STRATEGY FOR THE ADVANCEMENT OF ANIMAL TRACTION IN MALI

UNE STRATEGIE POUR LE PROGRÈS DE LA TRACTION ANIMALE AU MALI

Robert Shulman
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U. S. A. I. D. au Mali en Liaison avec la Division du Machinisme Agricole
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Preface

This study was authorized by USAID/Mali in order to provide technical information relevant to programs to improve animal traction in Mali. The study synthesizes information from agronomy, mechanized agriculture, and animal science.

From June 15-27, 1979, I made a brief visit to Senegal where I visited USAID, SODEVA, SISCOMA, CNRA/Bambey, and ICRISAT. I thank those organizations for their cooperation.

From June 27 - October 30, 1979, I visited many organizations and villages in Mali. I thank in particular, the CMDT, Opération Mils Mopti, Opération Haute Vallée, OACV and ICRISAT for their cooperation.

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A special word of thanks goes to Mr. Jerry Johnson of SAFGRAD (Semi-Arid Food Grain Research and Development, Mali) whose interest in and assistance to this study was indispensable.

Needless to say, none of the above individuals or organizations should be held responsible for any errors or omissions that might appear in this report.

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BRIEF SUMMARY OF MAJOR CONCLUSIONS

Part I:

1. The high labor requirement for weed control represents the greatest constraint on the expansion of total cultivated area. Improvements in animal traction can reduce this constraint.

2. Research results show that good yields are associated with the effects (immediate and residual) of plowing on soil structure, with timely weed control, and with incorporation of manure compost and rock phosphate at the start of a crop rotation.

3. Work oxen or bulls are a unique source of agricultural power in that they appreciate in value during their useful lives. They are the first stage of combining crop production and beef production.

Part II:

4. Plowing is advantageous unless the irregularity of rainfall delays plowing and consequently delays seeding. Techniques of soil preparation other than plowing should be planned into the crop rotation so as to maximize the earliness of seeding and, secondarily, the beneficial effects of plowing.

5. The labor requirement for weed control can be reduced by improved equipment for tracing parallel lines, for weed control closer to the crop plants, and for greater frequency in inter-row cultivation. A weed control technology project is needed to identify appropriate improvements.

Part III:

6. Given the rising prices of work oxen and bulls, credit programs to finance animal purchase by farmers are a good strategy to expand mechanization. Also necessary are programs to reduce the rate of calf mortality.

7. Expanded programs are needed to train farmers in animal care practices and to provide adequate local supplies of animal care products, especially for de-ticking and de-worming.

8. Dry season feeding of work oxen and replacement calves depends on improved techniques for conserving crop residues, and for hay-making and hay-storage (native grass and forage legume crops). Local marketing of hay needs to be studied.

Part IV:

9. Extension agent visits to contact farmers should be very frequent during periods of soil preparation, weeding and forage conservation. Some of the visits should be organized for the collection of field data on mechanized crop practices, which could be sent to research for analysis.

10. Short, dry season training programs for farmers appear to be a cost-effective means of upgrading management and technical skills. They can be linked to work animal credit programs.

11. Extension agent training at the Centres d'Apprentissage Agricoles (CAA) should provide better practical training in animal traction. Trainees should experience the time constraints on large-scale mechanical field operations.

Part V:

12. Blacksmith training programs should continue to be a high priority. It would be useful to investigate scrap metal markets and accessibility to imported tools, both of which affect local manufacturing and repair of animal traction equipment.

PART I: THE ECONOMIC POTENTIAL OF ANIMAL TRACTION

The economic potential of animal traction is most visible in the Koutiala region of Mali. Almost all of the farmers use animal traction, and most use it skillfully as a result of effective extension during the last twenty years. The region accounts for half of Mali's annual cotton production.

Conditions that make animal traction uneconomic are generally absent in Mali at present:

1) Land scarce relative to labor supply.
2) Inadequate infrastructure for marketing increased production.
3) Commodity prices far below the costs of work animals and equipment.

Condition three, however, is becoming a major concern in those areas which engage in little or no cash crop production (eg., the Dogon region). The rate at which farmers mechanize is price sensitive.

In Mali, the most important determinants of the economic efficiency of mechanization are management and technical skills. The timing of field operations, the choice and adjustment of the equipment and the care of the animals are extremely important.

A. Increase in Total Cultivated Area

In Mali, the high labor requirements for soil preparation and weeding limit the total cultivated area. Cultivated area can be increased by improvements in animal-powered mechanization.

In this regard, the history of maize production in the United States is interesting. In the early 1800's, 230 man hours produced a hectare of maize with wooden plows and hand weeding hoes. By 1870, man-hours per hectare dropped to 150 with the widespread use of the improved one-horse steel plow and the "ridger" or "lister shovel" for inter-row weed control cultivation. Between 1890 and 1910, man-hours per hectare dropped to 45 with the introduction of two-horse, multiple-row plows, seeders, and weeding cultivators. Cultivation after seeding was the most serious labor bottleneck overcome by the mechanization of maize production.[1/]

In semi-arid tropics, weeds are even a more serious constraint. Dr. Claude Charreau of ICRISAT* has written:

> One of the characteristics of tropical agriculture is the extremely vigorous growth of weeds. Problems of weed control are more difficult to solve than in temperate zones, and above all, farmers are much less well equipped to solve them. Generally speaking in the dry tropics weeding is the most limiting factor for crop production and accounts, to a large extent, for the much lower productivity per man than in temperate countries, given the same equipment.[2/]

The important point is that the time required for weed control lowers productivity per man. Weed control takes more time than soil preparation. If weed control time could be reduced by improved mechanization, the increase in total cultivated area would cause the time requirements of harvesting to be the greatest constraint on productivity.

The constraint of weeding can be measured by analyzing the time requirements for the major field operations in crop production (excluding harvest and post-harvest). It must be remembered that these operations overlap in time between the end of May and the end of July. Table I compares the time requirements for manual and mechanized field operations in Mali. The data have been synthesized from various sources.[3/] The data that currently exist in Mali are very sketchy. Better data are needed on the efficiency of equipment adapted to regional differences in climate and soil.

*ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)

Table I: Time requirements per hectare Maize or Sorghum **

Field Operation	Hours of Oxen Use (paire)	MECHANIZED Man-hours for 2 Operators (SMECMA equipment	NON-MECHANIZED Man-hours for manual hoeing (daba)
Plowing, harrowing	25	50	
Shallow ridging			100
Seeding	6	12	25
Mechanical Weeding 4 passes:	24	48	
plus manual complement:	*	100 ***	
Manual Weedings *2-3			225 ***
Totals:		210	350

* The time for manual cultivation may include simultaneous thinning and fertilizer side-dressing.

** Time requirements for millet and cotton are somewhat similar to maize and sorghum. For peanuts and rice they are higher.

*** Highly variable data. Better data are needed to improve analysis of the constraint.

Analysis of Table I brings out significant information.

1) Weeding is the most time consuming operation because it must be repeated. Farmers using the daba weed thoroughly two or three times per season. Mechanized farmers must make frequent passes with the equipment and, in addition, they must do clean-up work with the daba to eliminate weeds close to the crop plants. The clean up or "manual complement" is the major constraint.

2) Mechanical seeding saves relatively little time, but it is very necessary for accurate seeding in parallel lines which makes possible close mechanical cultivation.

3) Use of a single operator per pair of oxen would cut in half the man-hours required for all mechanical operations. A few farmers in Mali have adopted the single operator technique,[4/] and many more should.

4) The manual complement can be minimized if mechanical passes are frequent enough to keep weeds from becoming established. (See Part II). Thus, multi-row cultivators (See Part V) represent time-saving equipment. Another time-saving technique is to use two one-row cultivators, each pulled by a single ox and each with a single operator.

5) The time of plowing for soil preparation could be reduced by use of a two-bottom plow pulled by four oxen. This may be too large of an investment for the time saved. Time for soil preparation can be saved by using techniques of shallow tillage. (See Part II).

6) According to Table I, animal traction saves a total of about 140 man-hours per hectare. The value of labor saved, at 700 FM per day for 20 days, is 14,000 FM per hectare.

B. Increase in Yield per Hectare

Yield increases are attributable to the effects of plowing on soil structure, of timely weeding, and of incorporation of manure compost.

1. Plowing

The results of twenty years of research by IRAT/ISRA* in Senegal

* IRAT/ISRA (Institut de Recherche Agronomique Tropicale/Institut Senegalais de Recherche Agricole.)

are summarized in Table II.

Table II: Ave. % Increases in Grain Yields Over Unplowed Control (R. Nicou) (18% research locations throughout Senegal)

Crops	Plowed by Oxen Depth 15-20 cm.	Plowed by Oxen with Incorporation of Stover, Straw or Fallow Grasses
millet	19%±	23
sorghum	24	24
maize	50	73
seed cotton	17	31
peanuts (pods)	24	9
rice (rainfed)	103	112

Research by IRAT in other West African countries shows similar positive results,[5/] as does SRCVO* research in Mali.[6/] Plowing improves soil, porosity, soil moisture retention, rooting density, and depth of rooting. Incorporation of organic matter improves soil structure and adds to available nitrogen.

The effect of plowing on cotton yield is generally thought to be higher than the 17% shown on Table II.

Despite Table II, the peanut operations de developpement, OACV* and SODEVA,* recommend shallow soil preparation instead of plowing in order to achieve the earliest possible seeding dates for peanuts and millet.

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*SRCVO (Section de Recherche sur les Cultures Vivrieres et Oleagineuses, Direction de la Recherche Agronomique du Mali).

*OACV (Opération Arachides et Cultures Vivriers, Mali).

*SODEVA (Société de Developpement et Vulgarisation Agricole, Senegal).

