EXISTING CULTIVATION SYSTEMS
IN THE HIGH RAINFALL AREAS OF ZAMBIA

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I. INTRODUCTION:

For a long time different shifting cultivation systems have been practised by farmers in the high rainfall areas of Zambia. However, since the systems are geared to a low level of productivity and bound to become increasingly inadequate as the population continues to increase, there is need to adopt more stable agricultural systems to replace the present ones. But before designing new agricultural systems, investigations and review of previous and existing farming systems is important. This is one of the objectives of the Soil Productivity Research Programme (SPRP) in Phase I.

This report was supposed to bring to the SPRP informations regarding previous and existing agricultural systems in the high rainfall areas. Due to limited literature and time, I have only been able to obtain informations from the widely practical systems in Northern Province, the Chitemene and Grass mound systems.

....../2

II. SHIFTING CULTIVATION SYSTEMS:

Shifting cultivation is the name we use for agricultural systems that involve an alternation between cropping for a few years on selected and cleared plots and a lengthy period when the soil is rested to restore its fertility. Cultivation consequently shifts within an area that is otherwise covered by natural vegetation.

In a FAO Soils Bulletin No. 24, Shifting Cultivation and Soil Conservation in Africa, areas under shifting cultivation systems in Zambia has been estimated to 1,900,000 hectare while the total arable land and land under permanent crops are 4,800,000 hectare (Braun, 1974). These figures tell us that nearly 40 per cent of the land is under shifting cultivation systems. According to Mansfield et. al. (1975) shifting cultivation systems are the dominating farming systems both in Northern and Luapula Provinces. Counts made over the Makasa and surrounding areas between 1932 - 1933 revealed:-

a) Total hecterage 311,000

b) Number of gardens burnt 1,346.

c) Number of hectare lopped to provide wood for burn 5,470 ha.

d) Average yield of finger millet 1,680 kg/ha (Boyd, 1959).

It was further estimated that 1.8 per cent of the country was being cut annually and taking 15 years as a minimum requirement for tree regeneration, 30 per cent of the woodland was out of production at any one time. Further estimates states that 40 per cent of the country was not suitable for chitemene and only 30 per cent remained for cultivation. These figures have drastically changed with increases in population (Mansfield, 1973).

A. The Chitemene System.

This method of cultivation which includes the use of natural forest or woodland as the agricultural fallow crop has been well described by Trapnell (1953). The system involves the lopping of tree branches between July and September before the trees lose their leaves. The cut branches are led on the ground to dry and later collected to form a round stack on the predetermined site. The hight of the heap could be about 1-1½ m, but may also be determined by the type of soils prevailing as it is believed that heat enters a light soil much more easily than a heavy one; hence a greater heap is laid on heavier soils than on light ones (Boyd, 1959).

The stacked up area can be of any size depending on the availability of loppings and how easily they can be carried. This was illustrated by Peters (1950) in Serenje, showing the burnt areas as a percentage of total area cut.

Table 1: Cultivated area as a percentage of total cut Serenje District (Peters, 1950)

No. of years regeneration before cutting	9-12	13-16	17-20	20-
Burnt area as a percentage of total cut	4.41	6.26	7.31	9.57

The size of the burnt area differ also according to the tribes. The Southern Chitemene (small ash circle) is practised by the Bisa tribe in Mpika District while the Northern Chitemene (large ash circle) is practised by the Bemba, Lungu and some of the Mambwe tribes. In the first case Peters (1950) gave the area of cultivated millet per head as 0.06 ha which required 0.67 ha of woodland. Trapnell (1953) gave a more general estimate of 0.4 ha per family of four persons and a requirement of cleared woodland of 4-11 ha.

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For the Northern Chitemene Trapnell estimated that the surrounding cut woodland ranged from 6.5 to 10 times the garden area, depending on the growth of woodland. Alder showed an average ash garden size of 0.12 ha.

The stack of cuttings are burnt prior to the beginning of the first rains which normally is by the end of October. The first crop is usually finger millet (Eleusine coracana), and the seeds are sown in the ash patch towards the end of December. Where cassava is popular, it comes first by planting cuttings obtained from older branches.

