SUMMARY

I. BACKGROUND AND PROGRESS OF THE AGRICULTURAL VERIFICATION STUDY

General Situation of Zambia

(1) Zambia is an inland country located in the central southern part of Africa with a total land area of about 753 thousand km^2 and with about 1,000 ~ 1,300 m altitude for the highland. Although being in a tropical area, its climate is rather gentle throughout the year because of its high altitude, which is roughly divided into three seasons: a cool dry season from May to August, a hot dry season from September to October, and a rainy season from November to April with hot temperatures. Rainfall decreases gradually from north to south with an annual value ranging from 1,000 mm ~ 1,500 mm in the north, more or less 1,000 mm in the center, and 600 mm ~ 800 mm in the south. The population in 1990 was about 7.8 million with a density of 10.4 inhabitants per km^2. The population density is over $50/km^2$ in the Lusaka Province with Capital Lusaka, and in the Copperbelt Province which produces copper. 42% of the population is also concentrated in urban areas.

(2) The arable land area is about 5.3 million ha (1989) occupying about 7% of the country. Maize is the most produced crop with 1.0 to 1.9 million ton and a planted area of 0.6 to 1.0 million ha.

Other crops occupy 0.1 to 0.15 million ha at the most, or in many cases less than 10% of the area of maize. Apart from maize, other main crops include groundnuts, cotton, millet, sorghum, and sunflower. Rice occupies more or less 10 thousand ha mainly planted in the Northern and the Western Provinces representing 36% and 40% respectively of the country total planted area in 1990. Every crop shows unstable productivity due to rainfall fluctuations and the absence of irrigation facilities leading to large fluctuations of planted areas and production. Even maize, the most important crop, shows a nearly 50% fluctuation during the last five years.

Animal husbandry involves a large number of cattle with 2.7 million heads representing 80% of all livestock including sheep, goat, and pig. A large part of the farmers are traditional small farmers, but there are many commercial farmers along the rail road in the central part.

(3) The Agricultural Verification Study (AVS) was conducted in Mongu and its surrounding area in the Western Province. The Western Province is located literally on the western border of Zambia sharing boundaries with Angola to the west and Namibia to the south and is bordered by the Northwestern Province in the north and the Southern Province in the east. The Zambezi river streams from north to south dividing the Province into two parts. A large part of the province is based on Kalahari sand with high lands ranging from 1,200 in altitude in the northeastern part to 800 m in the southwest. The flood plain of the Zambezi river and its tributaries lays about 40 m altitude below the high lands to which it is linked by a gentle slope. Mongu is the capital of the Western Province and also the capital of the Mongu District which is located in the center of the province and is surrounded by five other districts.

In the Western Province, maize occupies the first place in terms of planted area, but the suitable production area is only in the Kaoma District and the total planted area in the province is about 40 thousand ha, representing only 5% of the total planted area of the country (1990). The planted area for cassava, millet, and sorghum is relatively high, representing 15 ~ 20% of the total planted area of the country. Rice occupies about 4,000 ha representing 40%. Food production in the Western Province is not enough for local consumption, and moreover, because of the little suitable production area for maize, increasing rice production is considered to be very important. Agriculture in the province is almost entirely controlled by small scale farms.

The Mongu district ranks first in rice production in the province and the main production area is the flood plain of the Zambezi river and its tributaries. It can be said that the Mongu area is the appropriate area for the AVS aiming for the development of agricultural technology for small farmers centering on rice cultivation.

Circumstances and Progress of the Verification Study

(1) After the series of droughts that have striken Africa since 1983, Japan has sent several missions for agricultural cooperation. In these activities the Japanese Government has recognized the shortage of information concerning agriculture, and decided to proceed with the AVS with the purpose to establish a development plan applicable for the conditions of the target area.

Following the four years of AVS conducted in Senegal, Western Africa, in 1986, the Japanese government agreed with the Zambian government in October 1987 to conduct an AVS in the Mongu area, Western Province, which has a high potential for agricultural development with wide expanses of yet unused land

(2) The Western Province is the country's main rice producing area, with Mongu being the Province's major producing area; an area mainly concentrated in the flood plain of the Zambezi river and its tributaries. The AVS farms were set in this area, and the verification trials in the farms and surveys in the surrounding areas were conducted for the development of comprehensive agricultural techniques centering on rice cultivation and proper farm land consolidation standards for these techniques, focusing on making guidelines for farming practices and land consolidation standards for the future agricultural development.

(3) The AVS has been carried out under the following principles

1) Small farmers are the main subjects of the system.

2) The system is the technology under irrigation facilities.

3) The system aims at a low cost and steady technology with rice-upland crops double cropping using animal and man power.

4) Two basic cropping patterns are considered in this system.

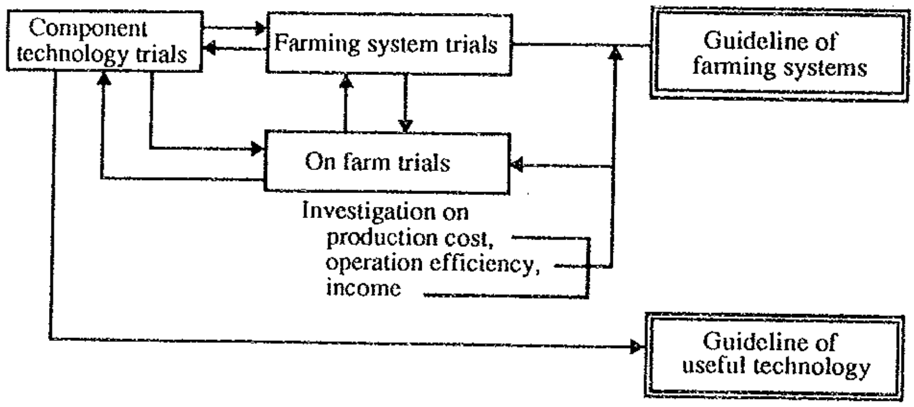
Early rice	-	Cool dry season upland crops
Late rice	-	Hot dry season upland crops

5) Soil improvement is emphasized for the improvement of plant growth. The heavy application of chemical fertilizers should be excluded.

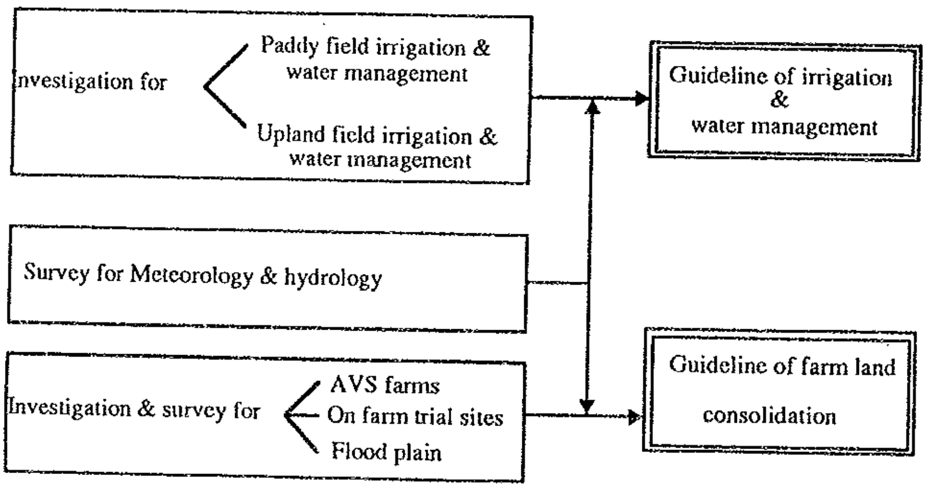
6) Considering the importance of inland fishery, the use of agricultural chemicals should be restricted for environmental conservation purposes.

(4) The study and survey for crop production and land consolidation technologies are conducted through the following processes.

① Crop production technology



② Land consolidation technology



(5) Namushakende and Lealui were selected as the verification farms from eight candidate sites proposed by the Zambian side. The selection was decided based on the surveys conducted in the surrounding area of Mongu from February to May 1988, and it was decided to conduct surveys for meteorology and hydrology in the Mweke Dambo.

The verification farms were constructed from July 1988 to December 1989, and using the constructed fields, trials began from November 1988. The study and surveys were conducted during four years till July 1992 following the process described in (4), and based on the results, guidelines were decided.

(6) When making the actual development plan, a minimum but necessary level of land consolidation will be considered by the agricultural civil engineers based on the guidelines of land consolidation technology. These guidelines which can be developed under national/provincials funds with possible foreign support anticipates grouping small farmers under a common irrigation system.

Following the land consolidation guidelines, a sustainable agricultural production can be achieved based on the guidelines of crop production technology and the assistance of the extension officers, which considers the conditions of the area and the farmers.

II. CROP PRODUCTION TECHNOLOGY

Component Technology

(1) Paddy cultivation

After examining the varieties through verification trials, which were obtained from the Kalabo Agricultural Development Project where they were first tested, it was found that promising varieties were the local long culm variety Angola Crystal, the early maturing short culm varieties, Xiang Zhou 5, C1158 and ITA series (breed from the International Institute for Tropical Agriculture in Nigeria), and the late maturing varieties, P1369, P2023 and IR8192. The early maturing varieties matured late March after sowing in late November and can be combined with the succeeding cropping of wheat, and onion crops for the cool dry season. Maize and tomato for the hot dry season with a harvesting time up to early or mid December, and rice as next crop starting in late December.

Concerning the span of planting time, the band with the thick peat-muck soil layer on the flood plain edge requires mid to end November sowing, while the Mataba-sitapa zone where sandy loam or loamy soils dominate can be sowed up until late December. Seeds should be screened with water, and dry seeds, 60 kg/ha, should be drilled in a 30 cm row space. 250 kg/ha of D'mix (10-20-10) is a standard dosage for basal dressing and 50 kg/ha of urea is applied in both the tillering and meiosis stages, respectively as a topdressing. The effect of phosphate applications in peat-muck soils is quite high. In amending soil acidity, lime of 1 - 1.5 t/ha is applied.

In single cropping system of paddy rice, incorporating rice straw during the dry season has the effect of building soil fertility, thus it is possible to build soil fertility of the whole field by alternating single and double cropping systems.

In the relationship between the introduction of oxen plowing operations and the soil bearing capacity measured once by a penetrometer, 0.8 kg/cm^2 was determined as the threshold value to support the weight of middle size oxen for plowing operations.

(2) Upland Crops in the Cool Dry Season

Among the tested upland crops, wheat, onion, and cabbage were selected as suitable crops for a double cropping system with early rice.

1) Wheat

Jupateco, Loeric II, J130, and Coucal are considered to be suitable varieties. It must be kept in mind that young panicles may get damaged by the cold when sowing is done before the middle of April. The standard amount of fertilizer is as follows; as based, 300 kg/ha of D'mix, and as a topdressing, 100 ~ 200 kg/ha of Urea are applied. In case of peat-muck acid soil 1 ~ 1.5 t/ha of lime, and 30 kg/ha of $CuSO_4$ are applied.

2) Onion

At present, onion cultivation is rarely found in the Western Province, however, its cultivation is considered rather easy in the flood plain. The optimum growth temperature is 10 ~ 25°C representing a suitable crop for the cool dry season. In March it is raised in a nursery, then transplanted in May, and harvested from September to October. It is necessary to apply lime where there is mucky acid soil, 50 m^2 of nursery is required per 0.1 ha of field. A standard fertilizer application for 50 m^2 of nursery is 5 kg of lime, 10 kg of cattle manure, 2.5 kg of D'mix, and for 0.1 ha of field, 100 kg of lime, 200 kg of cattle manure, 50 kg of D'mix as basal, and 10 kg of urea as a topdressing are applied. A well drained field should be selected to avoid occurrence of disease .

3) Cabbage

Similar to the onion crops, the cultivation in the Western Province is rare but is considered easy in the flood plain. The optimum growth temperature is 15 ~ 20°C representing a suitable crop for the cool dry season. It is raised in the nursery and transplanted in the field like the onion crops. Harvest can be done in August. The Nursery area is 30 m^2 for 0.1 ha of field. A standard fertilizer application for 30 m^2 of nursery is 4.5 kg of lime (in case of acidic soil), 6 kg of cattle manure, and 1.5 kg of D'mix, and for 0.1 ha of field, 150 kg of lime (in case of acidic soil), 150 kg of cattle manure, 50 kg of D'mix as basal, and 20 kg of urea as a topdressing, are applied. The control of self-topping caused by the cabbage web worm (Hellulla undalis Fabricius) is essential, making necessary the use of chemical insecticides.

(3) Upland Crops in the Hot Dry Season

Among the tested crops, maize and tomato were selected as suitable crops in a double cropping system with late rice. Although not well known, sweet corn is considered as promising.

1) Maize

For double cropping with rice, the harvesting period must be before 10th December, for the variety MM500 series which was sown before 15th August.

The planting pattern is 80 cm width rows with 25 cm plant distance, and as a basal dressing 1 t/ha of lime (in case of acidic soil), and 300 kg/ha of D'mix, and as a topdressing 160 kg/ha of urea, and 80 kg/ha of KCl are applied as standard. If the stalk borer is found, control should be done with the use of chemicals.

2) Tomato

For high yields, earlier sowing and earlier transplanting are desirable. Nursery raising is done during July and transplanting during August with about one month raising period. When the minimum temperature falls below 10°C, seedling growth is delayed, resulting in the elongation of the nursery period in the case of early July seeding, so that, it is desirable to protect the seedlings with straw mats, etc., if possible. The nursery area is 25 m^2 for 0.1 ha of field, with an application of 2.5 kg of D'mix, and for 0.1 ha of field 100 kg of lime (in case of acidic soil), 50 kg of D'mix, 30 kg of urea, and 24 kg of KCl are applied as standard.

3) Sweet Corn

The cultivation of this crop in Zambia is rare, but because of its short growth period it is considered as a promising crop in a double cropping system with rice.

Honeybantam 20 and Canadian Rocky varieties are considered to be suitable because of their short growth period. For a harvest before the 10th December, sowing must be done by 20th September. The cropping pattern is the same as maize or rather denser with 70 cm width rows. The standard amount of fertilizer is a basal 500 kg/ha of D'mix, and as a topdressing 100 kg/ha of urea.

Guideline of Farming System

Based on the findings through the component technologies and cropping system trials, guidelines of a double cropping system involving rice and upland crops, and a single cropping system involving rice, are found applicable for farming practices by small farmers on the edge of the flood plain area surrounding Mongu, considering the following prerequisite conditions.

① Management strategy : Diversifying the farming of rice and upland crops with the raising of 5 - 6 cattle.

② Scale of cultivation land : 2 - 5 ha

③ Regular workers/farm-household : 3 - 4 members

④ Basic means to work : Farming with a hoe except for plowing and harrowing operations which are done by oxen ordered from outside.

⑤ Cropping system:

Single cropping system of paddy rice
Double cropping system of "Rice-Cool dry season crops"
Double cropping system of "Rice-Hot dry season crops"

⑥ Field condition:

A double cropping system of "rice - upland crops" is suited to the area on the edge of the flood plain where peat-muck soils dominate (thickness of the said soil is around 20 cm) and to the area of sandy loam soils which are equipped with drainage and irrigation facilities.

A rice single cropping system is suited to the area associated with insufficient drainage conditions at the onset and end of the dry season.

With these considerations in mind, the following three major guidelines were formulated.

① Guideline of rice single cropping system

Early rice single cropping system	(in good field conditions)
" "	(in poor field conditions)
Late rice single cropping system	(in good field conditions)
" "	(in poor field conditions)

② Guideline of the double cropping system "Early rice-cool dry season crops"

Early rice - Wheat cropping system
Early rice - Onion cropping system
Early rice - Cabbage cropping system

③ Guideline of the double cropping system "Late rice - hot dry season crops"

Late rice - Maize cropping system
Late rice - Tomato cropping system

Each guideline shows a target yield, operation sequence figures, cropping patterns (operation items and operation details), and cost return analysis. A cropping system can be completed when each operation item is practiced following its operation details.

In the actual farmer's field, owing to his field and labor conditions, a combination of cropping systems will be practiced. As an example, a model is shown in Chap 2. 2.4, and the results calculated from the on-farm trials are shown in Chap 2. 2.5

Guideline of Useful Component Technology

As a result of the verification tests, some useful component technologies have been verified. Of such technologies, the ones which seem to be readily adoptable to the area are described below.

(1) Line Maker and Drill Seeder for Paddy Rice

Stripe seeding is often desirable for seedings including paddy rice. In order to construct row ditches for stripe seeding in the most labor saving way, a prototype line maker locally manufacturable is recommended.

For the cultivation of paddy rice, extensive broadcast seeding has been carried out by local farmers. Stripe seeding helps improve the germination and establishment of seedling and also makes weeding easier. However, stripe seeding requires a lot of time and labor if done manually. To make it easier, a prototype drill seeder which is locally manufacturable was used with the line maker; we are quite certain that it may be put to practical use in the future.

(2) Sowing Methods in Sandy Soil

The Lealui AVS farm entirely consists of sandy soil and water retentivity is low. Watering is required for both cases in which cropping is carried out in the dry season, or in which seeding is performed in the rainy season prior to the first rains. Nevertheless, the soil dries up quickly, causing uneven germination. In order to deal with the above problem and to eventually enhance water retentivity as well as to enable even germination, such countermeasures are taken as constructing deeper seeding ditches (5-6 cm) or applying a mulch of dried grass after seeding. Mulching also stimulates growth by suppressing temperature rises and evapotranspiration after germination.

(3) Fertilizer Application on Sandy Soil

A fertilizer is easily leached out by water in a sandy soil. As a countermeasure, a fertilizer application method along with the deep-ditch method as mentioned above was applied to prevent germination difficulties as well as to inhibit (to a certain extent) fertilizer loss.

(4) Sowing Methods on Peat - Muck Soil with Burning Grass

The burning of weeds and weed roots collected following plowing operations has been conventionally carried out before cropping. The survey of the above method revealed obvious effects on the soil including pH correction and a supply of mineral elements. A simultaneous application of burning and D'mix is effective.

(5) Utilization of Rice Straw Ash in Rice Cultivation

Rice straw ash obtained from the burning of the previous crop residues most likely replaces lime in terms of pH correction. Even after due consideration of the importance of rice straw as fodder for livestock, the significance of using it as a substitute for lime is still recognized.

