of egusi melon, sorghum, millet, cowpea,etc.			Weeding in millet and soghum fields			Drying of millet and sorghum				
Lowland fringe				Harvest of cassava, etc.	Preparation of rice fields								
						Sowing of rice	Weeding		Harvest of paddy				
								In case of water shortage, planting of cassava					
Valley bottom of lowlands		Weeding in upland crops		Harvest of cassava, eggplant, okra, red pepper and cowpea							Mound making	Planting of cassava, eggplant, okra, sweet potato, red pepper and cowpea	
				Leveling of mounds and preparation of rice fields		Sowing of rice	Weeding in rice fields (1st,2nd,3rd)		Harvest of paddy		Threshing and processing of paddy		Watering of sweet potato ; weeding in upland crops
Mid-basin flood plain		Preparation of rice fields, ridging		Sowing of rice		Weeding in rice fields		Harvest of rice	Threshing and processing of paddy				

intensive labor inpnt. In our survey, farmers claimed to recognize the importance of rice farming to them, but this recognition has not always been reflected on their actual behaviors in farming.

We have already pointed out that the traditional farming in Gadza has been systematized according to time and from the standpoint of farming techniques and food supply. If we introduce a new type of farming technology into this traditional system, how can we harmonize the former with the latter? There are many problems to be solved to achieve such harmonization.

Considering the problem of food production in Africa, many people argue that transferring modern technology to the region is the key to a revolution in African agriculture. In such a situation, P. Richards (1986) says that technology transfer is not a solution but only one of the problems. Believing that the problem was that modern technology introduced as a package was often inappropriate for small farmers, he conducted a survey on farming in Mogbuama, a village in Sierra Leone. He pointed out that farmers in the village carry out three types of rice farming and upland cropping at the same time, depending on differences in the ecological type of land and then discussed the problems arising in their food production activities in these different ecological areas from natural and socioeconomic viewpoints. The subjects he dealt with include, for example, the time when the rainy season comes, land preparation methods, relations between bush burning of fallow land and soil fertility, ratios of rice and upland farming taking account the output of food for family consumption, the procurement of labor force, cropping systems in upland fields, and selection of rice varieties for each ecological area. As a result, he found that to secure food and some cash income throughout the year, the most important management strategy for farmers was to optimize their farming activities by combining rice, sorghum, millet, and cotton in the best way in terms of production scale and techniques. He added that local farming techniques tend to make good use of different soil and topographic features and to minimize the risks that occur from various causes.

The existence of traditional small-lot quasi-sawah fields in the Gadza area should also be seen as a result of its farmers' long experience, and we should be careful about the introduction of an improved technology without understanding this fact and giving it a good deal of thought. To conserve and revive the agricultural and forestry ecosystem of inland valleys, we have to prove the sustainable productivity that would be realized by an agro-silvo-pastral system, that is, a compound form of agriculture including sawah rice farming, and to diffuse the concept of this system broadly. Many questions still remain to be settled in cooperation with local farmers. (Shohei Hirose)

2. Nupe's lowland farming systems

2-1. Introduction

In developing countries, many studies and surveys on agricultural development are being carried out. The major objective of the development projects so far has been and continues to be yield increase. Although some projects seem to have been successful in the initial stages using large amounts of energy, resources, and funds, these high input technologies may not to benefit local farmers in terms of sustainability. Assessments of past project revealed that most of the capital-based technologies did not last beyond the project time, with the farmers reverting to their indigenous system. The technology in such development projects was not adequate under either natural or socio-economic conditions or both. In many development projects, farmers were not able to receive any of the benefit that such projects had intended to provide. It is therefore necessary to apply technologies which farmers can adapt to their ecological environment and socio-economic conditions. The farmers' indigenous agricultural knowledge which reflects local limiting factors should be studied for technologies acceptable to farmers to be developed.

2-2. Nupe's traditional lowland rice cropping systems

A typical Nupe village, Gadza, was selected for the survey presented here. The village is located in the middle of the Emikpata river basin, Niger State, Central Nigeria, West Africa (Fig. 3-3). The major ethnic groups in this area are Nupe engaged in rice farming and Fulani cattle nomads.

Ethnopedological surveys were conducted during the period August to December in 1994 and June to November in 1995. Information in the Nupe language was collected from local farmers about rice-based low land farming. Distribution of land preparation patterns for lowland rice and sequential changes of the patterns were observed partly in the field and partly sketched, using the information given by leading farmers. The biomass and composition of weed species were surveyed. Soils were sampled from each of the land preparation patterns. Rice varieties were also surveyed in each farmer's field.

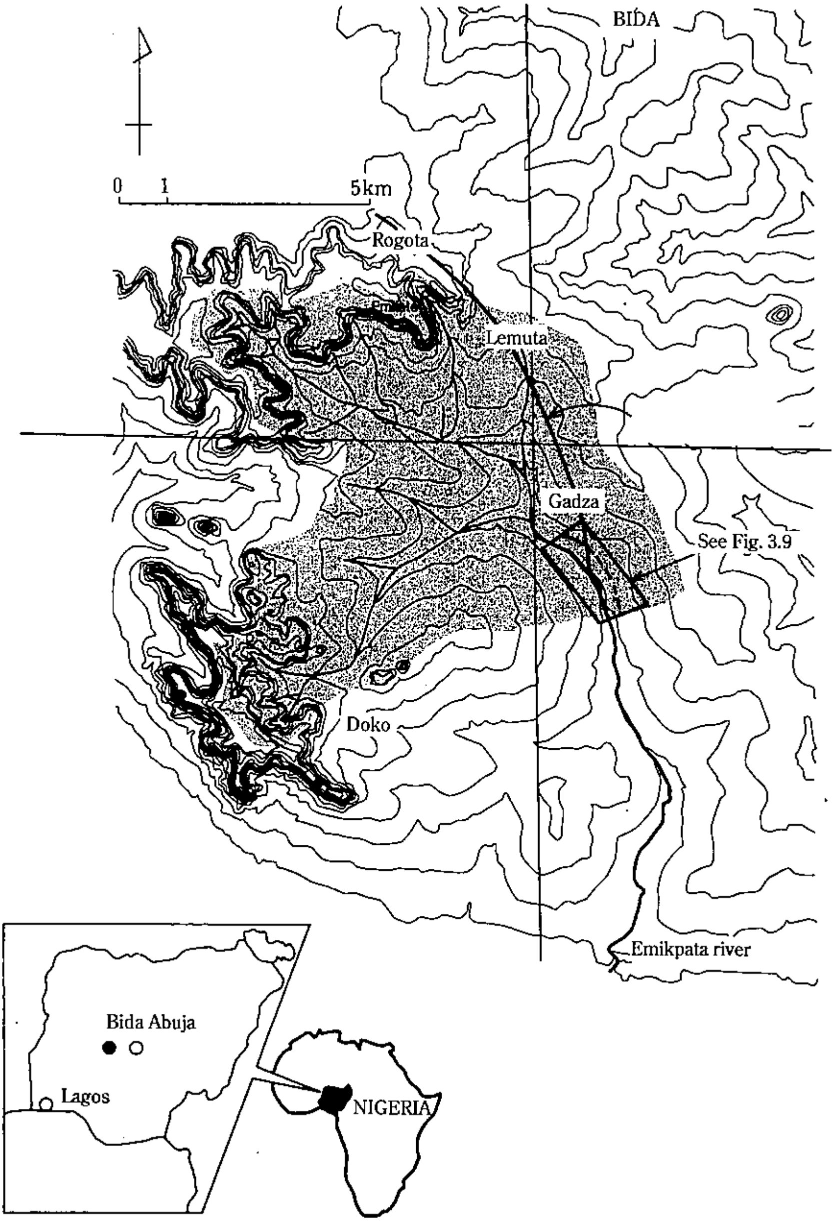


Fig. 3-3 Map showing the location of the research site.

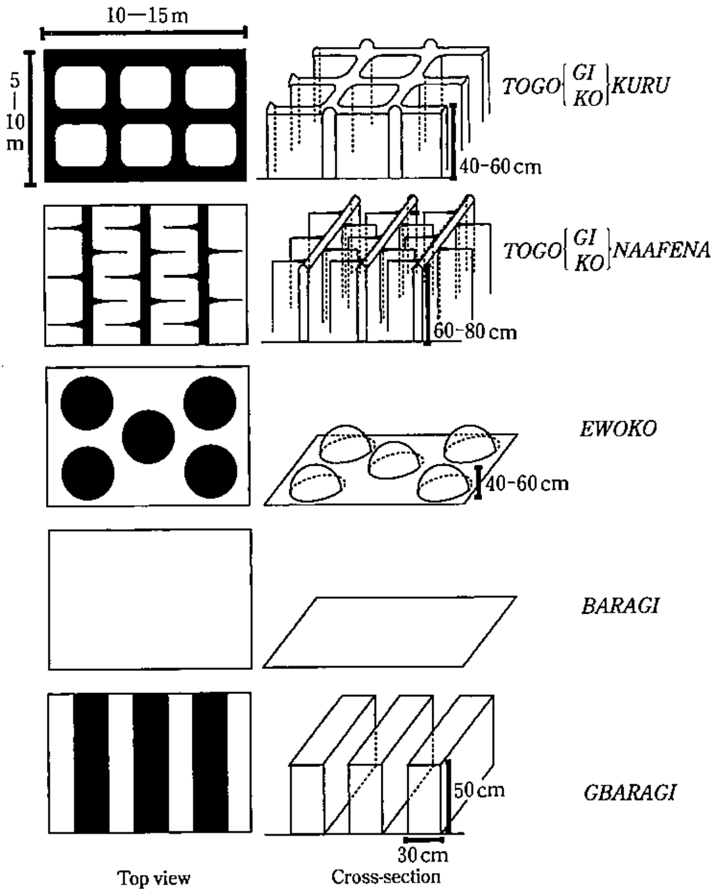


Fig. 3-4 Land preparation patterns at the onset of lowland rice cultivation.

Nupe's lowland farming is characterized by the construction of various types of ridges and mounds. Seven patterns of land preparation were observed in the lowlands, as follows; *Togogi kuru*, *Togoko kuru* (photo 3-10), *Togogi naafena*, *Togoko naafena* (Photo 3-4, 3-11), *Ewoko* (Photo 3-12), *Baragi* (Photo 3-13) and *Gbaragi*. Fig. 3-4 shows land preparation patterns at the onset of lowland rice cultivation. Black portions of the figure represent ridges or mounds. The rice planted by farmers is represented in the white sections except for *Ewoko*. Patterns of *Togogi kuru* and *Togoko kuru* appear like divided closed square blocks. There are also closed subdivided ridges inside the blocks. The size of a block determines the difference between *Togogi kuru* and *Togoko kuru*.

Photo3-10 *Togogi kuru* and *Togoko kuru*

Photo3-11 *Togogi naafena* and *Togoko naafena*

Photo3-12 Land preparation of *Ewoko*

Photo3-13 *Baragi* (right) and *Togogi naafena* (left) prepared at the later growth stage

The length of a side in *Togogi kuru* is about 2-3 m, while that in *Togoko kuru* is 5-15 m. *Togogi naafena* and *Togoko naafena* have hook-shaped ridges within each block. The area between hooks in *Togoko kuru* is wider than that in *Togogi kuru*. The height of ridges of *Togogi kuru* and *Togoko kuru* is about 40-60 cm, while in *Togogi naafena* and *Togoko naafena* the height is about 30-70 cm. Similar patterns of *Togogi kuru*, *Togoko kuru*, *Togogi naafena* and *Togoko naafena* had been reported (Kuraku 1991) in Yayoi Age Ohuro Archeological site (2500 years before the present), Gunma Prefecture, Japan. Similar small-lot quasi-sawah patterns of *Togogi naafena* and *Togoko naafena* were also observed (Takaya *et al*. 1981) in Tapanuri, Sumatra, Indonesia. *Ewoko* is a mound about 40-60 cm in height and 0.5-1 m in diameter. Cassava, sweetpotato, cocoyam (*Colocasia esculenta*) and vegetables are grown on it. *Baragi* is a flat rice field without any mound or ridge. *Gbaragi* has linear parallel ridges, about 30-50 cm in height and 30 cm in width, and farmers plant rice on it.

Each pattern is seasonally modified, with each sequence of pattern depending on rice and weed growth, water conditions, and rice varieties (Fig. 3-5). It is also a labor-saving method during the peak rice farming season, July to September. The time of operation changes according to each pattern. In this area the

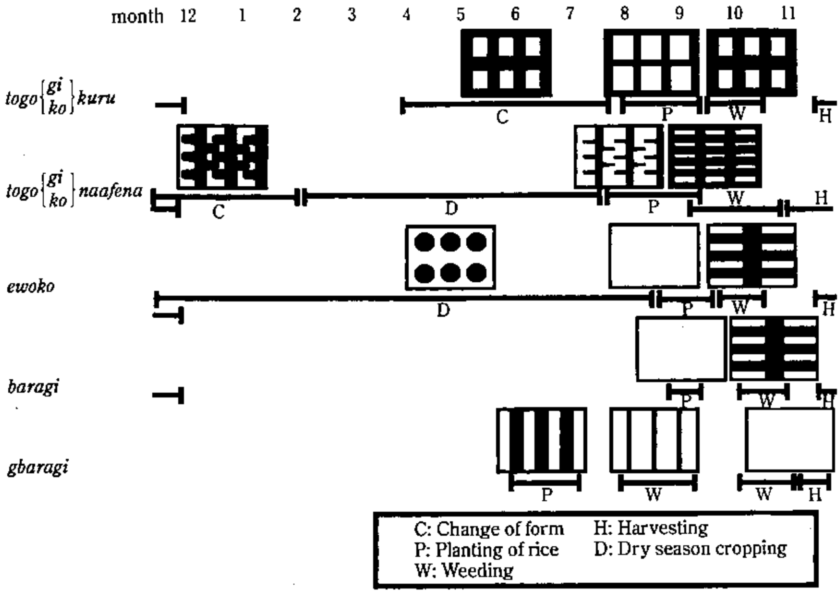


Fig. 3-5 Sequence of land preparation patterns for the cultivation of lowland rice.

rainy season starts from April and most of the rain falls between June to early October. In *Togogi kuru* and *Togoko kuru*, wide closed square ridges are formed by collected surface soils (Fig. 3-5, C), then they are cut down and spread to prepare for rice planting (P). At the time of weeding, weeds along with soils are scooped up and turned over on the ridges using a hand hoe to make wider ridges (W). Almost the same ridge-forming methods are applied in *Togogi naafena* and *Togoko naafena*. In *Togogi naafena* and *Togoko naafena*, the dry season crops are planted on wide hook-shaped ridges. At the time of weeding, the fine hook-shaped ridges are closed and change to square ridges (W). Names also change to *Togogi naatsuna* and *Togoko naatsuna*. Ewoko is, however, broken down and leveled to be some flat for rice cropping in years with heavy rainfall (P). *Baragi* does not exhibit any mound or ridge by the time of weeding (P). Wide closed square ridges are formed in both *Ewoko* and *Baragi* at weeding. The changed of pattern of *Gbaragi* is completely different from any other pattern mentioned above. Rice is planted on wide parallel linear ridges in *Gbaragi* (P), and only rice is left after weeds and soils have been removed from ridges at weeding time (W).

2-3. Meaning of the Nupe's lowland rice cropping systems

In order to understand the reasons for moving the soil sequentially and the farmers' selection of the seven various land preparation patterns, three aspects were emphasized as follows; (1) the control of weeds, (2) conservation of soil fertility, (3) water retention.

(1) Measures against weeds

All the weeds, excluding roots, were collected from unit areas in the seven observation patterns and from the controls in relation to each land preparation pattern. Sample weeds were air dried and weighed. The biomass of weeds in unit areas under the five patterns were less than 1/2 to 1/20 of that of the controls (Table 3-11). Table 3-12 shows the composition of weed species under each pattern and in the control. The "*" symbol represents the major weed species of inland valley bottoms and floodplains, and the "+" symbol indicates weeds in the savanna vegetation (Akubundu *et al*. 1986). The composition of weed species changed according to the water conditions. Based on the growing environment of savanna type weeds and our field observations, *Ewoko* and *Baragi* were prepared at relatively higher microtopographical positions.

Table3-11 Comparison of weed dry weight, under different land preparation patterns.

Land preparation pattern	Dry weight* (kg)	Area (m^2)	Dry weight*/unit area (kg/m^2)
Togogi naafena	2.62	17.48	0.15
Control	2.44	1.00	2.44
Sugarcane field	0.96	1.00	0.96
Togoko naafena	2.48	10.52	0.24
Control	1.12	1.00	1.12
Togogi kuru	1.52	6.24	0.24
Control	0.16	1.00	0.16
Togoko kuru	8.37	7.52	1.11
Control	2.35	1.00	2.35
Ewoko	0.27	2.80	0.10
Control	2.22	1.00	2.22
Gbaragi	0.80	1.00	0.80
Control	0.60	1.00	0.60
Baragi	0.28	1.00	0.28
Control	0.44	1.00	0.44

*Roots are not included.

(2) Measures for soil nutrient

Table 3-13 shows that the soils of the lowland area were very sandy and contained low concentrations of total nitrogen and carbon. In the table, 0, -15 and -30 indicate the depth (cm) of sampling points. Sand contents of soil samples exceeded 70 % in both the upper and lower parts of the lowland area. The amounts of clay and total nitrogen contents of the soil samples were very low. The amount of available phosphorus in lowland soil was not appreciably low, compared with the other nutritional elements.

Soils under *Baragi*, *Ewoko* and *Togogi kuru* contained a larger amount of exchangeable Ca, K, Mg and Na than each of the respective control soils (Table 3-14). Table 3-14 shows the approximate height of the cut in *Togoko naafena*: 70 cm in the top, 30 cm in the middle, and 0 cm in the base region. The soils of the ridges were seasonally moved. Soil parts that were moved showed a larger amount of exchangeable bases and a lower amount of exchangeable Al than soil parts that were not moved i. e., subsoils, -10 and -30 below the base of ridges.

The amounts of exchangeable Ca, K, Mg and Na were generally very low in rice fields compared to levels in sugarcane fields (Table 3-14). Potassium

Table3-12 Composition of weed species collected under different land preparation patterns.

Land preparation pattern	Species
Togoko naafena	*Digitaria* sp.
	Panicum sp.
	Aeschynomene indica
	Tephrosia sp.
	Sctaria pallide-fusca
	+ *Paspalum* sp.
Control of	+ *Echinochloa* sp.
Togoko naafena	*Setaria pallide-fusca*
	=*S. pumila*
	+ *Paspalum* sp.
Sugarcane field	*Vicoa leptoclada*
	Digitaria sp.
	Poaccae (*Graminea*)
	Oryza sp.
	+ *Cyperus distans*
	Tephrosia bracteolata
	+ *Paspalum* sp.
Togoki naafena	+ *Paspalum* sp.
	Sctaria pallide-fusca
	+ *Cyperus tuberosus*
	Indigofera sp.
	+ *Echinochloa* sp.
Control of	*Rottboellia cochinchinensis*
Togoki naafena	*Physalis angulata*
	Commelina benghalensis
	Setaria pallide-fusca
Togoko kuru	+ *Pasaplum* sp.
	Aeschynomene indica
	Vitex sp.
	Setaria pallide-fusca
	+ *Echinochloa* sp.
	Oryza sp.
	Ipomoea sp.
Control of	+ *Paspalum* sp.
Togoko kuru	*Caloplgonium mucunoides*
	Aeschynomene indica
	Rottboellia cochinchinensis
	Setaria anceps
	Setaria pallide-fusca

Togogi kuru	*Fimbristylis* sp.
	Digitaria sp.
	Tephrosia bracteolata
	+ *Paspalum* sp.
	Brachiaria comata (?)
	Schwenckia americana
Control of *Togogi kuru*	+ *Paspalum* sp.
	Tephrosia sp.
	* *Hyparrhenia* sp.
Ewoko	*Tephrosia* sp.
	Aeschynomene indica
	Digitaria sp.
	* *Hyparrhenia* sp.
Control of *Ewoko*	*Andropogon* sp.
	Daniellia oliveri
	Markhamia sp.
Gbaragi	*Paspalum* sp.
	Digitaria sp.
	Brachiaria mutca
	Tephrosia sp.
Control of *Gbaragi*	*Andropogon* sp.
	Setaria pallide-fusca
Baragi	+ *Cyperus* sp.
	Digitaria sp.
	Alysicarpus sp.
	* *Hyparrhenia* sp.
Control of *Baragi*	* *Hyparrhenia* sp.
	Fimbristylis sp.
	Aeschynomene indica

Note: + indicates species in savanna vegetation.
* indicates species in inland valley bottoms and floodplains.

Table3-13 Particle-size distribution, contents of total nitrogen, total carbon and available phosphorus in soils of the survey site

Sampling point	Soil depth (cm)	Clay (%)	Silt (%)	Sand (%)	T-N (g/kg)	T-C (g/kg)	C/N	PP* (mg/kg)
Upper part of lowland	0	8	4	88	0.07	1.39	20	6.32
	−15	8	3	89	0.27	3.32	12	9.45
	−30	7	2	91	0.16	0.68	4	4.07
Lower part of lowland	0	11	13	76	0.41	3.89	9	14.34
	−15	12	14	74	0.20	2.13	11	7.35
	−30	9	13	78	0.07	0.35	5	2.80

Note: determined by Bray No. 2.

Table3-14 Selected chemical properties of collected soil samples under different land preparation patterns.

Land preparation pattern	Soil depth (cm)	Exch.H (cmol/kg)	Exch.Al (cmol/kg)	Exch. Bases (cmol/kg)				eCEC (cmol/kg)	Base Sat. (%)
				Ca	K	Mg	Na		
Togoko naafena	70	0.13	0.50	0.89	0.05	0.16	0.03	1.76	64.17
	30	0.13	0.38	0.91	0.06	0.16	0.03	1.67	69.77
	0	0.13	0.51	0.42	0.02	0.06	0.01	1.14	44.85
	−10	0.13	0.18	0.38	0.02	0.04	0.01	0.75	59.95
	−30	0.13	0.21	0.30	0.03	0.04	0.01	0.72	53.06
Sugarcane field	0	0.06	0.04	5.40	0.09	0.87	0.01	6.47	98.42
	−30	0.05	0.04	8.22	0.09	1.29	0.01	9.71	99.08
	−50	0.05	0.00	9.30	0.10	1.43	0.01	10.89	99.53
Togoko kuru	45	0.03	0.03	1.39	0.15	0.45	0.02	2.05	97.55
	30	0.05	0.05	1.42	0.18	0.42	0.04	2.16	95.33
	0	0.05	0.21	0.50	0.08	0.10	0.03	0.97	72.80
	−30	0.05	0.00	0.39	0.01	0.12	0.02	0.59	91.51
	−50	0.05	0.01	0.41	0.01	0.22	0.03	0.73	91.45
Control	0	0.05	0.04	1.46	0.07	0.34	0.03	1.99	95.56
	−30	0.05	0.04	0.73	0.01	0.11	0.02	0.96	90.88
	−50	0.05	0.04	0.19	0.01	0.04	0.02	0.34	74.52
Ewoko	45	0.05	0.05	4.05	0.10	0.62	0.02	4.89	97.93
	30	0.05	0.03	5.90	0.39	1.07	0.01	7.45	98.98
	0	0.03	0.03	6.10	0.13	1.06	0.02	7.36	99.31
	−30	0.03	0.03	1.44	0.06	0.52	0.02	2.09	97.58
	−50	0.09	0.42	2.06	0.14	2.46	0.04	5.22	90.13
Control	0	0.03	0.03	3.07	0.25	1.03	0.00	4.40	98.86
	−30	0.06	0.18	0.24	0.07	0.15	0.00	0.70	66.04
	−50	0.03	0.23	0.11	0.03	0.11	0.00	0.50	49.67
Sugarcane field	0	0.03	0.03	4.70	0.20	0.65	0.00	5.60	99.10
	−30	0.03	0.03	1.26	0.03	0.29	0.02	1.66	96.97
	−50	0.03	0.41	5.85	0.12	2.23	0.03	8.66	94.96
Baragi	0	0.06	0.19	0.42	0.07	0.13	0.01	0.87	71.30
	−30	0.05	0.08	0.13	0.02	0.05	0.02	0.34	63.01
	−50	0.05	0.00	0.05	0.01	0.03	0.01	0.15	65.96
Control	0	0.03	0.03	0.25	0.04	0.09	0.00	0.43	88.39
	−30	0.03	0.03	0.13	0.01	0.05	0.01	0.25	79.60
	−50	0.03	0.03	0.04	0.01	0.02	0.01	0.13	62.29

deficiency causes excess iron accumulation in rice plants grown in the lowlands (Yamauchi 1989). Since termite mounds were often used for sugarcane fields, the fields were generally located at a slightly higher position (20-40 cm). In addition, farmer sapplied cow dung (from Fulani cattle) in sugarcane fields. Field observation revealed that mature sugarcane field can conserve soil and trap eroded soils from the upland area. This may account for the relatively high fertility of sugarcane soil and suggests another method of managing the soil.