Plowing has been observed observed to have more effect on peanut haulm (fanes) yield than on pod yield.[7/]

2. Weed Control

Weed competition for water, soil nutrients, and light is a cause of low yields. An experiment at Samanko, Mali showed that sorghum yields were 10-30% lower when the first weeding occurred 20 or 30 days after crop emergence instead of 10 days after emergence.[8/]

The slowness of manual weeding causes severe weeding delays. The last fields to receive attention invariably have a dense infestation of weeds.

Mechanical inter-row cultivation can be frequent enough to keep weeds from developing deep, extensive roots. Elimination by mechanical cultivation depends on: 1) the weeds being small and recently emerged and; 2) the absence of rain for several days after cultivation so that the weeds desiccate. The frequency of mechanical cultivations is proportionately related to the frequency of rainfall.

In Mali, the manual complement to mechanical cultivation causes serious delays. Improved mechanical weeding is needed to minimize the manual complement (See Part II).

3. Incorporation of Manure

From the attachment of two work oxen during the night, five to six tons of manure can be collected in the course of a year.[9/] If litter is placed around the attachment post, it will absorb the urine and will increase the tonnage of compost.

Manure compost has a quite variable chemical composition, but a rule of thumb is that one ton of manure (50-70% water) equals 50 kg of a 10-5-10 fertilizer. This is equivalent to 12.5 kg of N-P-K nutrients and at least 3 kg of Ca-Mg-S nutrients.[10/] Assuming 1.0 kg of nutrient to be worth 300 FM, the 15.5 kg of nutrients per ton is worth 4,650 FM ($11). Six tons per year is economically significant: 28,000 FM is 40 days' wages at 700 FM/day.

Two points need to be emphasized. First, the urine part of the manure contains about 40% of the nitrogen and 60% of the potassium. It should be collected carefully. Second, the nutrient balance of the manure should be improved by the addition of phosphorous. Fortunately, Mali has the relatively inexpensive rock phospahte de Tilemsi. Adding the rock phosphate to moist, composting layers of manure has the additional advantage of accelerating the dissolution of the rock.

A seven year experiment (1963-69) at M'Pessoba, Mali, showed the following yield responses to manure incorporated at the start of a rotation of cotton, sorghum, peanuts, and fallow.[11/]

Table III: Average Yields (seven Years) in kg/ha.

Crop	Burned Fallow No manure No fertilizer	15 tons/ha manure only	15 tons/ha of manure plus complete annual chem. fertilization	15 tons/ha manure plus 500 kg of rock phosphate, plus annual side-dress of N, and K chem. fertilizer
cotton	568	1,270	1,648	1,725
sorghum	487	973	1,525	1,979
peanut	919	1,128	1,613	1,770

The greatest obstacle to the practice of manuring is the time and effort of transport and spreading. Time-saving techniques and equipment need to be investigated.[12/]

C. Positive Impact on Beef Production

Using animals for work in many cases prevents their slaughter at less than maximum weight. Work oxen should be retired and fattened by the age of 8-9 years after 5-6 seasons of work. It is not unusual in Mali to find work animals aged 10-12 years. For this reason, the small farmer cattle fattening program (ECIBEV's* embouche paysanne) wants to facilitate the

*ECIBEV (Etablissement de Credit et d' Investissement Betail et Viande)

feeding and marketing of old work oxen. The problem is complex. Communication with farmers takes time. Farmers have doubts about finding replacement oxen. Local cattle buyers may not offer attractive prices. In the past, ECIBEV has experienced difficulty in finding marketing channels.[13/]

Because of extra care and dry season feed supplements, work oxen tend to make,and keep, good annual weight gains. Muscular development from working also contributes to good weight. Oxen are a unique and economical source of power for mechanization because they appreciate in value during their useful lives. If one assumes an average yearly gain of 40 kg and a price of 250 FM per kg liveweight, real appreciation is 10,000 FM per year per ox. For two oxen, the 20,000 FM/yr. real appreciation covers many of the costs of feeding.

In addition, rising meat prices (consumer demand and inflation) help farmers keep up with the inflationary prices of agricultural inputs. Subtracting the cost of replacement bulls from the income from the sale of old oxen should leave a significant profit which can be re-invested in equipment, or replacement calves.

Animal traction farmers are the farmers most likely to adopt effective techniques for dry season cattle-feeding. One of the highest priorities in production system research is to develop time-efficient techniques for the production and conservation of feeds. (See part III). Future beef production in Mali will in large part depend on the closer integration of crops and cattle-raising in the 800mm plus rainfall zones of Mali.

D. Positive Impact on Rural Employment

It is impressive to see in Mali so many blacksmiths, carpenters, apprentices, and dealers in salvaged materials. They meet the demand by farmers for wagons, field equipment, and repairs. In general, their prices are about 30-50% lower than the prices of SMECMA or imported equipment. The blacksmith training programs in Mali (actions forgerons) are trying to upgrade this industry in more remote rural areas. Blacksmiths can invest profits from animal traction business into other businesses that benefit the villages. (eg., welding, auto repair, flour mills). Often more apprentices are taken on.

Wagons create many jobs in the transportation of firewood, building materials, and foodstuffs.

11/

Some farmers make supplemental income by doing major field operations under contract for other farmers. In the Haute Vallée of Mali, the going rate is about 2,500 FM per day. Surveys of these contracts are needed[14/].

Water lifting with oxen for dry-season irrigation of onions and other vegetables seems under-utilized. There are many potential locations for shallow wells or riverbank diversion canals. Technical advising and pilot programs are needed.

PART II: IMPROVEMENTS IN SOIL PREPARATION AND WEED CONTROL

A. Planning Soil Preparation for Early Seeding.

In Mali the early rainy season is characterized by irregular rainfall. Usually plowing can begin after the soil is moistened by at least 20 mm of rain accumulated within one to three days. Plowing can continue for several days to a week until the soil dries and hardens. Frequently dry periods can delay plowing and seeding. Late seeding reduces yields roughly in proportion to the length of delay.[15/]

In the lower rainfall zones of Mali, farmers risk seeding late if they wait for enough rainfall to plow every hectare. See the Appendix for an analysis of early rainfall accumulation at Koro, Mali. There is a better chance of crop establishment if seeding occurs soon after a heavy rain on soil prepared in advance.

In the higher rainfall zones of Mali there are good years when rains begin early (late April) and continue without prolonged interruption. But each year is unpredictable, and a farmer must minimize risks of late seeding. It is not a good plan to postpone seeding until June "when rains are more regular". Dry periods causing crop failure can occur in June and July as well as in May. In parts of Mali this season (1979) there were frequent rains in May and early June followed by a dry period from late June to late July. Crops that emerged in May developed roots that reached deep soil moisture. Crops that emerged in mid-June were severely stressed.

Soil preparation must be planned for early seeding despite irregular rainfall. With early seeding there is always a risk of having to re-seed, but it is worth the gamble. The costs of seed and labor for re-seeding are less than the value of probable yield reductions from late seeding.

A plan of soil preparation should first maximize earliness of seeding and secondly maximize the immediate and residual effects of plowing. What follows is a review of technical options for soil preparation. These options should be planned sequentially in the crop rotation.

1. Plowing early in the rainy season

Advantages:

a) Improves soil structure.
b) Excellent seed control initially.
c) In some years the rains in April and early May give farmers a head start.

Disadvantages:

a) Irregular rains can delay plowing and in consequence delay seeding.
b) If early rains do not infiltrate well, plowing may be too shallow.
c) Usually little organic matter is incorporated.

2. Plowing under grass fallow late in the rainy season

Advantages:

a) Reduces time for soil preparation before seeding, even if shallow cultivation for weed control precedes seeding.
b) Incorporates a significant amount of organic matter which decomposes well during the dry season.
c) Conserves moisture in the root zone below the plow layer (i.e., below 25 cm.). Next season's crop benefits from this stored moisture in the event of deficit rains.[16/]

Disadvantages:

a) Requires technical skill to invert and bury effectively high grass.[17/]
b) Requires technical skill to choose the correct soil moisture conditions. If the soil is too dry it may become pulverized and susceptible to wind and water erosion; enough moisture for a rough, cloddy surface results in effective erosion control.
c) May conflict with labor demands of early harvesting, late weeding, or cotton spraying.
d) May require land-clearing at a time when labor is not available. This is minimized if the field is in a regular rotation of cropping and fallow.

3. Plowing under crop residues immediately after harvest

Advantages:

a) Same as option 2. It is appropriate when a short cycle crop can be harvested before the rains stop--for example, plowing under early harvested maize.

Disadvantages:

a) Most crops are harvested when soil has dried and hardened.
b) May not be the preferred use of crop residues which are useful as forage left on the field, or, as conserved dry-season feeding supplements, or as building materials
c) Requires same technical skills as option 2.

4. Shallow Cross-cultivation in the dry season (chisel points on tines)

Advantages:

a) Reduces time of land preparation before seeding.
b) Need not conflict with other labor demands.
c) Improves the infiltration of early rains.

Disadvantages:

a) Less improvement of soil structure than plowing, because it tends to be shallow (8-10 cm).
b) Traction effort is high, and is reasonable only on light soils.
c) Rate of equipment breakage and wearing out is high. (e.g., tines break, chisel points wear down, and bolts loosen and strip from the vibration).
d) Might have to be repeated early in the rainy season if weeds emerge before seeding.
e) Danger of erosion if the soil becomes pulverized.
f) Little organic matter incorporated.

5. Shallow cross-cultivation early in the rainy season (Chisel points or duck-foot sweeps or Canadiens tines)

Advantages:

a) Low traction effort required for depths of 10-12 cm.
b) Very fast land preparation if a wide tool-bar is used (e.g., a wide tool-bar extension on "CIWARA" or HOUE SINE" holds 5 tines; wide tool-bars of the "Tropiculteur," "Polyculteur", "Tropisem" hold 8-13 tines).