(6) Rice Straw Incorporation of Paddy Rice on Peat - Muck Soil

When paddy rice is grown in the peat - muck soil of the area, it often experiences helminthosporim leaf spot in its latter stage of growth. When rice straw is applied and aerobically and adequately resolved during the dry season in which farmland is under dry conditions, less helminthosporium leaf spot occurs and, eventually a higher yield is attained. This method is applicable to single-cropping fields which become dry enough in the dry season. Alternations of double - cropping and single - cropping as well as applying the above method helps enhance soil fertility.

Countermeasures of Production Constraints

(1) Improvement of Peat-Muck Soil

The dominant soil extended in a band of the floodplain edge shows high acidity, thus requiring amendments for crop cultivation; because this type of soil chemical constitution usually causes Zn deficiencies in Maize and Cu deficiencies in wheat. To overcome this, applying copper sulfate or zinc sulfate at a rate of 30 kg/ha is recommended with liming.

(2) Improvement of Sandy Soil

The soils in Lealui are mostly sandy with low CEC, but it is possible to increase the CEC through a dressing with black soil collected from the surrounding low land.

(3) Protection of Crops

1) Rat Damage

Rats usually cause damages over various crops at emergence and ripening stages. To reduce this damage, there are several methods to reduce the rat density by cleaning the grassy areas surrounding the field or placing rat traps around the field. On the other hand, scattering rice grains around the field as a lure crop is also effective in preventing rats to enter the field. Chemical methods need careful attention.

2) Weed Infestation

It is useful to suppress weed infestations at an early stage by enforcing intertillage cultivation. Regular plowing in fallow periods is also effective.

3) Pest and Disease Damage

The black maize Beatles on directly sown paddy rice cause chewing damage in upland conditions but are easily controlled by flooding the field. But only a chemical method can be used to prevent maize/sweet corn from the maize stalk borer, the self-topping of cabbage from web worm (Hellula undalis fabricius). White leaf spot (Phytophthora porri foister) in onion mostly occurs under excess moisture conditions in the field, thus it is important to select a field with good drainage conditions.

III. LAND CONSOLIDATION TECHNOLOGY FOR AGRICULTURAL PRODUCTION

Natural Conditions of the Zambezi Flood Plain Edge Area

(1) The edge of the flood plain located in the transitional zone between the high land and the flood plain is called the Mataba seapage zone, and is divided into three zones; The Litongo, the Sishanjo and the Mataba Sitapa. The Litongo is a gently sloping area connecting the high lands to the flood plain, and mainly consists of peat-muck from organic matter decomposition and in some cases mixed with basic sand, silt or loam.

The Sishanjo covers shallow swampy zones, which receives a steady lateral subsurface supply of seepage water from the sandy uplands. The soils of this area include very poorly drained, decomposed muck and mucky peat with loamy muck topsoils and are sometimes associated with a high degree of acidity when the peat-muck is deep (1 m or more).

The Mataba Sitapa is adjacent to the Sishanjo and constitutes a transitional zone to the so called Saana sand terraces which are located further out into the flood plain. The soils of Mataba Sitapa are mucky loams and sandy loams overlying sand.

(2) In addition to the Namushakende verification farm, two cultivated areas were selected at Sefula and Limulunga as model areas for rice cultivation in the flood plain. These model areas belong to the Sishanjo and Mataba Sitapa soil type areas. The permeability of the soils in these areas is relatively high and the permeability coefficients were of the order of $10^{-3} \sim 10^{-4}$ cm/sec. The average values of penetration resistance in both model areas were $1.5 \sim 2.8$ kg/cm^2, making the use of oxen for paddy rice cultivation feasible in these areas. Soils showed a weak acidity with pH (H_2O) values at $5.6 \sim 6.5$.

(3) Water discharge fluctuations of the Sefula river and the Namitome canal located near the model areas were 0.29 m^3/sec ~ 0.86 m^3/sec and 0.22 m^3/sec ~ 0.79 m^3/sec respectively, from Sep. 1991 to Apr. 1992. The minimum water discharge was observed in October and the maximum was in December.

The maximum inundated water depths in the model areas during flooding in 1992 were 0.25 m and 0.35 m in the Sefula and Limulunga, respectively. These depths were smaller than the ones of ordinary years, which range from 0.2 ~ 0.6 m, due to the small rise of the water level of the Zambezi in that season.

Guideline of Irrigation and Water Management

(1) Prerequisites for the elaboration of guidelines are determined as follows. Depending on a statistical analysis based on the last 10 years rainfall data, a drought year with a 3 ~ 5-year return period was targeted as a reference year for design. In this case, it corresponded to the year 1983. The required data to determine the relevant irrigation factors were obtained from the findings of the AVS. Supplementary data will be provided by additional surveys. The plan was made making allowance for loss caused by insufficient experience of the farmers in irrigation. We proposed that a irrigation and water management plan be made according to the farming plan described in the guideline, and that a farmers - oriented water management organization would be in charge of the maintenance and management of the water management plan under the supervision of the district agricultural office.

(2) Direct sowing on well-drained paddy field was considered for the water management plan in the flood plain edge. The initial ponding was determined to be carried out one month after seeding, and intermittent irrigation with an interval of seven to ten days would be employed.

In the water management plan, the evapotranspiration amount per day was obtained using the Penman equation, and by comparing it with the daily water loss obtained from actual measurements, the percolation amount was presumed. The initial ponding amount was set to be 150 mm. The upper and lower limits of effective precipitation were set to 60 mm and 5 mm respectively, and allowing 20% for safety makes 80% of effective precipitation per day. The calculation of decadal gross water requirement with a presumed irrigation efficiency of 85% resulted in a peak decadal water requirement of 120.1 mm (15.0 mm/day) in the third decade of February, which makes a peak water requirement of 86.9 l/s presuming a beneficial area of 50 ha.

(3) In the upland irrigation plan, TRAM (Total Readily Available Moisture) obtained from the calculation of soil available moisture in the Namushakende Farm was set to 59.4 mm. The maximum consumptive water use of 3.04 mm/day was obtained using the Penman Equation. The effective precipitation was obtained by calculating the effective precipitation per day with upper and lower limits being TRAM and 5 mm respectively, and by allowing 20% for safety. As a result of the calculation of gross water requirement with a presumed irrigation efficiency of 60% based on the above mentioned items, the total gross water requirement for the farming period of Feb., Mar. and Apr. was 618 mm. The average gross water requirement per day was 2.6 mm.

(4) The calculation of gross water requirement per period according to the double - cropping system of paddy rice (cropping acreage ratio of 100%) and upland field cropping (cropping acreage ratio of 60%) resulted in the total gross water requirement of 1,839 mm per year and the average gross water requirement per day of 5.04 mm.

Guideline of Farm Land Consolidation

(1) The guideline of farm land consolidation is to be mainly applied to the Sishanjo and the Mataba Sitapa soil type areas selected as the potential development areas in the Zambezi flood plain considering topography, hydrology, soil conditions, and present agricultural practices.

(2) Considering the actually existing farm size (0.5 ~ 2 ha) and the targeted cropping systems, a farm block of 2 ~ 5 ha is recommended as a basic unit of farming scale, and a typical farming system which groups several farm blocks with the size of 10 ~ 50 ha is proposed considering the village size in the targeted area.

(3) A farm road is planned around the farm land and was designed to protect the latter from the influence of the flood as well as to serve as a means of transportation for the farming inputs and harvests. The standard width of the peripheral road is proposed in a range of 3.0 to 3.5 m considering the introduction of small-sized agricultural machineries and trucks in accordance with farm land consolidation in the future. The maximum embankment standard height of the peripheral road is determined at 1.8 m

from a 3 ~ 5-year return period flood depth. It is proposed to include some impervious layers of clayey soils in the structure of the peripheral road, which can be dug out in the neighbouring areas.

(4) As for the farm land, minimum land grading and leveling with the provision of levels at the borders of the field lots are recommended considering that direct seeding of paddy rice in dry condition is adopted. The standard size of a field lot shall be 25 m by 50 m (half a lima) considering the present field sizes in the area and the means of farming. And surface soil handling is recommended during the earth work of land grading and leveling in case the thickness of the top soil layer of the area is small.

(5) A gravity irrigation system is to be introduced and a minimum number of irrigation canals are planned to minimize costs depending on the present topography and the grouping conditions of farm blocks in the farm land, and plot-to-plot irrigation is basically applied in the farm block.

(6) The most economical earth canal is selected, however, the adoption of a lining method using cohesive soil is desirable considering the high permeability of the ground in the area. Considering the soil conditions of the area, a maximum and minimum allowable flow velocities in the canal are set to 0.6 m/sec and 0.3 m/sec, respectively. And a minimum freeboard value is set to 0.3 m.

(7) The drainage is equipped aiming at the elimination of surface surplus water caused by heavy rainfall as well as rainwater in the period of upland farming and minimizing the canal section and density.

(8) The drainage canal is constructed without a lining with a standard depth of 0.8 m considering the elimination of groundwater to prevent wet injury in dry field farming and the soil conditions of the area.

IV. RECOMMENDATION

The agricultural verification survey resulted in the elaboration of technical guidelines for crop production and production infrastructure improvements. In order to achieve a stabilized production at the edge of the flood plain of the Zambezi River as well as in similar areas throughout Zambia, it is necessary, based on the above guidelines, to make agricultural technology available in the areas and further to spread and strengthen training systems for the enhancement of technology transfers. It is also required, along with the above, to establish a development plan for the project area and to implement the project. It is desirable that a development plan includes, in addition to the items included in the agricultural verification survey, social and financial surveys in the project area to examine necessary facilities and organizations for obtaining a post harvest that adds value to the negotiability of the harvest and the harvest itself. It is also desirable that the plan is such that it serves for the organization of infrastructures in farming villages as well as for the establishment of continuous agriculture. It is desirable that the implementation of the development project of agriculture and farming villages be accomplished through the effort of the government of Zambia, and aid from foreign countries. We also propose to the government of Zambia to immediately start studies on the operation of the project after implementation and maintenance of facilities along with the establishment of a guiding system.

These guidelines were made based on the results obtained from surveys and studies included in the agricultural verification tests performed over a period of four years. However, as surveys and experiments were limited to the aforementioned two farm areas, further surveys into expanded areas are required. It is strongly recommended that the proposed guidelines be revised based on added surveys.

The issues to be dealt with are categorized in the following two groups:

(1) Issues requiring short or middle-term review

1) The selection of paddy varieties adaptable for flood plain soil (depending on the soil types).

2) The selection of such varieties as wheat, maize and tomatoes that are adaptable for double-cropping with paddy in the flood plain soils.

3) The promotion of hydrological and soil surveys for farmland improvements.

4) The development of simple apparatus including man-operated threshers and transporters.

5) The spread of agricultural technology and the strengthening of training systems.

6) The promotion of the creation of farmers organization.

(2) Issues requiring middle or long-term reviews

1) The breeding of excellent varieties of paddy and that of field crops that constitute two-crop systems with paddy.

2) The grading and evaluation of potential areas for development.

3) The promotion of farmers organizations and the establishment of reinforcement system.

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CHAPTER 1.

BACKGROUND AND PROGRESS OF THE AGRICULTURAL VERIFICATION STUDY

CHAPTER 1. BACKGROUND AND PROGRESS OF THE AGRICULTURAL VERIFICATION STUDY

1.1 Agriculture in Zambia

1.1.1 Natural Environment

(1) Land

Zambia has an area of about 753,000 km^2 covering about twice the size of Japan and consists of the nine following provinces Central, Copperbelt, Eastern, Luapula, Lusaka, Northern, North Western, Southern, and Western. Zambia is an inland country which shares borders with eight countries including Tanzania, and Zaire to the north, Malawi and Mozambique to the east, Zimbabwe, Botswana, and Namibia to the south and Angola to the west.

Almost the whole country is high land with 1,000~1,300 m altitude, but there are the Muchinga Mountains with over 2,000 m in the north eastern area. On the other hand there is a low land area with 100 m altitude along the Zambezi valley in the east and south area. The watershed between the two large African rivers, Zambezi and Zaire, runs along the Muchinga Mountains and the boundary between Zaire and Zambia, resulting in a large part of Zambia belonging to the basin of the Zambezi river except the Northern and Luapula provinces which belong to the basin of the Zaire river. The name Zambia originated from the above mentioned facts (Figure 1.1.1).

(2) Climate

Zambia belongs to a tropical climate, however because of its high altitude it is relatively comfortable throughout the year. The seasons are roughly divided into three: a cool dry season from May to August, a hot dry season from September to October, and a rainy season with hot temperatures from November to April.

1) Temperature

In the cool dry season it is coolest in June and July and sometimes there is frosts in the southern area showing 5~10 frost days per year in the southwest area and covering almost the western half area of Zambia with 1~3 frost days, although these data are somewhat old (Fig. I.1.1.2).

The temperature in July is the lowest of the year with a country monthly mean temperature of about 15~17.5°C, but some areas of the southern part show temperatures lower than 15°C while some in the northern part show temperatures higher than 17.5°C. The temperature in October is the highest of the year showing a monthly mean temperature in most areas of the country ranging from 22.5~25°C, but some areas of the southeast and southwest with lower altitudes show temperatures higher than 25°C.

2) Rainfall

Rainy and dry seasons are clearly distinct. Rain begins from October to November reaches its peak from December to February and ends around April. There is almost no rain during May and September. The rain pattern is almost the same all over the country but differences in the amount of rainfall are recorded between the northern area showing more rain and the southern area showing less. The northern area gets more than 1,000 mm and even exceeds 1,500 mm in some places, the central area gets more or less 1,000 mm, and the southern area between 600 to 800 mm (Figure 1.1.4).

(3) Soils and vegetation

Soils are roughly divided in eight types as shown in Figure 1.1.5.

1) Fersiallitic soils

The parent material of this soil is rock with a high concentration of ferro magnesia and low acidity. The soil is clay loam with a deep clay and sand surface layer reaching 50~300 cm. The soil color is red, red brown or yellow brown when well drained, and gray brown or gray when poorly drained. The soil is distributed over the Lusaka, Mumbwa, Monza, and Mazabuka areas of the Central province, and over the Petauke, and Chipata areas of the Eastern province. The soil is most suitable for crop cultivation and is highly productive under sprinkler irrigation practised by the commercial farmers in the above mentioned areas.

2) Ferrallitic soils

The distribution of this soil is the largest in Zambia occupying 50% of the country. The soil is distributed over high lands with gentle slopes and can be divided in two groups; one group is in the northern part of the country with much rain and the other in the southern part with less rain. Parent rocks of the soil are granite, gneiss, sandstone, and crystalline schist.

The soil in the southern part is a loam layer with much sand and the color is yellow brown in poorly drained area, and grey brown in well drained areas. The surface layer is 180 cm deep in some cases, but generally shallower. The soil is distributed over the Southern, Western, and Central provinces. It contains a high amount of sand requiring more attention in crop cultivation.

The soil in the northern part contains high concentrations of clay and is acidic because of leaching owing to much rain. Surface soil is 180 cm deep with coarse loam colored white becoming grey when organic matter is present. It is distributed over the Northwestern, Western, Northern, and Luapula provinces. Good yields can be expected under the appropriate management on this soil.

3) Barotse sands

These are deep and soft and layers containing less than 5% clay. The surface layer is more than 180 cm deep with a white color becoming grey when organic matter is present. The origin of this soil is not clear and is distributed largely over the Western province and also in some parts of the Northwestern and Southern provinces.

4) Vertisols of the Kafue flats

This soil consists of fine clay with lime which is black in surface and grey in depth. The soil PH ranges from slightly acid to neutral and is alkaline in the subsoil. 120 cm from surface there are calcium carbonate layers. The flood area of the Kafue flats is almost occupied by this soil. Under drainage, cereal crops suitable for swamp can be raised.

5) Vertisols of the river valleys

This soil is distributed along the valleys of the Luangwa river in the Eastern province and the Luapula river in Luapula province and has a high concentration of clay.

6) Vertisols of the flood plains

This soil is distributed over the flood plan of the Zambezi river and its tributaries and also over the Dambo area. The surface layers are peat soils with sandy sublayers, showing strong acidity without drainage. When protected from flood and under appropriate drainage, cereal crops and grasses can be grown under good condition.

7) Lithosols

This soil is distributed over narrowly sloped land mixing with rocks on the surface. The subsoil is laterite or gravel or weathered rock and the surface is sand or sandy loam which is originated from weathered granite, gneiss, crystalline schist, and sandstone.

Vegetation is shown in Figure 1.1.6. A large part of the land is occupied by savanna woodland with trees having 3~5 m distance between them and height reaching 20 m at the most. It has characteristics varying between savanna and tropical rain forest. This vegetation is widely seen in the area south of the Sahara Desert in Africa. Traditional small farmers are practising shifting cultivation in this vegetation area by cutting branches and burning them during the dry season and sowing in the coming rainy season. The main crops are millet, maize, and cassava.