The main reasons why Nupe farmers practice sequential land preparation methods by moving soils throughout the year were considered to be effective for, (1) weed control (Table 3-11), (2) the maintenance of the soil fertility (Table 3-14) under the social and ethnical conditions in which the availability of chemical fertilizer and animal manure is uncertain and limited, (3) the retention of residual soil moisture for a longer period than when fields are left in a flat condition, and the promotion of dry season crop production (Fig. 3-4. D), (4) the reduction of the effect of iron (Yamauchi 1989, 1992), (5) saving labor as spreading mounds enable to save about 40% of labor time compared to the flat tillage method (Ashraf *et al.* 1988).

(3) Microtopography and rice cropping patterns

Fig. 3-6 shows the distribution of rice varieties along the microtoposequence in Gadza village. Egwazankpa, ITA306, Cisadane, Farance (FARO14), Mars (FARO8) and Manbechi were identified. All these varieties except for Egwazankpa are high-yielding varieties and were released by IITA or National Cereals Research Institute (NCRI). Egwazankpa is assumed to be a local variety, because it did not correspond to any previously released line. Fig. 3-6 shows that ITA306 was cultivated in the valley bottoms, while Egwazankpa was grown in the fringe between the upland and valley. As there was insufficient water for the rice crop in the fringe, yield response of varieties differed appreciably between fringe and valley bottoms (Palada *et al.* 1987). As a result, generally rice grown in the fringe produced significantly lower yields than that grown in valley bottoms. It was reported (Palada *et al.* 1987) that the yield of ITA306 was the highest, (5392 kg/ha), followed in decreasing order by FARO 29, (4884 kg/ha), ITA212, (3669 kg/ha), and local variety, (3475 kg/ha), in valley bottoms. The yield of ITA212 was the highest, (1332 kg/ha), followed by ITA306, (1008 kg/ha), local variety, (921 kg/ha), FARO 29, (852 kg/ha), in the fringe. It appears that for each field position in the toposequence one certain variety is more suitable than others. The variety most preferred by farmers was ITA306, because of its high yield (Palada *et al.* 1987). Water is usually insufficient to grow rice in the fringe. Therefore, if rice is to be cultivated, early maturing and drought-tolerant varieties should be identified in the absence of an improved water management system.

Fig. 3-7 shows the relationship between the distribution of land preparation patterns and microtopography. *Togogi naafena* tended to be observed in lower

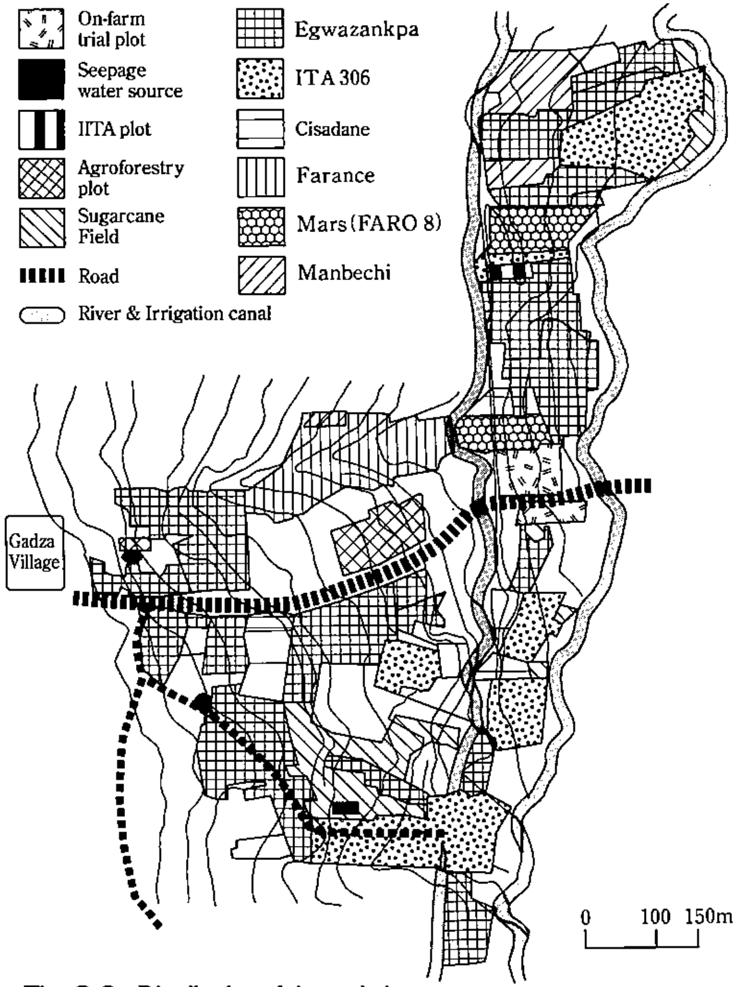


Fig. 3-6 Distribution of rice varieties. (Mapping position, see Fig. 3-3)

and sloping positions. *Togoko naafena* seemed to be applied in depressed or lower positions, and on comparatively flat ground. *Togogi kuru* tended to be distributed in convex and sloping areas. *Togoko kuru* was seen on convex and flat surfaces. *Ewoko* was observed in areas where there was not enough ground water for rice growth. *Baragi* was used when farmers wanted to cultivate rice again after fallow. Fig. 3-8 depicts the hypothesis put forward to explain why Nupe farmers' selected each land preparation pattern. The *Naafena* was used in lower positions or that resembled a hollow. The hooks of *Naafena* were made so that water could flow down to fields located in lower regions. Since *Kuru*

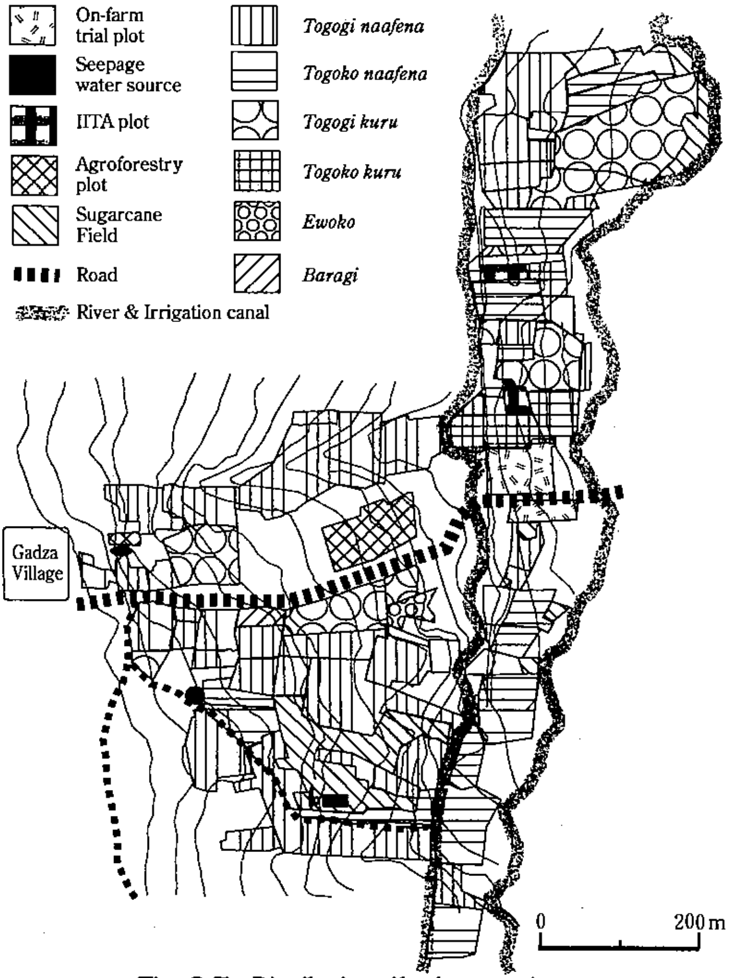


Fig. 3-7 Distribution of land preparation patterns.
(Mapping position, see Fig. 3-3)

was used in certain convex positions, the field required an enclosure to retain the water. *Togogi* was used in sloping positions, so that many small ridges were required for water control. *Togoko* was distributed in relatively flat areas. Consequently, fewer ridges were needed. *Ewoko* tended to be used in a location where water was scarce and did not allow rice production. The only reason why *Ewoko* was made was to save labor during heavy rainfall. *Gbaragi* was found in a floodplain or in areas where water is constantly stagnant. Ridges of *Gbaragi* may help to accelerate the germination of rice or to avoid rice seedlings bing

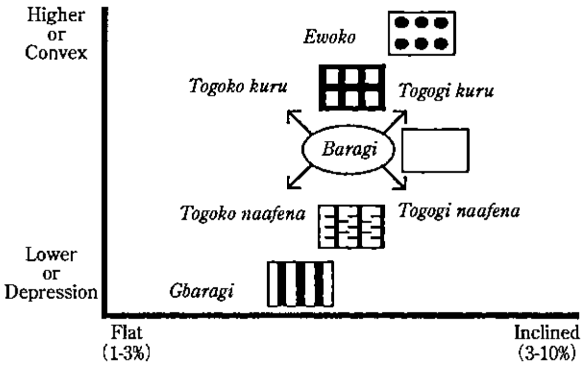


Fig.3-8 Hypothesis on relationship between topograpy and seven land preparation patterns.

washed of out of the ground.

For water retention in rice fields, leveling is done in Asian countries, Nupe farmers constructed ridges and mounds varying in shape and size in their traditional rice fields for water control instead of leveling. Small blocks, such as in *Togogi naafena*, *Togoko naafena*, *Togogi kuru* and *Togoko kuru*, were made due to the steepness of the slope and soil texture conditions in cultivated horizon and/or under cultivated horizon. Particularly in the latter case, if the horizon contains a large percentage of sand, water will not be retained, even if it is introduced. Before it becomes stagnant, it will rapidly flow to the subsoil. As a result, the small blocks reduce the loss of available water (Kuraku 1991). The changing patterns also seemed to play a role of cultivation.

3. Ethnopedological study of Nupe's farming systems

3-1. Ethnopedology

The most important characteristics of indigenous agricultural knowledge are as follows ; (1) it has been developed to change the cropping systems and adapt them to agricultural soil potential, (2) yield is the second priority, (3) it reflects problems and priorities in each cropping environment (Marten *et al.* 1986). Indigenous knowledge is expected to offer new aspects for long term sustainable and suitable farming systems. Computer modeling was used to generalize folk expert systems for indigenous soil classification in the highlands of Peru. Indigenous soil erosion control system in relation to water and soil conservation and management methods were surveyed (Bocco 1991). These models revealed that the major technical principle was the management of the accumulation of eroded soil rather than erosion control. However, small farmers in the highlands of Bolivia imitated the natural process to avoid soil erosion (Zimmer 1994). In Haiti soil conservation methods using agroforestry with perennial crops, Zare, Sakle en woulo, Ramp pay, Kleonaj, Bit, were also reported (White *et al.* 1995).

In the Bida area in Central Nigeria from 1986 to 1989, the International Institute of Tropical Agriculture (IITA), carried out on-farm trials for the introduction of the Asian lowland water management system of rice production. Although sawah produced higher yields and exerted beneficial effects on soil and water conservation (Ashraf *et al.* 1988, Carsky *et al.* 1991, IITA 1988, IITA 1989, Palada *et al.* 1987), the sawahs constructed at the benchmark site were not maintained by the farmers after on-farm trials carried out for three years. Although sawah seemed very promising to solve food and land degradation problems in West Africa, the actual integration was not easy (Wakatsuki 1996). A previous report (Ishida *et al.* 1996) characterized the indigenous soil knowledge, evaluation, management and classification system based on an ethnopedological survey for the Nupe people in the Bida area. In some benchmark sites around the Bida area, preliminary ethnopedological surveys on the Nupe have been conducted (Warren 1992). In this paper, Nupe's indigenous small-lot quasi-sawah rice farming and soil management systems were characterized to identify rice-based lowland farming systems that were long-term and sustainable from the crossing of culture between tropical Asia and Africa.

3-2. Lessons learned from failure in the introduction of Asian sawah field system

In the Bida area where Warren conducted interviews with the Nupe, IITA carried out various farm experiments, including the introduction of the Asian-type sawah rice farming system, in the 1986-1990 period as mentioned in Chapter 6, 1 and 2. These experiments consisted of (1) researches on hydrology and pedology, (2) monitoring of soil water dynamics and change of land use in the research site, and (3) assessment of influence from the Asian-type sawah system on the rice yield and soil. The Asian system excelled in yield increase and in soil and water conservation but in Gadza, just after the experiment project ended and sawah fields were transferred to local farmers, the farmers stopped the management of the fields. They destroyed the large sawah fields developed in the experiment, remaking them into the traditional Nupe rice cropping system. On the other hand, farmers in Gara accepted the Asian-type sawah fields and also voluntarily developed this type of fields in some other parts of the village. In 1993, the "Project for Regeneration of Agro-Forest-Ecosystems in Subsaharan Africa (Hirose Project)" supported by the Grant-in-Aid for Scientific Research of the Japanese Ministry of Education, Science and Culture started to investigate mainly the basic conditions needed for the introduction of the Asian-type sawah rice farming system into this region. In some areas, trials of farmers' participatory research were successful (see Chapter 6, 2-1). The Hirose Project aims at devising and implementing a development model with voluntary farmer participation that would harmonize with the traditional farming system. In other words, the project intends to propose a more intensive agricultural system with environmental conservation in inland valley watersheds. The integrated environmental conservation system which combines the Asian sawah system in the lowland, agroforestry systems in the upland, and indigenous knowledge of the Nupe and Fulani consists of forestry, livestock raising, upland cropping, lowland agriculture and fresh water fisheries. The failure of the preliminary IITA project was partly attributed to lack of information about the indigenous Nupe rice-cropping techniques referred to in the previous section. It was considered important to investigate the cultivation environment that has determined and developed the Nupe people's indigenous farming methods. In particular their classification system of soils, the basic resource of agriculture, was researched and analyzed by the methods of soil science. Our purpose was to know the limiting factors in the cultivation environment, which should be reflected on the classification system, and to identify priority matters.

3-3. Survey site and experiment method

The reseach site, Gadza, village is situated at Lat. 8°59' N. and Long. 6° E, about 12 km south of Bida, Niger State, Nigeria. It is in a middle-basin part of the Emikpata watersheds (Fig. 3-3). This area is inhabited by the Nupe, who have traditional rice farming techniques in lowlands, and Fulani, who are cattle nomads. Its vegetation belongs to the Guinea savanna zone and its mean annual precipitation is about 1200 mm. The bedrock underlying the soils is of Mesozoic (Cretaceous) origin, and is generally designated as Nupe sand-stones. Nupe's upland farming is characterized by bush fallow and mixed cropping systems consisting of sorghum, millet, maize and other cereals as well as okra, onion, spinach, sweet potato, and cowpea. In the lowlands, they grow rice in the rainy season and produce cassava, sweet potato and vegetables, such as okra, garden eggs, tomatoes, red peppers, and onions after harvesting rice, by forming various types of ridges and mounds.

The surveys were conducted from August to November, 1994 and from June to October, 1995. Soils were sampled from 36 typical soil profiles along two transects established from the mountain tops and valley bottoms. Interviews with Nupe farmers were also held in the field about the Nupe words for classifying soil color, soil texture, soil quality rating, and also the types of crops grown and reasons for their selection.

Soil samples were air-dried, ground, and passed through 2 mm sieve. Particle-size distribution was determined by the pipette method.

3-4 Results and discussions

(1) Nupe's topographical description and classification

Eight terms for topographical description were collected from interviews with Nupe farmers: *Pati edati* (mountain top), *Pati kapa* (mountainside), *Pati shin* (foot of mountain), *Kinda* (gentle slope), *Wada* (fringe of valley), *Eddin* (lowland), *Dinnye* (valley) and *Dinnye zoba* (valley bottom)(Fig.3-9). Two terms for slope inclination were collected: *Yara* (comparably steep) and *Fili* (flat). In the

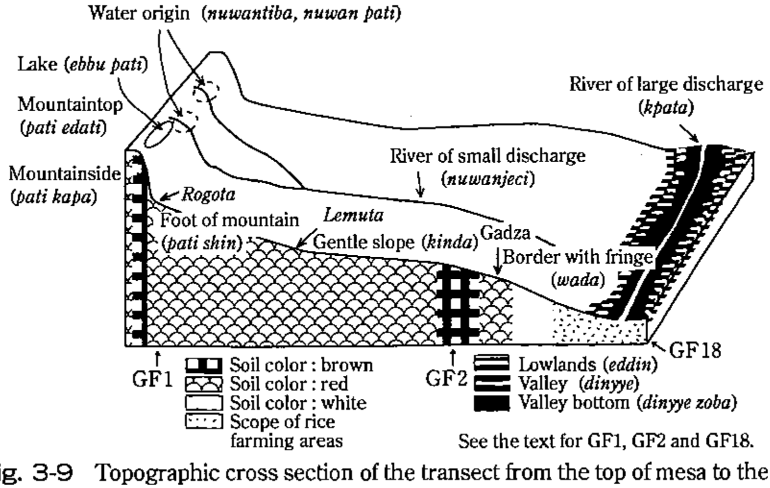


Fig. 3-9 Topographic cross section of the transect from the top of mesa to the Emikpata River, Nupe's names and soil colors (see Fig. 3-3 for the location of the transect.)

lowland, five terms, *Bata, Diye, Esunti, Gunji* and *Kotu* were used to distinguish microtopography in relation to water conditions. *Bata* means the "place where water comes", but is a general term for lowland. *Diye* is "the place where water does not lie stagnant and is comparably low". *Esunti* and *Gunji* mean "the place where are located in flooding area, but where water does not come even where the river flooded (surrounding the *Diye*)". *Esunti* is higher or wider than *Gunji* in the area where water do not lodge. *Kotu* is a term for "the place where water does not come in lowland sawah rice cropping area and usually sugarcane is planted". *Kotu* may in many cases be a termite mound. The Nupe have three specific names for termite mounds. *Gana* is made by big reddish termites (*Ekako*), *Kaji* by little reddish termites (*Eka*), *Dokun* by little whitish termites (*Eka bokungi*). A comparably higher position is called *Gbogbonti* and lower is *Gudu*. *Nuwantiba* and *Nuwan pati* are the terms for the source of a river, *Nuwanjeci* is a small stream and *Kpata* is a big stream. Soil colors are changed along the toposequence: there is red soil on the mountain top, from mountain foot to gentle slope and village, brown soil is on steep mountainside and the upper slope from villages, whitish grey soil in fringes and gray soil in the lowland. *Rogota, Lemuta, Gadza* in Fig. 3-9 are villages. All are located on red soils that are used for house construction.

(2) Nupe's soil classification

Eight terms for soil color, were collected from Nupe's general concept on soil: *Dzuru, Dzuru kpany, Nuwon'din, Yaran, Pura, Nuwon'din pura, Bokun,* and *Ziko*, and six terms for soil texture: *Jikana, Jikana wasagi, Jikana wasa, Jikana dzuru, Suku* and *Ezuru*. Two terms for specific soil names are *Egun* (sticky reddish soil on gentle slope from the mountain foot) and *Eddo* (grey soil used in lowland sawah rice cropping).

Table 3-15(a)(b) shows soil color distinctions in Nupe, and soil color from the Munsell color chart. Topograpically, *Dzuru* might be surface soil on foot slope of a mesa and the continuing peneplain, *Dzuru kpany* is the subsoil of *Dzuru*. *Nuwon'din* is a term for the surface soil on a hillside and upper slope of a village, and *Yaran* is its subsoil. *Pura* is the surface soil of a village and *Nuwon'din pura* is subsoil. *Bokun* is in furinge. In Munsell colour chart, *Dzuru* varies between 5YR4/7 and 4.5-5/8, reddish brown, bright reddish brown, *Dzuru kpany* is 2.5YR3/6, dark reddish brown. *Nuwon'din* is 7.5YR3/3, 4/4, dark brown and brown; *Yaran* is 7.5YR4/6, brown. *Pura* corresponds with 2.5YR4/6, reddish brown and *Nuwon'din pura* with 7.5YR3/4. *Bokun* is 10YR5/8, yellowish

Table3-15(a) Nupe's classification of soil colors and textures

		Nupe word	English translation
①Soil color	Red	*dzuru*	red
	Yellowing brown	*pura*	orange
	Brown	*nuwon'din*	brown
	White	*bokun*	white
	Yellow	*yaran*	yellow
	Black	*ziko*	black
②Soil texture	Clay	*ezuru*	clay
	Fine loamy sand	*suku*	fine loamy sand
	Sand	*jikana*	sand
③Soil name	Clayey red soil	*egun*	red and sticky
	Gley soil	*eddo*	loamy, sandy with water (mud)

Table3-15(b) Nupe's soil color classification compared with the classification of the soil color chart

Soil color in Nupe language	Standard soil color chart equivalent	English equivalent
dzuru	5YR5/8, 4/7, 4.5/8 Light reddish brown, reddish brown	red
dzuru kpany	2.5YR3/6 Dark reddish brown	
nuwon'din	7.5YR3/3, 4/4 Dark brown, brown	brown
yaran	7.5YR4/6 Brown	yellow
pura	2.5YR4/6 Reddish brown	orange
nuwon'din pura	7.5YR3/4 Dark brown	brown
bokun	10YR5/8 Yellowish brown	white

Table3-15(c) Soil texture classification in Nupe language

Soil texture in Nupe language	Soil texture type	English equivalent	Crops grown
jikana	Sandy Loam	sandy	Egusi melon, millet, groundnut, cowpea
jikana wasagi	Loamy Sand	not completely sand	Egusi melon, millet, groundnut, cowpea
jikana wasa	sand	completely sand	Egusi melon, millet, groundnut, cowpea
jikana dzuru	Sandy Clay Loam	sandy clay	Egusi melon, millet, groundnut, cowpea
suku	Silt Clay	fine loamy sand	Millet, groundnut, Egusi melon
ezuru	Heavy Clay	clay	Millet, cowpea, sorghum, maize

brown. When surface soil is compared to subsoil, *Dzuru* is redder than *Dzuru kpany*, *Yaran* is yellower and lighter than *Nuwon'din*. *Nuwon'din pura* tends to become brownish and darker than *Pura*.

(3) Comparison between Nupe's soil texture distinction and analytical data

Table 3-15(c) shows soil texture. *Jikana, Jikana wasagi* and *Jikana wasa* can be distinguished in sandy soil. *Suku* and *Ezuru* are in clayey soil. Fig. 3-10 shows the result of particle size analysis. GF1, GF2, and GF18 are typical survey pits located on mountain foot, peneplain and in the lowland fringe. In GF1, clay contents were 10-12%, sand contents were 80-90% from the surface to 23 cm depth ; clay contents increased by 48.5% and sand contents decreased by 43.8% at the lower levels. Silt contents were less than 10% through all horizons. In GF2, clay contents were less than 10% and sand contents 87-90% from surface to 25 cm depth and changed to 40.2% and 55.8%. Silt contents were less than 5% through all horizons. In GF18, clay contents varied from 7 to 10%. Sand contents increased from GF1 (mountain foot) to GF18 (fringe), and clay contents of all pits were less than 5.5% except at 135-180 cm depth in GF1. Silt contents from all horizons were generally quite low. The Nupe have only one term to describe silt, i.e., *Suku*. Sandy soils which distributed more than 40% were described in three terms, *Jikana*, *Jikana wasagi*, and *Jikana wasa*. If the amount is high and important, distinctive term also may become many. According to Nupe farmers' evaluation of GF1 soil is "good", GF2 is "relatively good", and GF18 is "bad".