After the initial millet crop, the cropping sequence is largely of personal choice and are not confined to any one locality (Trapnell, 1953). The most common however, are:-

a) Millet - Groundnuts - Beans - Millet

b) Millet - Groundnuts - Millet - Beans

c) Millet - Millet - Beans - Millet

d) Millet - Sorghum - Beans - Millet.

Where cassava was planted, they would continue harvesting it bit by bit after two years until exhausted and the field will be abandoned for a long fallow period which may last up to 20 years (Mansfield 1973).

According to Schultz, (1976) cassava is grown by 87 per cent of the households in the Northern Chitemene system and can be found on 33 per cent of their land. Maize is grown by 74 per cent while finger millet is grown by 65 per cent of the households. These findings do not correspond well with the traditional cropping sequence where finger millet is planted as the first crop in the system.

Table 2 Northern Chitemene, areas and ratio of crops (Schultz 1976).

163 samples	Maize	Finger-millet	Cassava	Ground-nuts	Beans	Mean area
Mean area of crops per farm household (ha)	0.56	0.32	0.72	0.20	0.20	2.16
Mean area of crops per those farm households only which grow the crops. (ha)	0.72	0.52	0.84	0.36	0.40	
Percentage of farms which grow the crop	74	65	87	60	57	

The Chitemene systems have different carrying capacities and hence different critical population densities for their survival. In assessing carrying capacity from sustained cut-and-burn chitemene culture four factors should be considered:

1. The period required for adequate regeneration for the woodland.
2. The ratio of ash circle garden to cut woodland required for that garden and the size of the ash garden itself.
3. The proportion of the whole area which has woodland growth suitable for chitemene.
4. The area of additional gardens used by the people to supplement the ash garden when these directly compete for woodland.

The period required for regeneration will naturally depend on the vigour of woodland growth which in turn depends on the type of woodland, soil and climate conditions found locally plus the degree of protection from late fires. Trapnell (1953) for his overall estimates used 20 years as regeration period. Allan (1967) gained the impression that in areas more favourable to tree growth than the Serenje plateau where Peters used a 35 years regeneration period, shorter periods than that required for full regeneration were sufficient to sustain Chitemene of the order of 22 - 25 years. Mansfield et al. (1975) is using 20 - 30 years as regeneration period. Investigations done by SPRP in Mwenesanso village indicate a shorter fallow period, 5-10 years (Haug, 1981). The reason for this maybe a shortage of forest. Traditionally has Northern Chitemene system a shorter fallow period than the other types of chitemenes. This is because they only cut the top branches and leave the rest of the trees intact. By doing so a much quicker regrowth appears. In the past, however, one has started to cut down the whole trees.

Approximately 1.0 ha of land per person is cleared annually for chitemene. Totally an area of 40 ha per person is necessary when 60 per cent of the land is suitable for chitemene (Mansfield et al. 1975 and Allan 1967). For a household of 7-8 persons they require approximately 300 ha.

Table 3 Area per person and critical population densities in Northern Chitemene. (Mansfield et al. 1975)

	Total area with suitable land for chitemene			
	100%	75%	60%	50%
Weighted area required per head of Northern Chitemene		33.6ha	42.1 ha	50.6 ha
Average critical population densities, in number of persons per unit areas persons/km2.	3.9	3.0	2.4	2.0

Critical population densities in chitemene areas is estimated to 2 - 4 persons/km^2 depending how much of the land is suitable for chitemene cultivation (Mansfield et. al 1975 and Allan 1967). In Northern Province the population density varies between 1-4 persons/km^2. In some areas the population density is 4-10 persons/km^2 or more.

B. Grass mound system.

In contrast to the Chitemene system the Grass mound system is practiced in the treeless areas which Trapnell (1953) refers to as the "Northern Grassland System". This is a semipermanent type of millet and cattle culture, practiced by the Aisa Mambwe in Mbala. It is similar to some East African systems. In this system green grass towards the end of the rains is collected and soil is thrown over to form a mound. The vegetation rots quickly under its earth cover. Sometimes the mounds are utilized for a late bean crop. During the following December the vegetation on the mounds is scraped into the hollows between the mounds. Then the mounds are broken into a very fine seedbed. In January millet is broadcasted and reaped 5 months later. After the harvest, the garden is left until the early rains when it is either:-

a) Mounded and maize/bean planted.

b) Mounded around sorghums.