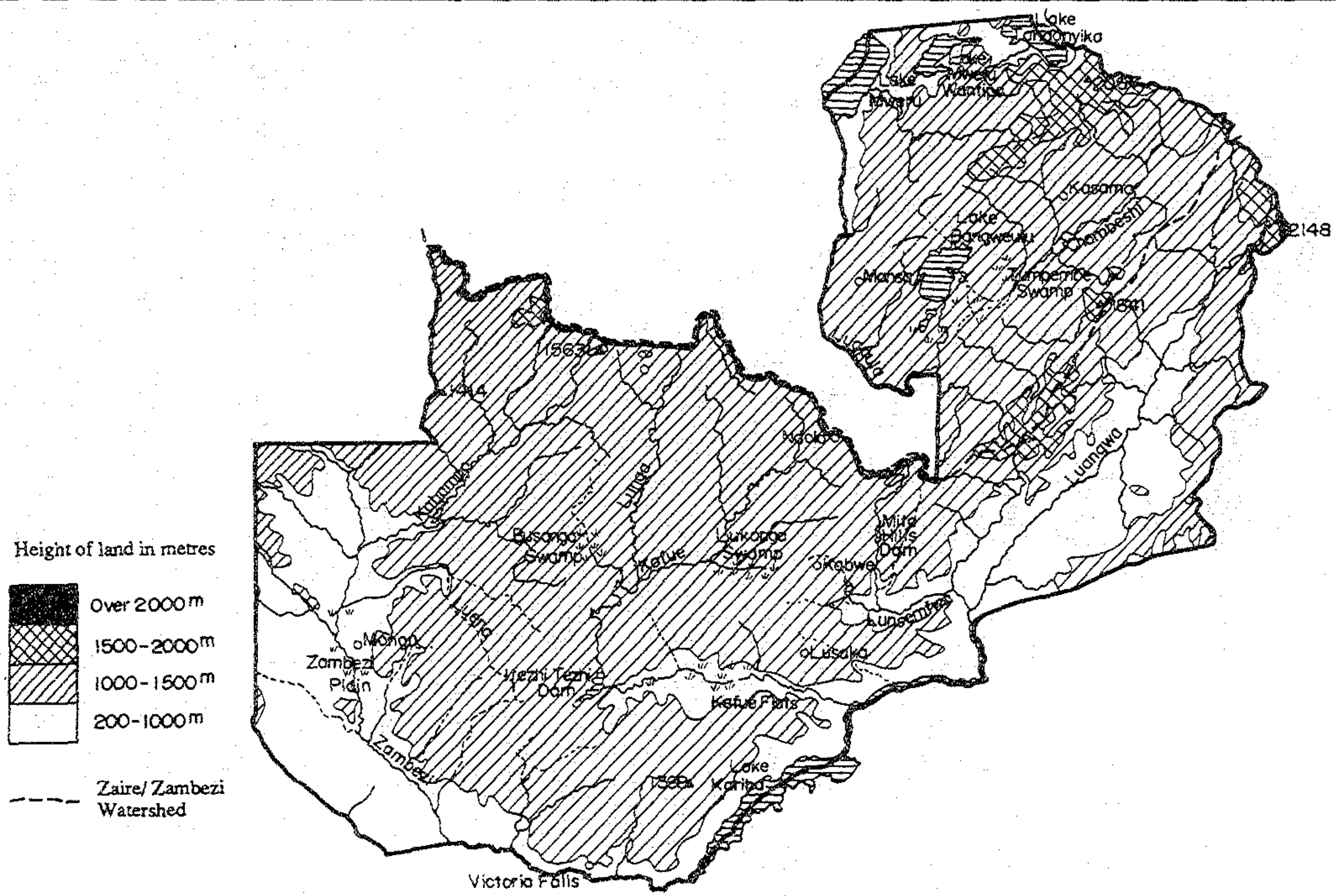

Figure 1.1.1 Topography of Zambia

Source : Basic education resource atlas for Zambia

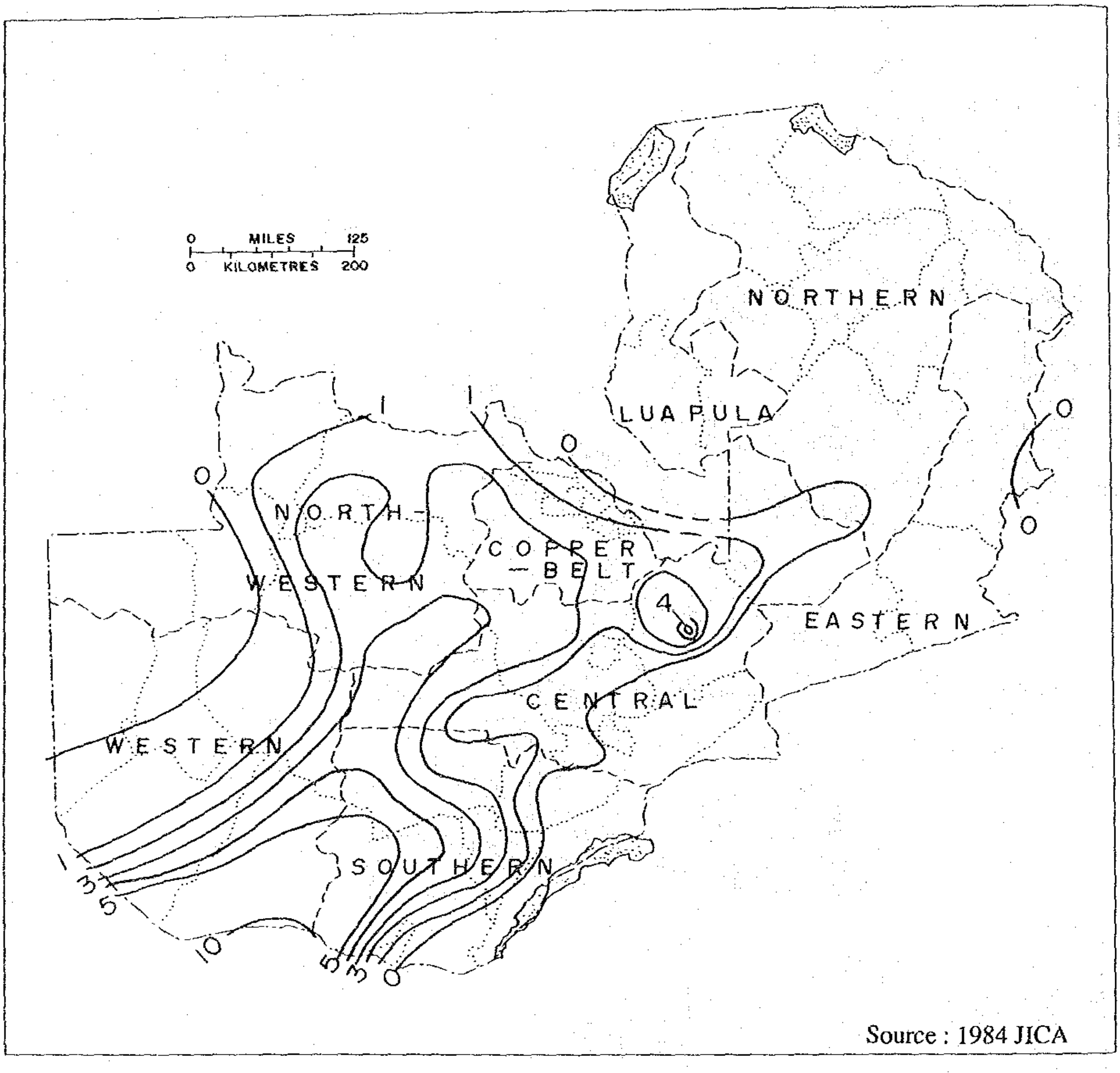

Figure 1.1.2 Number of Days with Frost

Mean Temperature in July

Mean Temperature in October

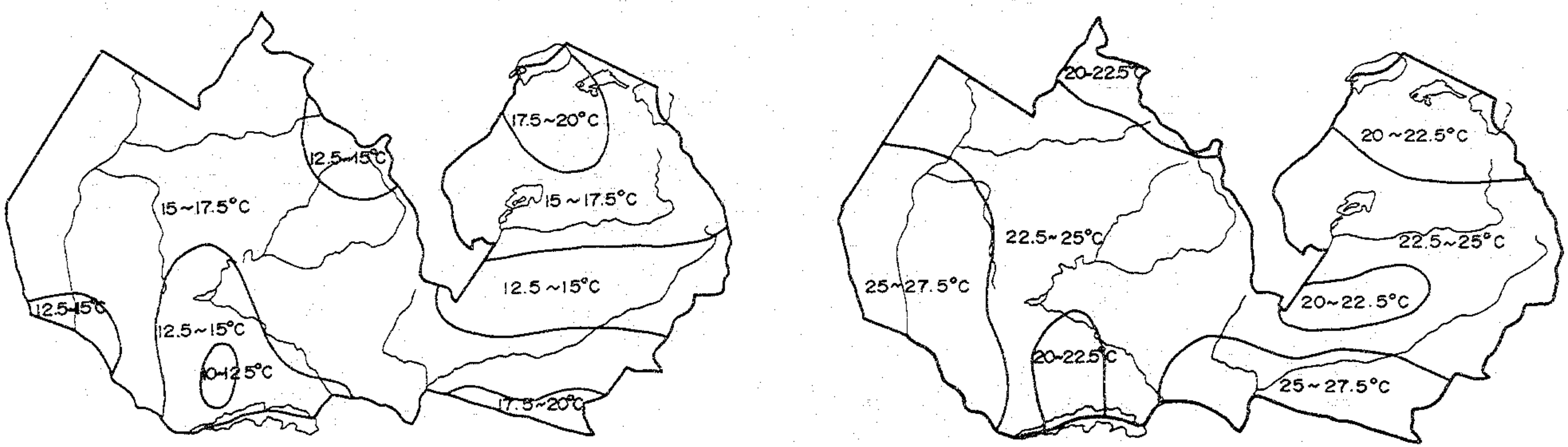

Figure 1.1.3 Mean Monthly Temperature

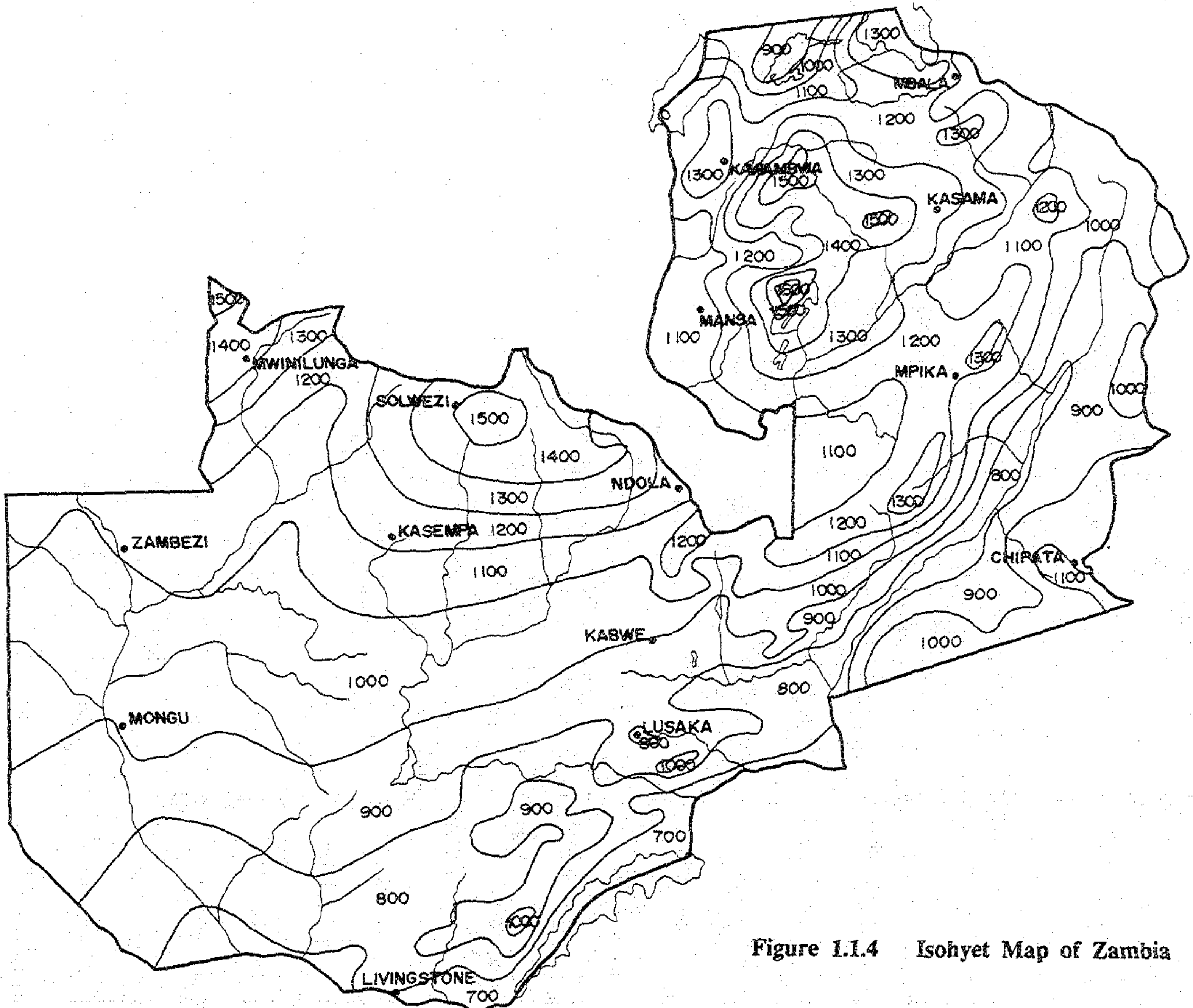

Figure 1.1.4 Isohyet Map of Zambia

Source : Basic education resource atlas for Zambia

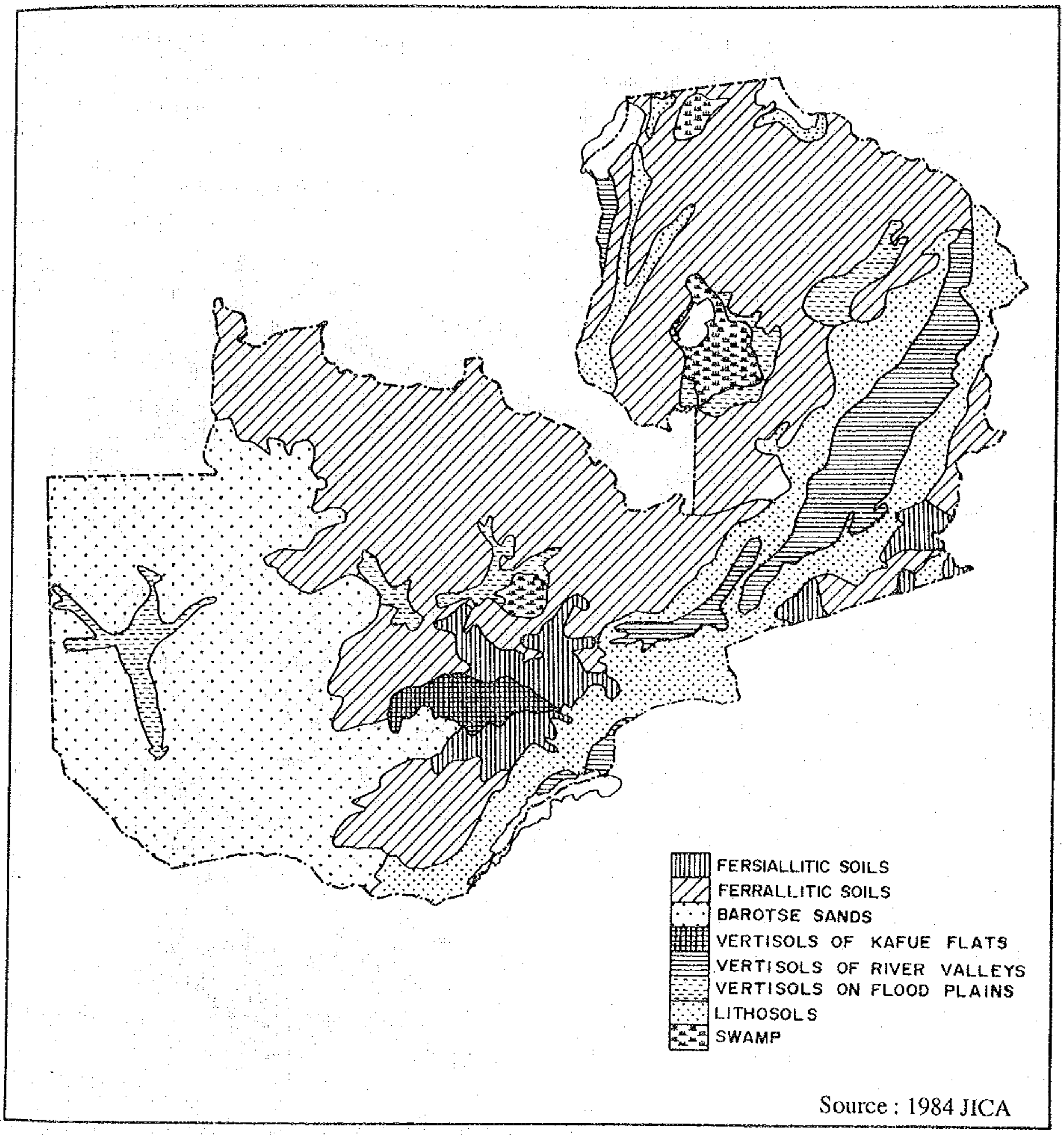

Figure 1.1.5 Soil Map

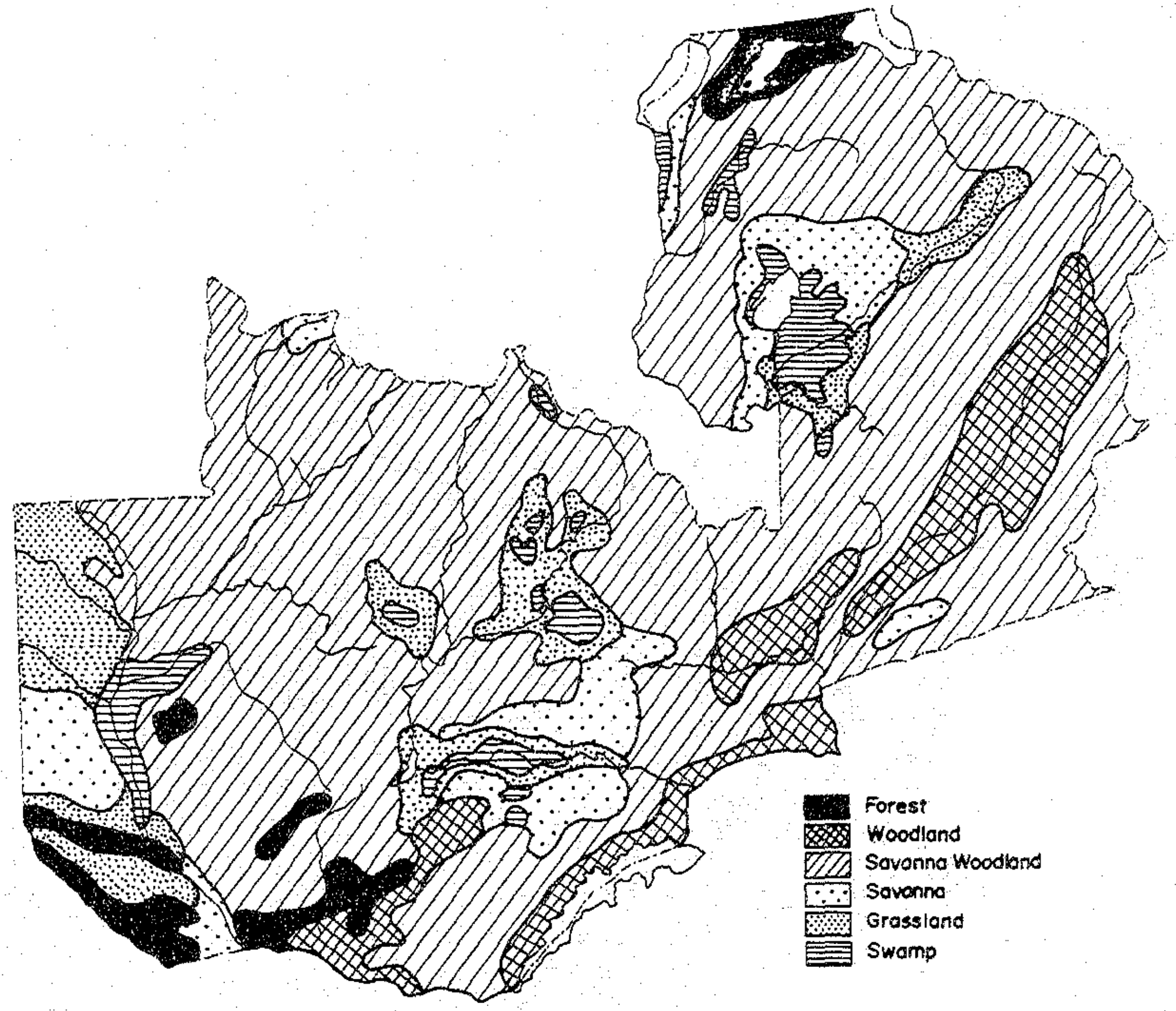

Figure 1.1.6 Vegetation Map

Source : Basic education resource atlas for Zambia

1.1.2 Social Condition

(1) Population

The 1990 census shows a total population of 7,818,447 with a density of 10.4 inhabitants per km^2. The populations of both the Lusaka province with the capital being Lusaka and the Copperbelt province producing copper represent 36% of the total population and a density per km^2 greater than 50, which exceed largely the national average of 10.4. The density of Northern, Northwestern, and Western provinces is low showing 5.9, 3.0, and 4.8 respectively. (See Appendix Table I.1.1)