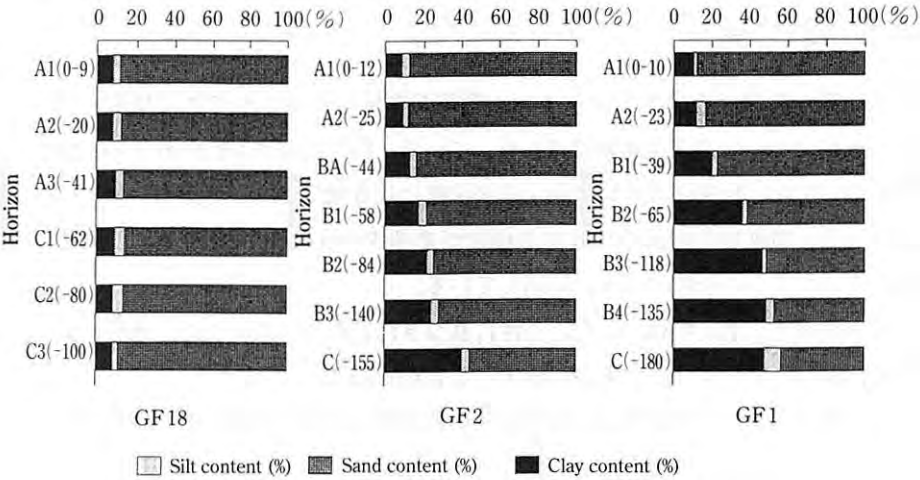


Fig. 3-10 Soil particle analysis

This assessment corresponds with the clay contents. The reason is possibly that clay contents play a dominant role in holding water under savanna conditions where the major limiting factor is the water contents in soil. According to Talawar (1991), farmers in semi-arid regions of India consider comparatively less fertile sandy soil as rich (fertile) soil because it has a rate of high water permeability. In rainfed semiarid agricultural areas, where farming is considered a gamble due to erratic rainfall patterns, moisture conservation is more critical than fertility levels for successful crop production.

3-5 Conclusion

The Nupe, who engage in lowland rice farming have classification concepts for topography, rivers, and soils, the elements closely connected with agriculture. In particular, they have the microtopographic classification for the lowlands where they grow rice according to water flows and stagnation on the groundsurface. They also classify termite mounds which sometimes determine ground shape (concave and convex), in microtopography depending on the types of termites.

The Nupe farmers' soil classification is based on its color and texture. They also recognize that different soil types appear in different topographical areas.

Their soil rating seems to correspond with the clay content of soil since clay is important for the retention of soil moisture, one of the limiting factors in the cultivation environment.

(Fusako Ishida)

Chapter 4

People and Forests in Guinea Savanna

1. Land and forest resources in the northern Nigeria

1-1. Introduction

(1) Outline of climate and vegetation

The geography of Nigeria is characterized by the Niger River that flows from the northwest border toward the southeast and the Benue River that rises in Cameroon. These two rivers join in the central part of the country, and then the mainstream turns off to the south and flows to the Gulf of Guinea. This geographical setting brought by the river has demarcated the three regions of the north, the southeast and the southwest, and has affected the historical process of colonization as well as the ethnic relations. The Hausa, the Yoruba, and the Igbo who occupy the main parts of the north, the southwest, and the southeast respectively have formed the three major ethno-linguistic groups of Nigeria.

All the land is situated in the tropics. The Southwest Trades bring the rainy season, while the *harmattan* brings dusty clouds in addition to aridity from the Sahara during the winter of the Northern Hemisphere. The average annual rainfall basically changes by the latitude : more than 4000 mm along the eastern Gulf of Guinea, around 1500 - 2000 mm in Enugu and Ondo, 1000 - 1500 mm in Ibadan, Jos and Bauchi, 750 - 1000 in Kano, and less than 750 mm in the northernmost regions as found in Sokoto and Maiduguri. These rainfall patterns are not only affected by a long-term influence of climate change but also fluctuates under 10 - 30 years cycle (Buchanan & Pugh 1955, 23-29 ; Oguntoyinbo 1982, 16-17).

The vegetation is basically determined by the extent of aridity/humidity. Mangrove and swamp forests are distributed on the deltas of the Niger River, while the southern region with 8 - 10 wet months is categorized to the high forest zone. The region with 1000 - 2000 mm annual rainfall accounts for almost a half of the country, where the vegetation is categorized to Guinea savanna or savanna woodland characterized by a combination of trees and undergrowth of high grasses. The region with the rainfall less than 1000 mm and 6 - 8 dry months is called Sudan savanna, which accounts for a quarter of the total land and the vegetation consists of thorny shrub and short grasses (Iloeje 1981, 56-63 ; Areola 1982, 24-25). Long-term human impact on vegetation, however, has created a derived savanna zone even in humid areas. As Areola aptly stated, the vegetation of Nigeria consists of forest and savanna (1991, 18). Distribution of forests is not only determined by humidity but also by the efforts of conservation.

The study area is located in the southern part of Niger State, or in other words, on the Niger-Benue trough that lies across the country. The trough is also called the middle-belt or the transition zone, since it is in between the moist climate of the south and the dryland of the north. Like the deltas along the Gulf of Guinea, the middle-belt holds various ethnic minorities, among which the Nupe forms the largest ethnic group. Following the usage of Hausaland or Yorubaland, here we call the region where Nupe people settle as Nupeland.

The annual rainfall of Niger State varies from 900 mm in the north and the west to 1200 mm in the south, which brings the difference in vegetation. Shrub grassland to woodland transition covers the major part of the state. Forest pockets are scattered, while fringing forests appear along the drainage courses of the major rivers (Niger State Committee on Desertification Problems 1988, 5-7). The soil of Nupeland is categorized to ferrisols developed on the sandstone formations (Areola 1982, 22-23). The red earth, mesas, and anthills rising from verdure farms impressively characterize the landscape of Nupeland.

(2) Expansion of derived savanna

The term of "desertification" immediately suggests Africa. Indeed the United Nations Convention to Combat Desertification (UNCCD) added the phrase of "particularly in Africa", and reports in relation to UNCCD place great emphasis on the serious conditions in Sub-Sahara Africa.

The country report on Nigeria prepared for the 3rd session of the Conference of the Parties held in 1999 describes this phenomenon as "gradual shift in vegetation from grasses, bushes and occasional trees, to grass and bushes and the final stages, expansive areas of desert-like sand", and estimates that between 50 and 75 percent of the ten northern states, or about 35 million people are being affected by desertification. In addition, seven adjacent states to these northern states, including Niger state, are reported to have about 10 to 15 percent of their land threatened by process of desertification (Federal Republic of Nigeria, 10-11 see Fig. 1-14).

This trend of desertification, or in other term forest degradation, was pointed out by Stebbing who visited West Africa in 1934 after long experience in the forestry department of India. He expected to observe a succession of forest vegetation from moist to drier climates during his trip. What he found near Bouaké, Ivory Coast, however, did not appear to be savanna but a degraded dry monsoon forest. Moving eastward to Nigeria, he had a confidence that Guinea savanna was no more than derived vegetation, and came to a conclusion that the canopy should be closed under intact conditions (Stebbing 1937, 1-12).

In contrast to Southeast Asia where the vegetation is categorized by a combination of various factors such as climate, locality, soil and elevation (Whitmore 1985, 155), the vegetation maps of Nigeria (Fig. 2-9) are roughly zoned to coastal forest, high forest, forest-savanna mosaic, Guinea savanna, and Sudan savanna, but no reference is found to distinguish the seasonal forest from the rainforest. Most of the area is more or less categorized to savanna vegetation formed as a result of the human impacts.

The course of degradation also shows difference by region. Forest degradation has been accelerated in many parts of Southeast Asia, despite the growing alarms by journalists, researchers, and NGOs on uncontrolled resource management. It suggests that at the initial stage there is an interactive course between the economic growth and the forest deterioration, or environmental destruction in a broader sense. When the limitation of resources is no longer negligible, the tendency of "first come, first served" is instigated. On this account, it is not easy to check the expansion of forest deterioration until it becomes a matter of fact for every stakeholders that further loss of forests will directly cause disadvantage. By contrast, savanna of West Africa was not derived by rapid expansion of commercial logging, agricultural plantation, or ranch as observed in Southeast Asia and Latin America, but rather by the historical process of interaction between the human activities and the nature.

While the problem of desertification has drawn worldwide attention, we should also take the contrary finding into consideration that in West Africa the forest area has increased in accordance with the spread of human settlements (Fairhead & Leach 1998), though Nigeria is not included in the cases. True or not, there is no reliable data on the total forest area and the forest resources in Nigeria. Moreover, population and agricultural statistics that are indispensable to assess current situation and future trend on forest resources are also insufficient, and the federal government has recently established a statistical data collection system[1]. To supplement this lack of information, primary data collection reflecting the realities of each area is required.

In regard to Niger State, the Niger State Committee on Desertification Problems once warned that a gradual reduction in rainfall and ground water level was being observed and concluded that the mismanagement of land and forest resources was the main cause of desertification. The report also put emphasis on the limited area of gazetted forest estates: only 3,521 square kilometers out of 72,444 square kilometers, or only 4.9 percent of the state land area (1988, 14-16). If the desertification problem is as serious as emphasized on public documents, this also suggests the necessity to review the forest and forestry regimes to find the root of the problems.

(3) Data collection

The first half of this section looks at the historical background of forest and land regimes established during the colonial period and discuss the adjustability of the regimes to already existing land systems, mainly based on literatures.

The term "land system" implies interactive relations between land tenure and land use. Traditional land tenure systems vary from place to place and are also inseparably related to the other social systems. Due to limited literatures, only the relation between the forest regimes and the statutory land tenure system is analyzed in general with supplemental explanation on the case of Nupeland.

The latter half of this sectoin turns the views to a case in Niger State, based on the results collected through interrupted short-term visits from 1992 to 1995. The steps and methods taken for primary data collection are described below:

a) RRA in Cis-Kaduna

The region called Cis-Kaduna represents the center of the Nupe culture and politics, which is geographically demarcated by the Kaduna River in the west

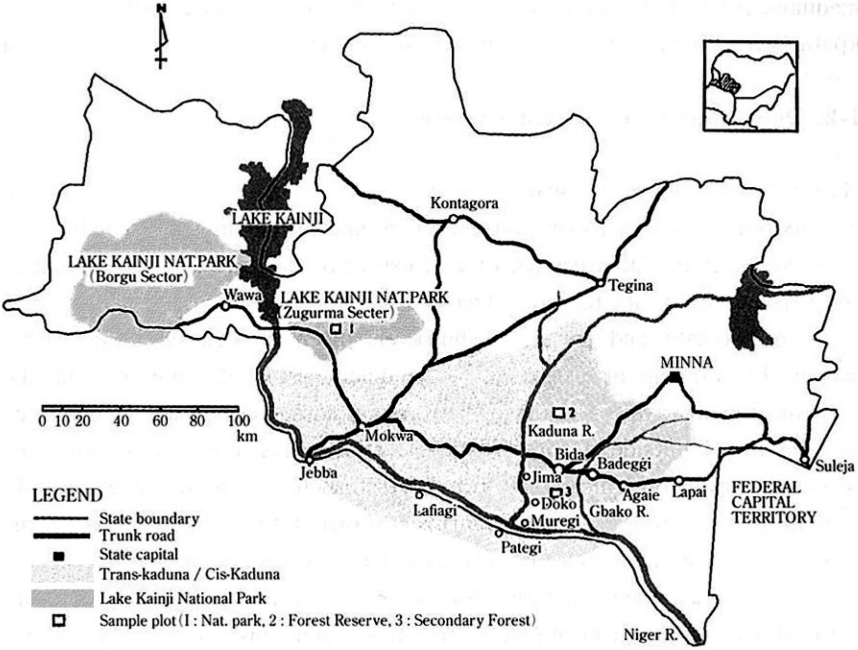


Fig.4-1 Niger State.

and by the Niger River in the south (Fig. 4.1). Together with the topography maps, Rapid Rural Appraisal (RRA) was carried out to categorize the rural settlements. Based on the results, four types of settlement were extracted: settlements on the mesas, the upland, the lowland along inland valley bottom, and the floodplains.

b) RRA along the Emikpata River

Since it represents all of the above-mentioned topography types within relatively short distance, the Emikpata River (Fig. 3-3) was selected for the next step of RRA. It is a small tributary that flows from foot of one of the mesas surrounding Bida toward the south and joins the mainstream of the Niger River. Interviews on the origin of the settlements and land occupancy were carried out with key informants of each settlement along the Emikpata in 1994.

c) Selection of a sample settlement

Since the inland-valley-oriented settlements seemed to be the most common type and also fit to examine the distribution of trees by different land use, a medium-sized G Settlement was selected from the settlements along the Emikpata River for intensive measurement and interview.

1-2. Development of forest regimes

(1) Creation of forest estate

It is axiomatic that a forest consists of inseparable combination of land and forest vegetation. The areas used for forestry are categorized to forest estates, and it is expected that there are trees on forest estates.

Forest estate and trees are, however, often dissociated in developing nations. Even though an area is demarcated as forest estate on a map, forest or trees are not always found there. Conversely, as mentioned later, forests can also be found outside a forest estate. Definition of forest vegetation also becomes a problem. Unless certain indicators such as canopy cover and minimum area are set to show the boundaries, it is difficult to define what is a forest, especially in semi-arid zones or seriously damaged ecosystems.

In many developing nations, forestland classification was coincidentally realized with acquirement of land by the state. Such a process took place during the colonial period, and similar forest regimes were established under the same suzerain. The British and the Dutch colonial governments, which had not developed forestry in their own lands, invited German foresters and researchers one after another in the late of the 19th century to establish forest administration and management bodies as well as legal structures.

Such a modernization process on forests was embodied separately from the land systems as a whole. From an outlook on the tropical rainforests in Southeast Asia, timber distribution during the colonial period was limited to local or regional markets, and the time did not allow the expansion of the timber estates. Consequently, forestland demarcation took place only in limited areas close to the centers of the colonial power or under Direct Rule.

After the Second World War, however, vast rainforests that were almost intact during the colonial period were suddenly incorporated to the state forest. In accordance with the growing demand on raw materials for plywood industry, primarily in Japan, wood provided from rainforests came to have a significant value. The physical nature of Dipterocarpus species especially satisfied the requirements for the plywood industry: round, straight, large-diameter, long, and without knots. Large-scale forest exploitation took place where the market demand, resources, institutional aspects, and necessary technology such as the heavy equipments for timber extraction and the capacity of marine transportation were present.

Thus, it can be said that forest resources determine the process of forest development as a prerequisite and are affected by the additional conditions of market and technology. Particularly in rainforests of Southeast Asia, forest regimes were established under the initiative of the government that expected private investment in forestry sector. It was conspicuous in Indonesia, where the Basic Forestry Law of 1967 declared all the forests as state property despite the people already living in the forests, and a series of regulations followed to call foreign investment to the forest resources (Masuda 1998, 28-36). Now forest exploitation has reached at a deadlock, and the next step is groped toward building new relations between the remaining seriously damaged resources and the people living in the forests.

For the regions without considerable market pressure, how did the relations between forests and people develop historically and what kind of impact has been brought on forest resources?

The economy of West Africa was also incorporated to Europe through the process of colonization. In regard to forest products, however, the European market has been basically closed within the area (Mery *et al.* 1999, 272). Consequently, such a strong market impact on forest regimes and forest resources such as in Southeast Asia cannot be easily observed in the forest history of West Africa. Moreover, in the savanna zone where economic importance of the forest resources is much lower than the rainforests, timber has never been an international commodity and only small-scale logging activities have been practiced for local demand. Then how did the modernization process in relation to forests take place?

(2) Colonization process until 1914

Though West Africa had brought various products, including gold and ivory, European concern until the 19th century was rather limited to the commerce on shore from Gambia to the Gold Coast. Davies said: "had it not been for the bountiful supplies of slaves, no European trader would have proceeded beyond the Gold Coast" (1957, 228). During the two centuries, a significant number of slaves was shipped, not only from West Africa but also from East Africa, under the collusion of native raiders and European merchants. It became known as the triangular trades that shipped manufacted goods in outward passage from Bristol, slaves in middle passage from West Africa, and sugar and mahogany in inward passage from Jamaica, for instance (Catchpole & Akinjogbin 1983, 43).

With the abolition of slave trade and slavery starting in 1807, the British traders turned their interest to natural resources, one of which was oil palm (*Elaeis guineensis*). It is recorded that the United Kingdom imported 130 tons of palm oil in 1790, which constantly increased throughout the 19th century and reached nearly 50,000 tons per annum during the 1880's. The plant was even introduced to Labuan, an island north of Borneo, and started to yield in 1878 (Moloney 1887, 34-37).

The Niger River deltas were one of the producing centers of palm oil. Increasing importance of Lagos as a harbor derived the attack of the naval force in 1851. After ten years, Lagos was formally annexed as a British colony and since that, the British power as well as the commercial activities gradually penetrated from the coastal line toward the hinterlands following the Niger River. Among those, the United African Company, founded by Goldie in 1879 and two years later changed to the National African Company, expeditiously took measures to counter the French and German rivals (Cook 1943, 79-94).

The most part of Nigeria, however, yet remained unknown. When means of mass transportation was limited to navigation, only the areas adjacent to coastal lines and navigable rivers were accessible. The mainstream of the Niger river, however, was broken by basement rocks to rapids between Yelwa and Jebba, where Mungo Park, the remarkable explorer of West Africa, lost his life in 1806. Consequently, Jebba was the northern head of trading zone for the European merchants. It was not until the 20th century when the inland became incorporated to colonial economy in accordance with railway construction (Buchanan & Pugh 1955, 17).

Since the potential of hinterlands was yet questionable, the land partition of West Africa by the colonial powers was based on the coastal line. A watershed was automatically appendant to the river mouth and then belonged to the suzerain that possessed the coast. As soon as Berlin Conference in 1884-85 confirmed British priority over the coast between French Dahomey and German Cameroon, Goldie started the efforts to acquire a British charter. With the approval of Foreign Office, his company became the Royal Niger Company Chartered and Limited (RNC) in 1886, empowered to engage in commercial activities while administering the territories. Heussler evaluated this process showing less strategic concern by the British government, which just did not care much for the idea of Northern Nigeria's becoming French or German (1968, 14-15). Similar circumstances can be found in the colonial history of Borneo that also formed a backward periphery of the British Empire. Owing to the uncomfortable environment of vast swamps surrounding the island, the administration of Sarawak was entrusted to a family and Sabah to a private company, while the Dutch Borneo also remained almost intact.

The revenue of RNC, however, was never sufficient to cover the maintenance expenses of the private army as well as the administrative and commercial activities, and the deficit was annually made up by the grant-in-aid from the British government. Due to the weakening of RNC that sustained damage through several battles against native resistant with the need to check the French advance, the British decided to revoke the administration authority from RNC with some compensation. The claims of Liverpool merchants against the trade monopoly by RNC also pushed it (Cook 1943, 96-114).

The short history of RNC ended in 1900. With the overthrow of Benin in 1897 by hostile operations, the already existing British protectorates along the coast were merged into the Southern Protectorate. Eventually Northern Protectorate was also proclaimed. Together with Lagos Colony created in 1861, Nigeria was nominally organized under British Rule, and the word Nigeria came into official use to describe these new protectorates (Nicolson 1969, 1). Lagos Colony and Southern Protectorate were merged again in 1906, and then in 1914, the amalgamation of Southern and Northern Nigeria was proclaimed. The colonial period was ended in 1960 with independence.

(3) Forest regimes during the colonial period

The development process of forest policy as well as the backgrounds during the colonial period, from 1897 to 1960, is already given in the substantiel work of Egboh (1985). Here we just review his work with some complementary materials.

The process to establish the colonial system is always described with the name of F. D. Lugard, the first high commissioner of Northern Nigeria Protectorate. He once left Nigeria in 1906 but returned again as the governor-general in 1914 after the amalgamation. During his service, Lugard founded Indirect Rule that utilized already existing Native Administration (NA), particularly in the northern Nigeria.

Lugard also played a significant role in founding the forest regimes. He first warned the Colonial Office of forest degradation, and suggested to strengthen the finance through natural resources development, particularly in the Southern Nigeria, which was much dependent on the import tax of alcohol. Ordinance No.

12 enacted in 1916 gave power to the governor in demarcating of forest reserves. At the same time, Regulation No. 10 designated certain tree species including oil palm to be protected and imposed fees and royalties for sale or export of such produce (Burns 1917, 58-62).

Notwithstanding the compulsory acquisition clause of the ordinance, the colonial government was reluctant to use it under the fragile political balance kept by Indirect Rule. The breakthrough was brought about with amendment of Ordinance No. 12 in 1927. In addition to the framework of government forest reserve, it empowered the traditional authorities to constitute and manage the Native Administration forest reserve (NA forest reserve) within their jurisdictions, under approval of the governor and supervisory control of the Forestry Department. In return for the expenses borne by NA, any revenue derived from the reserves was to be paid to the treasury of NA concerned (Egboh 1985, 52-58).

In 1938, a more integrated Ordinance for the Preservation and Control of Forests was commenced, and a part on Communal Forestry Area (CFA) was added in 1941. It aimed to encourage the local communities to restore the denuded lands, and authorized NA to establish CFA at a request of any community with the approval of the resident. The total area of the forest reserves started to expand, while CFAs were spreading out particularly in Plateau and Tivland where ethnic minorities inhabited without developing Kingdoms. In 1938, about 5.4 million hectares or 5.7 percent of the land area were demarcated, in which around 30 percent belonged to the government and 70 percent to the NA forest reserves. The estimated total reserved area reached 6.9 million hectares or 7.1 percent in 1945, and 9.2 percent in 1960 (Nigerian Forest Authority 1948, 91 ; Egboh 1985, 59-60, 198).

Egboh regarded the forest reserve as a countermeasure to forest destruction and evaluated the figures positively as the staged outcomes of decentralization and empowerment of local people through the creation of NA forest reserve and then CFA (Egboh 1985, 60). It might be true that the colonial government was facing an urgent demand to adopt a measure against uncontrolled forest resources exploitation, and to reserve certain portion of land and exclude unauthorized activities could be one of the measures. But how serious was the situation? How were the people empowered under the Indirect Rule, and what kind of benefit could people get from the forest reserves? To discuss the implicit meaning of those figures to show the progress in forest administration, it is necessary to examine the procedure actually adopted and the quantitative aspects of forest administration as well as native administration.

Forest officers at that time consisted of scientifically trained conservators and executively trained foresters, but very few of the latter were Europeans. The former were procured from the graduates in forestry from Oxford, Cambridge, or Edinburgh, who spent a year or one and a half year for elementary subjects such as botany and mathematics and then another one or two years for professional subjects in forestry including six months practice in Scottish or English forests. After the initial appointment as an assistant conservator on probation, a further three months course was taken at the Kew Gardens on taxonomy of tree species in Africa. Most of the forest officers were stationed in Ibadan, where the headquarters of the Forest Department for the southern provinces was located. The headquarters for the northern provinces was in Zaria (Unwin 1920, 184-185).

The British forest services in West Africa were established earlier compared to French colonies. Nevertheless, there were only three gazetted officers with one on leave in Sierra Leone; twelve, including two research officers, in the Gold Coast; and Nigeria, the largest protectorate of the three, had forty-six gazetted officers in 1934. These conservators were in charge of one or more provinces with assistant conservators attached to them. There were, however, no sub-divisions under the conservator's circle, and the assistant conservators had no regular programs of work and independent executive charge. Moreover, only six out of forty-six were assigned to the northern provinces (Stebbing 1937, 62-64).

Forest reserves in the southern provinces were mostly created under the government scheme, behind which clear motivation to secure forest resources for economic development under direct control by the government can be perceived. Forest Department once tried to set 25 percent quota of forest reserves for each division and entered into an agreement with some chiefs of Southern Nigeria during the 1920's, in exchange for withdrawing prohibition of commercial exploitation outside the forest reserves imposed by the Ordinance of 1916. However, the quota was abandoned in 1933 due to uneven distribution of population and hostile chiefs. The government attempted to use execution proceedings particularly for the eastern provinces but did not succeeded (Egboh 1985, 68-70).

Until 1960, approximately 13 percent of Southern Nigeria was demarcated as forest reserves, but of course forests or trees also existed outside the reserves. It was estimated that approximately 40 percent of the total land had a potential for timber exploitation. Logging activities were mainly done outside forest reserves, and only the number of felled trees was recorded for the payment of royalty. The foreign trade statistics on forest products, that is, raw and processed wood of 1934-38 show the total value of import exceeded export. Though the estimated annual export value of timber constantly increased from 1895 to 1960, the percentage to the total export value ranged between 1 and 4 (Unwin 1920, 164 ; Stebbing 1937, 198-199 ; Nigerian Forest Authority 1948, 3-5 ; Egboh 1985, 214-215).