Disadvantages:

a) If only 3 tines are used, then 400 passes are required for complete cross-cultivation. Plowing requires 500 passes, so not much time is saved in land preparation.
b) Tends to be more shallow than plowing but more deep than dry-season cross-cultivation.
c) Weed control is not good if weeds have already established themselves before the cultivation.
d) Little organic matter incorporated.

6. Ridging early in the rainy season (using the ridger or plow)

Advantages:

a) Very fast land preparation. One square hectare can be ridged in 150 passes (70 cm beds),

and a plow can do it in 300 passes.

b) Results in parallel ridges equivalent to parallel seeding lines which facilitate weeding.
c) Contour ridges and tied ridges help control water run-off (improving the per-cent infiltration)
d) Good technique for incorporating broadcasted fertilizer.

Disadvantages:

a) Soil under the ridge is not tilled, so root penetration is poor in fine-textured soils.
b) Weed control is good if the weeds are not too tall to be buried. Weeds afterward appear more on the sides of the ridge than on top or in the furrow. Equipment modifications are necessary for effective weeding of the sides of the ridge. (See Appendix).
c) Non-contour, non-tied ridges can accelerate erosion.
d) Mechanical seeders must be modified for stability on ridges. (Mouzon S.A. offers a ridge seeder attachment for the "ARIANA" toolbar and the "Tropiculteur").

e) Only a small amount of organic matter is incorporated.

7. Soil preparation techniques combined in a crop rotation

There are many possible combinations due to the variables involved. Localities will vary as to time available for preparation, difficulties of weed control, need to conserve moisture, use of donkeys or oxen, etc.

Combinations should be tested not only at Malian research stations (the PEP and PAR), but also in farmers'fields. Farming systems research is necessary for better understanding farmers' utilization of land and labor.
It is important to remember that residual effects of plowing on soil structure are better preserved by cereal roots than by the roots of cotton, dah, or legumes.[16/]

Here are two combinations that are worth trying:

A -- Plowing under grass fallow or crop residues late in the rainy season
B -- Plowing early in rainy season
C -- Shallow cross-cultivation (wet or dry)
D -- Ridging

Combination One: higher rainfall zone

Fallow -- A -- maize -- A or B cotton -- C peanuts -- B or D-- sorghum-- C -- forage legume

Combination Two: lower rainfall zone

Fallow -- A -- sorghum/millet -- C -- grain legume -- B or D-- millet -- C -- forage legume

16/

B. Improving Mechanical Weed Control in Order to Reduce the Manual Labor Complement.

The first mechanical weeding should occur at 10-15 days after emergence Because the crop plants are small and fragile, mechanical weeding cannot be close enough to eliminate weeds located in the row next to the crop plants. Therefore the first mechanical weeding must be followed by a manual labor complement with the short handled hoe ("daba"). This manual operation can be combined with manual thinning of crop plants when thinning is needed. It can also be combined with the manual side-dress application of fertilizer. But it would be more efficient if fertilizer application occurred mechanically during soil prepartion or mechanical weed cultivation. CEEMA* is now testing a prototype modification of the SMECMA* one-row seeder which would combine cultivation and fertilizer application.[19/] A fertilizer distributor should be designed for the "Ciwara" and "Houe Asine" toolbars so that fertilizer could be applied during soil preparation or mechanical weed cultivation.

For the above reasons, the manual labor complement cannot at the present time be completely eliminated from the first weeding operation. A realistic goal for the improvement of mechanization is to eliminate the manual complement in all subsequent weeding operations. This goal can be achieved by a program of high priority research and testing of appropriate mechanical equipment, and by special extension efforts to improve farmers' use of the equipment. This goal may be difficult to achieve, but it is absolutely essential for improvement of farming systems in Mali.

What follows is a brief description of the kind of equipment that is appropriate.

1. Equipment for seeding in parallel lines.

The SMECMA one-row seeder ("Dani Kele Wara") has line tracers. The equipment is appropriate for making parallel lines, but under

*CEEMA (Centre d'Etudes et d'Experimentations de Machinisme Agricole, at Samanko, Mali, under the Division de Machinisme Agricole, Ministère du Developpement Rurale, Bamako).

*SMECMA (Societé Malienne d'Etude et de Construction de Matériel Agricole, Bamako) (See footnote 45 for elaboration).

rough conditions this light-weight seeder may not perform to expectations. The major problem is that its cost is too high for many farmers. The model needs to be modified for manufacture by local blacksmiths.

Efforts should continue to find appropriate mechanical seeders, including hand-pushed seeders, that can be manufactured locally.

Farmers without a mechanical seeder can draw parallel lines by extending a rope or by pulling a tracer (rayonneuse). The rope method seems to be widely used in the CMDT* zone in Mali. Most tracers are like over-sized rakes with 3-6 adjustable tracing teeth. Tracers work well sometimes, but the lines can be invisible in rough conditions.

It might be appropriate to attach a heavy duty tracer (angle iron) to the toolbar. In the "Houe Sine" catalogue (Mouzon S.A.) a three row tracer (using small ridgers as tracers) is shown as attachable to the "ARIANA". Division de Machinisme Agricole has made an inexpensive tracer modification on the SMECMA "Ciwara" and "Houe Asine", but it has not been successfully extended.

2. Equipment for Weed Control close to the plants

There are many equipment designs for this purpose if one considers the possible arrangements of blades, sweeps, ridgers, rotary hoes and discs.

The designs appropriate for animal traction should be appropriate for local manufacture. The range of possibilities is great enough to warrant a well-funded appropriate technology developemnt project. A very good project was done in Northern Nigeria in 1971-73 by the Intermediate Technology Development Group Ltd.[20/]

The "Ariana" toolbar (Mouzon S.A. and SISCOMA)* is an excellent toolbar for weeding because the two front wheels permit the toolbar to ride with stability over the top of the row. The tines can be adjusted close to the crop. The relative expense of this toolbar, and its weight, are disadvantageous. In Mali there is interest in its extension for rice.[21/]

The SMECMA toolbars ("Ciwara" and "Houe Asine") used in Mali are equipped with three tines. Since the three sweeps must overlap slightly, the effective cultivating width is only about 50 cm. For 80 cm rows that is not close enough. Wider sweeps are a possible modification, but the use of five tines with narrow sweeps is more effective in my opinion. Five tines will not clog if the weeds are small and the soil not too moist. In Senegal, the five tine "SINE-GRECO" toolbar is very popular.

* CMDT (Compagnie Malienne pour le Developpement des Textiles)

* SISCOMA (Societé Industrielle Senegalaise de Constructions Mécaniques et de Matériel Agricoles)

Blacksmiths in Mali who are manufacturing cultivators, (See Part V), might be able to make some innovative designs if the nature of the problem is explained to them.

Ridge weeding equipment is needed. The sides of the ridge present a special problem. (See Appendix).

Once the crop plants have attained a height of 20 cm, the cultivation should attempt to move enough soil to cover the weeds close to the plants. Suffocating weeds, without burying the plants, is preferable to close cutting with sweeps or blades which might damage crop roots. Soil can be moved in that fashion by the ridger, with or without wings, or with short wings. Metal extensions on cultivating tines might move the right amount of soil.

3. Equipment to increase the frequency of inter-row cultivation

Mechanical weed cultivations must be frequent to keep weeds from establishing extensive roots. Dense roots hold soil during cultivation. Uprooting weeds with mechanical equipment does not guarantee their elimination. Weeds may merely be transplanted. Aggresive weeds, especially those with rhizomes, continue their establishment with subsequent rains. Only frequent cultivation stops weed establishment. Frequency of cultivation is proportionate to the frequency of rainfall.

A one-row cultivator may cover a hectare (80 cm rows) in six hours. To go faster than that requires:

a) using each ox separately with single yokes and two cultivators. For a single yoke prototype that is inexpensive, see Appendix. The single ox weeding seems very appropriate for narrow row crops like rice and peanuts.

b) using a multi-row cultivator such as the "Tropiculteur".

4. Herbicides combined with mechanical weed control.

Chemical weed control technology is now within reach of Malian farmers. A hectare can be covered with only 10-15 liters of liquid using the technique (ULV) of controlled droplet application (CDA). The flash-light battery powered, spinning disc sprayer is relatively inexpensive (Berthoud model, 15,000 FM).

This technology has been the key to the no tillage system of production being researched at IITA.* Instead of plowing, the fallow weed cover is sprayed. A manual "auto-feed" jab planter seeds into the mulch of dessicated weeds. The mulch does several things: it suppresses some reinfestation by weeds; it increases organic matter and biological activity at the soil surface; it protects against both erosion and excessive soil temperatures.[22] However, repeated spraying during the season may be necessary for weed

* IITA (International Institute of Tropical Agriculture, Ibadan, Nigeria)

control.

In Mali, several Ciba-Geigy herbicides [23/] are being sold by the Opèrations. Application is pre-emergence onto moist soil to prevent phytotoxic concentrations. The first mechanical weeding is postponed until 30-40 days after emergence. By then the plants are tall enough for complete mechanical weeding.

Cost is a major limiting factor. Gesatene for peanuts costs 8,450 FM (1978) for 2.5 liters/ha. If labor is available for 800 FM/day, it may be more economic to hire 10 workers to complement mechanical weeding.

OACV recommends herbicides only in the case of farmers with 10-15 hectares under cultivation.[24/] CMDT interest is mostly in the Sikasso Region. It is likely that herbicides will be most useful in high rainfall zones (Sikasso, Haute Vallée) and on narrow crops such as rice and peanuts. Herbicides may be especially useful where mixed intercropping prevents mechanical weeding. Row intercropping permits, in principle, mechanical weeding.

PART III: IMPROVEMENTS CONCERNING TRACTION ANIMALS

A. Donkeys and Horses

Donkeys are used mainly for wagon pulling, and probably exceed the number of pairs of oxen used for that purpose. In field operations their utilization is increasing. OACV has sold several thousand donkey toolbars ("Houe Asine") to farmers who grow peanuts and millet/sorghum in light soils. Opération Mils Mopti (OMM) is beginning the sale and extension of donkey equipment. Since donkeys are ubiquitous, the demand for donkey equipment is expected to be strong. In the low rainfall zone of Senegal, donkey traction is very popular.