   These are the sorghums planted as a catch crop at scattered sites. When the soil is mounded around the sorghums, the remaining flat areas are put under groundnuts.

c) Left until the late rains when it is again mounded over grass for the next season.

The third year is again millet on flatened mounds followed by a legame or a fallow crop. Then similar to the second year is the fourth year; hence the system follows a definite system of green manure-cereal-green manure-legume -cereal. Such a process retards exhaustion (Boyd 1959, Trapnell 1953).

There are few data on length of cropping and fallow for this system. Usually the cropping period is 4-5 years (Mansfield et al. 1975). According to Allan (1965) the minimum fallow period on the most fertile soil should be 8 years. Investigations done by SPRP (Haug, 1981) indicate a fallow period of only 5 years. The same result was obtained by Schultz (1976). Mansfield (1973) and Boyd, (1959) believe in a resting period of 15-20 years. Taking an average of 5 years cropping and a garden size of 0.4 ha per head, the total garden requirement would be about 1.3 - 2.2ha.

Maize is grown by all farmers in the Grass mound system. Then follows beans grown by 92 per cent, groundnuts by 77 per cent, finger millet by 69 per cent and cassava by 62 per cent (Schultz, 1976). Approximately 70 per cent of the farmers are using fertilizer in their maize crop. For the traditional crops the farmers do not use fertilizer but compost and/or cattle manure (IRDP, 1981).

The Mambwe are keeping oxen which is an advantage concerning drawpower and available manpower. Approximately 60 per cent of the farmers have their own oxen or lend/hire oxen for preparing their fields.

As has been mentioned before the critical population density in the Chitemene system is 2-4 persons/km^2. The figures in table 4 show that the critical population density in the Grass mound system is much higher, approximately 20-40 persons/km^2 (Mansfield et. al. 1975). Allan (1967) has estimated the critical population density to 12 - 27 persons/km^2.

......./9

The need for land is approximately 2.5 - 4-5 ha. In the chitemene system the figures are more than 40 ha per person. However, the figures depend on the lenght of the growing and resting period.

Table 4: Area per person and critical population density in the Grass mound system (Mansfield et al. 1975)

	Total area suitable land for Grass mound system					
	100%	75%	60%	50%	40%	30%
Neighted area required per head (ha)		2.4	3.0	3.6	4.3	5.1
Average critical population densities in number of persons per unit (person/km2)	56	42	34	28	19	17

III. INVESTIGATIONS INTO SHIFTING CULTIVATION SYSTEM

Trials on traditional systems started at Lunzuwa Agricultural Station in Mbala in 1928. Presented below are some results from experiments that have been performed at Lunzuwa for 1928-1958.

A. Ordinary hand cultivation Vs. burning chitemene

This experiments were conducted to investigate performance of the ordinary hand cultivation versus burning chitemene in a bid to control chitemene.

Table No. 5: Results of burning chitemene and ordinary hand cultivation.

The table presents yields of finger millet for hoed and chitemene cultivation. (Boyd, 1959 and Allan, 1967).

Year	Hoed Plots kg/ha	Chitemene plots kg/ha
1928	Failure	1177-1849
1929	448	1345
1936	Failure	1836
1937	- Groundnuts	-
1938	500	1673
1939	- Beans	-
1940	634	1361

In ordinary hand cultivation plots plants were stunted and weed growth was beyond control. Chitemene proved far superior in yield and weed control. Failure in some years was due to weeds that completely suppressed millet growth. Those results demonstrate clearly the value of ash and heat in finger millet cultivation (Boyd 1959, Mansfield 1973).

B. The use of fertilizers 1928-29

This experiment was set up to determine the effect of fertilizers on both hoed and chitemene plots using a fertilizer rate of 336 kg/ha. Below are the results obtained.

Table No. 6: RESULTS OF FERTILIZER USE ON CHITEMENE AND HOED PLOTS. Yields of finger millet in kg/ha from chitemene and hoed plots on plots with and without fertilizers. (Boyd 1959).