Despite concentration of personnel as well as facilities in the southern forests that provided valuable species like African mahogany (*Khaya* spp.), almost 70 percent of forest reserve area was established in the savanna zone of the north. In contrast to the southern provinces, demarcation in the north made progress after NA reserves and CFA were introduced. Egboh listed the factors that brought rapid expansion of the forest reserves in the north as : different character of the land rights from the south, low population density, absence of agricultural plantation, and more serious forest degradation. In addition, the colonial government was less interested in the direct control of reserves in the north and even transferred the then existed government reserves to NA after enforcement of Forest Ordinance of 1927 (1985, 71-73 ; 196-198).

It is not difficult to make a guess that there was no positive reason for the government to incur the expenses of control and management for the valueless savanna forests. But if so for the government, why did NAs in the north accept to keep certain portion of their jurisdiction for the reserves? What was the benefit for them? How could the constant expansion, from about 6,000 square miles in 1930 to 11,000, or annual average of 130,000 hectares, be realized with limited number of conservators and foresters?

(4) Current situation of forests and forestry

According to the *Forest Legislation in Selected African Countries* compiled on eleven member countries of African Timber Organization, the substantial part of the 1938 Forest Ordinance and its subsidiary regulations is still succeeded in each regional and state forestry legislation by introducing amendments. Modification was required principally with regard to adjustment of the clauses to the newly created government structures. For the whole of former Northern Nigeria, Forestry Ordinance of 1960 for Northern Region was still valid (Schmithusen 1986, 88-91). It consists of the following parts (*ibid.*, 261-277) :

Part I	preliminary
Part II	special provisions relating to government forest reserves and government protected forests
Part III	special provisions relating to native authority or local government council forest reserves
Part IV	government forest reserves converted to native authority or local government council forest reserves
Part V	native authority or local government council protected forests
Part VI	administration of native authority or local government council forest reserves
Part VII	communal forestry areas
Part VIII	general provisions
Part IX	repeal and savings

Part II determines the procedure for constitution of government forest reserves and protected forests. The process starts from the notification of government intension to create a reserve and the appointment of a reserve settlement officer through the regional gazette. The reserve settlement officer has to inform every stakeholder and keep a record on claims. Once this series of process starts, all transactions and activities on the land concerned are frozen. As soon as the period set for inquiries is over, the governor makes an order constituting the forest reserve and publishes it in the regional gazette. Eventually, all the rights on the land are extinguished and every individual, community, or chief concerned has to grant and convey the land to the government.

Part III, IV and V contain provisions on constitution of native authority or local government council forest reserves and protected forests[2]. The procedure is similar to that in Part II, but a difference is that native authority or local government council can take the initiative. Part VI determines protection, control, and management of native authority or local government council forest reserve to be undertaken by the local entity concerned under supervision of the chief conservator in forests of the region.

Part VII is on communal forestry area that can be created by any native authority or local government council at the request of any native community. With approval of the resident, a communal forestry area is declared in the same manner as native authority or local government council orders are published. It is recommended that rules are made between the native authority or local government council and the community concerned on duties and prohibitions in relation to control and management of communal forestry area.

Though this ordinance basically followed the series of regulations introduced during the first half of the 20^{th} century that made creation of forest estates the key point, little expansion of forest reserves could be achieved after independence. There was almost no politically stable period: the Civil War from 1967 to 1970, economic depression after the 1980s, and alternating military and civil administration hindered the functions of federal ministries. In addition, regional differences preserved or even strengthened under the Indirect Rule have dispersed and hindered centralization of information. In other words, it is such an autonomous administration system that has maintained the nation even under the serious political dislocation and, as the consequence, functionally disordered federal government. For all that, it seems that the state governments have not taken the initiative in forest administration and just followed the colonial system, which connotes the passive regionalism fostered under the Indirect Rule.

In accordance with the abrogation of province and NA and with creation of state and local government area (LGA) as sub-unit of administration, former NA forest reserves and CFAs were reorganized to the forest reserves belonging to either state governments or LGAs. The Federal government is to provide adequate technical and financial support for those reserves, which rather concentrated on plantation of exotic species such as *Tectona grandis* and *Gmelina arborea* on forest reserves. Things have stagnated, however, since the "oil doom" of the 1980s[3)].

The total area of forest reserves is 96,518 square kilometers, or 9.8 percent

Table4-1 Forest reserves by vegetation zone.

	Vegetation zone		Forest reserve		
	(km^2)	(%)	(km^2)	(%)^a	(%)^b
Sahel	31,460	3.2	2,521	2.6	8.0
Sudan savanna	342,158	34.8	31,247	32.4	9.1
Guinea savanna	400,168	40.7	38,271	39.7	9.6
Derived savanna			3,208	3.3	
Moist tropical forest	75,707	7.7	20,443	21.2	27.0
Fresh water swamp	95,372	9.7	256	0.3	0.3
Mangrove and coastal	38,345	3.9	522	0.5	1.4
Total	983,210	100.0	96,468	100.1	9.8

Note: %^{a} shows the percent to total forest reserves and %^{b} shows the percent to the total vegetation zone

Source: Federal Republic of Nigeria (1999).

of the total land area, including 6 national parks created through the National Parks Decree of 1991 (Federal Republic of Nigeria 1999, 33). Reflecting the vegetation of Nigeria that contains around 35 percent of Sudan savanna and 40 percent of Guinea savanna, almost 70 percent of the forest reserves are located in the savanna (Table 4.1).

Due to a lack of information to describe the management systems of the forest reserves that differs from state to state, Niger State is taken as an example. All the reserves located in the state belong to the state government and are divided to 19 zones, which jurisdiction corresponds to LGA. A zonal forestry office is organized under each LGA, responsible for the forest management of each zone. The state government controls all logging activities both inside and outside the reserves and collects royalties, while the local government issues other permissions for trees outside the reserves and the revenue belongs to the local government. Consequently, the personnel of zonal forestry office consist of foresters dispatched from the state government and also local government staff[4)].

In fact, logging has not been practiced inside the forest reserves for a long time, and sawmills around Bida obtain the raw material from the bush fallows outside the reserves or from southern states. Since high valued woods such as *Khaya senegalensis* are being exhausted, the sawmills are obliged to use inferior species such as *Daniellia oliverii*.

Permissions issued by the zonal forestry office for the local government allow palm wine tapping ; palm oil extraction ; the sale of palm wine, firewood, charcoal, and bamboo ; and per capital permission on carpenters and blacksmiths. Even though most of it remains a mere shell, the colonial system seems to have been inherited and enforced until today. Production of sheanut (*Vitellaria paradoxa*) is not categorized as an object of taxation by zonal forestry office[5)].

The modernization process on forest resources was partly embodied in demarcated forestland during the colonial period, but vast natural vegetation that still remain outside the reserves have been legally preserved as unclassified resources. To authorize the logging activities and impose royalties outside the reserves, however, it seems there was a necessity to enforce these supplementary regulations to keep the commercial resources under the government control.

1-3 Institutional changes on land and people

(1) Native Administration during the colonial period

Pre-colonial histories of the Northern Nigerian are always highlighted with the infiltration process of nomadic Fulani. They had migrated from the west, settled in Hausaland and identified with Hause during the 18th century. At the beginning of the 19th century, the Sokoto Caliphate was built up, and could afford to call up twenty five to fifty thousands cavalry (Smith 1989, 45). Many native chieftaincies had been conquered through their further eastward and southward movements, and the conquerors were bestowed the title of Emir from the Caliph and reigned the conquests. Such fiefs once encroached to French Niger and German Cameroon, and only few regions such as Borno, Plateau, and Borgu could remain unoccupied in Northern Nigeria (Lovejoy and Hogendorn 1993, 3).

The reason why such a highly developed political system easily capitulated to the British forces has already been discussed and explained by Nicolson that the medieval armaments and organization of the cavalry could not contend with Maxim machine guns (1969, 11-12). Within some years after the declaration of the Protectorate of Northern Nigeria in 1900, the British forces occupied major kingdoms such as Sokoto and Borno and set up puppet regimes by reading aloud the Letter of Appointment in public to show their superior power to the traditional authorities (Perham 1937, 33-49).

The following summarizes the political process that took place from the pre-colonial to the colonial period in Nupeland.

According to oral history, the origin of Nupe kingdom went back to the 16th or 17th century, when the Igara people of Idah, who lived around 80 kilometers downstream from the confluence of the Niger and Benue, wielded power over surrounding minorities. A slave named Edegi or Tsoede was sent to the *Atta* (king) of Idah from one of the tributaries, and was highly favored by the *Atta*. He was, however, compelled to escape from the revenge of the son after the death of *Atta*, went upstream the Niger River, and settled at the confluence with the Kaduna River. This first settlement lately developed to a town called Nupeko (Great Nupe), and Edegi became the first *Etsu* (king) of Nupe (Nadel 1942, 73-74).

Since Nupeko was located on a delta and could not suppot a larger population, the seat of *Etsu* Nupe was moved time after time. Feud and split among the royalty brought about small Nupe chieftaincies with various titles at every place. Fulani people who already reached the Niger River were looking for an opportunity to infiltrate, and gradually succeeded taking advantage of the disorder among the Nupe chiefdoms (Dupigny 1920, 7-8).

The logbook of the naval expedition along the Niger River in 1841 described the clamor of markets along the river after the confluence with the Benue. At Egga, one of the Nupe settlements still exists now, various products such as "calabashes beautifully wrought and curved, silk from Bornu, natron from the same place, country cloth, net work, Guinea corn, yams, Indian corn, sweet potatos, dried fish, a few European articles, a piece of cotton handkerchief, beads and gun-powder, about fifteen horses, and Guinea corn pounded with shea butter" were sold on the market day. Not less than two hundred looms were at work, and Hausa speaking slave traders were selling women and boys captured through battles against Fulani. Rabba, once important bases for the southward movement of Fulani, functioned as the largest slave market of inland Africa. It was the Fulani and sometimes the Igara downstream that threatened the people along the Niger River, and agricultural minorities were forced to pay tribute (Allen & Thomson 1848, 80-110).

Bida was just a small settlement of a minority called Beni. Then came the battle in the mid 1850s when competition for dominance occurred among the Fulani groups. The winning family was bestowed a turban, the symbol of emir, from Sokoto, and settled at Bida. The Emir of Bida allowed *Etsu* Nupe, who had already become a puppet of Fulani, to hold the title, but forfeited all the retainers. On the other hand, the Emir claimed the title of *Sarkin* (king in Hausa language) Nupe. This intricate system involving various traditional titles of Nupe as well as Fulani formed the political structure of Bida emirate, and the Emir subjected all Nupe people as well as migrated Fulani nomads to his rule. Owing to its favorable location connecting the dry north and humid south, Bida developed and flourished as the base of transit trade. Within the walled-town, hereditary craft-guilds of brass workers, bead workers, glassmakers, weavers, leather workers, blacksmiths and so forth were formed and economically supported the Fulani ruling class (Dupigny 1920, 9-15 ; Temple 1922, 322 ; Nadel 1942, 102-103 ; Imaogene 1990, 20).

Nevertheless, Bida was easily defeated and surrendered in 1897 when chartered RNC undertook armed operations against hostile traditional powers from 1886. RNC immediately dethroned the Emir of Bida and let a cooperative member of the royal family accede the emirate in order to control Fulani rulers and Nupe subjects. Under such a situation, orthodox descendant of *Etsu* Nupe, who was placed in confinement at Bida, became pro-British and anti-Emir. RNC also took advantage of this, recovered his title of *Etsu* Nupe, and dispatched him at Pategi to control Nupe outside the emirate, that is, along the south bank of the Niger River (Dupigny 1920, 20).

The British war potential to support the operation of RNC, however, was spared for the conquest of the Ashanti Kingdom in the Gold Coast. Accordingly, the reign of RNC could not reach further north and ended in 1900. A resident was dispatched, whose office was located inside the wall surrounding Bida to show the British suzerainty. In 1907 railway construction started to connect the north and south, and many Nupe farmers were requisitioned. It was completed in 1912 and a railway bridge was build over the Niger River in 1916. The substantial range under British control that first remained in Bida Emirate, which is geographically referred as Cis-Kaduna, gradually expanded to Trans-Kaduna and the north (*ibid*, 6).

According to the Northern Nigeria Population Census of 1911, Bida was one of the five largest cities with the population more than 200 thousand. It increased 20.4 percent in 1921 and became to hold the third largest population[6] (Meek 1925, 179).

The British Protectorate was administratively reorganized into provinces and districts which were governed by a resident and district officer respectively. On the other hand, emirates were preserved and rather strengthened throughout the colonial period under Pax Britannica. Each emirate, for example, traditionally held followers called *hakimi* (*hakimai*, pl.) to collect tribute from farmers. The colonial government made use of the system by promoting those *hakimai* to tax officers, and made them move from inside walled-towns to each district for effectiveness of tax collection (Shenton 1986, 35-38). Separately from the colonial treasury, a native treasury was established in each emirate to control the financial aspect of the native administration system that was based on tribute and fine collected from the people. When there is surplus, it could be diverted to the colonial treasury, and a part of the expenditure for the First World War was raised from native treasuries (Burns 1917, 102-104).

(2) Transition of land regimes

While the people were organized into the Native Administrations, what was the setting of the land? Following is to brief description of the statutory land systems, mainly depending on the work of Udo (1990).

The introduction of uniformed land system in Nigeria could go back to Land and Native Rights Proclamation in 1911. After returned to Nigeria as a governor, Lugard enforced the Land and Native Rights Ordinance in 1916 based on the Proclamation. The principle and framework of this ordinance has been succeeded by Northern Nigeria Land Tenure Law in 1962, and the Land Use Decree in 1978, which was amended to Land Use Act in 1980 (James 1987, 1-2).

The Proclamation of 1911 was based on discussions about the actual situation of customary systems on land. The proclamation avoided the terms of crown land or public land, which were often applied in other British colonies, and defined all land belonged to the collective whole. The government just functioned as the administrator. The individual could only gain right of occupancy, not ownership, and nobody, including the government, could own the land. In other words, so far as based on certain public purpose, the government, as executor of the public purpose, could exercise eminent domain (Egboh 1985, 51).

The Northern Nigeria Land Tenure Law of 1962 further defined that all lands belong to the native people, and two categories of customary right of occupancy and statutory right of occupancy were applied. Though statutory right was superior to customary right, eminent domain could be exercised even over statutory right for public purpose such as mineral resources development. This law gained positive appraisal in giving legal background to customary activities, while being criticized for the giving of power of land acquisition to the minister of land (Udo 1990, 33-34).

The land Use Decree of 1978 was promulgated by the military government and then incorporated into the new constitution, just before the military terminated its 13-years rule. Though civilian politicians proposed a bill to repeal the decree, the National Assembly was not convened because of the military coup took place again in 1983. This decree consists of the following 8 parts with 50 sections (*ibid*, 74-86) :

Part I	General provisions
Part II	Principles of land tenure, powers of military governor and local government, and rights of occupiers
Part III	Rents
Part IV	Alienation and surrender of rights of occupancy
Part V	Revocation of rights of occupancy and compensation therefore

Part VI Transitional and other related provisions
Part VII Jurisdiction of high courts and other courts
Part VIII Supplemental

It first defines that the state governor, a member of the armed forces and appointed by the federal military government, is vested the power on state land. This military governor functions as a trustee in place of former traditional authority, and is empowered to grant statutory right of occupancy, which can extinguish an existing customary right granted by a local government. Statutory right of occupancy is ensured by a certificate issued by the military governor, while rents or additional penal rents, fixed by the military governor, are levid in case of unlawful commitment. However, no rent is imposed on a customary right, as Lugard posited that charging annual rent for a native farmer meant he became a short-term lessee despite his ancestral land (*ibid*, 79).

Alienation of land is basically prohibited for both types of right, except with prior consent of the military governor as to statutory right and the local government for customary right. It complies transfer of possession, assignment, mortgage, or lease, which means particularly statutory right of occupancy can be regarded as almost the same as land ownership. When a holder of land-related right is dead, however, devolution of the right is regulated under customary law, and in any case, no statutory right or customary right is allowed to be divided without consent (*ibid*, 79-80).

Institutional aspects in relation to land have been transformed gradually in accordance with change of the regime as well as commercialization, industrialization and urbanization. Growth of capital required a uniform system of credit and transaction, while enlarging urban areas could not be regulated by customary systems due to mixture of various ethnicities. On the other hand, rural population still keep to their traditional way of living, which has led to the creation of dual, or rather discriminative structure of land tenure.

(3) Current situation of native authorities

The traditional political systems largely differ among the three geographical regions: the north, the southwest, and the southeast. The legal structure introduced for the amalgamated Nigeria tended to depend on the model established in northern Nigeria. The Land Use Decree, however, received great opposition of traditional rulers, both in the north and the south, since it weakened their control of land (Udo 1990, 96-102).

Current administration system under the federal government also reduces, though not to eradicate, the influence of traditional powers. Yet actual situations suggest both are not really separated, as shown in the following example of Nupeland.

When colonial province system was repealed and 12 states were established in 1967, Nupeland was organized as part of Northwestern State, with Sokoto as the capital. With creation of 19 states in 1976. Niger State was established but the capital was Minna, not Bida. Minna, just a former post of the British force, was selected as it was supposed to weaken the influence of the Emir of Bida (RIM 1989, 3). After reorganization of states in 1991, Niger State became the largest state with an area of approximately 76,000 square kilometers, accounting for around 9 percent of the nation. Nupe people live mainly in the southern LGAs such as Bida, Gbako, Agaie, Lapai and Lavun.

The relationship between the state government and eight emirates that still exist in Niger State is that the Niger State Council of Chiefs consists of these eight emirs plays an advisory role to the state government. The chair of the council is vested to the Emir of Bida who has the largest population under his jurisdiction (Baba 1993, 331). Nevertheless, particularly in Cis-Kaduna, it is often observed that the same person holds both a traditional title and in administrative position. Such substantialization of different functions helps the survival of traditional systems even under modernized legal institutions.

Administratively Niger State is divided to 19 LGAs, which are sub-divided into districts and then wards. Settlements that also represent traditional communities based on Kin and Locality relations are organized under wards. Among Nupe people, the district head is still called *hakimi* that means tax officer of emirates, and the ward head is referred as *etsunyankpa*, a Nupe traditional title. When administrative reorganization creates a new ward and so a new post of *etsunyankpa*, traditional leaders from influential communities under that jurisdiction dicide to which community they confer the post. The head of the highest descent of the community concerned automatically holds the post[7].

K Settlement of Table 4-2 can be taken as another example. It is once flourishing but is now an obsolete and featureless hamlet of average size. Owing to its location along a highroad connecting the north and the south through the ferry between Muregi and Patigi, K developed into a market town with a large population during the colonial period, and warehouses of rice, groundnuts, and sheanuts were built along the road. The British District Officer granted the post of *etsunyankpa* to K Settlement in order to support the *hakimi* of Jima and control neighboring settlements. With construction of a railway bridge at Jebba, however, the traffic bypassed this area, and the market eventually died with the population of K Settlement declining remarkably. Nevertheless, according to the elderly people of K Settlement, they have succeeded the title of *etsunyankpa* for over the last 80 years, with only a temporary interregnum at the change of emir around 30 years ago.

Even though district and ward heads are official posts, commitment of the state government is limited to demarcation of the jurisdiction, and following decision process is entrusted to traditional political system. The posts, or rather titles, can be inherited and the installation ceremony of *hakimi* and *etsunyankpa* are held at the emir's palace. Most Nupe people became Muslim under the influence of Fulani conquerors, but those in Trans-Kaduna with less influence or even some areas in Cis-Kaduna that resisted the conquest were Christianized during the colonial period. Nevertheless all Nupe people are equally organized under emirs probably due to assimilation of the socio-political culture between the Nupe and the Fulani conquerors formed during the pre-colonial and colonial period.

The relation between Nupe as conquests and Fulani as conquerors also produces a fragile symbiotic relationship between agriculturist and nomad in the lowest reaches. As described by Nadel in his outstanding ethnography, most Fulani conquerors had already lost their own identity during preceding expansion into Hausaland. They were numerically a minority and polygamized with Nupe women so they were easily absorbed by the culture and language of the people they subjugated (1942, 71). In contrast to such ruling class, or so-called town Fulani in Bida or other seats of emirates, lower class of Fulani herdsmen organized under small chieftaincies called *Sarkin Fulani*, who also serve the emir, still keep their traditional nomadic life and culture. The location of their temporary settlements and range of grazing overlaps croplands of Nupe farmers, which has led to an exchange of dairy produce and staple food with cow dung and camping site. At the same time, damage on crops by cowherds especially during the rainy season is a negative aspect, and farmers often resign themselves to the historical relationship.

Settlement type	Location	Livelihood by topography (▒ : main, ☐ : sub)						
		River	Bank	Floodplain		Lowland	Upland	Mesa
				Lowland	Pond			
Fishery [i]	Riverbanks and deltas	Fishery	Farming					
Wet rice farming [ii]	Floodplains			Wet rice	Fishery			
Complex of upland and lowland [iii]	Inland valleys			Wet rice*		Wet rice	Farming	
Upland farming [iv]	Top of mesas			Wet rice*				Farming

*Not practiced inside settlement areas but as lease farming in floodplains.

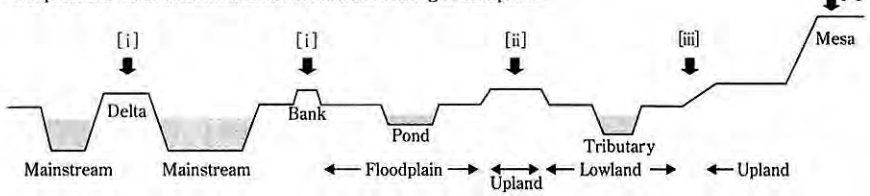


Fig.4-2 Patterns of settlement and livelihood.

1-4. Land system : a case study in Nupeland

(1) Pattern of settlements

Nupe settlements in Cis-Kaduna are characterized by locality and primary activities of dwellers (Fig. 4-2). Based on a combination of these two factors, they can be categorized to riverain (i), floodplain (ii), inland valley (iii), and mesa-oriented settlements (iv).

According to the oral history of the establishment of Nupeko, the first kingdom of Nupe, it can be assumed that Nupe people originally engaged in riverain-oriented subsistence and categories (i) and (ii) represent prototypes. They lived in settlements formed on holms or riverbanks, mainly dependent on fishery, while those on floodplain made their living by combination of wet rice farming and fishery in oxbow lakes scattered along the mainstream of the Niger River. As for (ii), more complicated and exclusive systems have developed on management of fishery resources provided by oxbow lakes, compared to still abundant land.

However, (iv) is rather exceptional. Life on mesas may not be easy because of water deficiency, though people put emphasis on relatively fertile soil provided by weathered rock. Limited carrying capacity makes them supplement their livelihood by tenant farming in floodplain. Winding roads with borehole wells constructed by the government once improved their quality of life but soon collapsed, and now those settlements are facing depopulization. This pattern of settlements can be regarded as refugee camps, a vestige of resistant against

Fulani conquest.

The settlement pattern of (iii) is numerically the most common one, which territory consists of two distinctive types of topography : upland and lowland. Uplands provide various cereal as well as leguminous crops important for subsistence, while lowland produce cash income through rice farming and secondary crops during the dry season. A hamlet with labyrinthine arrangement of housing compounds is located in between upland and lowland where percolated rainfall on upland sandy soil leaks after the rainy season is over.

(2)Land tenure in agricultural communities

As already mentioned, the term of land system is defined as an interactive relationship between land tenure and land use.

Nadel carried out a detailed study on the customary land system of the Nupe in 1934 and 1935/36 (1942 : 180-256). He firstly recommended on the clear distinction between Trans-Kaduna and Cis-Kaduna caused by the different historical background and population density. In sparsely populated Trans-Kaduna, land dispute was exceptionally observed only on relatively fertile lowland, while it often occurred in Cis-Kaduna with higher population pressure and a more complicated land tenure system created by Fulani conquest. Nadel then categorized the process of land acquisition into two : acquisition by virtue of membership, and acquisition by virtue of contract. By exercising his right as a member of an agricultural community, a Nupe man can acquire a portion of land from vacant or virgin land within the community territory with the consent of the chief. This way of land acquisition could be observed both in Trans- and Cis-Kaduna. Another way of land acquisition by contract consisted of temporary lease, long-term lease tantamount to purchase, and hereditary tenantship. The former was also observed both in Trans- and Cis-Kaduna, but the latter two, especially the hereditary tenantship, could occur only in Cis-Kaduna and formed the feudal system of the emirate.