The use of donkey equipment with one ox is an alternative that needs investigation in Mali. The continual traction effort of a donkey (or horse) corresponds to about 20% of its weight; for an ox it is about 15% of its weight.[25/]

A horse can provide a continual traction effort equal to about 20 % of its weight, and it works at a faster pace than a donkey or ox. Throughout Mali horses are used for wagon pulling, but they are rarely seen in field operations. In the Senegal peanut basin, north of the trypano zone, horses are extremely popular for field operations (using the SISCOMA "Houe Occidentale"). Horse traction has good potential for the 400mm to 800 mm rainfall zone in Mali, although there appears to be a strong cultural bias against using horses for tillage.

B. Oxen and Bulls

In Mali, most field operations are done either with oxen (castrated) or bulls (not castrated). Castration seems to be preferred because oxen tend to be more docile and safer for use by children and women who often help operate the team. Sometimes young bulls are castrated prematurely (before 3 years of age), and they fail to develop the musculature (neck and front shoulders) necessary for maximum traction effort. Castration at the proper time (3-4 years old) increases the rate of weight gain. Castration of older bulls is risky because the fibrous spermatic coils may heal slowly with increased risk of infection.

Castration is a matter of individual preference. I prefer not to castrate unless a young bull is difficult to control. Bulls have two major advantages. First, they have a more aggressive work temperament than oxen. Second, they can serve as breeding animals ("geniteurs") in the small herds that mechanized farmers are encouraged to keep.

In Mali, the Zebu breeds predominate in the 400-800mm rainfall zone. Further south, the N'Dama-Zebu crosses predominate. In the extreme south the N'Dama predominate. The N'Dama have no hump at the base of the neck, and they are short, stocky, and quite trypano-resistant. The obvious benefits of crossing the Zebu and N'Dama have not escaped the attention of farmers in the 800-1200 mm rainfall zone. The mixed breed ("Méré") is excellent for both traction and meat production.[26/] It is partially trypano-resistant.

C. Constraints on the Farmer's Acquisition of Work Oxen

By West African standards, Mali has many cattle, yet many farmers complain that the prices of work oxen are becoming prohibitively high.

The 1975 SEDES survey estimated 3.6 million head of which 200,000 were work animals. Government equipment sales are not a reliable indication due to the large volume of sales by private local blacksmiths. Opérations de Developpement conduct censuses from time to time.

Cattle prices vary according to the relative bargaining power of the transacting parties. For a medium-sized four year old bull, prices are approximately: (100,000 FM equals $250)

Haute Vallée:	80,000 - 100,000
Fana:	80,000 - 100,000
Sikasso:	90,000 - 110,000
Kati: (Dral Market)	100,000 - 120,000
Senou:	60,000 - 80,000

High prices are associated with proximity to the Bamako and Ivory Coast markets. Prices are lowest in November - December, and highest in May - June.

The high initial investment in oxen is a major constraint on agricultural mechanization in Mali. The price of oxen will continue to rise given the strong demand for meat in the domestic and export markets. The situation is ironic: meat prices favor the integration of crop and cattle operations, yet those prices disfavor animal traction which is the most direct means of integrating crops and cattle.

Improvement of the situation will not be easy, but two strategies seem appropriate. In the short-run, credit programs for oxen purchase can induce a modest expansion in the numbers of mechanized farmers. In the long-run, the reduction of the rate of calf mortality might increase the supply of cattle and slow down price increases.

D. Programs for Farmer Purchase of Oxen on Credit

1. Opération Buys Oxen and Resells Them on Credit

This type of program is usually combined with full season farmer training programs. (See Part IV). Opération Haute Vallée plans to give farmers a one or two week training as a condition of receiving credit. Opération Mils Mopti plans to offer credit, but it is uncertain if it will be linked to a special training program. Opération Baguineda sells on credit some 10-14 pairs of young oxen per year. The oxen come from the Baguineda herd (180) at a bargain price of about 70,000 FM each, without linkage to a special training program.

A five year credit term is most common, and usually a down-payment is required except the case of full season training.

This type of program may have some disadvantages: First, program costs may be high (personnel, overhead) for the number of pairs that can be handled. Second, the opération may experience difficulties organizing the purchase, transport, and holding of the oxen.[27] Still, this program has much to recommend it.

2. Opération Loans Money to the Farmer

This type of program has been tried in Senegal where SODEVA has sold hundreds of pairs on five year credit. The major problems were: 1) conspiracy between seller and buyer; 2) purchase of low quality oxen for an exaggerated price. Nevertheless, the program was a qualified success.

This type of program has enormous potential for Mali if it is organized with effective safeguards. An extension

agent should inspect and approve the purchase according to Opération guidelines. Farmers must be visited periodically during the growing season to verify appropriate use of the oxen. A written contract in French and local languages should clearly allocate the risks and obligations. Accident insurance for the oxen is a useful concept,[28/] although the costs of administration might be higher than if the Opération simply forgave the outstanding balance of the loan. A major farmer obligation is to report accidents to appropriate agents.

Such a program can serve a large number of farmers at low cost. Also farmers gain experience in using money as a form of agricultural credit.

Another potential benefit is that village associations, with the help of the functionally literate, can take over the local administration of the credit. The Opération's role would be supervising the association's revolving fund accounting, and inspecting purchases at random.

E. Program to Reduce Calf Mortality and Protect Work Oxen

Major infectious diseases[29/] are now under satisfactory control. Annual vaccinations are carried out jointly by the Service Elevage and the extension Opérations. The new Central Veterinary Lab in Bamako produces large quantities of live vaccine for these "Actions Sanitaires." Improvement is still needed, however, in transport and refrigeration of vaccines in remote areas. Since the vaccinations have been free, farmer cooperation has been good.

Brucellosis (Brucellose) which causes abortion and sterility in cows and can infect humans consuming fresh milk, has not been adequately surveyed or controlled in Mali.[30/]

Trypanosomiasis will be a continuing problem until the tse-tse fly is controlled. Work oxen seem to be more susceptible when they are underfed and overworked. Most work animals can be adequately protected by regular preventative treatments of Trypamidium or Antrycide. Because of trypano and other ailments,[30A/] it is not adviseable to work pure Zebus in the higher rainfall zone.

Work animals greatly benefit from treatments against ticks and internal worms. The Opérations are promoting the sale of deparasitizing products at the local level, but much improvement is necessary. Local delivery of adequate supplies is needed. This may be improved when the Central Pharmacy of the Service Élevage is expanded. Training farmers to administer proper dosages is also needed.

Veterinary interventions are gradually being improved by the Opérations. More infirmier-veterinaires are being hired for the Secteur level, and more agents d'élevage or vaccinateurs are being hired at the ZER level. These agents are supposed to give priority to traction animals and the small herds kept by mechanized farmers. These agents should give special attention to reducing calf mortality.

The estimates of calf mortality in Mali are not well-documented, but 20-30% seems likely. What is needed are diagnostic surveys in the zones where oxen traction has high potential. In those zones calves may already receive better than average care, but diagnostic surveys will pinpoint how the rate of mortality can be minimized. Mortality results from a complex of causes:

a) Dry season malnutrition: Milk and forage are deficient in Vitamin A which is derived from the carotene present in unbleached forages. Calves have a high Vitamin A requirement, but unlike adults they cannot store enough for long deficit periods.[31/]

   Calves have difficulty digesting the coarse forage (straw, stover) available in the dry season. Without legume hay, protein in-take declines. Calcium and phosphorus in-take may be negligible.

b) Gastro-intestinal parasites: Calves ingest the eggs of nematodes (helminthose and stronglylose), ascarus (Ascaridose) and fasciolus (fasciolose); eggs are in stagnant water and manure-contaminated feed.

   Medicines can be administered by bottle or by pill while the calves tongue is held. Dosages are color-coded for age.

c) External parasites--ticks: Ticks carry rikettsia, anaplasmosis, babeosis, and theileriosis--all potentially fatal for calves.

   Treatment can be by spraying of Ektafos, Procigam, or Tigal. The cotton sprayer Tecnoma T15 is often used (cost 32,400 FM). It is effective simply to pull off ticks with a kerosène soaked rag as soon as they appear.

d) Unsanitary environment: Flies transmit infections to eyes and superficial wounds. Dampness and manure can cause foot rot infections.

   Manure should be composted as often as possible, and cattle holding areas should always be well-drained.

Financing is needed for an expanded system of veterinary interventions. This means more agents to train more farmers to care properly for work animals and calves. This means an effective delivery system for veterinary supplies. The CMDT has made good progress. The OACV is experimenting with village veterinary clinics.

> The OACV has about ten "cliniques veterinaires" staffed by functionally literate villagers who have been trained in deparasitizing, castration, and proper treatment of wounds. They keep records of visits, treatments, and inventory. The village constructs a small building. Overhead is met by a 5 - 10% mark-up on product prices. Compensation for the "animateurs de clinque" has not been formally arranged.[32/]

F. Dry Season Feeding of Work Oxen and Replacement Calves

1. Analysis of the Problem

In the early part of the dry season there is adequate forage in the form of harvested fields, regrowth of burned perennial grasses, grass on low-lying humid soil, and native grass straw.

Between February and May (about 120 days) the only available forage is unburned native grass straw and stored forage. When these are insufficient, the cattle are herded or left to wander--further away from the village to sparsely populated areas or to the bourgoutieres of major rivers. The patterns of movement are extremely variable and tend not to be well-understood by outsiders.

Mechanized farmers with traction oxen and small herds increasingly prefer to maximize the time that the animals are located near the village. They want to assure adequate care and feeding of oxen, milk cows, and calves. They need feed conservation methods with reasonable time requirements. Labor requirements for collecting, harvesting and storing forage are high given the equipment available. Efficient and realistic timing of labor inputs is a major challenge for farming systems and appropriate technology research. A review of alternative feeds and their constraints may be useful.