The tendency of the population to concentrate in urban areas is clear and has increased from 29.4% of the total population in 1969 to 39.9% in 1980, and to 42.0% in 1990. Population growth is 3.0% during 1969 and 1980, and 3.2% during 1980 and 1990; especially in Lusaka province it is a high as 6.1% during 1969 and 1980, and 5.6% during 1980 and 1990. (See Appendix Table I.1.2)

(2) Political situation

Since the independence in 1964, the UNIP (United National Independence Party) headed by Dr. Kenneth Kaunda has kept political power, and has led the country.

After 1975 due to the fall of copper international price which had kept the economy of the country, great economic difficulties have followed with unstable social situations. The government has been endeavoring to seek out countermeasures like establishing new industries and developing agriculture to increase exports that would take the place of copper. However, these countermeasures have not been able to bring about the expected results and were instead followed by economic and socially unstable conditions.

Owing to such circumstances movements against one party rule were born, that have led to the recognition in 1990 of the multi-party system and the formation of the MMD (Movement for Multi-party Democracy) and other parties.

Multi-party elections were held on 31st October 1992 and Mr. Frederick Chiluba, leader of the MMD, was elected as the President replacing Dr. Kaunda for the first time since the independence of the country.

(3) *National economy*

Since the independence, 1965, the national economy has been supported by the copper production as much as during the colonialization period. As already described, the government has made efforts in searching substitute materials to take the place of copper for exports. However, the contribution of copper in the total export revenue was 80~90% in 1980s and still 86.2% in 1990, showing no extreme change in the national economy orientation. The amount of copper exported during the 1970's was 600 thousands ton, 500 thousands ton during the first half of the 1980s, and 400 thousands ton after 1985, showing a gradual decrease. In spite of this decrease, there have actually been nothing to replace copper with. (See Appendix Table I.1.3)

The consumer price index based on the 1985 level has increased to about 8 times in 1989, about 15 and 30 times respectively in June 1990 and 1991, and to about 50 times in December 1991. The inflation rate from 1985 to 1988 was between 35% and 60%, and after 1989 upto 1991 it reached 153%, 107%, and 100% respectively, showing severe economic conditions. The GDP showed an increasing trend from 1984 to 1988 but decreased markedly in 1989 and 1990. During these two years, the GDP decreased in many sectors, especially in agriculture. Manufacturing has however increased in spite of the decrease recorded in other sectors and has contributed a large part in the GDP, but it could not accelerate the whole economy (Table I.1.1). (See Appendix Table I.1.4 & I.1.5)

(4) Research and Extension Organizations

Owing to the National Research Action Plan, and the National Extension Action Plan, the Research and Extension Organizations are summarized as follows :

At the national level, there are three Assistant Directors under the Director of Agriculture in the MAFF, respectively taking charge of Research, Extension, and Irrigation/land Husbandry.

Under the Assistant Director(Research), there is a Chief Agriculture Research Officer (CARO), and under him/her, there are three Research Divisions, Crops, Soils/Agronomy, and Livestock with branches in every Province. Under the CARO, there are also three Regional Coordinators in charge each of one of the Regions I, II and III which separates the country agro-ecologically, mainly depending on rainfall. (See Appendix Figure I.1.1)

Under the Assistant Director(Extension), one Provincial Agriculture Officer(PAO) takes charge at the Province Level of extension matters, who is seconded by the District Agriculture Officer (DAO) under whom are the Block Extension Officers followed by the Camp Extension Officers. (See Appendix Figure I.1.1)

The highest responsible Zambian counterpart is the Assistant Director (Research). The results of the AVS are to be conveyed to Zambia related persons through him/her. Following the five years study, Guidelines of Crop Production Technologies and Land Consolidation Technologies are proposed. The Guideline of Crop Production Technology will be studied by crop scientists through the Assistant Director (Research) and the guideline of Land Consolidation Technology by agriculture engineering scientists through the Assistant director (Land Husbandry & Irrigation). Both Guidelines may be used as a support to the actual development plan with the information being disseminated to farmers through the extension organizations at the district, provincial, and national levels, which are headed by the Assistant Director (Extension).

Table 1.1.1 Value (kw. milion) and Percentage Distribution of GDP by Economic Activity at Constant (1977) Price

		1984	1985	1986	1987	1988	1989*	1990**
Agriculture, forestry and fishing	Value	333.2	343.8	373.8	365.6	436.2	111.4	99.7
	%	16.5	16.8	18.2	17.3	19.4	6.8	5.6
Mining and quarrying	Value	200.0	185.8	176.5	184.2	160.4	78.7	151.8
	%	9.9	9.1	8.6	8.7	7.1	4.8	8.6
Manufacturing	Value	309.3	421.6	425.3	462.9	547.0	542.6	628.2
	%	19.4	20.6	20.7	21.9	24.3	33.3	35.7
Electricity, gas and water	Value	70.9	72.7	71.1	62.2	61.3	57.6	107.5
	%	3.5	3.6	3.5	2.9	2.7	3.5	6.1
Construction	Value	88.6	77.1	81.1	77.3	70.3	32.8	30.6
	%	4.4	3.8	3.9	3.7	3.1	2.0	1.7
Wholesale and retail trade	Value	167.9	174.7	174.4	181.5	185.3	127.4	121.0
	%	8.3	8.5	8.5	8.6	8.2	7.8	6.9
Hotels, bars and restaurants	Value	49.0	51.3	46.8	46.5	48.6	25.2	30.8
	%	2.4	2.5	2.3	2.2	2.2	1.5	1.8
Transport, storage and communication	Value	116.2	109.2	110.1	114.5	113.3	31.3	35.9
	%	5.8	5.3	5.4	5.4	5.0	1.9	2.0
Financial institutions and insurance	Value	62.5	60.6	56.8	50.8	60.0	22.6	24.2
	%	3.1	3.0	2.8	2.4	2.7	1.4	1.4
Real estate and business services	Value	179.5	179.0	178.6	189.2	191.1	293.3	330.7
	%	8.9	8.8	8.7	8.9	8.5	18.0	18.8
Community, social and personal services	Value	340.2	365.6	358.1	371.5	373.5	303.8	190.0
	%	17.6	17.2	17.4	17.6	16.7	18.6	10.8
Total	Value	1,916.8	2,044.5	2059.3	2,114.3	2,247.1	1,628.8	1,757.6

* Preliminary ** Provisional
(Monthly Digest of Statistics Feb./Mar. 1991)

1.1.3 Agricultural Production

(1) Land use

According to the FAO year book (1990), cultivated land amounted to 4.98 million ha in 1974, 5.05 million ha in 1979, 5.15 million ha in 1984, and 5.26 million ha in 1989, showing 0.28 million ha increase in 15 years or 7% of the total land area, 75.26 million ha. Permanent grassland has remained unchanged at 30 million ha during the last 15 years.

Forests decreased about 1.05 million ha (4%) from 29.97 million ha in 1974 to 28.92 million ha in 1989, and other land areas increased about 0.77 million ha (8%) from 9.38 million ha in 1974 to 10.15 million ha in 1989. It can be said that about 30% of the deforested areas changed to cultivated land and about 70% changed to other type of land (Table 1.1.2).

Table 1.1.2 Land Utilization (1,000 ha)

	1974	1979	1984	1989
Total area	75,261	75,261	75,261	75,261
Land area	74,339	74,339	74,339	74,339
Arable land	4,978	5,050	5,150	5,260
Permanent crops	7	8	8	8
Permanent pasture	30,000	30,000	30,000	30,000
Forest and woodland	29,970	29,620	29,270	28,920
Other land	9,384	9,661	9,911	10,151

Note: Except total area and land area other items are estimated by FAO (FAO Production Yearbook Vol. 44 1990)

(2) Crop production

Maize production in Zambia dominates any other crop production. The planted area of maize has varied between 0.6 million ha and 1.0 million ha during the five years between 1986 and 1990. Except for 0.15 million ha of planted area for groundnut in 1987 and 0.1 million ha for cotton in 1989, there are no crops which involve over 0.1 million ha of planted area suggesting the importance of maize. Relatively much planted crops are groundnut, cotton, millet, sorghum, and sunflower, and their areas are 80 thousand ha, 64 thousand ha, 59 thousand ha, 48 thousand ha, and 44 thousand ha respectively, amounting to less than 10% of the area devoted to maize. The planted area for rice was more or less 10 thousand ha during the last five years (Table 1.1.3).

Table 1.1.3 Planted Area (1,000 ha) and Production (1,000 ton) of Main Crops

		1986	1987	1988	1989	1990
Maize	Area	588.50	609.50	723.10	1,020.60	763.30
	Production	1,230.60	1,063.40	1,943,20	1,845.00	1,092.70
Sunflower	Area	57.20	31.60	44.60	45.00	44.30
	Production	30.60	17.00	15.80	15.00	20.00
Soybeans	Area	13.90	16.90	20.30	21.30	29.80
	Production	15.90	13.50	21.20	20.60	26.80
Groundnuts	Area	34.40	149.00	81.80	62.90	80.40
	Production	18.20	47.40	33.40	30.10	25.10
Rice	Area	10.40	8.70	10.40	12.80	9.50
	Production	11.20	8.20	9.40	11.70	9.20
M. Beans	Area	19.70	23.60	17.60	18.70	26.40
	Production	10.20	15.50	10.90	24.30	14.30
Sorghum	Area	59.60	47.50	47.40	52.00	48.50
	Production	45.00	26.20	36.10	33.80	19.60
Cotton	Area	52.00	38.20	77.90	106.40	64.00
	Production	33.40	20.20	58.50	34.80	30.70
Tobacco (Virginia)	Area	2.84	1.25	3.97	3.69	3.59
	Production	3.35	2.90	3.74	2.62	3.37
Tobacco (Barley)	Area	0.64	1.21	0.92	1.35	1.48
	Production	0.55	0.65	0.61	0.98	1.27
Millet	Area	18.50	43.60	44.10	47.40	58.90
	Production	11.70	30.60	28.60	27.30	31.50
Wheat (Rainfed)	Area	-	-	-	0.20	0.36
	Production	-	-	-	0.17	0.33
Wheat (Irrigated)*	Area	-	7.40	6.93		
	Production	-	27.46	31.55		

Note: Official crop production and sales data 1990
* Agr. statistics Bulletin 1988

Planted areas and production are generally unstable due to the severe effects of rainfall fluctuations and the absence of irrigation facilities. Considering maize, the area was 0.72 million ton in 1988, and 1.02 million ha in 1989, and the production was 1.94 million ton and 1.84 million ton respectively. While the area was 0.61 million ha in 1987, and 0.76 million ha in 1990, and the production 1.06 million ton and 1.09 million ton showing near 50% deviation from the aforementioned two years.

The main crops are divided into three groups: one is almost a 100% commercialised one; one is almost non commercialized and sold on the farmers' field; and the third one is intermediate. The completely commercialized crops are cotton and tobacco and the almost non commercialized ones include beans, sorghum, and millet. 40~70% of the production of maize, sunflower and rice are sold at the market. Soybean and groundnut are commercially unstable as they are sometimes almost all sold on the market but sometimes almost not at all. (See Appendix Table I.1.6)

The production situation of the main crops are as follows: (See Appendix Table I.1.7)

1) Maize

As previously described maize is a very important crop in Zambia, being the staple food, but production deviates by almost 50% showing production problems. In 1990, the planted area amounted for the Eastern province to 262 thousand ha, for the Southern province to 233 thousand ha, and for the Central province to 104 thousand ha, these three provinces covering more than 100 thousand ha planted area or 80% of the total area devoted to maize. These provinces include much commercial farmers showing their commitment to maize production.

2) Sunflower

For three years, up until 1990, it has involved 44 thousand ha of planted area and a production from 15 thousand ton to 20 thousand ton with a per ha production varying from 0.33 ton to 0.45 ton. In 1990, the Southern province devoted 21.7 thousand ha to sunflower production, the Eastern province 12.2 thousand ha, and the Central province 7.0 thousand ha, these 3 provinces accounting for more than 90% of the total area devoted to this culture.

3) Soybean

The planted area has almost doubled in 5 years since 1986 reaching 30 thousand ha. Production also has increased from 15 thousand ton to 27 thousand ton but no sensible increase per unit area production was recorded, which varies from 0.7 t/ha to 1.1 t/ha. Soybean was cultivated as a rotation crop with wheat in commercial farms under irrigation, but is now also cultivated by small farmers. In 1990, the Central and Eastern provinces occupy a little less than 25% of the country's total planted area followed by the Southern, Copperbelt, Northwestern, and the Northern provinces, each of these provinces occupying more or less 10% of the total planted area showing a rather uniformly cultivated crop throughout the country.

4) Groundnut

This is a traditional home-consuming crop. The planted area has changed sensibly within the last five years, increasing in 1987 to three times its value in 1986 reaching 150 thousand ha, but decreases after that to almost half showing from 60 to 80 thousand ha. The last three years show a production from 25 thousand ton to 33 thousand ton or a yield of 0.3 to 0.5 ton per ha. In 1990, the Eastern and Northern provinces occupied more or less 25% of the country's total planted area respectively, followed by the Southern and Central provinces which show 20% and 10% respectively.

5) Rice

The planted area is not so sensible and amounts to only 10 thousand ha, but rice is considered as an important crop. The Western and Northern provinces are the two major production areas occupying 40% and 35% respectively of the country's total area. They are followed by the eastern province with 16% of the area and other provinces which account for a very small portion. Mainly, it is cultivated by small farmers in the flooded areas of rivers. Production is more or less 10 thousand tons with less than one ton per ha.

6) Cotton

This crop is a very special case as it is almost 100% commercialized. For five years up until 1990, the planted area has drastically changed. It was the lowest in 1987 with 38 thousand ha and increased to over 100 thousand ha in 1989. It decreased to 64 thousand ha in 1990. In 1990, the Central and Southern provinces occupied 38% and 33% respectively of the country's total cultivated area. They were followed by the Eastern province with 23%, these three provinces totalling more than 90% of the area.

7) Tobacco

Similarly to cotton this crop is 100% commercialized. The cultivated area for the Virginia species was 2,800 ha in 1986 and decreased to 1,200 ha in

1987, then became 4,000 ha in 1988, and after that kept the 3,600 ha level. In 1990, the Southern and Central provinces occupied 25% to 35% of the country's total area devoted to this crop. They are followed by the Eastern and Lusaka provinces with 15% each. The cultivated area for the Barley species amounts to less than half of that devoted to Virginia nationwide but occupies more than 80% of the cultivated area in the Eastern province.

8) Wheat

This crop is cultivated almost only by commercial farmers under irrigated conditions. In 1990, Lusaka and the Southern provinces controled 80% of the country total area and the Copperbelt province 10%. 80% to 90% of this crop is commercialized.

9) Sorghum, millet, cassava and beans

These crops are all traditional crops cultivated by small farmers. Within the last five years, the area devoted to sorghum has amounted to about 50 thousand ha with 20 to 40 thousand ton of production; the area for millet, about 40 to 60 thousand ha with 30 thousand ton, and that for beans, 20 thousand ha with 10 to 24 thousand ton. In 1990, sorghum occupied 25% of the country's total area in the Southern province, 15% in the Copperbelt, Eastern, and Western, Provinces each 13% in the Northwestern and 10% in the Central province, showing a uniform distribution throughout the country. Millet is also uniformly distributed at 26% in the Northern province, 20% in each of the Luapula and Western provinces, and 10% in each of the Southern and Eastern provinces. The growing of miscellaneous beans is concentrated in the Northern province and occupies 60% of the country's total area devoted to this crop. Cassava occupies 44% in the Luapula province, 20% in each of the Western and Northern provinces, and 14% in the Northwestern province.