After the end of Indirect Rule and creation of an independent modern state, how has the land system changed? We already learned from the Land Act that customary land tenure still exists particularly in rural areas. At the same time, the power of emirs in northern Nigeria has been weakened by establishment of states and local administration system under the federal government. Then, how has it affected the feudal land system of Bida Emirate? Table 4-2 is to show the current situation observed along the Emikpata River, a small tributary in Cis-Kaduna flowing to the mainstream (Fig. 4-1 and Fig. 3-3).

Table4-2 Relation between Nupe settlements and Fulani landlords: a case along the Emikpata River.

Settlement	Population[1)]	Location[2)]	Type of settlement[3)]	Origin of settlement	Primary landlord	Tribute[5)]
P	n. d	On a mesa	Upland	Migrated from Patigi	Absentee Fulani →died away	−
KY	4 (19)	Uppermost	Complex	Migrated from Kwala	Resident Fulani →moved out	−
K	6 (29)	Upstream	Complex	Nupe slaves brought from Bida	Absentee Fulani landlord	+
M	3 (28)	Upstream	Complex	Migrated from Bida	Absentee Fulani landlord	+
G	9 (24)	Midstream	Complex	Migrated from Patigi	Absentee Fulani landlord	+
EY	1 (2)	Midstream	Complex	Migrated from Mokwa	Resident Fulani died away	−
D	5 (26)	Midstream	Complex	Nupe slaves	Absentee Fulani landlord	+
KC	3 (11)	Midstream	Complex	Migrated from Kwala	Absentee Fulani landlord	+
MB	13 (65)	Midstream	Complex	Conquered by Fulani	Absentee Fulani landlord	+
KT	6 (31)	Midstream	Complex	Migrated to Fulani's land	Resident Fulani landlord	+
S	3 (25)	Midstream	Complex	n. d	Absentee Fulani landlord	+
ET	5 (24)	Midstream	Complex	n. d	Absentee Fulani landlord	+
DT	2 (17)	Midstream	Complex	Settled before Fulani conquest	No landlord[4)]	−
A	13 (n. d)	Midstream	Complex	Migrated to Fulani's land	Absentee Fulani landlord	+
T	>500 persons	Downstream	Lowland	Settled before Fulani conquest	Nupe landlord	+

1) In place of population that could not be specified by interviews, here the number of extended family (married man) is shown.
2) From the source to the confluence of the Emikpata and the Gebo is categorized to "upstream", to the edge of the floodplain of the Niger River is "midstream", and the floodplain is categorized to "downstream".
3) "Upland" refers to settlements engage in upland farming, "complex" to upland and lowland, and "lowland" to rice cultivation in floodplain.
4) A family member was married by the emire.
5) + : exists, − : does not exists.

Among fifteen settlements where interviews to key informants could be carried out, ten settlements answered that they were once under control of absentee landlords. KT Settlement holds not absentee but resident landlord. Nine excluding P Settlement on a mesa still pay annual tribute[8] to five absentee landlords. Among these five, a landlord who holds the title of *Tsoede* under Bida Emirate is the most powerful. He occupies the lowland of five settlements along the Emikpata River, and a total of nineteen settlements including other watersheds are under his control[9]. Following episodes collected from the settlements listed in Table 4-2 infer to the extent to which they can still exercise their influence over Nupe farmers:

People of A Settlement experienced hardship caused by *Tsoede* in the 1980s. With the economic crisis prevailing in the country, he expropriated the lowland to give it to his son and prepared a substitute lot. The villagers unwillingly accepted the offer, though the new appropriation was not in lowland but in upland. The son then brought laborers from Bida and dug an irrigation canal for wet rice farming. After some years, however, the land was abandoned when the sluice was broken. Since then, nobody could use the land, because expropriation has not yet been canceled.

As for G Settlement, originally *Tsoede* controlled the lowland and most of the upland, and another landlord in Bida who held a title called *Natsu* controlled the rest of upland. In the late 1980s a dispute occurred between villagers over farming right on the land belonging to *Natsu*, and the case was submitted to his arbitration. *Natsu* judged both sides were to blame in the quarrel, expropriated the land, and gave it to another settlement. Since then, only *Tsoede* has controlled the farmland within G Settlement.

There is another stock of Fulani called *Dagadza* connected to G Settlement. This family originally stayed in the settlement and engaged in land management for the absentee landlord while farming for themselves. Now the descendant stays in Bida and nobody remains at G, but their rights on the block where they once built the compound and farmed are still recognized by the villagers. Whenever they build a new house, the people of G Settlement report to *Dagadza*, not to *Tsoede*, for consent.

Among five settlements of Table 4-2 free from influence of Fulani, two settlements were once inhabited by farmer Fulani like *Dagadza*. Because the line ended in EY, or the descendents moved out to distant places in the case of KY Settlement, it is now not necessary for either settlement to pay tribute. This suggests the possibility that the historical relationship between Fulani con-

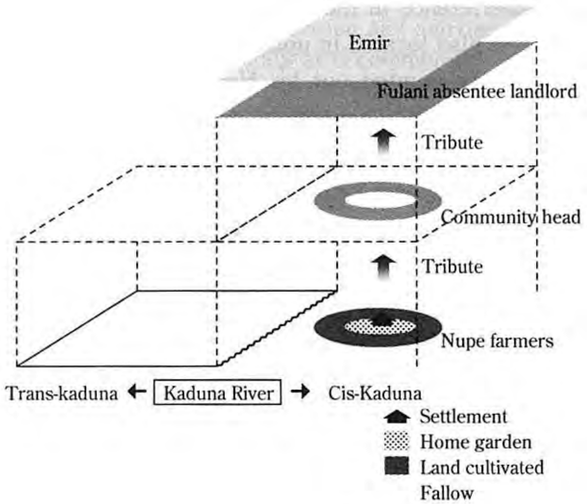


Fig.4-3 Stratified land use and control patterns in Cis-Kaduna.

queror and Nupe farmers can fade with expanding population mobility. Indeed, those who can tell about the origin of the settlements are now limited to elderly people and the concerns of the youth are not so different from those of developed countries.

Though of Nupe origin, DT is an exceptionally independent settlement, as one of the families is related to the mother of the present Emir in Bida. T Settlement downmost stream is located outside the conquest territory, and is categorized to wet rice farming settlement of Fig. 4-2. It also pays tribute, however, not to the subordinates of the emirate but to Gaba related to orthodox Nupe Kingdom. Gaba is located on the floodplain where the Gbako River flows to the mainstream of the Niger and is also categorized by rice farming settlements.

Fishery settlements on riverbanks and holms along the Niger River up to Jebba are traditionally organized under a chieftaincy called *Kuta* who has a base in Muregi. This *Kuta* is regarded as the title of a subordinate created by the first *Etsu Nupe* who settled *Nupeko* (Dupigny 1920, 83). In contrast to the title of *Etsu Nupe*, which was substantially assimilated to Emir, indigenous Nupe people have succeeded the title originated in pre-Fulani kingdom and *Kuta* still holds control over navigation of the mainstream and fishery settlements. The location of Fulani cavalry bases was limited to the upland, as a natural consequence. For example the vast less-populated upland of Ilorin became the first arena of Fulani interference in the Nupe Kingdom. The consecutively established emirates were also located in upland of Bida, Agaie, and Lapai, but not beyond floodplains. As pointed out by Nadel, riverain thickets and southern rainforests contaminated by trypanosomes could have been a natural barrier against the southward movement of the nomadic people (Nadel 1942, 4).

The pattern of control over land and land-related activities can be summarized in a three-layered structure (Fig. 4-3). The territory of a community as a whole is governed by the chief, normally the eldest man among lineal descendants of the first settler. His power is, however, restricted to allocation of farmland and management of vacant land, while each individual, group, or family can exercise exclusive right on the land on their own farming.

Another layer implies landlords as a remnant of feudalistic system of the Nupe Kingdom. It consists of absentee or sometimes resident landlords: the former formed the privileged class of town Fulani and the latter, or rather farmer Fulani, probably originated from subordinates or slaves. Finally, the emir is dominates the traditional value system that still regulates the people's daily life. His power, however, does not reach every corner of the land, but is limited to the people. The title of emir has not been monopolized by a lineal descendent but circulated among three royal families. Therefore, an emir of the day can directly control his estates but not other lands belonging to various title-holders forming noble class.

A Nupe settlement in rural area is formed by several extended family called *emi* or symbolically *katamba*. When the population grows, it splits and produces a new settlement to keep the farms close enough to the settlement. In regard to spatial arrangement, Nupe settlements can be categorized in nucleated type. A *katamba* consists of irregularly combined bowers allocated to each wife and matured boys, storerooms, sheds, garners, and one or more small courts for post-harvest processing and cooking. A roofed and walled round or square hall with doors is constructed at the entrance of a compound. This hall is *katamba*, and the number of *katamba* shows the number of extended family.

In brief, extended family system of the Nupe is accompanied with patrilineal, patri-local, and Islamic polygyny. Though it can be categorized to exogamy, intermarriage is prohibited only among the same extended family members. Marriage including deuterogamy inside a community that consists of several extended families often occurs, which makes the kinship structure complicated. The eldest man becomes the head of a consanguine family (*emi tsuo*) and controls his family that involves plural conjugal or polygynic families.

Table4-3 Number of population and married man by extended family at G community[1].

Extended family	Origin	Population	Married man
AA	Etsunyankpa[2]	44	6
DO	Etsunyankpa	37	4
ND	Etsunyankpa	26	4
EN	Etsunyankpa	23	5
MD	Etsunyankpa	16	1
GA	Etsunyankpa	10	1
GZ		8	1
UN	Etsunyankpa	7	1
SH		4	1
Total		175	24
Average size of family		19	3

Note: 1) Data collected on 1 September 1995.
2) The first settler.

The extended families of G Community can be divided into descendants of the original settler and new comers (Table 4-3). Among nine extended families, those headed by GZ and SH are the latter. GZ is a young family head from the second generation. His father settled at G and was a barber, whose occupation is shown in the name and inherited. SH was born in a neighboring settlement and married a woman of G Community. He still holds his portion of lowland in his home village, but at the same time cultivates the land of G Community. This shows a rare exceptional case of matri-local lineage.

Another seven families stem from three wives of the first Nupe settler called Etsunyankpa or Muhammad Dokochi who migrated from Patigi, and the first four have expanded to 167 people in the fifth generation. It means the population expanded more than 2.5 times every generation. Among these family heads, EN holds higher cultural importance due to being of mixed Fulani blood. His maternal grandfather was the first Nupe settler, but his paternal grandfather was a Fulani farmer called *Dagadza* who once settled and farmed at G, while functioning as an intermediary between the Fulani absentee landlord and Nupe farmers. Now the lineal descendants of *Dagadza* stay in Bida but EN family is still related by blood. However, AA family holds more political influence over the villagers, due to the largest population and higher educational background.

Land of G Community is basically divided, in the sense of control, by these two elders as authorized successors of the first settlers: EN represents collateral descendants of *Dagadza* and AA represents the descendants of M. Dokochi. At the same time, EN holds the position of settlement head (*etsu lati*), while AA is the farmers' head (*etsu enunuchizhi*). *Etsu lati* is succeeded by the eldest man of the community, and *etsu enunuchizhi* is normally selected from different compounds. The function of *etsu enunuchizhi* is to control farming activities, for instance, seed storage and maintenance of canals, which suggests the possibility that this position was relatively recently created by the government or a former traditional position has been transformed through agricultural extension provided by the government. Neither *estu lati* or *estu enunuchizhi* always link to land ownership.

The agricultural land system is basically not different from the age observed by Nadel (1942, 180-256). So far as the land is under cultivation, the exclusive right of land utilization is given to the cultivator. Once it is abandoned, however, the land becomes under the control of authorized elders : EN and AA in case of G Community. With a new offer of cultivation, the land is reallocated to the applicant. When a cultivator dies, the priority to use the land is given to the successor, but it is not ensured if cultivation is interrupted. A cultivator can rent out the land under cultivation, so that he/she can be categorized as the primary landowner so far as cultivation is not interrupted, and the settlement head can be regarded as secondary landowner. These basic rules are applied to both descendants and newcomers without differentiation, but there may be some difference in the amount of tribute to either primary or secondary landowner in accordance with the distance of kinship.

Tribute is imposed on land acquired by exercising the right as a member of an agricultural community, and normally in form of cereal harvests like sorghum and millet. Normally community chiefs collect tribute from cultivators and send it to the Fulani absentee landlords, or if the settlements are not under their control, to original Nupe landlord like *Gaba* for floodplain communities and *Kuta* for fishery communities (Table 4-2). According to the case of G Settlement, the payment is not over ten percent of the harvest.

Land acquisition in virtue of contract is also common in Cis-Kaduna area. The most dynamic movement is that from inland valley, upland, and mesa-oriented communities to floodplain. It occurs as a result of population growth, and especially among the youth, rice farming in floodplain during the rainy season has economic importance. As shown in the following section, lowland along tributaries has already been divided among families due to the practice of sedentary farming so that additional land for wet rice farming can only be found in vast frontier of floodplain along the Kaduna and Niger River. Land acquisition in the floodplains where there is no Fulani influence is based on economic relation, which is a combination of fixed tenancy and sharecropping. Though the payment can also vary in accordance with kinship, a tenant usually pays advance money, 1,000 Naira per acre for instance, and render some percent of harvests afterwards. This amount is far less than the standard of tenancy observed in Southeast Asia. It is probably caused by low land productivity, as well as too low population density to lead to an uneven distribution of resources and rigid tenant system. The existence of advance money also suggests the fluidity of the relation between landowner and tenant.

Tenant farming can also be observed on narrow strip of lowland along small tributaries. In the case of G Settlement, some of the members cultivate the lands belonging to neighboring communities, while outsiders can also acquire land of G on contract basis. This asymmetric or open bilateral fluidity of land seems to occur particularly based on affinity, and also seems to have a function to solidify the alliance between a man and his wife-giving family. Another type of alliance between a married-out woman and the extended family in which she was born is also observed. At the first marriage, both bride and bridegroom have to take a special meal consists of rice, tea and bread, fried egg, and so forth for several months prior to the marriage. When one of the married women among the paternal cousins of the bridegroom offers to take care of this special meal, she is called *gogoyawo* and has a right to claim the first daughter of the married couple. During infancy, the daughter is adopted to *gogoyawo* and grown the same as other children. Such adapted girls are often found in every community.

Both of the two different categories of land allocation pointed out by Nadel (*ibid.*), fixed one to adults (*efako*) and temporary one to minors (*buca*), are also observed. Boys of each compound are socio-culturally organized to age groups, and even from infancy, they tend to borrow a small portion of land from the elderly and engage in collaborative farming works. By contrast, there is no particular horizontal link among girls. A girl is vertically integrated to her mother or stepmother (*gogoyawo*), grandmother, or also to the first wife of her father if her mother is not the first, and trained up in housekeeping matters, processing of harvests, or commerce.

(3)Land use and distribution inside a community

In the case of G Settlement, clear difference of land use pattern could be

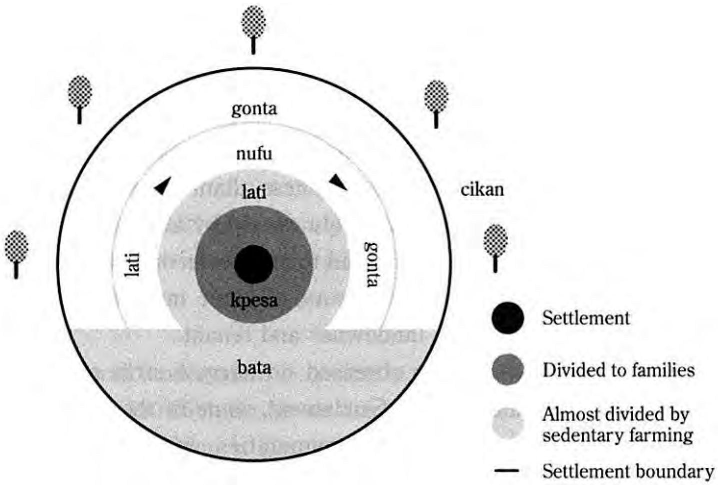


Fig.4-4 Land use patterns at a Nupe settlement.
bata: lowland, *lati*: upland, *kpesa*: home garden, *nufu*: grass fallow, *gonta*: bush fallow, *cikan*: primary forest

observed following the transition of topography from the upland toward valley bottom (Fig. 4-4).

1)Lowland (*bata*)

There is a simple canal dug by farmers under direction of Agricultural Development Project (ADP) in parallel with the Emikpata River. It is possible to practice double cropping on the irrigated lots (*dife*) and around springs scattered along the slope from upland to lowland (*danca* or *ewan*). The main crop is rice, and sweet potato, red pepper, okra, eggplant, and roselle (*Hibiscus sabdariffa*) are planted during the dry season. Sugar cane is planted along the river, and other humid-tropics-oriented crops such as yam and cassava can also survive in lowland. Shifting cultivation has already turned to sedentary farming, which caused *de facto* land partition to individuals or individual families, even though there is no clear demarcation from the nature of traditional wet rice farming system of Nupe, that is, without permanent borders. Most of these are cash crops, and annual double cropping brings the highest land productivity compared to other types of land use.

2)Home garden (*kpesa*)

The land surrounding a settlement is traditionally divided to each compound and intensive management is encouraged to keep off invading weeds and trees.

Together with housing lots, this part of the land is exempted from tribute. Crops that require relatively fertile soil, such as maize, sweet potato, roselle, henna (*Lawsonia inermis*), and kenaf (*Hibiscus cannabinus*), are planted annually.

In case of G Settlement, there is an obviously distinguished plot consisting mainly of fruit trees, and various annual agricultural crops are also combined filling up the gaps of tree shades (see 4-2). Though Nupe settlements are often accompanied by large trees, it cannot be generalized to a particular type of land use ; it is rather a variation of *kpesa* than a traditional practice of agroforestry like *pekarangan* in Indonesia. The size of trees in this orchard, however, suggests the potential of tree growth without any stress like cutting, pruning, and bush fire.

3)Upland farm (*lati*)

The cultivation and fallow cycle in upland is shifting to longer cultivation and shorter fallow period in accordance with population growth. The fallow period has already disappeared around larger-scale market towns like Doko. Within the territory of a community, there is a concentric difference of land use intensiveness : the further from a settlement, the more extensive use of land. Regardless of distance, however, roadsides are more likely to be cultivated because of less damage caused by noxious wildlife, especially monkeys.

Cereal crops arranged in upland are maize, sorghum (*Sorghum bicolor*), and early and late millet (*Pennisetum glaucum*). Maize is planted just after clearance or when barnyard manure is available because it requires the most fertile soil. It is planted alone or mixed with sorghum. Following maize, sorghum is planted with chemical fertilizer. Millet can grow under worse soil conditions, even after several years of continuous cropping. At the last stage of cultivation period, leguminous crops such as cowpea (*Vigna unguiculata*), groundnut, and sometimes bambaranut (*Vigna subterranea*) are grown. These leguminous crops as well as egushi melon (*Colocynthis citrullus*) are also mixed with sorghum or millet.

The way of land preparation also changes in accordance with decline of soil fertility. At the early stage of cultivation, Nupe farmers make relatively large ridges (*gbara*), which are tuned to small mounds (*ewogi*) that result in less crop density. The cultivation period ends with monoculture of leguminous crops on smaller ridges. When fallow land with thick trees is cleared, the remnant such as roots and stumpages obstruct subsequent land preparation. In such cases, the farmers temporary make large mound (*ewoko or ewokogi*) in spite of *gbara* especially in the first year.

4)Grass fallow (*nufu* or *enufu*)

The early stage of fallow period is called *nufu* or *enufu*. It is distinguished from bush fallow (*gonta*) not by the difference of vegetation but by the traces of ridges evident from past farming. So far as there is enough room for fallow, farmers do not clear this type of land. There are several pioneer tree species, typically *Daniellia oliverii*, which spread as soon as the farmland is abandoned, or even under cultivation. Indeed, it is more difficult to eliminate such fast spreading and growing shrubs and trees than to weed an upland field, which becomes one of the reasons to make farmers cautious against planting of indigenous species.

5)Bush fallow (*gonta*)

When the traces of past farming disappear, the land is called *gonta* and ready to be claimed by anybody for clearance. Shoots sprouting from stumpages are gathered by women for firewood, both for self-consumption and for sale. Coppice lots for firewood collection are sometimes formed as a result of repeated cutting but not on purpose. The pruned branches are left on the site for several days for drying, and brought back to the settlement in fagots of 20 to 30 kilograms. Various nonwood forest products are also collected from this type of land.

6)Forest (*cikan*)

The land that has not yet been cultivated is called *cikan*. At one time, every settlement was surrounded by *cikan*, but gradually these no-man's-lands were reduced. Now all of the community territories adjoin each other in Cis-Kaduna, where *cikan* has already disappeared. Exceptionally, forest reserves with natural vegetation, Gunu Hills Forest Reserves discussed in the next section for instance, can be categorized to *cikan*.

An example of land cultivated by GZ family suggests that not only the land categorized to *kpesa* but also the surrounding area is already under permanent cropping (Table 4.4). Even the upland closer to the settlement had been cultivated for seven and ten years, but monoculture of cowpea on *gbara* shows those will be abandoned before long. In contrast, GZ was going to plant sorghum on the newly opened farm far from the settlement. The long fallow period of the newly opened *gonta* shows uneven rotation, the closer to the settlement, the

Table4-4 Land cultivated by GZ family in 1995.

Farm NO.[1]	Location	Cropping period	Crop 1st	Crop 2nd	Shift of the land preparation way	Tribute
Compound	*Kpesa*	Permanent	Sorghum+maize		Gbara	None
			Sorghum+sweet potato		Gbara	
			Late millet+cowpea	Cowpea	Gbara	Cowpea (2 bowls)
Upland 1	Adjacent to *kpesa*	Semi permanent	Early millet+late millet		Gbara	Late millet (10%)
			Sorghum+late millet+melon		Gbara	Sorghum (10%)
Upland 2	Near road	Already 20 years	Late millet+melon		Ewogi[2]	Late millet (10%)
Upland 3	Near road	Already 7 years	Cowpea		Gbara	Cowpea (2 bowls)
Upland 4	Near road	Already 10 years[3]	Cowpea		Gbara	Cowpea (2 bowls)
Upland 5	Surrounded by *gonta*	Newly opened[4]	Sorghum		(Gbara)	Sorghum (10%)
Lowland 1	East to road	Permanent	Melon	Rice	Ewoko→katangi	Rice (2 tins)
Lowland 2	West to road	Permanent	Cassava	Rice	Ewoko→(interval)→gbaragi	Rice (1 tin)
Lowland 3	Near river	Permanent	Cassava+okro	Rice	Ewoko→katangi	Rice (2 tins)
			Pepe+okro	Rice	Togoko→katangi	
			Garden egg	Rice	Ewoko→katangi	
			Sugar cane			

1) The number shows the distance from the settlement (the larger, the more distant).

2) The land is becoming exhausted and will be changed to monoculture of cowpea and groundnut next year.

3) The land had been cultivated by SH family since 1985 but was taken over by GZ after abandoned in 1994.

4) According to GZ, the fallow period was more than 30 years.

longer cultivation period.

1-5. People, land, and forests in Guinea savanna

(1) Population and farming system

As already mentioned, Nupeland is located in the transition zone that demarcates the humid south and arid north. The agricultural crops reflect this geographical position ; that is, all of major staple crops, from tuber to cereal, not only for commercial purpose but also for home consumption, can be found in Nupeland. Nadel referred to another factor explaining this diversity in staple crops in his observant accounts on Nupe farming system ; Nupeland was once

Table4-5 Comparison of land area under cultivation between GZ and SH family.

Extended family			Upland[2]			Lowland[3]		
Name	Member	Labor force[1]	Total area (ha)	Number of percel	Area per caput	Total area	Number of percel	Area per caput
GZ	8	2	3.48	6	0.44	1.48	3	0.19
SH	4	1	0.71	2	0.18	0.48	2	0.12

1) The number of men above 18 years old.

2) Including home garden (*kpesa*).

3) Including a farm on the adhacent settlement area.

located on a strategic point of trading routes connecting the north and the south (1947, 2-3). The only difference in crops compared to the colonial period is drastic decline in export crops like cotton and groundnut.