2. Crop Residues: Stover and Straw

The stover (stalk and leaves) of corn, sorghum, and millet can be a significant source of roughage and carbohydrates (UF equals 0.30 - 0.35; UF is "Unité Fourragère" or the energy value for livestock based on a scale where barley grain or peanutcake is UF 1.0).[33/]

It is adviseable to conserve some stover in good condition for the dry season. If it is chopped, animals will eat more. This practice is widespread in the Senegal peanut zone.[34/]

Rice straw is not very palatable because of its high silicon content. Digestibility is also low (UF equals 0.25). Sodium hydroxide (NaOH) in a 4% solution raises digestibility and is being tried in Mali by ILCA.* [35/]

Stover and straw that are uneaten make good bedding for cattle and, with urine, should be added to the manure compost.

3. Crop Residues: Legumes

Peanut tops ("tiga-cala") and cowpea vines ("cho-cala"), are good sources of protein, calcium, carbohydrates and carotene if they are still green when dry. These are highly valued by many farmers who typically store them on top of a hangar.

There are three major problems.

1) Shattering of leaves:: Leaves are lost when the peanut pods are beaten off with sticks. Leaves shatter when dry cowpea vines are rolled up.

2) Mold and rot after early harvest of peanuts: In southern Mali the rains continue well after early peanuts are harvested. The only solution is to cure the tops well and store them inside a rain shedding structure.

3) Hangar storage volume is low: The storage capacity on top of a hanger is much less than could be obtained

* ILCA (International Livestock Center for Africa)

in a simple barn. A roof also protects more against sun-bleaching of the leaves, night-dew, and ultimely rains. Barn construction must consider small livestock, termites, and fire.

4. Grass Silage (Pit Silos)

This technique has been tried many times in many areas of Mali. Silage in the dry season is valuable for both nutrients and succulence in the ration.

Between 1974 and 1977 a U.S. Peace Corps project supervised construction of about 500 silos in high and low rainfall zones. The silos (3m in diameter and 2m deep) were packed with 8-10 tons of fresh grass (often chopped and sprinkled with water and salt), and were covered by soil. Approximately 90% of the silos were productive, but most villagers have not continued the practice. The problems were:

1) High labor requirement in September: Filling the pit, and cutting and transporting grasses must be done quickly or spoilage results. Handling such large volume of forage in a few days often exceeds the labor capability of a single exploitation. Smaller volume silos are possible and should be tried, but the percentage of spoiled grass increases as volume decreases.

2) Labor depended on artificial cooperation: To meet the labor requirement, otherwise unrelated villagers cooperated in the work. When the silo was opened it was difficult to ration fairly for three months.

3) Rain subsequently damaged the pits: During the following rainy season, side-walls often caved in, pits flooded with water, and the cover soil eroded away. The project found that silos in some areas required low mud banco walls and a straw roof.

5. Grass Hay

Native grasses collected after the rainy season are likely to be sun-bleached and coarse (fiber, lignin, cellulose). They are straw. Grass hay, on the other hand, is cut in early bloom (September, as for silage grass). It is handled so as to preserve the green color and fragrance which indicates good carotene content, digestible protein of 5-7%. The UF of grass hay (good quality) is 0.35 - 0.45.

Hay-making is a complicated procedure because of September-October weather which includes heavy night-dew, high humidity , and inter-

mittant rainstorms. This moisture causes losses of nutrients from leaching, prolonged cell respiration, and mold. A brief description of the general procedure [36/] will demonstrate its labor intensiveness.

1) Initial rapid drying in sun: Nutrients are preserved if the grass is desiccated rapidly. After cutting, the grass must be spread out in a thin layer (1-3 plants thick) from late morning to late afternoon. The humidity of the soil retards drying, so care should be taken to spread the grass on top of other vegetation so that air circulates underneath.

2) Temporary stacking of partially cured hay: By late afternoon the grass should be light and brittle, having lost perhaps a third of its moisture content. Hay is injured most by moisture when it is nearly cured. It is adviseable to rake the hay into bundles and to stack the bundles together so as to shed rain and minimize exposure to heavy dew.

3) Opening the partially cured stacks. By late morning of the next day, the bundles should be removed from the stack and set apart to continue drying during the mid-day heat.

4) Repeated Stacking and Re-opening bundles is necessary until the hay is cured. Rainfall or very high humidity may prolong this part of the procedure.

5) Permanent stacking. There are a number of possibilities, an important subject for farming systems research.

a) transport in wagon to a large barn made out of banco, wood, and straw. An elevated floor guards against termites and soil humidity. Protection from wind-blown rain may be needed, depending on stacking arrangement.

b) stack in temporary barn near the cutting area. A roof and straw mat walls around posts may be sufficient. The dangers are termites, other animals, and fire.

c) stack on wooden tripods ("perroquets") so that the stack sheds water but is open underneath for air circulation. Good results have been reported in Mali, but my own observations have not been favorable. The volume of each tripod is only about 200 kg of hay. The wood for many tripods could make a barn for better protection of the hay.

Hay can be made from native grasses or from seeded forage grasses. For the time being, seeded forage grasses are not appropriate. Seed is expensive and difficult to obtain. Also, seeded forage legumes are more nutritious and higher yielding, so they are a more attractive investment.

Two native grasses seem very appropriate for hay.

1) Pennisetum pedicellatum ("n'golo" or "wild millet"). An annual grass in abundance in Mali. After cutting it will regrow vigorously and re-seed itself. May also have potential as a seeded forage grass--the purpose being to obtain a large, dense stand that can be cut by an oxen drawn mower or with a scythe.

2) Andropogon gayanus ("waga"). A tall perennial grass that is popular for making straw mats ("karata"). Regrows after being cut or burned, but re-seeds with difficulty. Distributed throughout southern Mali on fertile soils.

Hay making with native grasses is one of the most promising dry-season feed alternatives. The man-days of labor per ton may be almost as high as for silage, but the work can be spread out over several weeks. Also, unlike silage, small amounts of hay (1-3 tons) can be preserved efficiently. One ton of grass hay is a good 120 day supplement for two dozen oxen (4 kg/day each). Good quality hay is marketable in some areas. In Barouéli, a wagon-load of straw may sell for 5,000 FM in April.[37/]

6. Legume Hay

Forage legume hay is high in protein (9-11%), carbohydrates (UF 0.45 0.65), and calcium (0.7%). Under research conditions, dry matter yields are in the 3-5 ton/ha range.

Unless leguminous crop residues are plentiful, a legume hay crop is essential for balancing the maintenance ration during the dry season. Some forage legumes can be planted the end of July after other crops have been planted but while they are still being weeded. Unless weed control is efficient, time may not be available for soil preparation and seeding of the forage crop. An alternative is to seed the forage crop immediately after early harvested maize. There are also intercropping possibilities currently being investigated by ICRISAT.

More farming systems and agronomic research is needed for preparation of extension packages. This includes date of seeding, soil fertility, weed control, and seed production. Making seed available to farmers is a major problem at present. This year farmers in the CMDT zone have planted over 120 hectares of forage legumes. Farmer demand is much stronger than that. CMDT tries to collect or buy-back seed from the few farmers who produce seed. What is needed is expanded seed importation and seed multiplication by contract growers. In the alternative, forage seed multiplication centers should be analyzed for cost-effectiveness.

Production research is needed on legume hay-making in Malian conditions. The procedure is similar to the making of native grass hay except that forage legumes may sometimes be cut several times with the final cutting occurring in the dry season. Legume hay cures more slowly than grass hay. It is also more fragile and requires careful handling to avoid loss of leaves. The value of legume hay justifies an investment in appropriate storage structures. Localized research is needed on the labor-time and cost of materials for high-security storage structures.

Of the many forage legume possibilities,[38/] the most promising at the present time are:

1) Cowpea (Vigna unguiculata)(annual): Traditionally inter-cropped with cereals, "niebe" makes good forage in a pure stand. Improved forage varieties exist, but need to be made more available to farmers. In southern Mali, forage cowpea can successfully be seeded after early harvested maize and peanuts.

2) "La Dolique" (Dolichos lablab) (annual): Certain varieties outyield cowpea and have more protein. The CMDT has extended it on a limited basis. Its long growing cycle may make seed production uncertain.

3) "Velvet Bean" (Mucuna atterima) (annual): A fast-growing vine with large leaves. A high yielder (5 tons/ha). Slightly less nutritious than cowpea. Same seed production problem as Dolique.

4) Stylosanthes (numerous species, humilis, gracilis etc.) (perennial): Gives very high yields in the second year. Seeding may successfully follow an early harvested crop. Seed production is difficult because seeds are tiny and are scattered rapidly.

31/

5) "Pigeon pea" (pois d'angol") (Cajanus cajun) (short-lived perennial): The seeds are a high protein human food much consumed in India. The leaves of this deep-rooted shrub stay green well into the dry season. May be cut several times in the season and regrow (ratoon) well.

Extension of forage legume hay practices should be a very high priority in Mali. The economic profitability is constantly improving. Crop residue legumes are marketed in towns in the dry season in small rolls (25-50 FM/roll). This market needs to be studied so that the profitability of forage legumes is better understood.

7) Other Important Dry Season Supplements

Small amounts of other feeds are needed for supplemental protein and minerals during the dry season.

1) Bran ("Son","Farine basse")(of rice, millet, sorghum): Compared to cowpea hay, bran has more carbohydrate and phosphorus, but slightly less protein and negligible calcium. It complements legume hay very well. (Rice bran equals 0.42 UF; millet bran equals 0.86 UF)

2) "Nere" powder: It comes from the seed pod of the nere tree (April). It is a by-product of "sumbala" food preparation. It is marketed locally. Farmers often use it as a carrier for feeding mineral supplements to cattle. (UF equals 1.0)

3) "Dreche": (Millet/Sorghum): Nutritious by-product of cereal food preparation. Fed most often to horses and small livestock. (UF 0.8-0.9).