(3) Animal husbandry

Animal husbandry in Zambia involves a large number of cattle. In 1988, this number was 2.7 million or 78% of the total livestock. Sheep and goat amount to 16%, and pig 6%. In 1988, the largest number of cattle was concentrated in the Southern province accounting for 43% of the country's total number of heads. This province was followed by the Western and Central provinces with 19%

respectively, and the Eastern province with 10%. Sheep and goat are also concentrated in the Southern province which accounts for 50%, of the total number of sheep and goat in the country, and pig in the Eastern province which also accounts for 50%. The Southern province is the number one province in terms of the total number of cattle, sheep and goats, and the number two in terms of the number of pigs followed by the Eastern province, showing the prosperity of animal husbandry in the province.

17% of cattle, 3% of sheep and goat, and 14% of pig are raised by commercial farmers, and in the southern and Central provinces much more livestock are raised by them. Also in Lusaka, Luapula, and the Northwestern provinces commercial farmers raising livestock can be seen. There is however no livestock being raised by commercial farmers in the Western province which ranked second in the total number of cattle and in the Eastern province which ranked first in the number of pigs, second in the number of sheep and goats, and accounting for 10% of the total number of cattle. From these facts, it can be said that provinces with much livestock are divided in two types, one is owing to commercial farmers, and the other to traditional small farmers (Table 1.1.4).

Table 1.1.4 Head of Livestocks (1,000 heads, 1988)

	Cattle				Sheep & Goat				Pigs			
	Traditional sector	Commercial sector	Total	% in country	Traditional sector	Commercial sector	Total	% in country	Traditional sector	Commercial sector	Total	% in country
Central Province	278.2	182.4	460.6	17.2	24.2	10.7	35.0	6.2	6.4	8.4	14.7	7.1
Copperbelt Province	21.6	-	21.6	0.8	7.3	-	7.3	1.3	2.6	-	2.6	1.2
Eastern Province	274.2	-	274.2	10.2	146.3	-	146.3	26.0	108.5	-	108.5	52.6
Lusaka Province	39.4	57.9	97.3	3.6	5.6	-	5.6	1.0	1.8	-	1.8	0.9
Luapula Province	10.9	2.5	13.4	0.5	30.7	-	30.7	5.5	0.8	-	0.8	0.4
Northern Province	94.9	-	94.9	3.5	20.4	-	20.4	3.6	2.4	-	2.4	1.2
Northwestern Province	57.1	4.1	61.2	2.3	12.7	14.6	27.4	4.9	11.9	13.6	25.5	12.3
Southern Province	945.4	208.2	1,153.6	43.0	267.9	17.5	285.4	50.7	40.0	6.7	46.7	22.6
Western Province	507.4	-	507.4	18.9	4.9	-	4.9	0.9	3.4	-	3.4	1.6
Total	2,229.1	455.1	2,684.2	100.0	520.0	42.8	563.0	100.0	177.8	28.7	206.4	100.0
% in country	83.0	17.0	100.0		92.4	7.6	100.0		86.1	13.9	100.0	

(Agr. Statistics Bull. 1988)

(4) Farm size

A large part of the farmers in Zambia are traditional small scale farmers, and from estimates in 1980, out of a total of 607 thousand 76% are small farmers at 463 thousand. Large scale commercial farmers exist mainly along the railroad of the central part of the country resulting in a large difference of percentage ratio between commercial and small farmers among the provinces. In the provinces which are located along the railroad, the percentage of commercial farmers is high at 89% in the southern, 61% in the Central, 32% in Lusaka, 27% in the Eastern, and 12% in the Copperbelt provinces. In other provinces there are almost no commercial farmers, especially not with over a 40 ha holding. In these provinces there are not so many middle scale farms with 10 ha to 40 ha, resulting in the existence of small scale commercial farms with one ha to 10 ha, especially in the Western province which is characterised by a total absence of middle scale farms.

1.2 Agriculture in the Western Province

1.2.1 Natural Environment

(1) Location

The Western province is located literally in the western border of Zambia and its area is 126,386 km^2 occupying 16.78% of the country. It is bordered by the Northwestern province in the north, the Southern province in the east, and it shares boundaries with Angola in the west and Namibia in the south. It consists of six districts, the Mongu district with Mongu as the capital of the province in the center, the Kaoma district in the northern side of the eastern part, the Sesheke district in the southern side of the eastern part, the Senanga district in the southwestern part, the Kalabo district in the western part, and the Lukulu district in the northern part, all these five other districts surrounding the Mongu district. Mongu, the capital of the province is located about 600 km from Lusaka, the capital of the country.

(2) Topography

The province is characterised by a wide presence of sandy soil and high lands ranging from 800 m in altitude in the southwestern part to 1,200 m in the northeast. Between the high lands, about 40 m below, lies the flood plain of the Zambezi river and its tributaries, which covers an area of 13,000 km^2.

The province is divided into two parts by the Zambezi river stream which runs from north to south, resulting in district locations such as the whole of Kalabo is located west of the river, Senanga, Sesheka, and Lukulu are divided by it, and the whole of Kaoma and a large part of Mongu are located east of it (Figure 1.2.1).

On the high lands there are some hollow-like craters called Dambo with 1 ~ several km in diameter. These Dambos are widely distributed in the neighboring countries like Zimbabwe, Malawi, Mozambique and Tanzania, expressing a characteristic of the East African topography.

(3) Climate

Rainfall distribution and yearly temperature variations are described in the items concerning the whole country. Concerning the temperature, during the cool season the minimum temperature is the lowest in the southern part where more frost days are observed; however, in the hot season, temperatures higher than the country's average are recorded.

Annual rainfall shows a tendency to increase gradually toward the north; for example, 1,000 mm are recorded in Lukulu, northern part, 900 mm in Mongu, central part, 800 mm in Senanga, a little south, and 700 mm in Sescheke, southern part. But the main problem associated with rainfall is its large fluctuation which causes serious effects on agricultural production.

(4) Soil

A fairly large part of the Western province is covered with Barotse sand (Kalahari sand) with over 80 m depth, and its origin is not clear. In this sand there are various kinds of sediments varying following the topography; in other places there is only pure sand.

The soils of the high lands are divided into two types; one type is yellowish grey sand with a low content in organic matter, and the other is Humus Podzol which is deposited humus on Kalahari sand in hollow parts with high groundwater levels.

The flood plain is divided into two areas: one is the edge of the flood plain (Mataba seepage zone) connected to the high lands and the other is the outer plain with high and low land terraces. On the flood plain there are many types of soils differing according to the groundwater level, to the difference of altitude, rate of erosion, difference of sediment on Kalahari sand, and difference of depth of layer.

In the lower area of the flood plain, there are accumulations of poorly decomposed organic matter owing to high groundwater levels, resulting in peat-muck layer accumulations sometimes reaching 1 m depth.

Towards the center of the flood plain, peat-muck layers become shallower and are decomposed. There are somewhat fertile soils containing silt and clay on the edge of the flood plain towards the center of the flood plain.

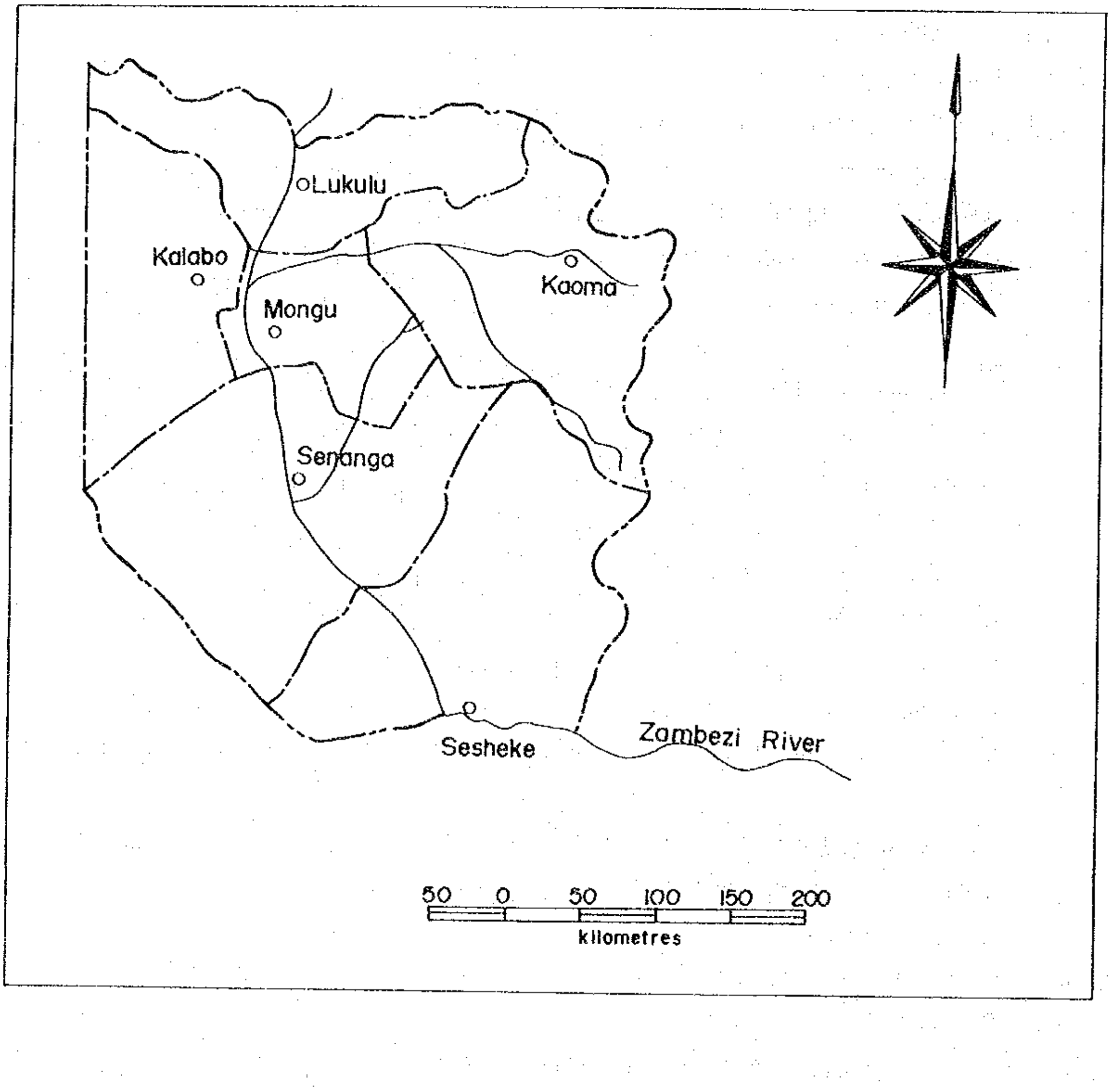

Figure 1.2.1 District Boundaries in the Western Province

1.2.2 Social Condition

(1) Population of the Western province

From the 1990 census, the total population in the province was 607.5 thousand representing 8.5% of Zambia's whole population, and the density was 4.8 inhabitants/km^2 showing less than half of the country's density of 10.4 inhabitants/km^2. This density ranks the second lowest following the Northwestern province with 3.0 inhabitants/km^2.

Among the districts, except Mongu which has a density of 14.1 inhabitants/km^2, a value above the national value, all districts show a density lower than 5 inhabitants/km^2 except Kalabo with 5.8 inhabitants/km^2, showing the population concentration in the Mongu district. In 1980, the density of the whole country was 7.5 inhabitants/km^2, whereas 3.9 in the Western province showed a little more than half of the whole country. But in 1990, as described above, the Western province density became less than half that of the whole country showing a lower rate of increase than that of the whole country during the last ten years. (See Appendix Table I.2.1)

(2) Economic situation

A large part of the Western province is on the Kalahari sand resulting in difficulties for road construction. Except for the paved national road, Lusaka-Mongu-Senanga, there are no roads passable without a four wheel drive. Also, the province is divided into two parts resulting in the difficulties for traffic on the flood plain which depends on boat transportation. Owing to these bad traffic conditions and also to the wide scattering of the population, there are many socio-economic difficulties.

Employers in the Western province deal in the rice milling business, flour milling, food processing, wood industry, and etc. These are all small scale business requiring few employees resulting in the flow of laborers out of the province. Also these enterprises have the disadvantage of being far from the central part of the country. It is very difficult to get laborers because of the small population and the flow of laborers leaving the province because of the difficulties in getting work.

As will be described later, the Western province can not provide food for its population; therefore, it is very important to develop the agriculture and the dependance on that economic development for the province should be considered.

1.2.3 Agricultural Production

(1) Crop production

The main crops in the Western province, in the order of the most planted ones, are maize, cassava, millet, sorghum, and rice. Maize ranks first in the province as beeing the most cultivated crop but it only occupies 5% of the country's total cultivated area for maize and ranks fifth in the nine provinces. Cassava and millet occupy each 20% of country's total area and ranks second and third respectively in the country. Sorghum occupies 15% of the area and is third in the country. For rice, the planted area represents 39.5% of the country's total making the Western province the largest production area, which is followed by the Northern province occupying 36%.

From these facts, the Western province produces crops for local consumption and rice is suitable for production in the province (Table 1.2.1).

Table 1.2.1 Planted Area of Main Crops in Western Province and Percentage in the Country (1990)

	Planted area (ha)	% in country (%)	Ranking among provinces	Commercialised percentage in the Western Province	
				1989	1990 (Estimated)
Maize	39,175	5.1	5	51.3	54.4
Cassava	21,057	20.4	2	-	-
Millet	11,914	20.2	3	7.4	6.6
Sorghum	7,350	15.2	3	0.8	3.9
Rice	3,806	39.5	1	35.0	66.5

(Official crop production and sales data 1990)

The characteristics of each district for crop production are as follows: maize production in Kaoma is very high compared to other districts being six times higher than that of Sesheke which has the same planted area, and accounting for three to six times more production per unit area than other districts. Kaoma is the only suitable area for maize production. Kaoma is also the main production area for cotton in the Western province, this production being almost nil in other districts. Soybean is also produced mainly in this district and contributes a large part in the production of the province. Concerning other districts, Sesheke produces a little less than 70% of the groundnut of the province, and Kalabo 90% of the beans other than soybean. Rice, the outstanding crop of the province, is planted and produced in both Mongu, 50~60% of the province, and Kalabo districts, 20~25%. (See Appendix Table I.2.2)

Among the above mentioned five crops, in 1989 and 1990, maize and rice were about 50% commercialized, millet 6~7%, sorghum 1~2%, and cassava 0%, showing that the latter three crops are for local consumption. (See Appendix Table I.2.3)

The production of maize, main and important food crop, depends almost entirely on the Kaoma district. In fact, taking the average of 1988~1990 food self sufficiency in any district was under 100% with the exception of the kaoma district which shows 166%, the percent for the province amounting to 60%. As seen in the Development Plan in the Western province, the achievement of food self-sufficiency in the province is important and the agricultural development of the flood plain is emphasised. (See Appendix Table I.2.4)

(2) Animal husbandry

In 1989, cattle numbers were five million and thirteen thousand, which shows that it is a very important livestock as compared to pig with 37 thousand, and goat with 69 thousand. The Western province holds 20% of the country's livestock and ranks second nationally following the Southern province with 40%. Cattle in the Western province are all raised by small farmers.

In each district, Senanga accounts for more than average with 31% of the livestock of the province, Kaoma accounts for being 4.9%, and the others are between 10 to 20%.

The province has a plan to increase cattle raising through the development of the high lands, Dambos, and small river basins other than the Zambezi flood plain which is now utilized as grazing land. (See Appendix Table I.2.5)

With respect to crop production in the Western province draft cattle play a very important role. Apart from cassava, 40 to 65% of the crop production fields are cultivated by draft cattle. The province has a target to raise this percentage up to 75% by 1994, especially for rice cultivation. At present, the number of draft cattle in the Western province are 87 thousand showing 16 heads per farmer, and 0.9 head per ha. At the district level, Senanga keeps as many as 1.6 heads both per farmer and per ha, whereas Kaoma keeps less than 0.5 head per farmer and 0.2 per ha. Other districts rank close to the average of the province. The same observations were made in the discussion concerning the total cattle distribution described above. (See Appendix Table I.2.6)

(3) Size of farm

A large part of the farmers in the Western province own small farms. Five main crops, maize, rice, sorghum, millet and cassava, are cultivated by these small farms which represent more than 90% of the total number of farms. The cultivated area for maize by the small farms is 77% of the total area devoted to this crop, and 80~90% for other crops. (See Appendix Table I.2.7)

From these facts, agriculture in the Western province is supported by small farms and the province is focussing on the development of small farms in the Development Plan.

1.3 Agriculture in the Mongu District

(1) Population

TheMongu district is located in the center of the Western province, and the population centered around Mongu, capital of the Western province. Owing to the 1990 census, the population of the Mongu district was 140 thousand representing 23% of the total population of the province and its density of 14.1 inhabitants/km^2 is well over not only the province's density of 4.8 inhabitants/km^2 but also the country's 12.4 inhabitants/km^2.

(2) Topography

The Zambezi river runs through the province from north to south, and a large part of the Mongu district is located on the east side of the river. The high lands which essentially consist of the Kalahari sand with 1,000 m altitude run from the Kaoma district and connect with the Zambezi flood plain through gentle slopes with a relative height difference of 40 m. The high lands consist of ridges, the highest parts bordering the flood plain, the dune areas lying inside the ridges with dambos, and upland seepage valleys. The flood plain consists of the edge of the flood plain (Mataba seepage zone), and the sandy terraces (Outer plain) towards the river (Figure 1.3.1).

1) High lands

a) High ridges

These are the highest parts of the high lands bordering the flood plain. They have 50~80 m relative height from the flood plain, the east side of it is the dune area with 20~30 m lower elevation, and the west side slopes towards the flood plain connecting with the Mataba seepage zone.

b) Dunes

These are divided into high dunes and low dunes. The former are relatively 20~30 m higher running almost from south to north, and the latter occupy a large part of the high lands and are almost flat.

c) Dambos

There are many dambos in the high lands but they are rarely found in high ridges. Their shapes are circular, ellipse or pear like, with 1 ~ several km diameter. There are two types: one is periodically dry and is not affected by groundwater; and one is wet and forms a permanent pond.

d) Upland seepage valley

The few streams on the predominantly sandy high lands show rivers with wide widths, shallow valleys and gently sloping banks.