Various types of mix cropping as shown in 1-4 was also practiced during the colonial period, and Nadel categorized them to simultaneous and successive intercropping. In terms of cropping frequency, lowland could be cultivated for ten years or more, while the period was shorter in upland, for instance, four to five years in Mokwa, six to seven years in Kutigi, and three to four years in Doko in the 1930s (*ibid*. 205-211). Here we can find undergoing change: now lowland is annually cultivated, and even in upland, fallow periods are disappearing under continuation of cultivation with shortened fallow period.

This trend can also be confirmed by population census. According to the 1931 Census, the population density of Bida District and Agaie-Lapai District was 35.2 and 21.7 persons per square mile, or 13.6 and 8.4 persons per square kilometer respectively (*ibid*. 11). In contrast, the 1991 Census, which results were partly published but mostly unpublished, reported that the total population of Niger State was 2,482,367 while the area was 76,000 square kilometers (Baba 1993, 331-334). Though administrative jurisdiction has often been changed since the colonial period, even the state average of 32.7 persons per square kilometer in 1991, which includes many of less populated areas, is 2.4 times and 3.9 times as many as that of densely populated Bida and Agaie-Lapai in 1931.

The area of G settlement located in former Bida District is approximately 190 hectares, while the population in 1995 was 175. It means the population density (92.1 persons/km^2) has almost tripled compared to the average of the state. To examine the carrying capacity of land in more detail, an example of the hardest worker (GZ of Table 4-5) and another example of the idlest worker (SH) were selected from G Community based on recommendation of villagers. Unexpectedly the family size of GZ is just twice as large as SH, which makes the comparison easier.

The family of GZ consists of eight persons from three generations, with two adult men, two adult women, and four children, while SH consists of a nuclear family with two children. GZ together with his unmarried younger brother cultivated three plots in lowland and six plots in upland in 1995 as shown in Table 4-2, while SH worked on two plots in lowland and another two in upland. The average area per capita on hardworking basis is 0.19 in lowland and 0.44 in upland, totaling 0.62 hectare. On an idle basis the average is 0.12 and 0.18 respectively, totaling in 0.30 hectare. Comparing the total area and population of G Settlement, land under cultivation can be estimated to be in the range of 27.4 to 57.1 percent, which allows 1 : 1 or at most 1 : 2 ratio of cultivation and fallow.

(2) Land system and forests

The theory of Boserup on agricultural growth (1965) is better applicable to the peneplain in West Africa, where only rivers could be obstacles to human mobility. Not only in savanna zone but also in high forests, the settlements are scattered and connected to one another by honeycomb-like network of roads and paths. Once such a network covers the region, the slow process of forest degradation is brought about following population growth.

Since there were no natural hazards like precipitous mountain ranges to check the invasion of human settlements, it seems large area of intact forests could not be found when the colonial government began to establish forest reserves in the beginning of the 20^{th} century. The government tried to solve the problem by imposing a quota to every native administration, which resulted in small-scale forest reserves scattered over the country including dryland in the northernmost region. By contrast, several game reserves were secured in larger scales, and are now incorporated to national parks.

As already mentioned, it is not likely that the total percent of forest reserves will increase. The necessity for estimating the importance and future of trees and forests outside forest reserves is not only found in Nigeria ; it is rather a common problem in Africa. The following section is to show the current situation of trees and forests, as well as the stress caused by human activities, under different land categories : national land, state land, and communal land. (Misa Masuda)

2. Trees on farmland

2-1. Introduction

(1) Data collection

This section is to describe the current situation of forest resources both inside and outside forest reserves, with special attention on floristic biodiversity.

Firstly, the area controlled by G Community referred in the first section was selected for the measurement of trees outside forest reserves. According to the land use classification, a 100 × 100 meters quadrat was set on each category: home garden (*kpesa*), farmland (*lati*), and matured fallow land (*gonta*). Tree measurement was carried out for the home garden and farmland plot in 1992. Since the quadrat first established on a fallow in 1993 was cleared and burnt in the next year by a Fulani group for their temporary settlement, another quadrat was established in 1995 (Fig. 4-5).

To compare the distribution of trees in rural areas with that of demarcated lands, a forest reserve with relatively intact vegetation and a national park were added to the study sites. Since no natural vegetation closer to G Settlement

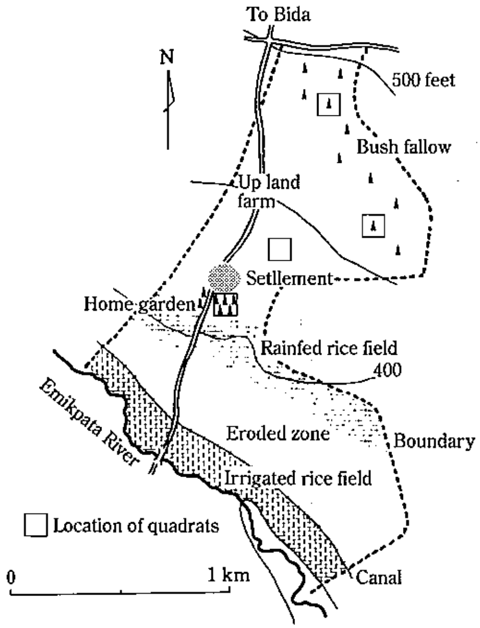


Fig.4-5 Location of the quadrats at G Setllement

Table4-6 Human impact on forest resources

	Cultivation	Firewood collection	Forage collection	Grazing	Bush fire
Settlement Home garden	+	(+)	(+)	−	−
Fallow 93	++	++	+	+	++
Fallow 95	++	++	+	+	++
Gunu Hills Forest Reserve	−	+	+	+	+
Kainji Lake National Park	−	−	−	−	++

− : No influence
+ : Certain influence (Very limited)
++ : Significant influence

could be found, Gunu Hills Forest Reserve and Zugurma Sector of Kainji Lake National Park were selected despite the distance from G Settlement: approximately 50 kilometers to the north and 140 kilometers to the northwest respectively (Fig. 4-1, Section 1).

Gunu Hills Forest Reserve is located along the main road near the town of Lemu and consists of a mass of mesas as the name implies. The total area is recorded to be 488 hectares but existing woodland seems to cover around the half the area. Here an oblong plot of 25 × 400 meters was established from the foot that faces to the main road toward the mid-slope. In regard to the national park, a quadrat of 100 × 100 meters was established.

(2) Human impact on forest resources

It is obvious that these selected sites have been under different types of stress caused by various human activities, which can be categorized to cultivation, burning, wood and forage extraction, and grazing (Table 4-6). Even already demarcated forest reserves cannot be saved from burning and grazing by nomadic people. Farmers from neighboring settlements also engage in firewood and craftwood collection, since there is almost no guard system for scattered forest reserves.

National parks are exclusively demarcated and most strictly controlled so that the vegetation should be saved from these impacts. Kainji Lake National Park, however, has been intentionally burnt in order to restrain the tree density and maintain the open canopy. This so-called "controlled burning" aims at checking uncontrolled fires set by poachers and Fulani nomadic people or those caused by naturally, whilst at the same time, promoting the growth of grasses to feed savanna-oriented fauna. The park rangers have carried out controlled burning twice a year: early burning from the beginning to the middle of the dry season, and late burning from the end to the beginning of the rainy season.

Such impact laid on fauna rather than flora is caused by the historical background: Kainji Lake National Park was first established as Borgu and Zugurma Game Reserves and belonged to the state but later in 1979 these two reserves were reorganized to a national park belonging to the federal government. With review of the role as a game reserve for tourists, however, controlled burning, especially late burning which may result in unexpected conflagration hazard, is now discouraged and a new zone named Strict Nature Reserve is set up in the middle of Borgu Sector. (Misa Masuda)

2-2 Distribution of trees outside forest reserves

(1) Home garden

The land surrounding a settlement is called *kpesa* and often divided to each family. Contrary to upland fields, families are encouraged to always keep the space open against invading woody weeds. Usually annual food crops or perennial nonfood crops are arranged on *kpesa* and daily wastes provided from the settlement makes sedentary cultivate possible.

Fruit trees such as mango are often arranged on *kpesa*. In case of G Settlement, a corner of *kpesa* was vertically utilized combining various tree crops and annual food crops (Fig. 4-6(a), (b)). Among the tree crops, mango has the highest commercial value, and Hausa middlemen from the north come round villages during the fruiting season. The way of transaction is that these middlemen purchase the harvesting right of each tree, employ villagers to collect fruits, and transport the harvest by hired vehicles. Other fruit species were relatively recently introduced and are consumed by children.

Ownership of trees belongs to individual who planted the trees. Trees that grow naturally, such as sheanut and locust bean belong to those who control the land. This is particularly apparent on *kpesa* and also *lati* under farming, but trees on fallow land are under open access. The only exception among planted trees is *Gmelina arborea*, which was introduced by the government for greening movement but does not provide any specific utility except shade to villagers. Indeed, one of largely grown *Gmelina* trees was felled down at a villager's own discretion for a reason of troublesomeness to deal with fallen leaves.

(2) Farmland

Woody plants remaining on farmland mostly consist of useful indigenous trees

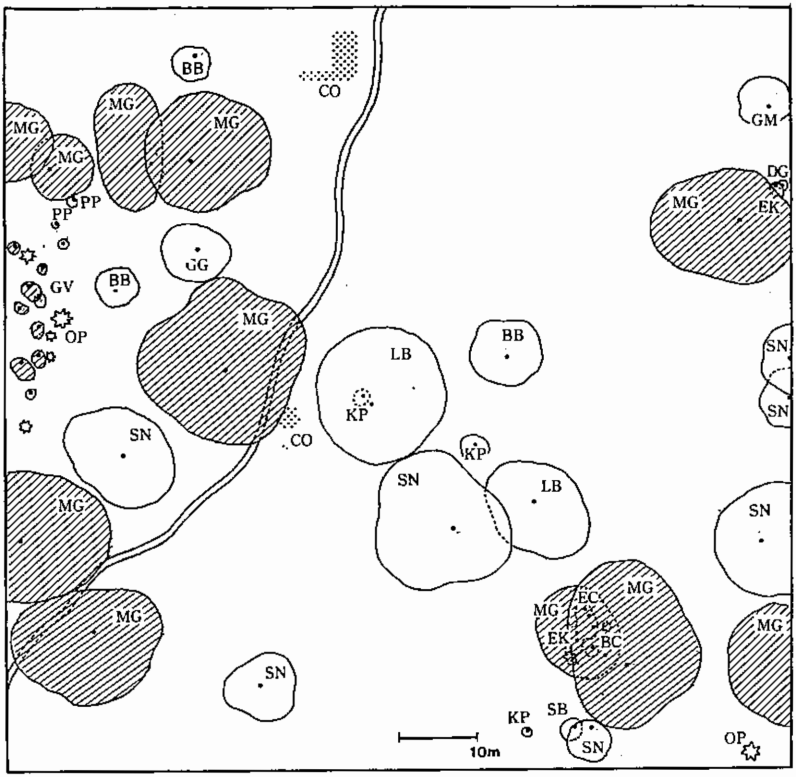


Fig.4-6(a) Tree arranged on the home garden.
BB, *Adansonia digitata*; BC, (*Banchi*); CO : *Ricinus communis*, DG : (*Dangodi*), EC : *Sterculia setigera*, GG : (*Gbagun*), GM : *Gmelina arborea*, GV : *Psidium guajava*, KP : *Bombax costatum*, LB : *Parkia biglobosa*, MG : *Mangifera indica*, OP : *Elaeis guineensis*, PP : *Carica papaya*, SB : (*Shambota*), SN : *Vitellaria paradoxa*;
● : Planted trees.
Note: ( ) shows Nupe Vernacular names for unidentified trees.

such as sheanut, locust bean, tamarind, and palm (*Borassus ethiopium*). Mango trees on farmland were originally natural undergrowth of home garden and were transplanted by children on the border between the lands controlled by different families (Fig. 4-7, and Fig. 4-8, Photo. 4-1).

Not only some selected trees but also stumpages of various species can survive during the farming period. They start to grow as soon as the land is abandoned and left for fallow. As already described, a fallow where remnant of ridges is still visible is called *nufu* or *enufu*, and after the ridges disappear, it is distinguished as *gonta*. It should be emphasized that the criteria to distinguish *nufu* and *gonta* is not the vegetation change but the evidence of previous

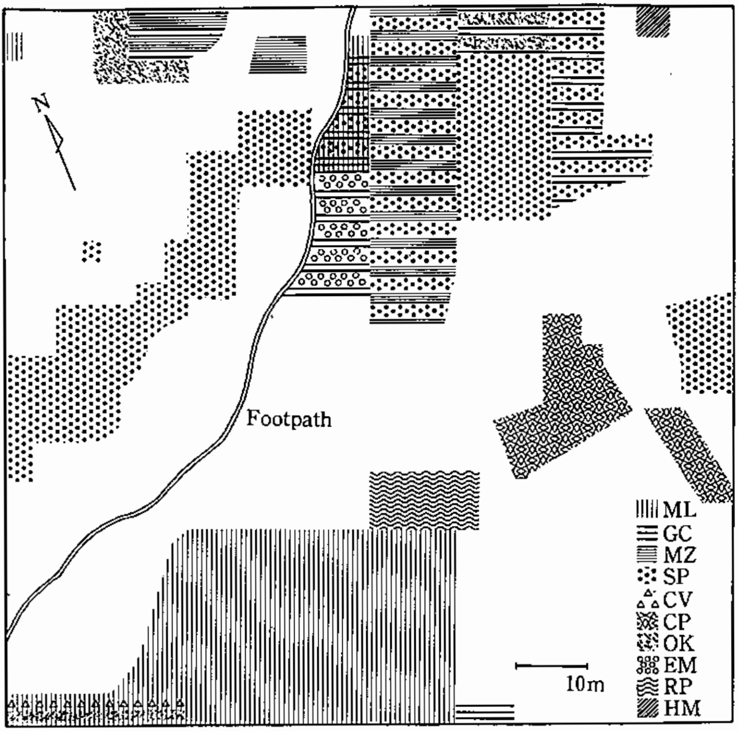


Fig.4-6(b) Agricultural crops under the canopies.
ML, millet ; GC, guinea corn; MZ, maize; SP, sweet potato; CV, cassava; CP, cowpea; OK, okra; EM, egushi melon; RP, red pepper; HN, henna.
Note: Combination of patterns shows mix cropping.

farming activities.

(3) Comparison of biomass and floristic biodiversity

The number of trees and total basal area largely differ between secondary growth on fallow land and primary vegetation inside forest reserves including national parks (Table 4-7). The average of total basal area obtained from two fallow plots accounts for around one forth of the average of the forest reserve and the national park. However, the total basal area of the home garden where the trees can escape from bush fires is larger than the national park. Though there is a difference between natural vegetation and introduced fruit trees, above all, mango, this shows the possibility to increase the biomass through proper selection of species and management.

The highest number of trees at the forest reserve plot reflects the peculiar vegetation of mesas. The mid-slopes of mesas are covered by coppice that grows

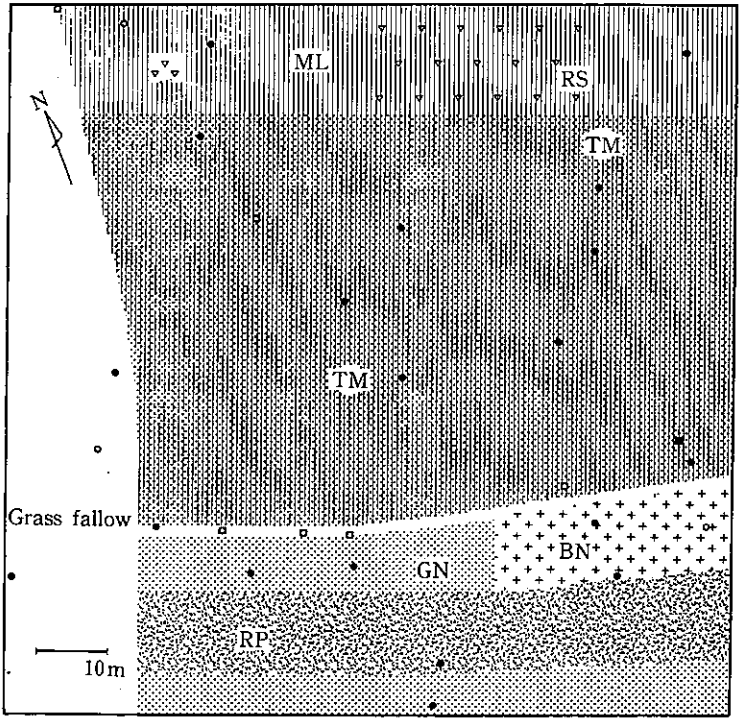


Fig.4-7 Distribution of trees on the farmland plot
ML, millet ; GN, groundnut; BN, bambara nut; RP, red pepper; RS, roselle;
●, sheanut; ○, locust bean; ■, oil palm; □, mango; TM, termite mound.
Note: Combination of patterns shows mix cropping.

on pebbly ground and consists of few species. The number of trees on the fallow plots is also smaller than the reserve, since only the trees with a diameter of 5 centimeters up at breast height were counted. If all the stumpages that still survived on the fallows were included, the total number is equivalent to the forest reserve.

Though the number of savanna species itself is much smaller than those of humid climate, identification was difficult. The results on the same specimen were often inconsistent among the sources, which was partly caused by the seasonal bias. Though many of savanna species flower and fruit during the dry season, the field trip were carried out only in July and August. It was not possible to collect perfect specimens through the visits during the rainy season, which caused great difficulties especially in identification of leguminous species.

Even though the data is incomplete, some observations are still available (Fig. 4-9). In proportion to the extent of stress caused by human activities, not

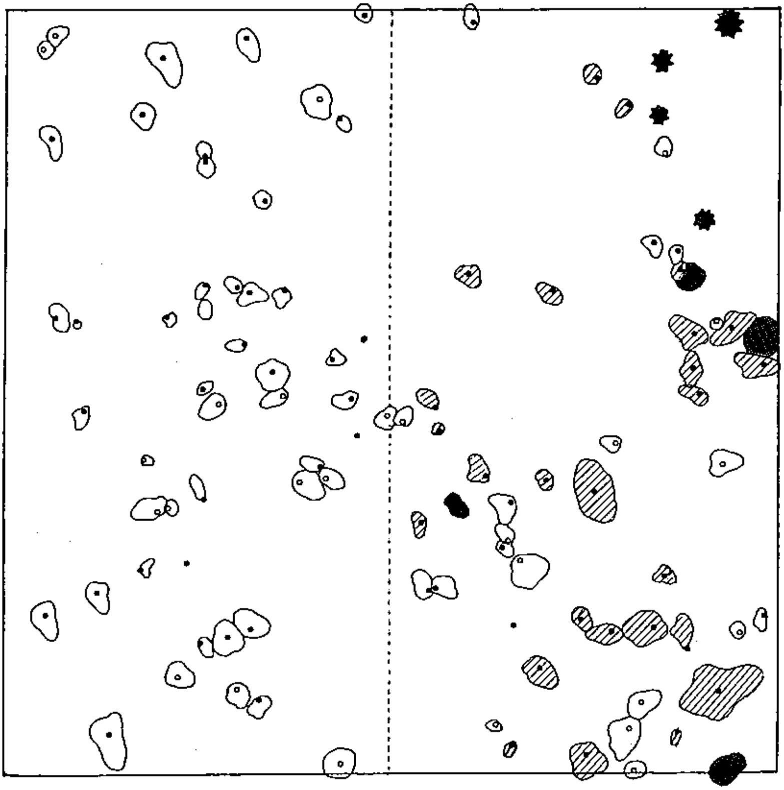


Fig.4-8 Distribution of trees on fallow plot

● : stem of sheanut, ○ : stem of non-sheanut, ⬡ : palm (*Borassus ethiopium*)

▨ : Sheanut remained in 1994 after land clearance.

⬬ : Non-Sheanut remained in 1994.

Note: Though this quadrat was established in 1993 after confirmation with the landowner that there was no schedule to cultivate it, the right half of the quadrat was cleared in the following year.

only the biomass but also the diversity is much lower in the secondary growth outside forest reserves. The higher diversity found in tree species of the forest reserve than that of the national park is caused by the island-like location of forest reserves as a sanctuary and also by the topography that involves different landforms from foot to hilltop. There we can find both groups of trees : natural vegetation, and adapted species to human impact. Even taking the fact that Kainji is far from the others into consideration, some overlapping is found between national park and forest reserve, and also forest reserve and secondary growth, but a little between national park and secondary growth in rural areas.

The result also suggests the importance of barely remaining natural vegeta-

Photo4-1 Girls sowing *egushi* melon seeds on the farm where sheanut trees are arranged.

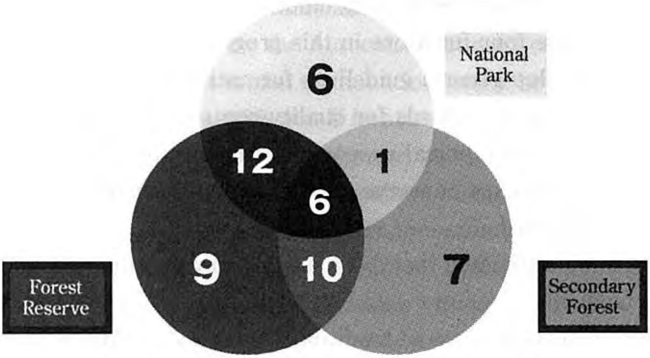


Fig.4-9 Overlap of tree species among different land Uses.
Note: The area of each plot is 1 hectare.

Table4-7 Comparison of the number of tree species, density, average DBH, and total basal area by land use.

	Species		Density (number/ha)	Av. DBH (cm)	Total basal area (cm^2)
	Total	Planted			
Home garden	14	(6)	37	55.2	144,757
Fallow 93	19		134	13.4	23,718
Fallow 95	13	(1)	68	18.5	22,928
Forest reserve	37		811	9.1	78,952
Narional Park	25		455	14.7	103,770

Note : The area of each plot is 1 hectare.

tion inside forest reserves like Gunu Hills. There is an urgent need to make a correct map of forest reserves together with a description on the vegetation, and take some measures to protect the remaining natural vegetation, since the intact nature has already been lost in Niger State, and probably in the whole savanna of Nigeria. Moreover, denudation of forest cover is taking plan accompanying by genetic erosion. (Misa Masuda)

2-3. Traditional use of medicinal plants

(1) Traditional medicine in Africa

Though modern medicine has become dominant in the world, traditional medicine still exists not only in peripheries but also in industrialized countries. Such traditional medicine took root in people. The Regional Programme on Traditional Medicine supported by The World Health Organization Regional Office for Africa (AFRO) aims at promoting the rational use of traditional medicine. There are four functions in this program:

1. To develop general guidelines for national policies;
2. To develop standards for quality control of traditional drugs;
3. To provide technical support for capacity building;
4. To develop and conserve medicinal plants for the global community (AFRO 2001).

In Africa, it is estimated that more than 80 percent of people still depend on traditional medicine.

The development process of traditional medicine in Africa can be roughly categorized in three stages. Before the colonial period, only traditional healers took care of people's health. During the colonial period, governments rather oppressed traditional medicine under European influence, but people did not stop to relying on their indigenous knowledge of medicine.

The third stage came after independence. Traditional medicine has gradually been reinstated in accordance with restoration of social-cultural identities. In 1976, Africa Regional Committee Meeting was held and discussed "traditional medicine and its role in the development of health services in Africa". After this meeting, the Regional Office was given strong impetus to the programs related to traditional medicine both at regional level and national level. In some cases, traditional healers collaborate with modern medical doctors to treat disease. Traditional medicine committees and national laws have also been established in some countries (Ramanohisoa 1983), and the Nigeria Union of Medical Herbalist Healers Practitioners was organized in Nigeria. It presides over various local groups on a nationwide scale.

(2) Native doctors in Niger State

Under Bida Emirate of Niger State, Association of Native Doctors was established in 1966, which also functions as a branch of the union. It consists of secretariat in Bida township and nine branches in Mokwa, Gbako, Katcha and Edati Local Government Area. The secretariat holds membership of Bida Emirate Council, which suggests that traditional healers are closely connected with the traditional administration system.

Activities are different among the branches. At Bida, they preserve and promote traditional knowledge and techniques not only in relation to medical treatments such as local midwives, herbalists, bone setters, snake specialists and barbers, but also about Islam doctrine, magic and blacksmithing. Above all, holding clinic and granting certificates are their important activities.