Treatment	S/A	SPP	KCL	KSO_4	Lime	FYM	Mean
Un.Fertilized Chitemene.	1547	1345	1393	1603	1158	1331	1396
Un.Fertilized Hoed.	485	373	493	373	434	538	450
Difference	1062	972	900	1230	727	793	946
Fertilized Chitemene	1850	1505	777	1902	1360	568	1327
Fertilized Hoed.	1090	844	762	355	463	389	651
Differences	760	661	15	1547	897	179	676

S/A = Sulphate of Ammonium (21%). KSO_4= Potassium sulphate (60%)
SPP = Single super phosphate (42%) FYM = Farm Yard Manure.
KCL = Potassium chloride.

As can be seen from the table, chitemene plots are markedly superior to dug plots but the superiority decreases with fertilizer applications. There is a large response to fertilization in the absence of burning for N, P and K.

From observations taken during the course of the experiment, it was found that the addition of all elements except nitrogen to the dug plots gave a poorer germination. In potassium and phosphorus plots, those plants that germinated grew well and it was believed that potash seemed to encourage stolling and early ripening. It was also pointed out that the stricking difference between potassium sulphate and potassium chloride may have a bearing on chloride toxicity or a need for sulphur. (Boyd 1959). The nitrogen plots showed excellent growth and germination. Growth was rapid and greater than with ordinary ash but there was a great deal of rust and a tendency to lodge. In the presence of ash the plots on which nitrogen had been added gave stronger plants with better heads but again with a great deal of rust (Boyd 1959, Mansfield 1973).

C. Fertilizer Effect of the Ash.

The local systems of agriculture place emphasis on the top 15 cm of soil which is the portion believed to receive the ash dressing and the greatest heat under Chitemene. Boyd (1959) says early investigators were of the opinion that the heat generated in the process of burning played an important role as a soil sterilizing agent and in the preparation of a fine tilth seedbed. This led to the design of an experiment to find out the fertilizer effect of the ash. The experiment so conducted was not carried to its logical conclusion but results obtained are of interest.

Table No. 7: FERTILIZER EFFECT OF THE ASH (Boyd 1959).

The table presents nutrient status on two chitemene plots, one burnt in 1929 and sampled 1930. The other burnt and sampled the same year.

Nutrient	Burnt 1929 Sampled 1930	Control	Burnt 1930 Sampled 1930	Control
Available P_2O_5 (ppm)	8.5	8.7	34.6	5.0
Total P_2O_5 (ppm)	36.1	31.4	42.0	30.4
Available K (ppm)	17.8	12.7	23.7	14.7
Ca CO_3 (%)	Nil	Nil	0.03	Nil
p H	5.9	6.0	7.6	5.6
Base exchange capacity.	2.6	2.1	4.5	2.1

The results indicate an enhanced mineral status in respect of P,K and Ca after burning. There is an amelioration of acid conditions and an increased exchange capacity. It was found that there was a quick return of soil conditions to normal after only one year of cropping.

......./13

During the course of the experiments, leaching was observed hence, an attempt was made to investigate the local tradition of burning in October but not sowing the garden until late December. Between the samples 280 mm of rain had fallen. Sample I was obtained from the ash layer and the top 2.5 - 5.0 cm of soil and sample II was obtained from the top 2.5 - 5.0 cm of soil only. On analysis the following were observed.

Table No. 8: SOIL CONDITIONS ON CHITEMENE BEFORE AND AFTER FIRST RAINS.

Nutrient status immediately after the burn and the time when gardens are sown following the first rains. (Boyd 1959).

Nutrient	Control	Sample I	Sample II
Organic Carbon	0.94	1.68	2.55
Total N %	0.04	0.12	0.06
Ca m.e. %	2.86	16.85	4.97
Mg m.e. %	1.30	5.48	1.43
K m.e. %	0.37	2.15	0.51
pH	5.40	7.90	6.80
Available P (ppm)	25.0	> 100	53.90

As can be seen from the table before the crop is planted Nitrogen, Magnesium and Potassium will have returned to normal. High Calcium content is together with heat associated with the improving of the soil structure. But the problem of nitrogen supply is still unsolved. In his conclusion Boyd (1959) stated that from a chemical point of view ash as a fertilizer presents a very confused picture.

D. The beneficial effects of heat.

Until 1939 this question was one of speculative. Evidence indicated that the part that heat played was important but a measure of this was never obtained.