2) Flood plain

From the high lands to the Zambezi stream (Meander plain), there are three zones; "Mataba seepage zone", "High sand terrace" and "Low sand terrace". The latter two terraces from the "Outer plain" are called Saana.

a) Mataba seepage zone

This zone is the edge of the flood plain with 0.5~1.5 km wide being supplied with groundwater from the high lands, and consists of a sloping zone from the high lands followed by a flat zone.

b) High sand terrace

This is a zone at a somewhat higher altitude barely getting affected by the floods of the rainy season; especially, the mound areas in high altitudes almost never flood.

c) Low sand terrace

This zone lies the nearest to the stream area (Meander plain), and gets flooded during the rainy season.

(3) Soil

The characteristics of the soil are described in the items concerning the Western province, however, they will be again explained here in detail with a particular emphasis put on mainly the ridge of the flood plain (Mataba seepage zone) where the verification study is being conducted.

The Mataba seepage zone is divided into three zones: Litongo, Sishanjo, and Mataba Sitapa (Figure 1.3.2).

The litongo is a gently sloping area connecting the high lands to the flood plain. It is divided into dry litongo and wet litongo, and mainly consists of peat-muck from organic matter decomposition and in some cases it is mixed with basic sand, silt or loam.

The sishanjo is slightly swampy peat-muck soil originating from accumulated but not fully decomposed organic matter, with sometimes the peat-muck layer reaching 1 m depth. This soil is strongly acidic sometimes associated with the deficiency of micronutrient elements such as copper and zinc. Towards the center of the flood plain, the peat-muck layer becomes thinner and connects with the Mataba Sitapa zone.

The Mataba Sitapa is a transitional zone to the Saana sand terraces which are located further out into the flood plain. The Mataba Sitapa central part consists of higher silt or clay with a high fertility, but its surrounding areas are always affected by the floods and are characterized by sandy soils with humus deficiency.

(4) Agricultural production

The main crops in the Western province are rice, cassava, maize, millet and sorghum. Among these, in the Mongu district, rice occupies 60% of both the planted area and the total production (Table 1.3.1). As described in the items concerning the Western province, 50% of the rice production is commercialized making it an important crop for farmers' income. Mongu holds an important position as the center of the rice production area in the Western province.

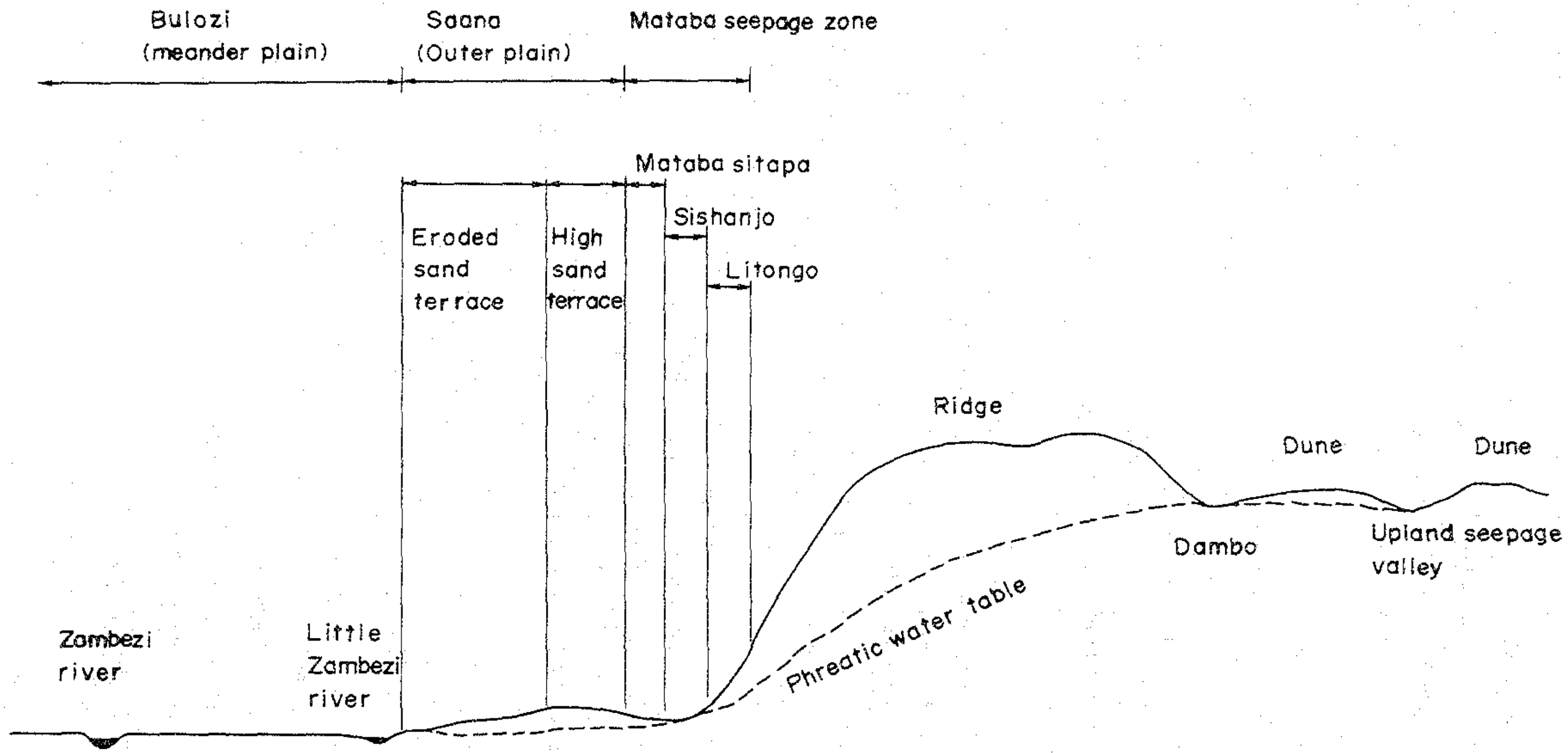

Figure 1.3.1 Schematic Cross Section of the Zambezi Flood Plain

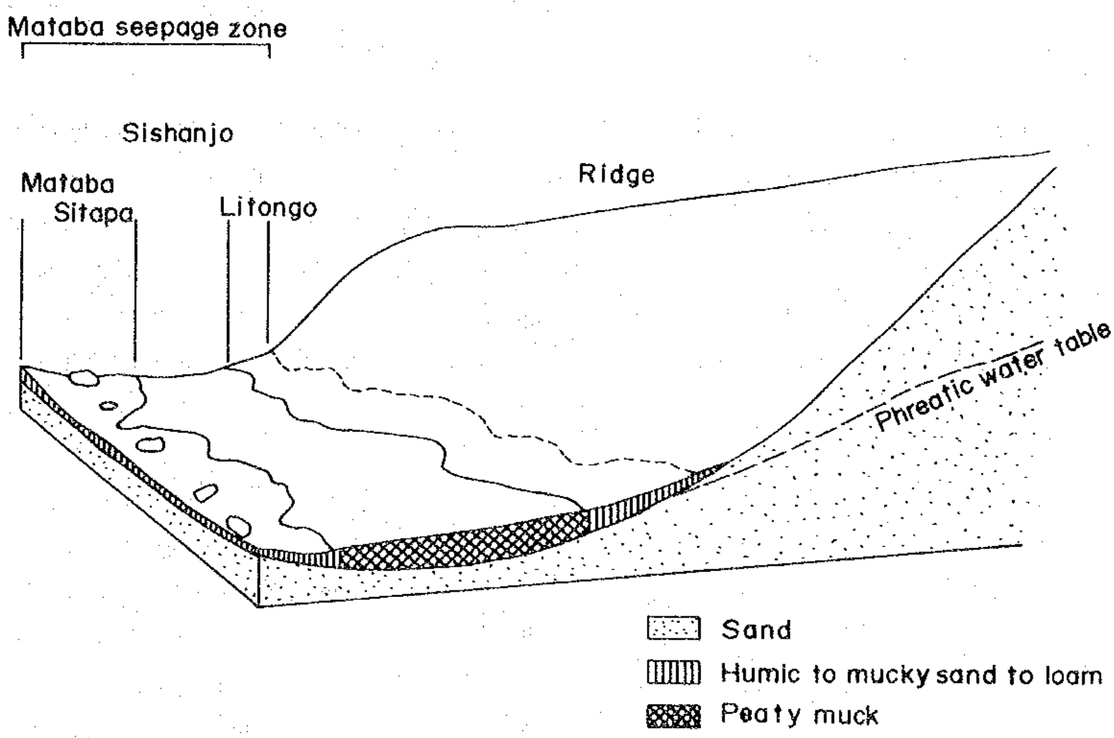

Figure 1.3.2 Schematic Diagram of the Matapa Seepage Zone

Table 1.3.1 Planted Area and production of Main Crops in Mongu District (1990)

	Area			Production		
	ha	Percentage in Western Province	Ranking among districts	ha	Percentage in Western Province	Ranking among districts
Rice	3,713	59.6	1	2,549	62.2	1
Cassava	8,005	38.4	1	3,634	30.7	2
Maize	4,828	12.3	4	2,083	5.5	4
Millet	1,799	12.5	4	584	13.1	5
Sorghum	524	7.2	5	194	8.9	5

(Crop forecasting 1990)

Among the crops destined for local consumption, cassava holds the highest rank in terms of planted area and the second rank in terms of production level among the provinces. Maize, millet, and sorghum show 4~5 rank, being not so important. Maize is the most important in Zambia, but as already described, the Western province produces only 5% of the whole country's productivity with the Kaoma district being the only production area and Mongu the fourth rank in the province with a low production per unit area.

Concerning these five crops, more than 90% of the planted areas are cultivated by small farmers, and about 10% by emergency farmers without any commercial farms, and a few institute farms. The planted area per crop per farm is 0.5~1.0 ha for small farmers, more or less 1.0 ha and at the most 2.0 ha for emergency farmers. From these numbers it is estimated that the planted area per farm is about 1.0 ha in Mongu. (See Appendix Table I.3.1)

The animal husbandry situation in the Mongu district is almost the same as in the province.

1.4. Subject and Progress of the Agricultural Verification Study (AVS)

1.4.1 Circumstances of the Execution of the Study

In the 1970s, the Sahel Club was created by western developed countries in the headquarters of the OECD in Paris for the purpose to exchange information and ideas on measures to stop drought in Western Africa which was followed by direct action. Afterwords Japan began its grant aid program in 1976.

After 1983, more severe droughts occurred, and an increase and a broader type of aid to these countries became an international theme. Japan has sent several missions since October, 1984 for the purpose of agricultural cooperation.

During these activities the Japanese Government recognized the shortage of information concerning the natural environment, crop cultivation, water management, etc... in making development plans. To resolve these problems a decision was made to organize a Verification Study for information collection which would be included when making development plans. Because of the above mentioned reason a new type of budget system was organized and the Agricultural Verification Study (AVS) started with a slightly different approach to ordinary development surveys.

At first in Senegal, a semi arid area of West Africa, an AVS was carried out for four years from 1986. After Senegal, the same study was planned for an East African area and Zambia was selected because of its high potential for agricultural development due to its vast amount of unused land. The Japanese Cooperation Agency (JICA), entrusted by the Japanese Government, sent a survey mission to Zambia in February 1987 to prepare a master plan for an AVS. The mission group and the relevant Zambian authorities agreed in principle on the implementation of the aforementioned studies around Mongu in the Western province. JICA sent another mission to work out the framework for the studies in October 1987 following the request in August 1987 of the Government of Zambia, and the representatives of both the parties signed a plan of the scope of work for the study.

1.4.2 Objectives and Principle of the Study

(1) Objectives of the study

The agricultural verification study aims at the establishment of stable agriculture in a target area through the collection/assimilation of data and information concerning the actual conditions prevailing in the agricultural sector and also through the trials and surveys to proceed in the verification field and the surrounding local fields by referring to the results of previous studies in Japan concerning development of agricultural technologies and land consolidation.

Based on the fact that the Mongu area is the main rice producing area in the Western province and the province itself is also the main rice producing area in Zambia, the actual objectives are set to develop comprehensive agricultural techniques centering on rice cultivation followed by upland crops, and proper land consolidation standards for these techniques, focusing on making guidelines of farming practices and land consolidation standards.

(2) Plan of the Study

The study consisted of three stages: the first stage is field survey and data collection; the second is the construction of the verification farms; and the third is the conducting of verification trials and surveys on verification farms and their surrounding areas.

1) Stage I (March 1988 - June)

After a general survey of the target area, two verification farm sites, namely Namushakende and Lealui were selected from eight candidate sites, and the plan for the verification trials to be conducted on the verification farms were examined.

TheMweke Dambo was selected, not from the candidate sites but for the data collection of meteorology and hydrology, although verification trials were not conducted.

2) Stage II (July 1988 - December 1989)

After deciding on land-consolidation standards for the verification farms, topographic and soil surveys were conducted in and around the verification farms. The design of the farms and their facilities were done and later the farms were constructed.

Verification farms	:	NAMUSHAKENDE FARM (4.9 ha)
		LEALUI FARM (2.0 ha)
Hydrological observation site	:	MWEKE DAMBO (observation road, observation wells)

3) Stage III (Nov. 1988 - Jun. 1992)

Using the verification farms constructed during Stage II, trials for crop production techniques centering on paddy rice and also irrigation and water management trials for these crops were conducted. Associated with these trials, investigations of equipment for the verification farms, were conducted along with soil, hydrology, and topography surveys which were carried out in areas considered to be appropriate for agricultural development. Based on the results of these trials and surveys, guidelines of farming practises, irrigation/water management, and land consolidation standards were determined.

(3) Principles of the study

In the targeted areas, agriculture is managed almost entirely by small farmers and the development plan of the area emphasizes on the development of small farms. The main agricultural area is on the edge of the flood plain and rice is the main crop of this area. In the flood plain, at present, there are no facilities for land consolidation resulting in unstable agricultural production owing to fluctuations in rainfall. However, under the conditions of land consolidation, there is the possibility to establish stable agriculture centered on rice cultivation. Considering these circumstances, the principles of the study were decided as follows:

1) Small farmers are the main subjects of the system.

2) The system is technology under irrigation facilities.

3) The system aims at a low cost and steady technology with rice-upland crop double cropping using animal and man power.

4) Two basic cropping patterns are considered in this system.

- Early rice - Cool dry season upland crops
- Late rice - Hot dry season upland crops

5) Soil improvements are emphasized for the improvement of plant growth. The heavy application of chemical fertilizers should be excluded.

6) In consideration with the importance of inland fishery, the use of agricultural chemicals should be restricted for environmental conservation purposes.

(4) Process of the study

The study and survey for crop production and land consolidation technologies were conducted through the following processes.

1) Crop production technology

a) Trials for component technologies of the farming system will primarily be carried out.

b) Depending on the component technologies and related information, the farming system will be tried and verified. Problems in the system, if found, would return to component technology trials.

c) Production cost, efficiency, income, etc. in the farming system will be calculated for the evaluation of the system.

d) The adaptability of the farming system may be investigated by the means of on-farm trials.

e) Depending on the established farming system and supplementary component technologies, guidelines of farming practices will be formulated.

2) Land consolidation technology

a) The irrigation and water management trials, and the survey for the structure and functions of facilities will proceed on the constructed verification farms and the data will be utilized for determining the land consolidation standards.

b) Surveys for topography, hydrology, soil, and on the existing agriculture will be conducted in the area of the flood plain where somewhat different conditions from the verification farms are found and traditional agriculture is practiced. Thereby the land consolidation standards will be investigated by selecting the area, as a model.

c) Finally, the guidelines for the land consolidation standards applicable to the agricultural development in the flood plain will be determined.

d) Surveys for meteorology, hydrology, topography, and soil will be practised and standard land utilization will be investigated for determining the suitable crops and their location in the Mueke dambo.

1.4.3 Progress of the Study

As already described, during I, natural and socio-economic conditions, and farming practises in the study area of the Western province including Mongu were surveyed, and based on these data, verification farm sites were decided; during Stage II, the verification farms were constructed, and the plans to be carried out on the verification farms were decided; during Stage III, verification studies were conducted on the farms for crop cultivation, water management and surveys for the facilities of the farms, and also surveys for topography, hydrology, and soil in the surrounding areas to be considered appropriate areas for agricultural development were conducted.

(1) Selection of the verification farms (February - May 1988)

The natural conditions, socio-economic conditions, farming practices, and etc. which prevail in the study area were surveyed utilizing useful materials and data offered by the related Zambian national and provincial organisations. Furthermore, precise surveys for the surrounding area of the eight designated candidate sites for verification farms offered by the Zambian side were conducted. The candidate sites are shown in Fig. I.4.3.1. Considering the above mentioned data and also consulting with the Ministry of Agriculture and the Western Provincial Agricultural Office, the two sites, Namushakende and Lealui, were selected. Both Namushakende and Lealui area located in the Zambezi flood plain.

Besides the flood plain, many dambos are located on tableland and they are considered as important agricultural production areas, but because of the little hydrology and meteorology data on the concerned dambos, it was difficult to determine consolidation standards for the verification farms construction. Therefore, the selection of a dambo as a verification farm was abandoned. However, considering the agricultural utilisation of a dambo in the future, surveys for meteorology and hydrology and also for topography and soil were to be conducted in the Mweke dambo which can be accessed from Mongu although not included in the original candidates.

(2) Construction of the verification farms (July 1988 - December 1989)

Topography and soil surveys for the two selected sites were conducted during July to August 1988. The construction of the farms were planned to be implemented over a two year period, considering a feasible construction pace. In the first year 2.3 ha out of 4.9 ha for the Namushakende farm and 2.0 ha of the Lealui farm and roads, levees, irrigation canals, and drainage ditches for both farms were constructed, and in the second year the remaining 2.6 ha in Namushakende and warehouses for both farms were completed. The construction of the observation pipe and its access road in the Mweke dambo were completed in the first year.

(3) Verification trials and surveys (November 1988 - June 1992)

Using the verification farms constructed, cultivation trials for paddy rice in the wet season and upland crops in the dry season which constitute cropping systems with paddy rice and also water management trials concerning these crops, have been conducted. With these trials, the investigation of equipment for the verification farms, and surveys for soil, hydrology, and topography in the areas which are considered to be appropriate areas for agricultural development in the future, have been conducted. From the data acumulated from the above mentioned trials and surveys, guidelines of farming practises and of land consolidation standards will be determined.