4) Fish Powder: When it is spoiled for human consumption it is most likely given to poultry. It has twice the phosphorus and over ten times the calcium content of cottonseed. Excellent for calves.

5) Cottonseed: (whole, undelinted): In recent years Malian farmers have been convinced of the value of this feed. It has 15-17% protein, 1.2% phosphorus, and a UF of 0.90-1.10. Present demand at 15 FM/kg exceeds supply. By 1982 a CMDT oil mill at Koutiala will process much of the cottonseed now available. CMDT plans to sell cottonseed cake or a concentrate based on it. Cake has more protein and phosphorus than seed (on a kg basis), but fewer carbohydrates.

6) Mineral Supplements: Most Opérations sell salt bricks containing NaCl, Ca, P $MgSO_4$ and minor elements. Price is about 300 FM/kg. A factory at Gao makes bricks. KNZ bricks are imported from Holland. Demand is great and even private business is importing mineral supplements.

8. Combining Dry Season Supplements

A simple "maintenance ration" can be recommended from the following information:

1) Carbohydrates: A 250-350 kg bull needs 2.5 - 3.0 UF per day for maintenance and 0.5 for growth. One UF is supplied by each of the following (approximately): *

   3.5 kg of straw or stover
   2.2 kg of grass hay
   1.5 kg of legume hay
   1.0 kg of cotton seed
   1.2 kg of bran of millet
   2.3 kg of bran of rice

2) Protein: A 300 kg bull needs about 0.2 kg/day which is supplied by each of the following (approximately):*

   2.5 kg legume hay
   1.5 kg cotton seed
   4.0 kg grass hay

3) Carotene (Vitamin A): No problem if hay is cured correctly.

4) Calcium: Major source is the legume hay. The grass hay and salt brick contribute also.

5) Phosphorus: Present in low amounts in all the above feeds, but cottonseed and bran are particularly good sources.

When oxen are working, the maintenance ration must be increased by 50-100%.

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* The amounts indicated assume complete consumption (no waste) by the animal.

PART IV: TRAINING AND EXTENSION NECESSARY FOR ANIMAL TRACTION PROGRESS

A. Advising of Farmers: Field Visits by Extension Agents

Regular visits to selected farmers is a basic extension method in Mali. The details of implementation vary from Opération to Opération. The method as used in Mali resembles the "Training and Visit System" successfully promoted by the World Bank in India, Thailand, Turkey, and other countries. It is described in Agricultural Extension, The Training and Visit System, by Daniel Benor and James Q. Harrison, (World Bank, 1977). This book should be made available to extension services in Mali.[39/]

Regarding animal traction, the extension visit system should aim at the following objectives:

a) The selection of contact farmers should include farmers in different stages of mechanization, not just the most advanced farmers. The selection should be changed every year or two, but only among farmers willing to try new practices at their own risk.

b) The new practices to be tried should involve cropping practices and animal feeding. Since animal traction represents an integration of crops and cattle, the extension agent must include both in technical advising. Fortunately the CAA graduates are trained in both. Encadreurs probably need more training on the animal side. If an Opération has special agents for cattle (eg., "infermier-veterinaire", "encadreur d'elevage"), these agents should focus on deparasitizing, village veterinary clinics, and calf care (See Part III). The agricultural agents should focus on the conservation of crop residues and hay, manure compost, forage crops, and feed mineral supplements.

c) The frequency of regular visits should be increased at certain times of the year. Times of plowing, weeding, and hay-making are the most important for animal traction. At these times, the secondary job responsibilities of the agents should be postponed or eliminated. For instance, monthly reports could be done on short, standard, blank forms instead of being handwritten. Also, the collection of statistics on the "general progress" of the season should be minimized because they are not very useful for anything but report-writing. Statistics on cultivated area and yields can be collected later in the season. Finally, the distribution of agricultural inputs should be done before May 15, or it will interfere with frequent visits for the farmers.

d) The visit system should produce detailed baseline agronomic information on mechanized cultural practices for feedback to research. Agents should fill out Crop Observation forms for at least five fields. (See Appendix for a sample form). The resulting data on cultural practices and yields

should be sent to research for analysis. The other four fields should represent good practices at various stages of mechanization.

One of the five fields might even be based on a field trial protocol designed by the Opération and collaborating research organizations such as SAFGRAD* ICRISAT, IRCT* or DIV. MACHINISME AGRICOLE.

As Benor has written: "To remain effective, extension must be linked to a vigorous research program, well-tuned to the needs of the farmers. Without a network of field trials upon which new recommendations can be based and without continuous feedback to research from the fields, the extension service will soon have nothing to offer farmers, and the research institutions will lose touch with the real problems farmers face." 40/

Baseline agronomic data is at least as essential as baseline economic data. Field observation data, in detail, collected by extension agents, is an inexpensive means of providing baseline agronomic data. Agents visit the field regularly as part of their current job. All they need is training in making accurate observations on the farms.

B. Training of Farmers

1. Village Functional Literacy ("Alphabetisation")

Several Opérations in Mali have functional literacy programs. Village classes are taught by village animateurs who are in turn supervised by a Chef de ZAF (Zone d'Alphabetisation Functionnelle). A ZAF covers about 40-50 villages, but only a few villages are chosen initially.

Newly literate villagers can use technical information and arithmetic to help the village in crop commercialization, field measurements, village enterprises (eg., flour mills, retail shops), and small clinics for administering medicines and simple treatments for people or for cattle. They can also help administer village revolving credit funds for oxen or equipment.

A current need is for post-literacy technical booklets on agriculture. DNAFLA* in Bamako is translating technical terms in

*SAFGRAD (Semi-Arid Food Grain Research and Development, Sotuba Research Station, Mali)

*IRCT (Institut de Recherches de Coton et de Textiles)

*DNAFLA (Direction Nationale d'Alphabetisation Fonctionelle)

various local languages. The CMDT (Koutiala Region) has written excellent booklets on cereals, field measurement, and cotton pest control.[41] Both DNAFLA and the Opérations are constrained by insufficient financial resources. Booklets on animal traction are needed, but the information must be adapted to the local conditions of each Opération.

2. Full Season Farmer Training Centers

The Centres d'Animation Rurale (CAR) under DNFAR* have two-year training programs for young farmers. Upon completion, the farmers receive oxen and equipment on credit. These centers are currently declining in number.

Formerly DNFAR also offerred two years of training for young adults going into agriculture after some formal schoooling. These Centre d'Orientation Practique (COP) had one year of classroom training and one year of practice in mechanized agriculture. This program has been discontinued.

The CMDT sponsors one season training programs for young farmers (married farmers are now preferred). The farmer received oxen and equipment on credit of five years' term. So far repayment has been excellent (well over 90%). The CMDT plans to operate six center ("Centres Saisonniers") each with 15-20 trainees. In the future, newly literate farmers will be favored in the selection process.[42]

The full season training center has some value. Its major benefit is the large credit given to young farmers who are unable to invest in mechanization. A long training program can be more thorough than a short one, but the question is whether difference is worth the high cost. The cost of the program limits its effect to a small number of farmers. Shorter training programs, reaching more farmers, seem more appropriate.

3. Short Training Programs in the Dry Season

In conjunction with its oxen-credit program, Opération Haute Vallée is planning to give one or two weeks of training to farmers during the dry season when time is available.

As proposed, the training will be organized around temporary traction center. The centers will have a holding corral and dry season feed supplements. Although farmers may already know how to train oxen, they will still train their oxen under the supervision of the center's trainers. During the ten days average time of oxen training, the farmers will be exposed to improved practices concerning: soil preparation, weeding, crop rotation, forage legumes and animal care and feeding. (See Parts II and III).

* DNFAR (Direction Nationale de Formation et Animation Rurale)

The animal traction centers will do experiments on the practical problems of implementing the "improved practices" recommended by research organizations.

The experimentation will also involve the adaptation of field equipment and cattle-feed storage structures to local conditions in the Haute Vallée.

The purpose of the animal traction centers is to improve animal traction in locations close to the farmers served by the Opération.

C. Training of Extension Agents: Animal Traction at the CAA

Extension agents at the moniteur level are trained at the Centres d'Apprentissage Agricole (CAA), located at Samé, Samanko, and M'Pessoba. The two year [43/] program at the centers offers classroom and practical training in crops, animals, construction, and metal and wood shop. Practical training occurs during the first half of the morning. A third year of training for moniteurs consists of specialization by means of on-the-job training with an operation or other relevant development organization.

The important question is whether the CAA training provides enough practical experience in animal traction to enable the moniteur to advise on improved practices.

(a) Do the trainees experience the time constraints in a cropping calendar fully dependent on animal traction?

At each center the 70 (soon to be 140) trainees grow crops on the 35-40 hectare state farm associated with the CAA. Operations are done with tractors (MF 185, 285), with oxen and manually.

For plowing there was heavy reliance this year on the tractors. At Samanko, only 21 out of a planned 34 hectares were cropped due to the breakdown of the two tractors. Since there were only three trained pairs of oxen, a tractor was borrowed. At M'pessoba, the 6 pairs of trained oxen were not used in plowing.

For weeding there was heavy reliance on manual labor at Samanko where the oxen were not well trained. M'pessob weeded with oxen and the manual labor complement,but the tractor was also used this year for the first time.

Although the trainees are taught about plowing and weeding with oxen, they cannot under the above circumstances confront and overcome the major constraints in mechanization in Mali. They will not have personal experience in timely mechanical plowing and weeding with a minimum of manual labor.

37/

An improved program would perhaps use ten pair of oxen exclusively on 30 hectares in rotation appropriate for the animal traction farmer. The remaining hectares could be used to demonstrate advanced equipment and tractors.