The certificates executed by the Association consist of several systematic grades. At first an applicant has oral examination, and if he passes the examination, he can get a temporary certificate. If he attends training for six months and can pass another examination, he is registered at the Association and given a certificate that allows him to practice anywhere in Bida Emirate. Afterwards, if he trains for another year and can pass the examination, he can get the certificate to practice anywhere in Niger State. Finally, when the certificate holder spends two years as a traditional healer without any trouble and attends a seminar for one month, he can get the certificate that allows him to commence practice anywhere in Nigeria[10].

Many of traditional healers commence practice in their own house because the number of clinic is limited. Farmers also utilize various medicinal plants for cordial, bathing newborn babies, and so forth. Usually elderly people have such knowledge and engage in gathering medicinal plants, but that of traditional healers is believed to be more superior to that of people. In Nigeria, not only rural but also urban population tends to depend on traditional medicine, rather than modern medicine, especially in case of chronic diseases.

(3) Traditional use of medicinal plants

The following is based on interviews with a Nupe certificated traditional healer and a Fulani apprentice healer. The Nupe healer stays at E Settlement that consists of only one compound and neighbors on G Settlement of 4-1. The camp

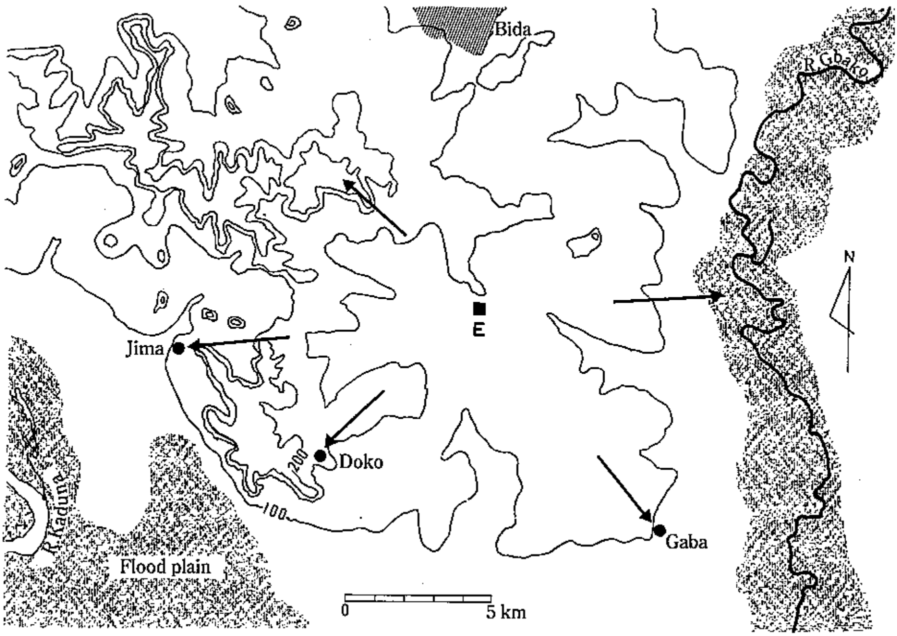


Fig.4-10 Range of medicinal plant gathering : the case of a healer at E Settlement.

where Fulani healer stays is also close to G. Such healers are called *boci* or *cigbejinci* in Nupe, whose meaning is closer to herbalist.

Both of them utilize various parts of almost all plants in their environment. In addition, the way to process these fresh or dried grasses, herbs, leaves, stems, barks, roots, fruits, algae, and parasitic plants is also varied : for example, soaking, squeezing, pounding, boiling, and fermenting. They often blend some different plants, and if necessary, mix various crops such as garlic, onion, lime, cereals, spices, and tobacco, oils, animal-oriented materials such as honey, egg, skin, and placenta, insects, reptiles, birds, and minerals such as potassium. They treat not only disease and injury but also mental problems including those caused by witchcraft.

While purchase the crop-, animal- and mineral-oriented materials at markets or directly from farmers and hunters, they collect naturally grown materials by themselves. The range of their gathering activities is not limited to the fields around their settlements. They often go far away looking for plants that they cannot get around settlements. *Burkea africana*, *Gardenia* spp., and some species of climber are only found on the uncultivated foot of mesas, while grasses and herbs can be collected in floodplain after the undergrowth disappear in upland during the dry season (Fig. 4-10).

The plants they do not use for medicinal purpose are so few that they can be numbered. The Nupe healer expressed "I am not aware of the use" instead of "the plant does not have any use". Generally, Nupe farmers share a sense that all plants in their environment exist with certain significance. If there is a useless plant, they say they do not how to use it. That is to say, all the ecosystems in various landforms are necessary for the daily life of farmers, not only in a practical but also in a philosophical sense, and there are no useless trees and herbs.

The traditional knowledge of plants is succeeded through several routes, and the position of a traditional healer is not always inherited. Taking the Fulani apprentice healer as an example, his father knows nothing but cattle. He became interested in medicine in his teenage years, and whenever a member of his camp became sick, he followed the patient and watched the treatment of healers. Afterwards, he was apprenticed to three certificated Fulani healers and has learned their knowledge. He has also participated in the training course periodically provided by the Association of Native Doctors in Bida.

Modern medicine has not yet prevailed in Nigeria. By contrast, traditional medicine has played important role in physical as well as mental health care especially in rural areas. From the case of Bida, in addition to the practical aspects, it is implicated in the traditional value system, which overlaps with the political hierarchy, the emir being on top. Though the scientific mechanism of the Nupe traditional medicine and medicinal plants has not yet been studied and proved, it seems necessary to maintain the indigenous biodiversity that supports the traditional medicine, so far as the traditional medicine keeps public peace and there are no efficient alternatives.

(Kayo Shoji, Takashi Hiramatsu, and Misa Masuda)

2-4. Importance of trees to improve the quality of life

Trees are utilized in various aspects of our daily life, and among Nupe people likewise. No matter how poor the savanna vegetation is, or because of the poor vegetation, remaining natural plants inside communal lands are fully utilized by the villagers. One of the Nupes stated, "We believe all that exist have certain functions, and if there is a useless plant, it means we have not yet known the function".

One of the elderly men of G Settlement counted 32 vernacular names of species including shrubs, among which 23 were utilized for firewood, 12 for forage. Other usages are : food like edible fruits and leaves, various parts of plants for medicine, and wood for housing construction and crafts such as mortar, pestle, and handles. One of the most important species is sheanut, which is further referred to in Chapter 6. Fermented seeds of locust bean are utilized as the material of traditional flavoring called *dadawa*. In contrast to sheanut that is gathered by almost all women including little girls (Photo. 4-2), those who engage in *dadawa* processing are limited to a family in the case of G Settlement. The wastes of pods are put on walls to protect the walls against cracking by heavy rain.

Photo4-2 A Nupe girl carrying sheanut on her head

On the other hand, we also have to pay attention to the fact that what is important for villagers is individual existence of plants rather than forest as a whole. Contrary to common belief, dense thickets are not in favor with the farmers, since they entice pest like monkeies. For instance, there were linear thickets along the Emikpata River in 1992, but after several years one of the tenant farmers cleared them completely for his sugar cane farm. Some pioneer tree species like *Daniellia oliverii* is regarded as a weed, and indeed to up root *Daniellia* from the farms are harder than grass weeds.

Nupe farmers regard naturally grown trees as free goods. Even commercially useful plants like sheanut are not given much attention due to decreasing market demand, although it was once monopolized by the traditional rulers (Nadel 1942). Their customary system does not imply the functions to check denudation, biodiversity loss, and the consequent degradation of the quality of life. Under ever growing population, the land system has been maintained by reduction of fallow period, but when it reaches saturation point, there are no alternatives in the existing system.

Unlike in the humid climate, the agricultural sector and forestry sector in drylands need to change the conception of productivity of each component to comprehensive approaches toward well-being of rural societies. Under deficiencies of essential component such as water and fertility, careful discussions involving farmers themselves on various approaches are expected. If there is an exotic species, for example, that can provide higher utility, there should be no need to discriminate it by reason of being exotic, so far as there is no fear of overgrowing and intrusion into natural ecosystems.

In Niger State, Zonal Forest Offices and ADP maintain several nurseries for the public service. There is highest demand on seedlings of fruit trees, especially grafted or budded ones, but the supply cannot meet the demand. To arrange small-scale nurseries in every community with technology transfer of grafting and budding can help to improve their environment and also provide additional income. To support such decentralized nurseries and to secure necessary amount of scions, existing ADP nurseries would do better to change from the current design for the purpose of forest plantation to orchards of improved varieties of fruit trees or other attractive species to the farmers. Such a change in conceptions has been required in the forestry sector since the slogan "Forest for People" was adopted at the 8^{th} World Forestry Congress held in 1978. (Misa Masuda)

3. Climate and growth of trees in savannas

3-1. Growth environment and information of tree rings

(1) Method of tree ring analysis

Gadza, a village in Niger State, in central Nigeria, is located in an area known as humid savanna, where sparse woodlands called savanna woodlands are usually distributed. Most of these woodlands are not natural vegetation established under the climate; in particular, so-called village woods around village communities are those formed as a result of strong human disturbances. But it has not fully been understood how farming, grazing and other human land-use activities have changed original vegetation. To find out this, it is necessary to examine the formation process of present forests. Several methods are applicable for this study and one representative method is tree ring analysis of trees that grow in the forest.

In the areas like the Temperate Zones where there are distinct seasons, most trees form a regular growth ring[11] each year and hence this is called the annual ring. If we measure the ring width of a tree, we can know the tree age and radial growth rate, and if we measure the wood density, we can obtain information about environmental changes (about whether the environment has been favorable or unfavorable to the tree). Then based on the data, we can investigate the formation process of forests and the regeneration history leading up to the present composition of tree species. However in the tropical and subtropical areas, seasonal changes, especially in temperature, are much smaller than in the temperate zones and so most trees in these areas form no distinct or regular growth rings. Because of this, it is far more difficult to study the process of forest establishment in these areas by the conventional methods of tree ring analysis.

In conventional methods, the morphological changes of cells caused mainly by temperature changes have been observed. Recently methods based on chemical analysis have come to be used to detect changes in the constituents of wood, and thereby it is becoming possible to detect the seasonal growth rhythm of trees in the tropics as changing constituents, which is hard to check by observation. One of such techniques is to measure stable carbon isotope ratios. Here we report the results of this method applied to sheanut (*Vitellaria paradoxa*) and African mahogany (*Khaya senegalensis*), the representative tree species in the Gadza district.

(2) Savanna climate and the formation of growth rings

The data of temperature and precipitation observed at a location about 20km from Gadza are shown in Fig. 4-11. The mean monthly temperature is 25-30°C throughout the year. The mean annual precipitation is about 1,100 mm but is

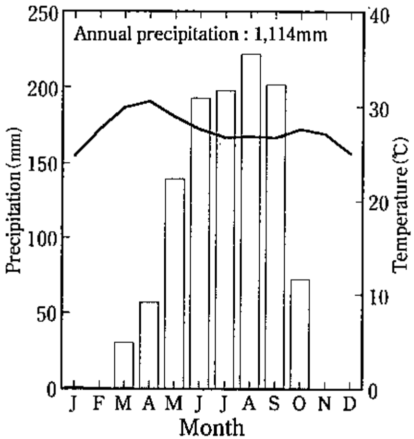


Fig.4-11 Mean monthly temperature and monthly precipitation in the survey site (Badeggi; Lat. 9°5' N) (Averages of the 1981 - 1994 period)

mostly concentrated in the period from April to October and the months from November to March in the following year have little rainfall. From this fact it can be said that the growth of trees in this district is determined mainly by rainfall. In the tropics, vegetation generally changes from humid evergreen forests to dry deciduous forests along latitudes. In Gadza situated at about Lat. 9°N, many tree species are supposed to defoliate in the dry season but unfortunately no detailed data have been available. According to few available literature, sheanut is deciduous (Hopkins, 1970, pp.795-825) and African mahogany is evergreen (Keay, 1989, pp.340-342)[12].

Several workers have reported that tree rings are formed not only in trees in savannas with the distinct rainy and dry seasons but in some tree species even in the humid tropics as well (Amobi, 1973, pp.211-218 ; Killman & Hong, 1995, pp. 329-335 ; Worbes, 1995, pp.337-351). Few of the ten or so species, however, had clear growth rings in Gadza and its neighboring areas. In most of the species, irregular and indistinct growth layers like those observed in sheanut existed as ring-shaped patterns (Photo 4-3). Only African mahogany had distinct and concentric growth rings (Photo 4-4).

(3) Structure of growth rings

In the trees in the temperate zones, we can see distinct growth rings because the cells formed in the late growth period of a year differ in size and type from those formed in the early growth period of the following year. In this case, the main cause of growth ring formation is attributable to the seasonal changes in the radial growth according to temperature. In the tropics where temperature

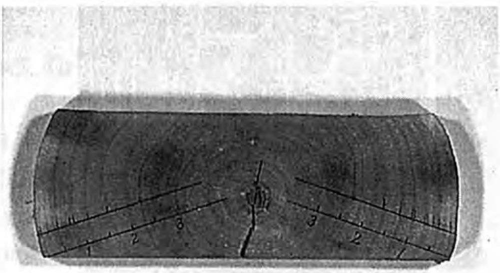


Photo4-3 Cross section of sheanut
(Ring-like patterns of irregular and indistinct growth layers can be observed.)

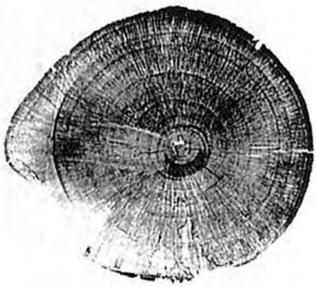


Photo4-4 Cross section of African mahogany
(Concentric growth rings can be observed.)

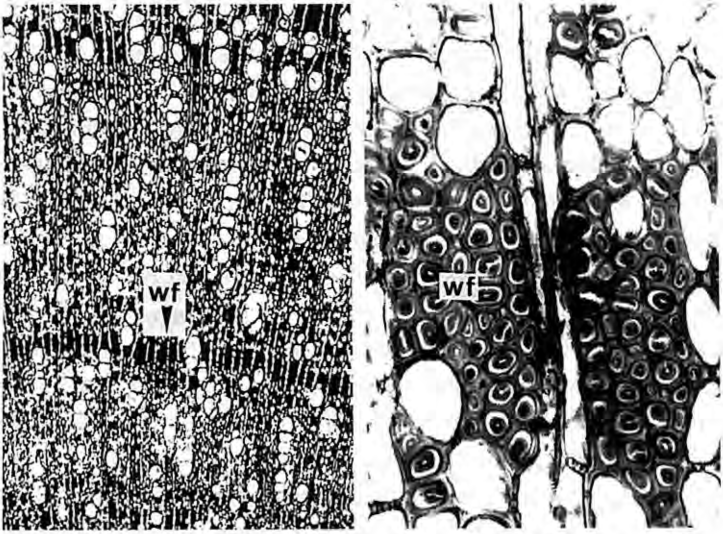


Photo4-5. Light microscopic images of the cross section of sheanut.
(The photo at right is an enlarged version of that at left and the top parts are on the bark side; thick-walled fibers (wf) exist in belts.)

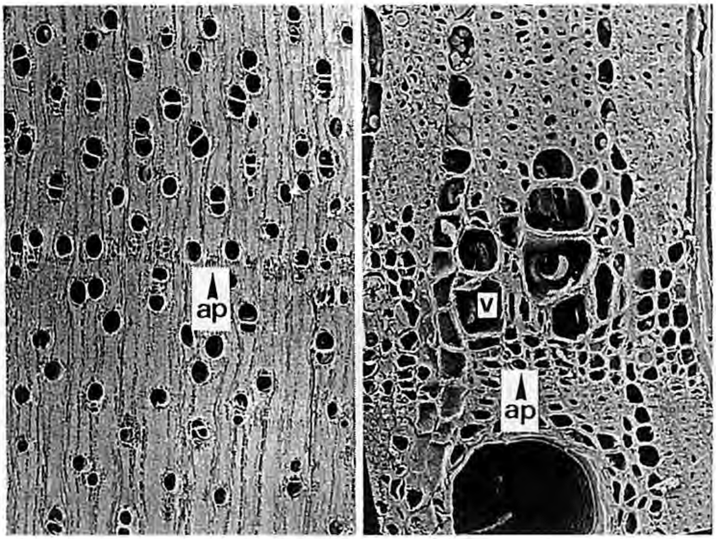


Photo4-6. Electron microscopic images of the cross section of African mahogany.
(The photo at right is an enlarged version of that at left and the top parts are on the bark side ; axial parenchymas (ap) exist in belts, accompanied by small-diameter vessels (v) just outside of them.)

changes are smaller than in the temperate zones, trees do not generally form growth rings as regular and distinct as those in temperate tree species. However, still ring-like structures that are supposed to have been formed by periodical changes in growth can be recognized on the cross section of many tropical trees.

A microscopic observation of these ring-like structures of sheanut shows that they are the thick-walled fibers arranged in tangential direction (Photo 4-5). These parts generally have a low distribution of vessels and lack axial parenchyma cells[13]. Sheanut has streaks supposed to have been made by colored substances, but they are not regular and often not continuous. Therefore, a microscopic examination cannot judge that these ring-like structures are formed each year.

On the other hand, the growth rings seen in African mahogany are more distinct and concentric. Microscopic observation reveals that these growth rings are the tangentially connecting axial parenchyma accompanied by small-diameter vessels just outside the ring (Photo 4-6). In the temperate zones, some hardwood species form such axial parenchyma at the beginning or the end of a growth period, which are known as initial parenchyma and terminal parenchyma. If the tangentially connecting axial parenchyma of African mahogany is either initial or terminal parenchyma and are formed by the alternation of the rainy and dry seasons, they can be regarded as annual rings. However, we cannot know only by microscopic observations how the growth rings have been formed in this tree and hence cannot conclude either that they are annual rings. To answer this question, we should determine at what point in the year the tangentially connecting axial parenchyma is formed.

3-2. Growth process of trees estimated by means of carbon isotope ratios

(1) Growth of trees and carbon isotope ratios

Carbon is one of the most fundamental elements of organisms. In nature, there exist three carbon isotopes whose weights (mass number) differ from one another ; they are carbon 12 (^{12}C), carbon 13 (^{13}C) and carbon 14 (^{14}C). ^{12}C accounts for 98.9% of all, ^{13}C accounts for 1.1% and ^{14}C is far less than the former two.

The ratios of ^{12}C and ^{13}C contained in natural substance change for various reasons and by measuring this carbon isotope ratio ($^{13}C/^{12}C$), we can obtain information about the origin and formation process of the substances. An isotope ratio mass spectrometer is used for the measurement. The isotope ratio is generally expressed as a permillage (‰) of the deviation from the isotope ratio of the standard material using the following equation:

$$\delta^{13}C_{PDB}(‰) = (R_{sample}/R_{PDB}-1) \times 1000,$$

where PDB is the international standard material of carbon isotopes, R_{sample} is the $^{13}C/^{12}C$ ratio of the sample analyzed, and R_{PDB} is the $^{13}C/^{12}C$ ratio of PDB.

The isotope ratio of the carbon incorporated in plants during photosynthesis by absorbing carbon dioxide from the atmosphere changes according to the temperature, moisture and other conditions. If available moisture is small in quantity, or the plant is under moisture stress, the isotope ratio of the carbon incorporated in plants is generally high and in an opposite circumstance, the ratio is low. Thus in the area like a savanna where there are the distinct rainy and dry seasons and plants are exposed to dryness in a certain period of the year, the isotope ratio of the carbon incorporated in plants will change periodically. If we detect this periodical change, we should be able to estimate the growth rate and age of trees in savannas.

(2) Carbon isotope ratios of sheanut and African mahogany

To measure the carbon isotope ratio of wood, only cellulose, the main component of cell walls, is isolated from the wood and is combusted, and then the carbon dioxide produced is collected and put on a mass spectrometer. The xylem of the sheanut and African mahogany were cut from the outside into 1 mm-thick sections, from which cellulose was extracted and carbon isotope ratios measured. The ratios were measured along two radii for each tree species and the results are shown in Figs. 4-12 and 4-13.

In the case of sheanut, four peaks of $\delta^{13}C$ appeared in the sections between the cambium and the inside part 2.5 cm deep. As already mentioned, a $\delta^{13}C$ peak implies that the plant was exposed to a dry condition. Thus, the peak is supposed to be the point of the growth period of sheanut when there is a little rain, that is, the beginning or the end of the growth period. If so, the distance between the two of the peaks corresponds to a growth period, or the rainy season. Sheanut is a deciduous tree and all of its leaves fall in the dry season, which indicates this tree probably does not make radial growth at the season. The sample was taken in July, in the midst of the rainy season, and the part of the cambium is at a bottom in Figure 4-12, which suggests the existence of an adequate moisture supply. This agrees with the assumption made above.

In African mahogany, six to seven $\delta^{13}C$ peaks exist in the section between

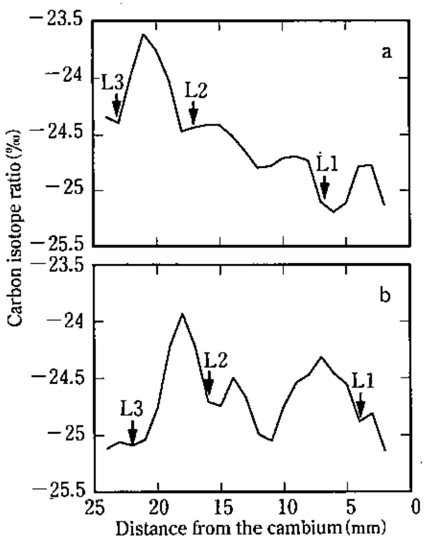


Fig.4-12 Carbon isotope ratios of sheanut

a and b show the results of measurement from two different radii, and L1 - L3 are the different positions on the same growth layer. The far right parts are the tissues formed around July 1993 when the tree was cut.

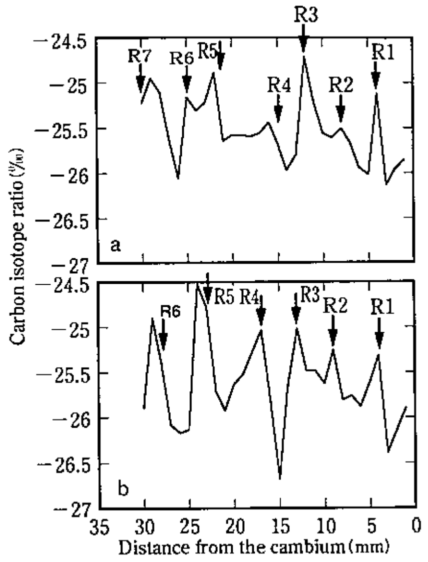


Fig.4-13 Carbon isotope ratios of African mahogany

a and b show the results of measurement from two different radii, and R1 - R7 are the different positions on the same growth ring.

the cambium and the inside section 3 cm deep, and they all agreed roughly with the positions of growth rings. Therefore, we should consider that the belts of axial parenchyma cells, which are equivalent to growth rings, are formed in the early or late growth period when there is only a low rainfall. Thus, these cells are considered either initial or terminal parenchyma. This means that the belts of axial parenchyma cells observed in this sample are annual rings. The sample used for this analysis was taken from the stump of African mahogany after the tree had been cut, but we were unfortunately unable to determine at what point of the year the tree was cut.

The trees known as African mahogany are not limited to *Khaya senegalensis* discussed here but the term African mahogany is usually used as a general term for Genera *Khaya* and *Entandrophragma* of Family Meliaceae (Tropical Agriculture Research Center, Ministry of Agriculture and Forestry of Japan, 1978, p.402). While some trees of the African mahogany group are known for distinct growth rings, there is a report saying that in *K. grandifoliola*, which belongs to the same genus as *K. senegalensis*, growth rings are sometimes not distinct or do not appear (Hummel, 1946, pp.103-107). In the case shown in Fig. 4-13, all the $\delta^{13}C$ peaks have corresponding growth rings, but there were other samples in which no distinct growth rings were observed but $\delta^{13}C$ peaks were detected. Thus it is supposed that even *K. senegalensis* forms no distinct growth rings just like *K. Grandifoliola* in some years. This is probably the effect of precipitation, soil moisture and other conditions that differ from year to year.

There is no report on the time of the year the radial growth of sheanut and African mahogany starts. Considering the water supply required, the growth seems to begin when the rainy season starts but the problem does not appear to be so simple. If we consider that the rainy season begins in the month with a rainfall of 60 mm or more, there is two to three months' difference in the time the rainy season starts from year to year. However the period when the cambial activity of tropical trees starts does not differ very much according to year, and that of some savanna trees begins its activity in the dry season when no leaves have developed (Amobi, 1973, pp.211-218 ; Njoku, 1963, pp.617-624). In any case, there is no doubt that radial growth starts before the rainy season begins in earnest and so it will be reasonable to consider that the $\delta^{13}C$ peaks in Figs. 4-12 and 4-13 are the points just before or after the dry or rainy season and the bottoms are the rainy seasons. From this we can conclude that savanna trees have what should be called tree rings of carbon isotopes, though invisible to us.