In Namushakende, the trials began from the 1988/1989 paddy rice season and involved a total of four paddy rice seasons including 1989/1990, 1990/1991, and 1991/1992, and all three cool and hot dry seasons of 1989, 1990, and 1991. The cool dry season upland trials were conducted only in Namushakende because the cropping system with early rice can only be practiced there. In Lealui, the three paddy rice seasons of 1989/1990, 1990/1991, and 1991/1992, and the three hot dry seasons of 1989, 1990, and 1991 were involved.

Farming system trials in Namushakende and on farm trials in farmers' field, based on the aforementioned component trials of each crop, began from 1990/1991 paddy rice season.

The Namushakende verification farm is located on the edge of the flood plain where, at present, traditional agriculture is widely practised despite the lack of land consolidation. The results of the verification study could be applied if some land consolidation is carried out in this area. The soil of the Namushakende field belongs to the Sishanjo area with 0.5 ~ 1.5 m deep peat-much layers as described at Section 1.5.1. After one season of paddy rice and upland crops, it was observed that the soil became highly acidic with a marked micro nutrient deficiency in thick peat-muck layers. With these consideration in mind, a study of countermeasures associated with soil surveys conducted on the edge of the flood plain and farmers' field, and trial using several types of soils were carried out. With these tests and surveys, the results of the tests carried out in Namushakende would be widely applicable. On the other hand, the Lealui verification farm is located in the center of the flood plain, Saana, and consists of an entirely sandy area with water control difficulties.

Considering these circumstances, after the end of the second year trials (upland crops of 1989, and rice of 1989/1990), we reexamined the plan of the study and the priority of the study was set on the trials in Namushakende. Consequently, the determination of guidelines for farming practices and land consolidation standard were determined depending on the trials and surveys of the Namushakende verification farm, and also on farm trials and surveys surrounding Namushakende. In Lealui, only the component technologies trials were performed for water utilization under sandy conditions.

The progress of the study is shown in Figure 1.4.2, and depending on the results, guidelines for farming system technology, useful component technology, irrigation water management technology, and land consolidation technology were determined as the materials for agricultural development of the area.

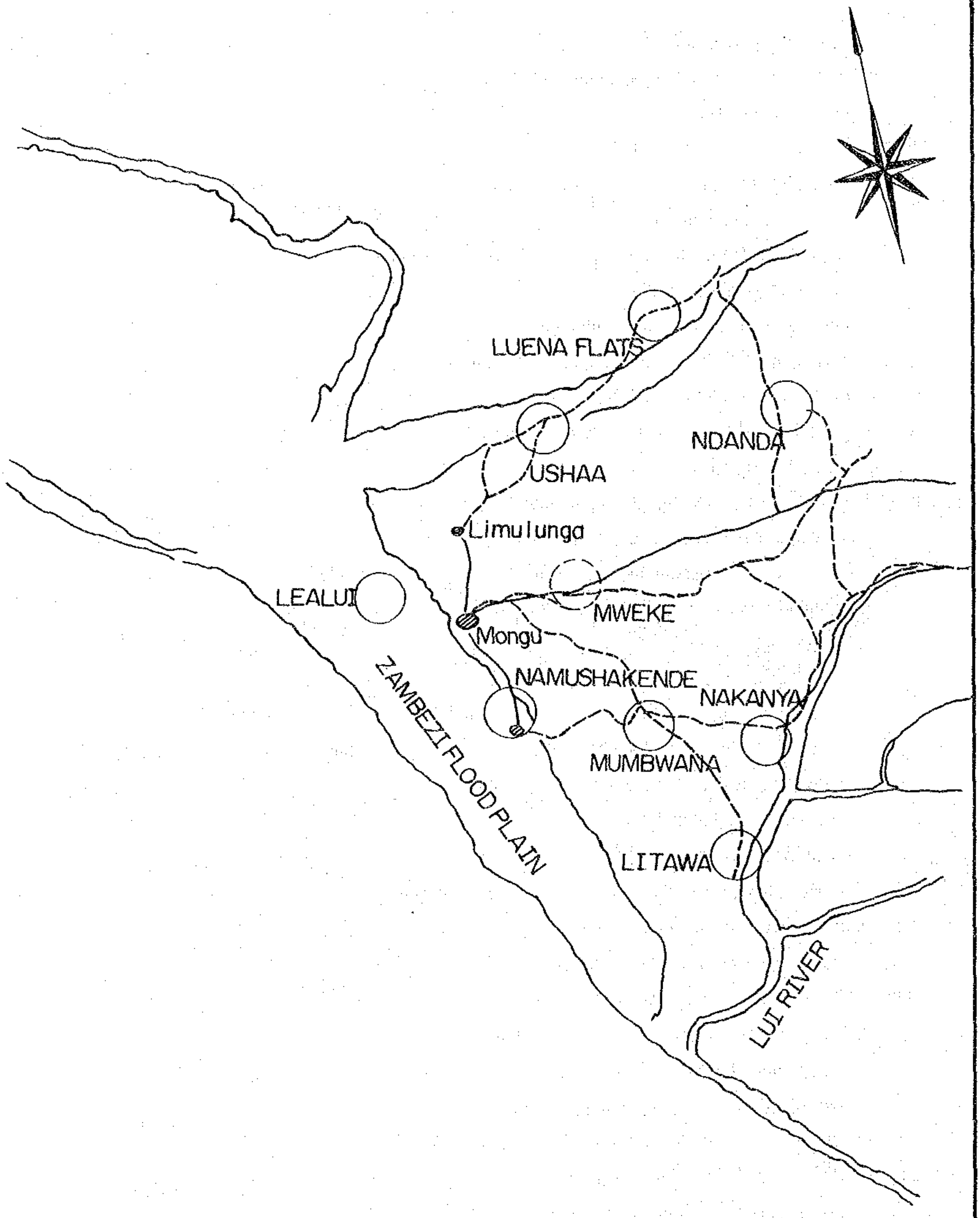

Figure 1.4.1 Map of Sites Proposed for the Potential AVS Farms

0 10 20 30km

Crop Production Technology

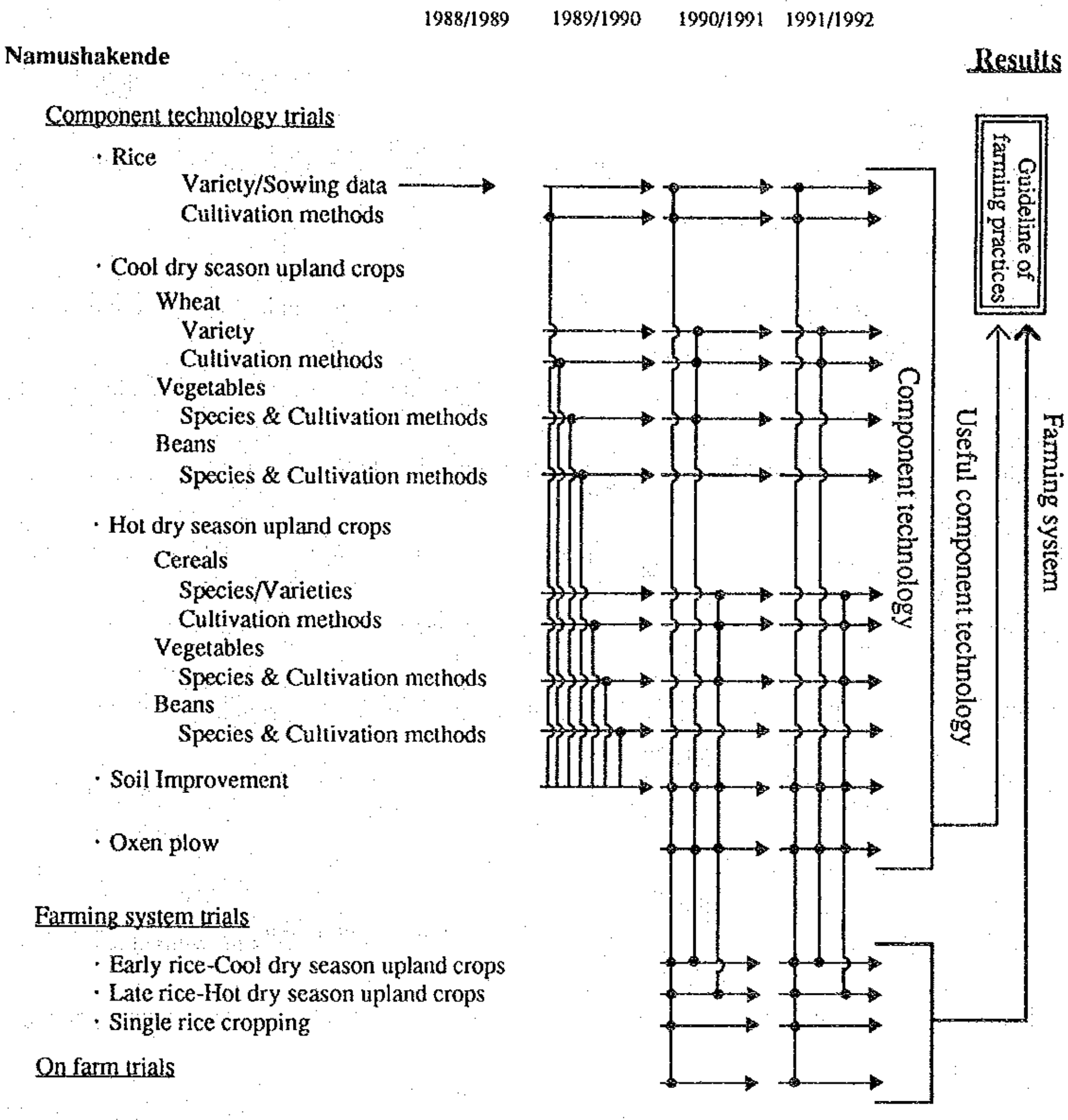

Figure 1.4.2 (1) Progress of the Verification Study (No.1)

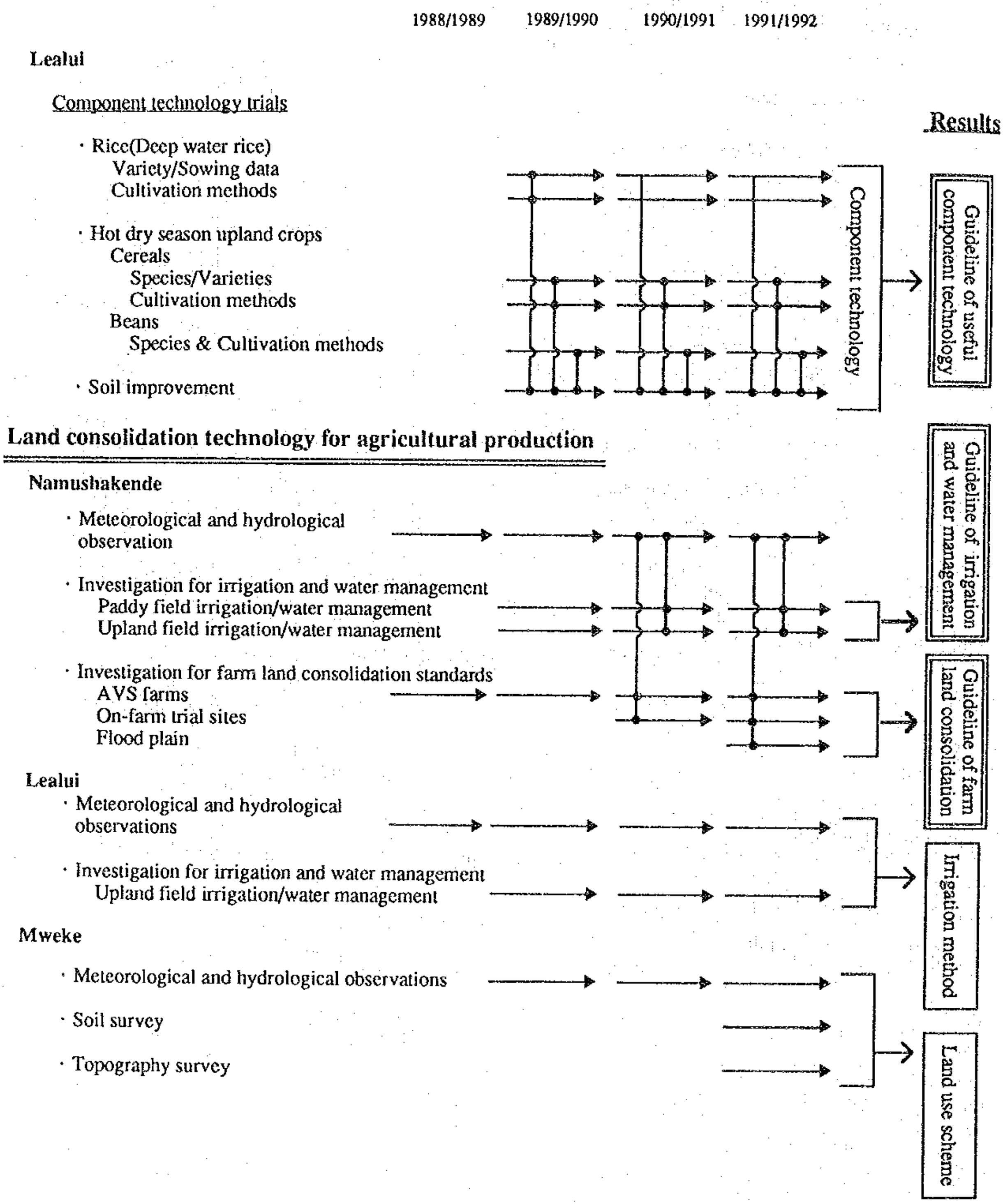

Figure 1.4.2 (2) Progress of the Verification Study (No. 2)

1.5 Outlines of the AVS Farms

1.5.1 Conditions of the AVS Farms

(1) The Namushakende AVS farm

The Namushakende AVS farm is located on the main stream side of the Zambezi River adjacent to the Musiamo Canal that runs parallel to the upland edge at the edge of the flood plain situated at approximately 25 km south of Mongu. The farm is easily accessible from Mongu using the paved national highway.

The topography of the farm and its surrounding area, with the micro highland on its west side (the Zambezi River mainstream side) and the planate lowland on its south side, is relatively flat with a maximum relative height of approximately 1 m. The Namushakende AVS farm generally belongs to the Sishanjo soil zone excluding the micro highland on the west side which is included in the Mataba Sitapa soil zone.

The surface soil of the micro highland on the west side is composed of well resolved black soil with a thickness of nearly 20 cm and sand underneath, and drains well. However, on the east and south side, the peat and muck strata becomes thicker (0.5 - 1.5 m and approx. 1.5 m respectively), causing poor-drainage (Figure 1.5.1).

The said conditions become even worse when the soil is acid and is thickly stratified with peat and muck. For the above reason, acid adjustments, which will be mentioned later, are required. The growth of field crops requires a thickness of 20 cm and under which enables good drainage conditions.

As the Namushakende AVS farm is located on the swampy lowland at the edge of the flood plain, spring water from the upland is available throughout the year and is utilized as an irrigation water source. On the other hand, the groundwater level is constantly high, causing poor drainage in this specific area excluding the micro highland on the west side. Being separated from the main stream of the Zambezi River by the sand terrace located near the center of the flood plain, this region is rarely hit by the direct influence of floods.

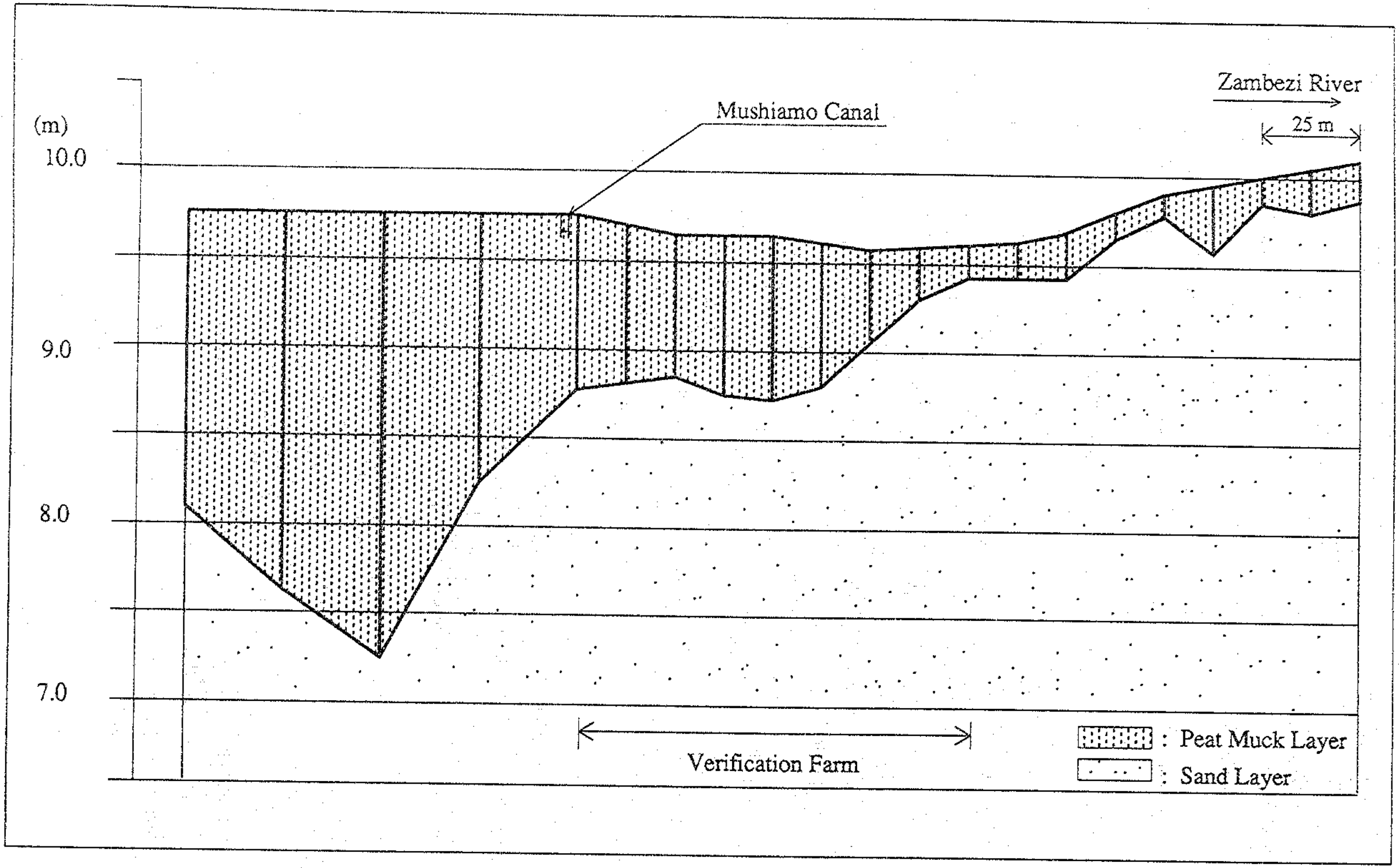

Figure 1.5.1 Peat-Muck layer in Namshakende

(2) The Lealui AVS farm

The Lealui AVS farm is located east of the Lealui village situated in the Mound of the flood plain, which is northwest of Mongu. It is approximately 15 km from Mongu by land. As the road is not paved, it cannot be used during the rainy season, instead, waterways are commonly used.