(b) Do the trainees learn advanced techniques for ox-training?

At M'pessoba the trainees participate in training pairs of young bulls taken from the center's own herd (about 120 head). At Samanko, the permanent hired employees train the oxen before the trainees arrive in May.

Trainees should participate in ox-training from start to finish. It will prepare them to advise farmers on efficient, non-brutal ox-training methods.

In addition, the trainees should practice advanced training techniques: 1) using a single ox for seeding and weeding; 2) using four oxen in a team (appropriate for plowing heavy rice land, pulling a large harrow, or pulling a two bottom plow on the Tropiculteur); 3) using a pair of oxen or a single ox with one-man operation.

(c) Do the trainees learn to use types of equipment appropriate for improving mechanization in Mali?

The equipment at M'pessoba represents well what is extended for animal traction in Mali. The old models of "Arara", "Ebra", and others have been replaced with new SMECMA equipment. At Samanko the new has not yet replaced the old, but that is planned.

The M'pessoba and Samé centers are receiving new equipment under financing from U.S.A.I.D. Samanko's financing is through the World Bank.

If the centers use animal traction exclusively on 30 hectares, additional pairs of oxen will be needed. Each additional pair will need a complete set of SMECMA equipment. (See Part V).

In addition, trainees should have experience using equipment more advanced than the current SMECMA output. Since current trainees will be moniteurs for the next 20-30 years, they will be advising farmers who purchase more advanced equipment. Therefore the center should have:

--multi-purpose, multi-row toolbars with seeders (Part V, C,1)

--small tractors and accessories (Part V, C,2)

The Division de Machinisme Agricole is capable of advising the centers on the use of advanced equipment.

Finally, the centers and the trainees should be used for the testing of prototypes of improved or modified equipment. The trainees should evaluate the efficiency of the equipment under actual conditions.

When the moniteurs work in isolated areas, they will rarely be exposed to innovative equipment.

(d) Do the trainees receive reference information on animal traction?

At present, they do not. Appropriate reference information might include some of the following:

--CEEMAT technical manuals on animal traction.[44/]

--Sales literature from manufacturers and designers of animal traction equipment.

--CMDT publication: Matériel Agricole (Mémento No.3, A l'Usage des Encadreurs, 1979, 75 pages)

--A textbook could be written especially for CAA trainees.

--Division de Machinisme Agricole publication: Manuel d'utilisation des Principaux Matériels Manuels et a Traction Animale Vulgarisés du Mali (1973)

PART V: FIELD CROPS EQUIPMENT IN MALI

A. Variety and Appropriateness

1. Yokes

a) Neck yoke (Joug de garrot)

Origin: Village made
Weight: About 6-8 kgs.
Appropriateness: inexpensive and functional. It could be improved by using neck irons (12mm bar) instead of neck ropes. With irons, the elaborate carving (and wasted wood chips) is not necessary because a straight round log will sit well on the neck. Carving interrupts the grain and causes points of weakness.

The plowing yoke is 120 cm long. The weeding yoke is 240 cm long and is carved so that the oxen can weed 80 cm rows. Again, neck irons would eliminate carving of the wood. Adjustable neck irons could be inserted in a seried of holes for cultivation of rows at 60 cm, 70 cm, or 80 cm.

b) Head yoke (Joug de tête)

Origin: Village made
Weight: 6-8 kgs.
Appropriateness: These yokes are elaborately carved so that straps (leather, rope, or canvas) can be wound tightly around the horns. Plowing length is 120 cm and weeding length is 240 cm.
Advantages: Pulling from the horns is slightly more efficient than pulling from the neck; control by guide reins is improved, so one person operation is easier (See footnote 3A); well-adapted for bulls without humps, such as the N'Dama.
Disadvantages: more expensive (wood, labor) than the neck yoke; tying and untying straps is more time-consuming; straps break often in the rainy season; the horns must be straight or forward-tilting; and, no adjustment for weeding 60-70 cm rows.

2. Single-Purpose Moldboard Plows

a) Bajac TM

Origin: SMECMA[45/] (output about 10,000/year)
SCAER*[46/] price: 52,870 FM
Appropriateness: Very popular. Slightly lighter and more easily pulled than the "Ciwara" plow.

b) Copy of Bajan TM

Origin: Village blacksmiths
Price Range: 20,000-40,000 FM
Appropriateness: Lower quality than SMECMA's, but it is more than adequate given the low price. Blacksmiths also make modifications such as: lighter weight and shorter plow-bar (l'age); wide-angle moldboards for turning the plow-slice at very slow speeds.

* SCAER (Societé de Credit Agricole et d'Equipment Rurale (for elaboration see footnote 46)

c) Bajac B-2 and B-4 ("Liancourtoise")

Origin: Parts from France assembled by SMECMA
Weight: 73 kgs (B-2)
58 kgs (B-4)
SMECMA price: 90,000 FM B-2
Appropriateness: Popular in the Niger inland delta for plowing heavy rice soils. Traction effort required is great enough that one occasionally sees a four-ox team pulling these plows. High quality, very durable.

d) Bourguignons (donkey plow)

Origin: Ets. Bourguignons, 26300 Bourg de Péage, Drôme, France.
Weight: 26 kg
14 kg
Opération Mils price: 58,200 (26 kg)
Appropriateness: The 14 kg model is easily pulled by one donkey, but the 26 kg model is likely to over-tire one donkey. The "Houe Asine" plow by SMECMA is superior to either model Bourguignons.

3. Single-Row, Multi-Purpose Toolbars (without seeders)

(one moldboard plow, one ridger, 3 or 5 tines, and peanut lifter).

a) "Ciwara" multiculteur.

Origin: SMECMA (output about 10,000/year)
SCAER price: 88,795 FM
Weight: 30-40 kgs.
Appropriateness: Based on design of the Houe Sine, made by Mouzon[47] and SISCOMA[48] Weeding attachments make it far superior to the single-purpose plows. It is the first equipment a farmer should buy.

The toolbar holds only three cultivating tines. It should be modified for five tines like the Houe Sine-Greco (SISCOMA). Additional attachments should be adapted to local conditions to make weeding more efficient.

b) Copy of the "Ciwara"

Origin: Village blacksmiths
Price range: 60,000-75,000 FM
Weight: 30-40 kgs
Appropriateness: SMECMA's quality is higher, but the copy is adequate given the price. Blacksmiths show tremendous skill in transforming scrap metal into a multi-purpose toolbar.

c) "Ariana" Bati-Cadre (square toolbar)

Origin: Mouzon, S.A., France
SISCOMA, Senegal
SISCOMA price: about 70,000 CFA
Weight: 60-90 kgs.
Appropriateness: Very functional design by M. Jean Nolle.[49] The square frame permits attachment of many combinations of weeding equipment. Highly recommended by the CNRA/Bambey Senegal, but sales in Senegal have been slower than expected.

The Division de Machinisme Agricole in Mali has found it useful in rice weeding, and is trying to adapt a heavier plow to it at farmers' request.

Unfortunately the Ariana is not being extended vigorously in Mali. Mouzon, S.A. has developed for it double-row seeders a seeder for beds or ridges, a two-bottom plow, and disc cultivators for ridges.

d) Houe Asine (donkey multiculteur)

Origin: SMECMA (output about 2-4,000/year)
Weight: 18 kg (with plow)
SMECMA price: about 52,000 FM
Appropriateness: Based on the design of the Houe Occidentale (SISCOMA) which has been very popular in Senegal. The ridger could be improved by adding adjustable/removeable wings. The toolbar should have extension bars permitting use of five tines to weed one meter wide rows of millet. Like the "Ciwara", it needs modifications for weeding, fertilizing and line-tracing.

4. Single-Purpose Seeders

a) "Dani Kélé Wara"

Origin: SMECMA (output about 8,000/year)
Weight: 37 kg
SCAER price: 58,000 FM
Appropriateness: This is a basic one-row multi-crop seeder that can be pulled by a donkey or by one or two oxen. It is similar to the "Super-Eco" seeder made by SISCOMA of which 25,000/year are sold in Senegal.

The aluminum seed-metering discs have been improved recently. A Koutiala blacksmith, M. Bouraima Balo of Sirakélé, developed an improved cotton disc which the CMDT is ordering by the hundreds (price 1,500 FM). The Division de Machinisme Agricole in Mali has developed an improved millet disc that meters seed more precisely.

Except for the gear mechanism, local blacksmith could make functional copies of this seeder.

b) "Mopti" or "Nodet" rice seeder

Origin: SISCOMA (trademark, Nodet-Gougis, France)
Price: about 550,000 FM
Appropriateness: It seeds four to seven rows at 20-40 cm. It is used in the Niger inland delta by large exploitations or by custom operations.

5. Harrows

a) SMECMA two-section harrow

Origin: SMECA (output 2,000/year)
Weight: 56 kg
SCAER price: 48,000 FM
Appropriateness: Thirty teeth are bolted onto two "Z" shape metal frames. It is a basic design very similar to SISCOMA's harrow. Being relatively lightweight, it is not very efficient on heavy soils.

6. Single-Purpose Inter-row Cultivators

a) Expandable Cultivator ("Houe à expansion angulaire")

Origin: uncertain (could be Ets. Techine, 82400 Valence d'Agen, France)
Weight: 45 kg
Appropriateness: This is a basic expandable 5-tine cultivator. A hand crank and worm gear make it adjustable to various row widths. Formerly it was sold by the CFDT. It is not presently sold, but some farmers want it. This type of equipment is popular in India and East Africa.

b) Three Tine and Five Tine cultivators

Origin: Village blacksmiths
Price range: 30,00-40,000 FM
Appropriateness: In response to farmer demand, local blacksmiths have been making a variety of cultivators. Tines may be fixed or adjustable. The sweeps and points vary in size and angle. M. Bouraima Balo (Koutiala) has an interesting model with five short, sliding tines.