......./14

The effect of heat was finally investigated in a truly unique experiment which started in 1939 and went on for five years. The treatments consisted of the following and laid in a 9 x 9 Latin Square.

a) O = as a control having neither burn nor ash but dug over.

b) B = burnt and ash removed by sweeping.

c) 2B = burnt with double quantity of loppings and ash removed by sweeping.

d) A = unburnt but with ash from treatment (b) added.

e) 2A = unburnt but with ash from treatment (c) added.

f) BA = ordinary chitemene with single quantity of loppings burnt and ash retained.

Without going into details of the results, some general conclusions can be drawn. The ash and heat combination treatment has a positive effect on soil and yield. Ash alone (treatment d and e) or heat alone (treatment b and c) do not give as superior result as from the ordinary chitemene. However, it is remarkable to notice the much better yield results from burn only compared to ash. See results in table No. 9.

Table No. 9: The effect of ash and heat only compared with chitemene (Mansfield, 1973).

	Yield in kg/ha
Chitemene	1177
Burn only	944
Ash only	579
Control	268

Doubling the ash quantity or heat intensity had very little effect on the finger millet yield which may explain that the quantity of burning material used in practice is sufficient.

We have just seen the good yield results of finger millet from chitemene trials. According to Allan (1967) the positive effects of the chitemene technique are:-

Seedbed preparation (resulting is a very porous fine tilth from heat and/or ash).

Soil sterilisation (resulting in good weed control).

Increase in mineral carbon.

Increase in availability of nutrients.

Increase in soil physical status.

Increase in soil pH.

E. Traditional Grass mound System.

As was pointed out in the introduction, the **Grass** mound system follows a definite system of green manure - cereal - green manure - legume sequence. Under this experiment millet, and beans were used in rotation and results for it were as follows:-

TABLE NO. 10: RESULTS OF TRADITIONAL GRASS MOUND SYSTEM
In the table are the yields of beans and millet under the Grass mound system (Boyd, 1959).

Year	1	2	3	4	5	6
Crop	Millet	Beans	Millet	Beans	Millet	Beans
Average Production	1445	402	1249	311	571	160

The progressive deterioration of yields in respect to millet taking year 1 as unity is 1:0.864:0.395 and for the bean crop the equivalent ratio is 1:0.771:0.398. Hence the Grass/mound system cannot be economically continued after the third year as the bean crop of the fourth year is only 2/5 of the opening year. So a man would be better off opening a new garden after the third year if land is available. (Boyd 1959).

F. Continuous Millet.

The experiment was attempted using three levels of compost 0, 10 and 20 tons/ha. Mounds in accordance with the correct system could not be made earlier and so were made after a millet crop was reaped and then burying their straw. The results obtained are as presented in table 11.

Table No. 11: RESULTS ON CONTINUOUS MILLET.

The table presents experimental results on the use of compost in plots involving continuous millet. Yields are in kg/ha. (Boyd, 1959).

Compost Level in tons/ha	YEAR		
	1	2	3
0	Uniformity	1223.78	87.32
10	Trial	2139.64	121.25
20	1185.57	3224.07	133.73

Observations made during experimentation say, compost had a great effect on millet yields in the second year but stimulated the growth of Eleucine indica whose density suppressed millet growth and led to disastrous results. (Boyd 1959).

G. Millet Rotations.

Experiments regarding this sequence were carried out half heartedly due to constant destruction of results especially in sweet potatoes by wild pigs (Boyd 1959). Because of this reason, records were not properly kept. However, observations taken during the course of experiments involving:-

a) Control with and without abiannual application of compost on a Millet - Bean - Millet rotation.

b) Millet - Groundnuts - Millet with and without compost.

c) Millet - Sweet potato - Millet with and without compost and

d) Millet - Millet - Millet with and without compost; showed that in all cases there appeared a steady decline in yields and the application of compost to half the millet crop gave a better control to the weed problem encountered earlier. It was also discovered that the local system succeeds over the weed problem by allowing the weed growth following the millet to be burried before it seeds and further control takes place in the early rains when the mounds are spread (Boyd 1959).

H. Timing the application of manure.

After it was discovered that manure plays a role in fertilizing plots and also promoting weed growth, an experiment was performed to determine the optimum time of applying it to plots. The design involved applying manure during the making of mounds and at the time when mounds are spread. Results for these were as follows:-

Table No. 12: TIME OF APPLYING MANURE IN A GRASS MOUND SYSTEM.