The Lealui area belongs to the Saana soil zone close to the center of the flood plain of the Zambezi River and is located from the high sand terrace to the low sand and eroded terrace. The former is free of flood influences and colonies are seen while the latter, where the Lealui AVS farm is located, experiences flooding.

The major part of this specific region including the AVS farm is flat and its soil is composed of thickly accumulated uniform coarse sand from the surface down to the lower stratum. Hardly any organic matter is found on the surface due to the fact that the region is covered with retarded grassland, thus only a small amount of organic matter is supplied, and the regrowth rate is low under dry conditions, plus it is washed away by floods in the rainy season.

On the surface of the micro highland on the south side of the farm, dark greyish-brown earth including a small amount of organic matter is observed. Meanwhile, in the swampy lowland on the east side, tall herbs densely grow and fine textured surface earth can be seen.

The flood water level widely ranges from year to year. The flooding depth in and around the AVS farm is approximately 0 -1.0 m. The groundwater level in the dry season is 1.5 - 2.0 m under the surface. In the Lealui AVS farm, the Mushiamo Canal on the east side is used as an irrigation water source, however, surface water sometimes dries up during the dry season, which necessitates the pumping-up of groundwater. In the rainy season, irrigation by gravity flow is possible if a normal flood water levels are attained, however, when water levels are low, pumps are used. On the other hand, when water levels are too high, the control of water levels over the farm area is difficult due to the fact that the soil mainly consists of sandy earth and permeability is quite high.

1.5.2 Construction of the AVS Farms

(1) Construction period

The Namushakende and Lealui AVS farms were constructed over the period from July, 1988 to December, 1989. This period was roughly divided as follows:

i) Measurement, design and preparation : July, 1988 - October, 1988
ii) The 1st construction phase : November, 1988 - February, 1989
iii) The 2nd construction phase : August, 1989 - December, 1989

(2) Outline of farm facilities

The number of major facilities constructed for both farms are shown as follows:

1) Namushakende AVS farm

	1st phase	2nd phase	Total
Farm land	2.3 ha	2.6 ha	4.9 ha
Main farm road	360 m	–	360 m
Branch farm road	600 m	460 m	1,060 m
Main irrigation canal	415 m	–	415 m
Farm ditch	305 m	525 m	830 m
Farm drain	300 m	165 m	465 m
Field road	500 m	200 m	700 m
Work shop	1	–	1
Cross culvert	–	1	1
Store house	–	1	1
Fence	750 m	640 m	1,390 m

2) Lealui AVS farm

	1st phase	2nd phase	Total
Farm land	2.0 ha	–	2.0 ha
Farm road	1,250 m	–	1,250 m
Main irrigation canal	310 m	–	310 m
Farm ditch	490 m	–	490 m
Farm drain	400 m	–	400 m
Pump station	–	1	1
Work shop	1	–	1
Store house	–	1	1
Fence	760 m	–	760 m

(3) Repair of facilities

Right after the first construction, the Lealui AVS farm was severely hit by one of the largest floods of the Zambezi River in the past decade and its surrounding farming roads and arterial canals were damaged. As a result, in the second construction phase, such repairs including the widening and rising of destroyed farm roads were carried out, also, the excavation of sedimentation at the bottom of the canal plus the repair and the earth lining of slopes were also conducted.

1.6 Scope of Utilization of the AVS Results

Based on the tests and surveys and the on-farm trials conducted on the edge of the flood plain, the results of the verification study have been presented as guidelines of crop production technology and land consolidation technology as shown in Fig. 1.4.2.

These guidelines are explained in details in Chapters II and III and should be understood as follows:

They are aimed at the Mongu area, mainly the flood plain where agricultural characteristics, natural environment, and farmers' social conditions vary according to the location in this area.

Consequently, the application of the guidelines necessitates certain revisions in relation to the area of interest.

The guidelines of crop production consider the application of the guidelines of land consolidation technology. This latter technology will apply to a group/groups of small farmers sharing a common irrigation and drainage system and consider a minimum but necessary level that can be developed under national/provincial fund with a possible foreign support.

The guidelines of land consolidation technology should constitute the bases of an actual development plan.

Thus, the guidelines of land consolidation technology (guideline of irrigation/water management and guideline of farm land consolidation) should be used by the agricultural civil engineers when making the actual development plan, and the guidelines of crop production technology should be used by the extension officers and the emergent farmers.

CHAPTER 2.

CROP PRODUCTION TECHNOLOGY

CHAPTER 2. CROP PRODUCTION TECHNOLOGY

Agricultural verification study involved in the component technology trials to elucidate each component technology and the farming system trials based on these results, and carried out on-farm trials in the farmer's land as well. Based on these trial results, this chapter covers the component technology in Section 2.1 which led to the guideline of the farming system expounded in Section 2.2 and furthermore, Section 2.3 explained the useful component technology which is directly applicable to the local condition. In addition, the elucidated countermeasures against growth constraints are described in Section 2.4.

2.1 Component Technology

The production technologies related to each crop are described.

2.1.1 Paddy Rice Cultivation

The annually increasing demand for rice grain in Zambia exceeds the supply, which was only approximately 9,200 tons per annum in the 1989 - 90 cropping season (paddy rice basis). The Western province of the country ranked as the 2nd largest rice-producing province after the Northern province covered 35.5% or 3,275 tons over the national output in the same season. Further, the area devoted to rice in the Province covers 39.9% of the entire rice area cultivated nationwide and tends to increase along with production. However, the grain yield per unit area in major rice-producing provinces only showed a minimum of 9 bags/ha (equivalent to 720 kg/ha).

Rice cultivation in the Province is mainly conducted in 3 different landscapes : along the depressed inland area called "Dambo", the river land at inland valleys, and at the edge of the floodplain, and the outer plain of the Zambezi river where alluvial deposits are distributed. The local practice of paddy rice cultivation depends on rain-fed paddy fields or flood water without levees in the local paddy fields.

Rice like maize, is an important cash crop, and harvests are transported to Lusaka, the capital city, through the Western Cooperative Union. Since rice cultivation in the Province depends on rainfed paddy, production is therefore unstable due to variations in rainfall. Furthermore, the extensive farming practices which entails a limited use of labor like broadcasting, no fertilizer nor weeding practices, result in low standard yields. The strict enforcement of selecting promising varieties, water use improvements, fertilization and weeding practices is, therefore, expected to bring about stable production and yield increases.

(1) Selection of promising varieties

There are 5 varieties, including the long and short culm varieties, which are most widely cultivated in the Western province. Deep water rice is cultivated in depressed landscapes like dambos and deeply flooded areas. However, except for Malawi Faya supplied by ZAMSEED, a system for the supply of certified rice seeds to the farmers has not been officially established. On the other hand, the short culm variety ITA222 was recently introduced experimentally in fields with shallow flood water depths, and became popular.

In this verification study, the promising varieties recommended are based on variety test results of 22 varieties which were acquired from the Kalabo Agricultural Development Project (KADP) in the Province, where the National Rice Variety Test (NRVT) on a nationwide scale was carried out.

They are the local long culm variety of Angola Crystal, the early maturing short culm varieties of Xiang Zhou 5, C1158 and ITA series, and the late maturing varieties P1369, P2023, IR8192. The characteristics of these varieties gathered from the past 4 cropping experiments are shown in Table 2.1.1.

Table 2.1.1 The Characteristics of Major Varieties

Variety	Grain yield (t/ha)	Culm length (cm)	Growth span (days)	Variety	Grain yield (t/ha)	Culm length (cm)	Growth duration (days)
Xiang Zhou 5	4.6-7.2	44-85	114-117	P1369	4.3-5.9	44-45	133-152
C1158	4.5-6.5	33-42	117-131	P2023	4.3-5.3	46-50	134-150
ITA222	4.1-5.8	41-46	120-138	IR8192	4.5-5.6	53-54	134-153
ITA225	4.0-4.7	41-50	120-138				
ITA234	4.8-5.3	38-42	120-140				
Angola Crystal	4.5-6.2	81-123	119-127				

Note: Growth span is based on direct sowing method.

These results are the summary of various trials including the variety test of different sowing dates over 2 months spanning from late October to December with a certain interval, and with seed rates of 60 kg/ha, 30 cm row space, the incorporation of rice straw, liming of 1.5 t/ha, D'mix of 250 - 300 kg/ha and urea of 100 - 120 kg/ha.

The growth duration of the varieties were extended as shown earlier; that is, the early maturing varieties of the late October sowing date was around 130 - 140 days, while that of those sown in late November were shortened to more or less 120 days. The late maturing varieties were shortened to more or less 130 days from 150 days. The early maturing varieties sown in mid-November ripened in mid or late March, becoming sufficiently suitable to the double cropping system of the following crops, onion and wheat. Of the early maturing varieties, Xiang Zhou 5 was a promising variety which could grow under flood conditions of 47 cm depth, and water stress conditions caused by long dry spells by developing deep root systems.

(2) Important points in cultivation practices

1) Optimal cultivation time

The cropping time varies widely depending on the soil type. Direct sowing in dry soils in the fields with thick peat muck soils located on the Zambezi floodplain edge called "Sishanjo" should be completed by mid-November because oxen plowing operations get into difficulty during the progressive rainy season. In fields of sandy loam or loamy soil which extend in the outer plains, however, sowing can be allowed on dry soil until the beginning of January, together with oxen plowing, due to good drainage conditions and an adequate soil bearing capacity.

From the observations made so far, a single cropping of paddy rice is suitable in the areas on the Sishanjo band where peat-muck soils are thickly distributed. Meanwhile, double cropping and direct sowing on dry soil even until late December is also possible in the fields of Mataba-Sitapa and the Saana zone where good drainage conditions and a high bearing capacity of the soil are available.

2) Planting density

The screening of seeds via water, and the sowing of dry seeds at 60 kg/ha with 30 cm row spaces are recommended. The emergence rate depends upon the condition of the harrowed field, hence the field should be harrowed thoroughly making clods smaller than a fist size. It is also important to prevent rainwater from pooling over long periods of time after direct sowing on dry soil.

3) Fertilizer dosage

Any of the N, P, K elements are essential to the growth of the rice plants, and the effects of N, P elements are considered significant, particularly in peat-muck soils. Hence, the lack of basal fertilizers would result in poor growth with low yields. 250 kg/ha of D'mix is a standard dosage for a basal dressing. Nitrogen fertilizer shall mainly be used as a top dressing, and 50 kg/ha of urea shall be applied in both the tillering and meiosis stages, respectively.

The top dressing dosage should be lessened in case of highly productive soils planted with local long culm varieties. The effect of phosphate in Sishanjo soil is quite high in terms of the increased number of panicles/m^2 (see Table 2.1.2). However, potassium produced no significant effects when applied on the said soil.

Table 2.1.2 Effect of Phosphate in Peat-muck Soil

Field	P-treatment	Grain yield (gm/m^2)	Culm length (cm)	G/S ratio	No. of Panicles/m^2
A	NK	317	44.8 ± 3.9	1.0	117
	NPK(S)	340	41.7 ± 4.1	0.79	161
	NPK(H)	433	43.0 ± 2.6	0.90	198
B	NK	341	39.9 ± 2.1	0.91	148
	NPK(S)	417	42.8 ± 1.9	0.78	231
	NPK(H)	463	42.3 ± 3.5	0.75	256
C	NK	368	40.3 ± 1.7	0.89	151
	NPK(S)	360	39.7 ± 1.7	1.26	120
	NPK(H)	388	39.4 ± 2.1	0.87	162
D	NK	248	38.2 ± 8.7	0.56	170
	NPK(S)	383	38.6 ± 1.3	0.66	232
	NPK(H)	343	39.1 ± 7.4	0.68	253
E	NK	333	39.1 ± 2.1	0.87	158
	NPK(S)	402	40.6 ± 2.9	0.85	186
	NPK(H)	380	38.8 ± 6.6	0.74	192

Note: S: Standard dosage of phosphate treatment (60 kg/ha)
H: Heavy dosage of phosphate treatment (120 kg/ha)
Variety: P1369 transplanting

4) Countermeasures for Akiochi-symptom

The rice plants grown at the edge of the Zambezi floodplain usually show brown spot (Helminthosporium oryzae) during the late growth stage due to a deficiency of fertilizer. The results of the tissue analysis of the flag leaves of the rice plants showed deficiencies of N, P, K (although silica is also an important element, which is difficult to analyze in local research institutes). Thus, it is important to maintain soil productivity by applying organic materials like cattle manure. Rice straw should not be applied in this double cropping system due to its slow decomposition before the planting of the second crop.

However, rice straw application in the single cropping system is possible as there is enough time for decomposition during the cool and hot dry season. Thus this method can be applied as a countermeasure to the Akiochi problem and can increase rice yields.

Table 2.1.3 shows the results of rice straw incorporation trials done during the 4th year. The rice straw treated plot boosted a 43% increase in grain yield and the smallest occurrence of brown spot. This was achieved by plowing the field three to four times in order to accelerate the decomposition of rice straw after application.

Table 2.1.3 The Effect of Rice Straw Incorporation in Peat-muck Soil (1991 - 92)

Treatment	Grain yield (gm/m^2)	No. of Panicles ($/m^2$)	G/S ratio	Culm length (cm)
+ Straw	579	205	1.25	51.1 ± 3.7
– Straw	404	172	1.16	46.4 ± 4.4

5) Determination of optimal harvest time

The determination of the optimal harvest time is a very important post harvest technique, and is normally set 30 days after flowering. From the appearance of the rice plants, the optimal harvest time is determined when the panicle changes the color of most of its spikelets into gold and 2/3 of the tip of the rachis turn yellow. A delayed harvest would usually result in a severe break-out of cracked rice kernels, while an early harvest would induce the increase in green rice kernels. In any case, the grain quality inevitably deteriorates. Therefore, it is very important to determine the most appropriate time for harvest.

The harvest method employed entails the cutting of the base of the stock and heaping the rice in bundles with the panicles arranged inside to avoid bird damage. Observations made on local fields indicated severe shattering when the grains became too dry as a result of an untimely harvest, leading to the inevitable deterioration of the grain quality regardless of the variety used.

6) Disease and pests

The problems related to the onset of emergence are damages caused by birds and rats, and chewing damages by the black maize beetles (Heteronychus spp). Birdscarers must be present in the fields to prevent bird damages, and rat traps must be placed to reduce the rat population with the cleaning of the grassy areas around the rice fields. The scattering of rice grains around the field as a lure crop for rats is a good substitute in case rat traps are difficult to acquire. On the other hand, the black maize beetles can be easily exterminated by flooding the paddy fields. Weed infestation, in both the Sishanjo and Mataba-Sitapa areas, is severe during the upland crops period from the emergence stage to the flooding of the field. Therefore, interrow cultivation combined with a good weeding practice should be enforced after applying the basal dressing, otherwise the initial growth of the rice plants will be severely suppressed and this will induce a reduction in grain yield or no grain yield at all.

Bird and rat damages intensify during the ripening period, but these can also be controlled through the use of rat traps, lure crops, and through birdscarers. Bird damages observed in the Sefula on-farm trial site amounted up to 40% of the yield when it was concentrated on one lot of land, hence enforcing bird scaring operations is important.

The extent of the sucking damages caused by rice bugs (Sletocorisa Varicornis) varied according to variety and place. In the Namushakende farm, sucking damages frequently occured. Rice blast diseases (Pyricularia oryzae) usually occured when local long culm varieties are grown in upland conditions due to continuous dry spells. Irrigation management, therefore, should be conducted with proper care.

(3) The Relationship between oxen plowing and soil bearing capacity

1) Predicted threshold value of cone bearing capacity (CBC) with respect to the introduction of oxen plowing

The relationship between the soil bearing capacity and the introduction of oxen plowing operations in the farming system which mainly relies on animal draught power, is very important in the beginning of the progressive rainy season.

This relationship in peat-muck soils was studied at the Namushakende verification farm located in the Sishanjo zone of the Zambezi floodplain edge. The predicted threshold values of the CBC for the oxen plowing operations were 2.45, 1.13 and 0.72 kg/cm^2 (corresponding to 5, 10 and 15 cm depth) in the peat-muck soils beyond 60 cm thickness. On the other hand, the CBC of oxen getting stuck in the same field was 1.81, 0.68, and 0.87 kg/cm^2 from top to bottom respectively.

The 2nd measurement conducted the following year in the same fields resulted in 0.94, 0.79 and 0.87 kg/cm^2 when middle size oxen were going through without getting stuck. Meanwhile, the CBC at the points where the oxen did get stuck were 0.96, 0.38, and 0.34 kg/cm^2 from top to bottom. From these studies over 2 measurements, the CBC of 10 and 15 cm depth appears to be more significant than that of 5 cm depth in the introduction of oxen plowing operations, and at least 0.8 kg/cm^2 up to 15 cm depth appeared to be necessary for plowing operations by middle size oxen.

2) Change of CBC over time and the introduction of oxen plowing

The CBC and moisture ratio in peat-muck soils and sandy soils in the Sishanjo zone were measured from the beginning of the rainy season up to the period when the field was flooded. The CBC of the peat-muck soil decreased from the top layer downwards when the soil surface was relatively dry in the early rainy season, while opposite results were observed in the sandy soil.