(3) Radial growth rates of sheanut and African mahogany

From the values of $\delta^{13}C$, it can be estimated that, in the past four years, the diameter of sheanut increased by about 12mm per year on average and that in the past seven years, the diameter of African mahogany increased by about 8 mm a year on average.

There have been very few studies of the growth rate of tropical trees and the same is true of savanna trees. As for sheanut, there is a report saying that the diameters of three samples, whose diameters at breast height ranged from 27 cm to 41cm, increased by 0.3 mm to 1.6 mm per year on a two years' average (Hopkins, 1970, pp.795-825). As to African mahogany, it has been reported that the diameters of 31 samples increased 36mm per year on a seven-year average (Ramsay, 1967, pp.310-316). The results of both of these reports are those of periodical measurement of the circumference of the trunks of the samples but the method of measuring the circumference from the bark inevitably causes some margins of error mainly because of the swelling or shrinkage of the bark resulting from exfoliation, water absorption or drying. According to a report on the study of African acacia species in which the belts of parenchyma cells observed on the cross section were used as indicators, the diameter increased by 12 mm to 14 mm per year (Gourlay, 1995, pp.353-359). Probably because of differences in the tree species and measuring methods used, the growth rates of savanna trees vary widely.

No sufficient data have been available for estimating the average radial growth rates of individual tree species in savanna forests, but in the future it will become possible to estimate tree ages roughly based on the diameter of trees. If this is achieved, we will then be able to get information about, for example, the land use cycle and the time the land was brought under cultivation, on the basis of the age of trees left in upland fields and fallow.

The number of tree species in savannas is much smaller than that in tropical rain forests. Even so, if we visit national parks and forest reserves in Nigeria, we find that there used to be many forests of various species in the country. However at present, we can see only a few species, including sheanut, in the areas where human activities have been carried out (Photo 4-1). To prevent deforestation and to consider effective land use, it is important to study how present forests were established. The tree rings of savanna trees may give us one of the means to examine their development process. (Naoki Okada)

4. Multipurpose use of trees in Bauchi State, Nigeria

4-1. Characteristics of the survey sites

The part of the African continent from the southern end of the Sahara to South Africa is generally known as sub-Saharan Africa. The trees indigenous to this region are the providers of food firewood, medicines, feed, construction materials and green manure, making them important resources for residents (Abbiw, 1990 ; Advisory Committee on the Sahel, 1984). Some of the trees are intentionally selected and planted to produce lumber for housing construction and earn cash income or to increase the fertility of farmland (Burkill, 1985). These activities are regarded as the cases of traditional agroforestry using multipurpose tree species.

The International Center for Research in Agroforestry (ICRAF) and other agroforestry research organizations have made attempts to select trees for multipurpose use and introduce them into an agroforestry system (Cook and Grut, 1989 ; D'Hoore, 1964). But since the methods of using trees differ according to area and village, they have not fully known (Gbile, 1980). This section reports the results of the survey on the traditional use of indigenous trees by farmers,

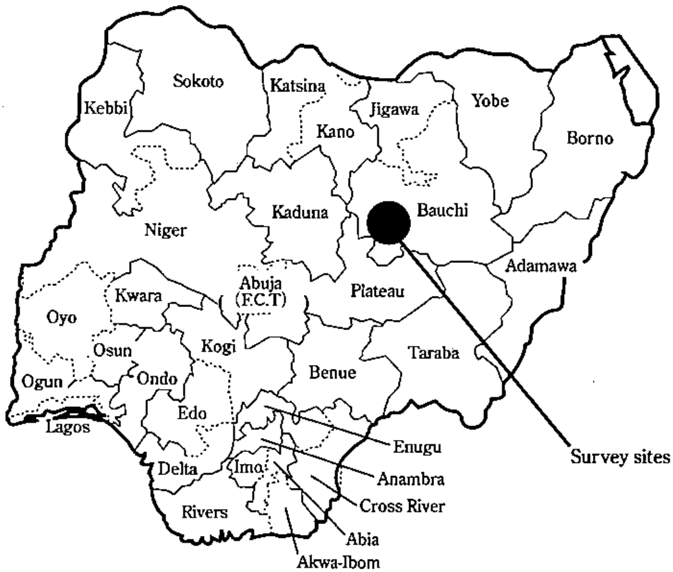


Fig.4-14 Location of the survey sites

which was conducted in the northern Guinea savanna zone.

The survey sites are Liman Katagun, Yamrat and Bajama, the villages in Bauchi State in northeastern Nigeria and their neighboring areas (Fig. 4-14). According to the agroecological climatic classification, these villages belong to the northern Guinea savanna zone; the mean annual precipitation is 900-1,200 mm and the number of rainy days is about 140 days, while forest vegetation is open savanna woodland. The rainy season usually begins around May and continues to around September or October. The dominant soil is Lithosols. In the dry season, the climate is so dry that even weeds can be seen in the field, and by the end of this season the field turns into literally bare land since even the crop remainder has been eaten by animals. But neighboring areas, you can see the cool of the green color of shrubs around the field, leaves of trees planted in the field and weeds under the canopies, though the color may be darkish because of fine sand carried by Harmattan.

All of the three villages are situated in flat areas without many undulations. They were selected by IITA's researchers of agricultural economics based on access to the market economy zone and population increase rates. Liman Katagun is in a suburban area; it has paved roads and a considerably developed market economy and large forests no longer exist around it. Main residents are Hausa and Hausa-Fulani. Yamrat is only 2 km from Liman Katagun but the road linking the two villages is in a very poor condition and, in the rainy season, is covered with water in many parts. Thus it is hard to go to the market from this village. Its residents are Bankarawa people. Bajama is far from urbanized areas and the roads are underdeveloped; because of this, its access to the market is not easy. The residents belong to Jaru tribe. While rural communities are formed in Liman Katagun, farmers in Yamrat and Bajama are few. The population growth rates have been high in all of the villages, and this fact seems to be promoting intensive land use.

4-2. Uses of trees in Bauchi State

The trees surveyed are the 28 species from the 25 genera and 14 families shown in Table 4-8 (Huxley and Westley eds., 1989). These species were chosen because they were those which local farmers wanted to leave in their fields and forests and because they were observed in the villages more frequently. Therefore, all of the trees are regarded as useful by farmers. We got elderly residents and those familiar with trees together from the villages and conducted hearings

Table4-8 Main tree species and their uses in the three villages surveyed

Species Local Name (Hausa)	Family	Main uses	Locality
Sclerocarya birrea Danya	Anacardiaceae	medicine, fruits fence...	B
Lannea acida Faru	Anacardiaceae	medicine, fuelwood...	B
Balanites aegyptiaca Aduwa	Balanitaceae	medicine, tools, vegetable	B/F
Adansonia digitata Kuka	Bombacaceae	vegetable, feed, rope...	B/F
Commiphora dalzielii Ararabi	Burserceae	fence, medicine	B
Tamarindus indica Tasmiya	Caesalpiniaceae	fruits, medicine, fee...	B/F
Daniellia oliveri Maje	Caesalpiniaceae	medicine, vegetable, feed...	B
Piliostigma reticulatum Kalgo	Caesalpiniaceae	rope, medicine, feed...	B/F
Detarium microcarpum Taura	Caesalpiniaceae	medicine, fruits, feed	B
Terminalia avicennioides Baushee	Combretaceae	medicine, food, tools...	B
Combretum molle Wuyan damo	Combretaceae	medicine, fuelwood, tools...	B
Anogeissus leiocarpus Markee	Combretaceae	manure, medicine, roofing	B
Diosopyros mespiliformis Kanyan	Ebenaceae	medicine, fruits, tools...	B/F
Khaya senegalensis Madachi	Meliaceae	medicine, timber, manure...	B
Azadirachta indica Neem	Meliaceae	medicine, fuelwood	F
Parkia biglobosa Dorowa	Mimosaceae	spices, medicine, manure...	B/F
Acacia polyacanthe Kankaraa	Mimosaceae	manure, medicine, fee...	B/F
Prosopis africana Kiriya	Mimosaceae	medicine, food, chacoal...	B
Entada africana Tawatsa	Mimosaceae	medicine, feed, fuelwood	B
Ficus iteophylla Shiriya	Moraceae	manure, medicine, feed...	B
Ficus polita Durumi	Moraceae	medicine, fruit, feed...	B
Ficus ingens Kawuri	Moraceae	medicine, feed, fuelwood...	B
Ficus sycomorus Bauree	Moraceae	manure, medicine, feed...	B/F
Dalbergia melanoxylon Dalbergia	Papilionaceae	medicine, fuelwood	F
Pterocarpus erinaceus Madobia	Papilionaceae	medicine, feed, roofing...	B
Ziziphus mauritiana Magariya	Rhamnaceae	manure, medicine, feed...	B
Vitellaria paradoxum Kadanya	Sepotaceae	manure, medicine, fruits...	B/F
Vitex doniana Dinyar	Verdenaceae	fruits, medicine, fuel wood...	B

Locality : B, in bush. B/F, in bush and farm, F, in Farm in Farm.
Local names were cited from 'Vernacular uames of Nigerian Plants (Hause) by Gbile (7).

Table4-9 Number of utilized items of the 28 tree species in the three villages

Tree species	Liman katagun	Yamrat	Bajama
S. birrea	8	6	7
T. indica	3	6	6
P. biglobosa	5	6	6
K. senegalensis	6	6	6
D. mespiliformis	4	6	7
D. melanoxylon	3	n	n
A. indica	3	4	4
P. erinaceus	4	4	6
V. doniana	4	7	6
F. polita	3	5	6
D. oliveri	5	2	7
V. paradoxum	6	5	5
P. reticulatum	3	4	5
D. microcarpum	3	4	7
F. ingens	2	3	5
B. aeqyptiaca	4	2	5
C. dalzielli	1	1	3
F. sycomorus	6	6	6
T. avicenninoides	3	3	6
L. acida	3	2	4
A. polyacantha	4	3	5
P. africana	5	5	7
F. iteophylla	1	2	5
C. molle	2	2	5
Z. mauritiana	5	3	6
E. africana	4	4	5
A. leiocarpus	5	5	4
A. digitata	4	6	6
Average	3.89	4.15	5.56

Note: 'n' means the species not found in the villages.

from them during our tree observation tours in fields and neighboring forests. Seventeen of the 28 species were found only in the nearby forests, while the other 11 were observed in the field. The species seen here and there in the field were mostly those which farmers had intentionally left without cutting at the time of reclamation or those which they had grown from seedlings.

The questions about the uses of trees were divided into green manure, medicines, food, feed, firewood, tools, construction materials and others for each tree species and were concerned with the parts of trees used, convenience, frequency of use and importance. As a result, we found that though the frequency of use and importance differed from species to species, all of the trees were used for more than one purpose. As for eight of the 28 species, respondents answered that they used these trees for all of the purposes mentioned in our questions. The frequency of use was especially high for medicines and food mainly as fruits and vegetables.

The average number of utilized items of the 28 species was 3.89 in Liman Katagun, 4.15 in Yamrat and 5.56 in Bajama (Table 4-9). This suggests that trees are considerably more important in Bajama than in the other two villages.

Table 4-10 shows the efficacy as folk medicines and parts used of the trees. Bark is most frequently used as medicines but fresh leaves and roots are also used for some diseases. If the bark is boiled down and taken orally, fruit or other natural sweeteners are frequently added, while in the case of external application, the boiled-down sap of bark is directly applied to the affected part. In some emergency cases, bark and other parts of trees are applied raw.

About a half of the trees surveyed are used as the medicines digestive organ troubles. For example, *Danya* (*Sclerocarya birrea*), *Tawatsa* (*Entada africana*), *Tauraa* (*Detarium microcarpum*), *Baushee* (*Terminalia avidcennioides*) and Kankaraa (*Acacia polyacantha*) are used as diarrhea medicines, while Tsamiya (*Tamarindus indica*) is a nausea medicine. Kadanya (*Vitellaria paradoxa*), Madachi (*Khaya senegalensis*), Dorowa (*Parkina biglobosa*), Neem (*Azadirachta indica*) and Wuyan damo (*Combretum molle*) are stomach ache medicines, and *Tsamiya*, Madachi and Markee (*Anogeissus leiocarrpus*) are used to relieve constipation.

The same parts of the same trees are often used for completely different diseases. In addition, several tree species are considered to be effective on malaria, yellow fever and other tropical infectious diseases; Neem, Dinyar (*Vitex doniana*) and Ararabi (*Comiphorea dalzielii*) are believed to work for malaria and Aduwa (*Balanites aegyptiaca*), Ararabi and Neem, for yellow fever. As medicines for cold, there are Kadanya, Bauree (*Ficus sycomorus*) and Kanyan (*Diosophyros mespiliformis*). Kadanya and Faru (Lannea acida) are considered to be efficacious for injuries and Kanyan, Tsamiya, Taura and Ararabi, for bites by animals. Wuyan damo, Bauree and Kiriya (*Prosopis africana*) are used to cure skin diseases. As noted, these trees are frequently used as medicines and this fact suggests how important the trees are to local people.

On the other hand, the three villages were different from one another in the utilization of trees as medicines. While the residents of Bajama still use 25 three species as medicines, those in Yamrat use only 13 species and those in Liman

Table4-10 Efficacy as folk medicines and parts used of the 28 tree species

species	Pharmacological efficacy	useful parts
S. birrea	diarrhea (K, Y, B)	bark
	guinea worm sore (B)	fruit
T. indica	vomiting (Y), snake bite (B)	fruit
	hallucination (B), constipation (B)	bark
P. biglobosa	temporal paralysis (B), stomachache (K, Y)	bark
K. senegalensis	stomachache (K, Y), constipation (B)	bark
	irritable for children (B)	pod powder
D. mespilliformis	dog bite (Y), sore throat (B)	bark
D. melanoxylon	post childbirth (K)	leaves
A. indica	malaria (K, Y), yellow fever (K, Y, B), stomachache (K), hypertention (Y), post childbirth (Y)	leaves
P. erinaceus	control of menstruation (B), liver disease (Y)	bark
V. doniana	malaria (Y), hypertention (Y)	bark
F. polita	promotion of maternal milk (B)	bark
D. oliveri	nightmare (B), snake bite (B)	bark
V. Paradoxum	wound (Y), stomachache (B), cough (B)	bark
P. reticulatum	swelling of breast (B)	leaves
D. microcurpum	diarrhea for children (Y), snake bite (B) swelling of arms and legs (B)	bark
F. glumosa	(reproduction for cattle) (B)	bark
B. aegyptiaca	yellow fever (B)	leaves & roots
C. dalzielli	malaria (K, Y), yellow fever (Y), insanity (B), snake bite (B)	bark
F. sycomorus	rash (K)	bark
	cough (B)	roots
T. avicennoides	diarrhea (B)	leaves & roots
L. acida	wound (B)	bark
A. polyacauthe	diarrhea (B)	bark
P. africana	sun burn (B), toothache (K)	bark
F. iteophylla	(seed treatment for pest purification for animal) (B)	bark
C. molle	stomachache (Y), hot temper (B)	roots
	reah (B)	leaves
Z. mauritiana	swelling intestine (B)	roots & bark
E. africana	bloody excrement of children (B)	bark
	malalia (B)	
A. leiocarpus	constipation (Y, B)	bark & roots

Note: letter in parenthesis shows K, Y and B are Liman Katagun, Yamrat and Bajama village, respectively.

Katagun, only 8 species. This difference is probably affected by the distance between the villages and urban areas where pharmacies and clinics are available, and also by the existence of convenient means of access to these facilities. Since a health center was established in Bajama several years ago, the use of trees as medicines in this village, which is far from a city, is expected to gradually decrease in the future as in the two other villages.

As food, either the fruits of trees are directly eaten or other parts are used in cooking as vegetables or spices. An especially liked food material is a soup spice known as Dawadawa cakes that is made by fermenting the seeds of Dorowa (African locust bean) and has a flavor like natto (fermented soybean). Dawadawa cakes are one of the daily foods throughout West Africa and because the surplus part is sold on the market, they are the valuable source of cash income. Kadanya is another tree having a high commercial value since shea butter is made from its nuts. Shea butter is used not only as edible oil but also as a medicine, cosmetic, soap, etc. (Abbiw, 1990). Kuka (*Adansonia digitata*) is well known by the name of baobab and Hausa people cook the new leaves of this tree as a vegetable or use dried leaves as a soup material they call mian'kuka.

Sweet fruits are usually plucked as required. These fruits help farmers quench their thirst during farm work under the burning sun and children can supplement their meals, which are apt to be insufficient. The trees used as food provide local farmers and growing children with valuable sources of nutrients. The detailed data of the nutrients contained in the nuts and leaves of the trees listed in Tables 4-8 to 4-10 are available from the analysis by Irvine (1961).

The farmers of the villages say that the leaves of some trees have a high effect as green manure. The author also saw the maize planted under the canopy of Kadanya, Kanyan, Bauree and Kankaraa grow much better than those grown out of the canopy or under other trees. According to the farmers who left these tree species in their fields, they plow in the branches and fallen leaves they cut at the end of the rainy season and burn them into ash in the dry season. On the other hand, many of the trees investigated are considered to be useful mulching materials (Von Carlowitz, 1986). These species include Neem, Aduwa, Maje (*Daniellia oliveri*), Kanyan, Shirinya (*Ficus itephylla*), Dorowa, Kiriya, Danyaa, Tsamiya, Kadanya and Dinyar. However, farmers in the survey sites have no custom of using branches and leaves for mulching purposes. This will be one of the problems when an agroforestry system is introduced into these districts.

Farmers in the three villages raise cattle, goats and sheep. While they feed these animals on the leaves and nuts of many trees, they give some species of trees only to cattle, goats or sheep. For example, they feed the leaves of Madobiya (*Pterocarpus erinaceous*), Kawuri (*Ficus ingens*) and Markee to goats only. On the other hand, there are some trees, such as Tsamiya, Kanyan, Darbergia (*Darbergia melanoxlon*), Neem and Faruu, that are not used as feed in the survey sites though these are widely given to animals as fodder trees in other savanna areas.

Some of the trees have a high added value. For example, the boiled-down sap of the leaves of Durumi (*Ficus Polita*) is also given to calves since farmers believe that it promotes their growth. Madachi's bark is given to cattle as an antiparasitic, and Ararabi is used as a binding medicine for cattle.

Firewood is the main fuel for cooking and the families using charcoal are rare in the villages investigated. Thus all of the 28 tree species are used as firewood but the frequency of use is different from species to species according to combustion efficiency and the quantity of smoke discharged. Villagers seem to avoid the trees that emit bad odors, such as Maje, because they spoil the taste of meat. They consider that Kiriya is the right tree for charcoal making.

In general, Hausa people's houses are made of walls plastered with red clay, while the straws of millet and sorghum and the branches and leaves of trees are used for roofs and fences. The branches and leaves of 15 species of trees are used for roofing, and those of 13 species, for fences. Trees having hard quality are used for making millstones and the handles of hoes and hatchets. Because the bark of Kalgo (*Piliostigma reticulatum*), Faruu, Wuyan damo and Kuka contains much fibers, they are used for twisting ropes. In all of the tree villages, we heard that Aduwa is used as writing boards; this tree appears to be tolerant to moisture and hard to be deformed. In Bajama, they used West African ebony (Kanyan) to make handmade gun supports for hunting.

Other uses of trees mentioned include the shade for taking a rest from farm work and for animals, borders of fields and houses, wind breaks and the shade for the crops that dislike strong sunlight.

4-3. Future directions

We have had a general discussion on purposes in the survey sites use trees in the northern Guinea savanna zone. Considerable differences in the use of trees were observed between the three villages. As already noted, this is probably related to the distance from urban areas, access to the market and the economic situations of the villages. The most remarkable difference appears in the frequency of use of trees as medicines. (In Liman Katagun, residents can visit the nearby, a public medical institution relatively easily and medical costs are low), so the value of trees as medicines is decreasing. By contrast, people in Bajama, who have had less opportunities to enjoy the benefit of modern medical care, seem to have no alternative but to rely on the efficacy of trees near at hand, that is, their traditional means to cure diseases. Because of this, traditional knowledge of trees for medical uses is still handed down not merely to the elderly persons but also to young people and children in Bajama and Yamrat.

In other uses of trees, too, residents of Liman Katagun, who have periodical market days and are relatively rich, tend to depend on kerosene for a fuel and to buy construction materials and instruments. Therefore, their demand for firewood and other forestry products is lower than in the two other villages.

On the other hand, residents in Yamrat and Bajama lead a near self-sufficiency life, still relying on trees for most daily necessities. But with increasing population and spreading money economy, production systems and lifestyle will change gradually in these villages, too. As a result, their traditional and indigenous knowledge of trees is likely to be lost sooner or later.

The agroforestry development projects recently promoted in the tropical countries in Africa, Southeast Asia and Middle and South America are mostly attempting to introduce the tree species usable for many purposes. What is essential to this effort is the indigenous knowledge of native tree species.

In the savanna areas surveyed, it will be a promising alternative to develop agroforestry by an Agro-Silvo-Pastral System, which is one of farming systems for realizing sustainable farming production. It is hoped that the data obtained by this survey will become useful basic materials for such development studies.

(Yukihiro Hayashi)

1) Interview at the Federal Ministry of Agriculture, Water Resources, and Rural Development, Abuja on 19 August 1992.
2) After World War II, Eastern Region Local Government Ordinance, 1950, Western Region Local Government Law, 1952, and Native Authority Law, 1954, were enforced in Western, Eastern, and Northern Nigeria respectively. In Northern Nigeria, there were 70 native authorities controlled by Emins, Chiefs, or councilors (Oka Orewa, 1966).
3) Interview to the Forestry Department, Federal Ministry of Agriculture, water Resources and Rural Development, on 19 August 1992.
4) Interview to Bida Zonal Forestry Office on 2 July 1994.

5) Interview to Lavun Zonal Forestry Office on 18 August 2000.

6) Though under the name of census, it remained rough estimation by sex in 1911. A more detailed one with additional categories of age, occupation, religion, and educational background was carried out in 1921, but yet based on estimation.

7) Interviews with several community heads in August 1993.

8) According to Nadel, compulsory tribute or tithe called *zanka* once supported Fulani feudal landlords in Bida to maintain their armed force, but gradually lost importance under Pax Britannica (1942, 189-200).

9) Interview to *Tsoede* on 23 August 1993.

10) Interview in Bida branch on September 28, 2000.

11) The xylem layers formed on the cross section of wood as a result of the seasonal change in trees' cambial activities are referred to as growth rings, and one growth ring formed in a year is called annual ring. If growth rings are not distinct, the xylem layer formed in a growth period is here referred to as growth layer.

12) A further examination is needed to see if *Khaya senegalensis* is always evergreen in any growth environment. Considering the climatic zone of the Gadza district, the tree species there should be and actually are deciduous, and *K. grandifoliola*, the tree belonging to the same genus as *K. senegalensis*, is deciduous (Hummel 1946, 103-107).

13) The wood of broad-leaved trees is generally composed of vessels, wood fibers and parenchyma, which consist mainly of vessel elements, libriform wood fibers and parenchyma cells, respectively.

Acronyms and vernacular terms

* H means Hausa language and N means Nupe.

ADP	Agricultural Development Project
bata	lowland (N)
CFA	Communal Forestry Area
cikan	primary forest
Cis-Kaduna	the area east of the Kaduna River
emi	compound or a community consists of several compounds
enufu	= *nufu* (N)
etsu	king (N)
etsunyankpa	village head or ward head (N)
ewogi	small mound (N)

ewokogi	large mound (N)
gbara	farm ridge (N)
gonta	bush fallow (N)
hakimi	originally tax collector, now district head (H)
katamba	entrance hall of a compound (N)
kpesa	land surrounding a settlement (N)
lati	upland farm (N)
LGA	Local Government Area
malam	Islamic scholar (H)
NA	Native Administration, or Native Authority
nufu	grass fallow (N)
RNC	Royal Niger Company Chartered and Limited
RRA	Rapid Rural Appraisal
sarki	emir or head (H)
Trans-Kaduna	the area west of the Kaduna River
UNCCD	United Nations Convention to Combat Desertification