The table presents millet yields in kg/ha from plots differing in the time of manure application (Boyd 1959).

TIME OF APPLICATION	YIELD KG/HA
No Manure	1306
Compost in April when mounds are made.	2168
Compost in December when mounds are spread.	1917

From the table it is clearly seen that manure applied at the time of making mounds will benefit the crop than applied at the time of spreading. It was also observed that, manure applied at mound making time is also able to suppress some weed growth.

I. Critical comparison of chitemene and Grass mound systems.

Chitemene is the system of the treed areas where as Grass mound is of the treeless areas. The problem posed is how the Grass mound system would fare in the chitemene areas. If the Grass mound could succeed then it could replace the Chitemene and so save tree destruction. The other aspect is with respect to crop rotation that may go with each system i.e. rotated with millet. Early demonstrations had proved chitemene superior to the Grass mound although encouraging results were obtained from mounding. For comparison of the two systems, the Grass mound system was established in the chitemene area.

Table No. 13: MILLET YIELDS OF THE TWO SYSTEMS.

Below millet yields in kg/ha from the two systems conducted in chitemene area. Other crop yields were deliberately left out (Boyd 1959).

Year	1	3	5	7
Crop	Millet	Millet	Millet	Millet
Chitemene	2658	2430	1149	112
Mambwe	1518	1130	538	85

In all cases crop yields declines with time and the Grass mound is proved inferior in chitemene areas. Other crops tried like beans and groundnuts showed that under chitemene they give more than they do under Grass mound hence, in woodland areas chitemene cannot be replaced by Grass mound system (Boyd, 1959, Mansfield 1973).

Concerning the main crops rotated between successive millet crops (beans and groundnuts), both crops are higher yielding under Chitemene and on either system groundnuts outyield beans (Boyd 1959).

IV. Investigations pertaining to a more settled system of agriculture.

Early attempts to formulate a system of more permanent cultivation involved the application of manure. Attempts to investigate permanent agriculture as such was done locally and no attempt was made to replicate this work on soil types prevelent in the Province. Work done on this however, enabled investigators to conclude that liberal manuring and spirited weeding with frequest fallows may make permanent cultivation possible (Boyd 1959).

b) Over nearly all cereal-non cereal-cereal-cereal rotations the drop in yield from one cereal to the next was approximately $\frac{1}{3}$ of what it was in continued cereal rotation.

c) Continuous cultivation with or without nutrient assistance is not compatible with the prevailing soil and the problem of length of cropping, length of fallow and type of fallow crop will remain a problem for a long time to come. (Boyd 1959).

Experiments that have been presented were conducted on millet as the main crop and no other proven suitable crop was tested against it other than beans and groundnuts. Although finger millet is a good crop that have few diseases and is of high yielding so safe and profitable in the high rainfall areas (Sarmezey, 1978), it is mostly confinded to remote settlements where it is grown for subsistence. Most settlements near urban and periurban centres utilize maize meal and use millet to brew local beers. Such then does not warrant too much effort into its production. Besides this, there is a problem of labour when it comes to harvesting.

In the experiments, it has been pointed out that chitemene system cannot be stopped until all trees have been cut down and that the Grass mound system is difficult to improve. For the chitemene this is absurd. The ecology of the area depend on trees. In the absence of trees the implications are even difficult to image. As for the Grass mound system its got to be improved at all costs. These systems must be improved or alternatives leading to high productivity have got to be found and found soon. One way of solving this problem is through high technology transfer. Although technology may not be always successfully transferred from one agricultural environment to another, the scientific principles on which sound agricultural practice is based may be transferable.

The approach for this can be through:-

a) Use of fertilizers to replace the slow return of nutrients to the surface of soil through the fallow vegetation.

b) When high yielding crops are grown the return of crop residues should at least partly compensate for losses of organic matter.

c) Proper use of machinery and mechanized tillage equipment can create the seed beds and tilth desirable for increased crop production.

d) Pests and diseases can be controlled by suitable chemical sprays and erosion can mostly be controlled by contour ploughing, construction of bunds and carefully graded water channels.

This may sound over ambitious for few of these remedies are available to small scale farmers but is one way the system can be changed.