Local experimentation is essential for the development of weeding equipment that is adapted to local conditions.

B. Rural Blacksmiths and Industrial Extension

Traditionally, blacksmithing skills were quite well-developed in Mali. Gradually, blacksmiths have learned on their own to make animal traction equipment. In remote areas, blacksmiths are poorly equipped and make at best simple spare parts. In larger towns, blacksmiths make complete equipment, start to finish, from scrap metal. Supplies of scrap metal (usually from the coast via Ivory Coast and Upper Volta) are a major constraint. Scrap metal markets should be studied.

Blacksmiths make many of their own tools, such as hammers, chisels, punches, anvil-blocks, and air-blowers. At Bancoumana, M. Bala Traoré, even makes his own taps and dies for threading nuts and bolts. There are many examples of such great ingenuity and resourcefulness. Still, it would be helpful if certain tools were more available. For example, most often mentioned in my interviews were:

1) Large anvils (55 kg, 100 kg)
2) Large sledge hammers
3) Metal bending machines
4) Taps and Dies
5) Post-vises
6) Measuring instruments (T-square, vernier caliper)
7) Electric generators for welding and electric hand drills
8) Oxy-acetylene welding equipment.

Additional training of blacksmiths is mainly required for steel-tempering techniques, welding, measurements, tolerance and tool design.

Actions Forgerons

Several Opérations in Mali have provided training and the sale of tools on credit to rural blacksmiths located in animal traction zones. CMDT and OACV have the most advanced programs.[50/] Both follow certain important principles:

1) Respected practicing blacksmiths are chosen in strategic rural locations.
2) There are three training levels, with different tools available on credit at each level. Blacksmiths can choose to buy as much of the package as they think they can afford.
3) Credit is conditioned on 25% downpayment, commitment to monthly repayment schedule, and construction of an improved workshop.
4) Training is done by certified professionals at the workshop of a previously trained blacksmith.

The CMDT program has certain aspects that deserve to be noted.

1) There is training in small business management, including record-keeping in local languages by means of linkage to the functional literacy project.

2) In Koutiala an "Association des Forgerons" has been organized by the blacksmiths to improve the procurement of metal and tools. Dues are 250 FM/month for an insurance fund. M. Bouraima Balo of Sirakélé is the current President.

3) Flour grinding mills ("Nova", Champenois S.A., 52170

Chevillon, France) are sold with electric welding equipment to help amortize the cost of the generator.

4) Third level blacksmiths can choose to double their monthly repayments (normally 25,000 FM/month) in order to have an equipment replacement fund. CMDT helps banks the money in individual accounts. After five years, 1.5 million FM should be accumulated.

5) SMECMA has subcontracted light work to first level CMDT blacksmiths. Income from making hooks and chain regulators helps their credit reimbursement. (SMECMA should look into subcontracting for a local supply of plowshares, ridger points, and other parts that it imports. If quality is not "first-rate", the parts could be offered for sale by SCAER as second-line, bargain merchandise.)

I have observed one problem with the actions forgerons programs. As a condition of credit, the blacksmiths have to build inside forges. Most prefer to work outside in the shade where it is cooler. Requiring an inside work bench and storage area would be sufficient, and would cost less in terms of wood and labor.

C. The Future? Advanced Animal Traction Equipment and Small Tractors

1. MULTI-ROW, MULTI-PURPOSE TOOLBARS WITH SEEDERS

a) "Tropiculteur" (Mouzon, S.A.)

Two pneumatic tires (adjustable to row widths) supports a heavy-duty toolbar to which attaches: (partial list)

--two botton plow
--wagon platform
--6 row cereal seeder or three one-row seeders
--18 tine cultivator
--forage mower
--fertilizer spreader
--roller and harrow; and disc harrow

The "Tropiculteur" should be tried in Mali.

b) "Polyculteur" (Mouzon and SISCOMA)

Basically the same as the Tropiculteur, but the tires are not adjustable and the range of attachments is smaller. Only one moldboard plow, so does not save time in plowing. Very useful for shallow tillage and multi-row cultivation.

ICRISAT/Mali is using several. Division de Machinisme Agricole has field data on tests done in Mali.

c) "Tropisem" (Ets. Sulky, France)

Two large steel wheels support a toolbar that hold a variety of attachments. Functionally equivalent to the Polyculteur. Technical design came from SATEC. 51/

There are two being tried at Cinzana (Segou), one by OACV and one by ICRISAT.

2. Small Tractors

a) Bouyer TE

Designed in 1974 by Bouyer S.A., CFDT, and CEEMAT. Has 24 horsepower Lister diesel engines. Equipped with four seeder units, two-bottom plow, and three-row cultivators. Has four tires.

CMDT (Koutiala) has extended 25 under the close supervision of M. Nauleau and Actions Motorisation. Price is 3.6 million FM (600,000 down, plus annual 400,000 deposit for cost of operation). Qualified farmers are those with a good record of farming 20-25 ha with five or more pair of oxen.

A one-row corn harvester is being tried with it.

b) Bouyer MT 80

Two wheel tractor with a Lombardi diesel engine (8 or 10 horsepower). Pulls the two wheel Tropiculteur described above.

It is being tested in the Kita region (Danabougou) by OACV and the Division de Machinisme Agricole. DMA has data on its time for various field operations. Price about 1.9 million FM.

c) Combiculteur "Lelous"

Four wheels with 12 horsepower Lombardi diesel engine. Partial list of attachments: two plows that operate alternately; 12 cultivating tines; five seeder units; two ridgers. Future attachments: forage mower, threshers, sprayers etc.

Designed by M. Lelous at SODIA-SATEC. Manufactured by Mouson, S.A. Technical advising by CEEMAT during its development in 1976.

Currently being tested at Danabougou (Kita) by the Division de Machinisme Agricole. Price about 2.5 million FM without attachments.

3. Future Developments

Several periodicals carry information regularly on animal traction equipment and small tractors.

-- Machinisme Agricole Tropicale (3 issues/year), CEEMAT, Parc de Tourvoie, 92160 Antony, France

-- Machinisme Agricole au Mali (3 issues/year), Division de Machinisme Agricole, B.P. 155, Bamako, Mali.

-- Afrique Agriculture: Mensuel d'Informations Agricoles, 11 rue de Teheran, 75008 Paris. (monthly)

Footnotes

1. Leonard, Warren H. and John H. Martin, Cereal Crops (New York, 1963), pp. 59-61.

2. Charreau, Claude, "Soils of Tropical Dry and Dry-Wet Climatic Areas of West Africa and Their Use and Management," Agronomy Mimeo, Cornell Univ. (1974), p. 252.

3. Various sources for time requirements are as follows:

   a) Plowing: Farmer interviews indicated about 4-5 mornings of 4-5 hours of plowing is needed for one hectare. A square hectare requries 500 0.20 m wide passes, and each pass takes about 2.5 min (including turns and rest-stops), according to my observations. Harrowing time is variable. Often it is not necessary; sometimes it takes 1 or two passes (5-10 hours).

   b) Ridging (daba): Farmer use the rule of thumb of 20 people for a 5 hour long morning. This is equivalent to about six 100 m long rows per person.

   c) Mechanical seeding: The SMECMA one-row seeder can cover a square hectare in 125 0.80m wide passes. At 2.5 min. per pass, figure 6 hours. Farmers agreed that one day was sufficient time.

   d) Manual seeding: SRCVO recorded 23 hours for sorghum and 22 hours for maize, in Commission Technique, Mars 1978, "Techniques Culturales", p.43.

      J. Monnier at ISRA/CNRA Bambey Senegal has suggested 30 hours as standard time for line-drawing and seeding millet at 1.0m x 1.0m on 1 ha.

      CEEMA at Samanko, Mali, recorded 30 hours for maize and 20 hours for sorghum (1978-79).

   e) Mechanical weeding: A square hectare can be covered in 125 0.80m wide passes at 2.5 min. per pass, or figure 6 hours. This is true for the one-row cultivator or ridger. At least two or three cultivations with tines are needed, followed by one or two ridgings.

      The manual complement: The time is quite variable since it depends on the efficiency of the mechanical weeding. Usually hand-weeded is an area defined by a 10-20 cm radius around the crop plant. This manual complement is needed mainly after the first two mechanical weedings when the plants are small, and when thinning and side-dressing of fertilizer occur. The 100 hours per hectare is a low estimate, according to my observations.

   f) Manual Weeding: At least two or three are needed during the season. The first two are complete. I estimated that each takes as long as ridging with the daba. Some farmers concurred with this.

      At IITA, Ibadan, Nigeria, it was reported that two manual weedings took about 280 hours per hectare (World

Crops, May - June 1978, p. 132).

SRCVO reported maize weeding at 215 hours/ha, and peanuts at 333 hrs/ha. Commission Technique, "Technique Culturales" March 1978, pp. 60 and 61.

The 225 hours per season is probably a very low estimate.

3A. In the Haute Vallée at Bancoumana, I observed efficient plowing by one operator (M. Koman Konaté, farmer) who used voice commands to guide the oxen in a plowing pattern ("labour a la Fellenberg") to which the oxen were trained. (August 30, 1979)

At CEEMA, Samanko, M. Albert N'Diaye is the expert trainer in single operator techniques of guide reins and voice commands. M. N'Diaye is also very well-informed about the use of head yokes (joug de tête) in Mali.

4. Nicou, R. Le Travail du Sol dans les Terres Exondées du Senegal, CNRA, Bambey, Senegal (March 1977) p. 18. Also reported by Charreau, (footnote 2) p. 240.

5. Agronomie Tropicale, XXX-2, p. 129

6. For Mali, see: IRAT, Bilan Des Rechercehs (1962-74, 74-76) Conduites au Mali; SRCVO, Cellule Techniques Culturales, Rapports Synthetiques, 1977, 1978, 1979.

IRCT research in Mali sows very positive results for plowing cotton and maize.

7. Conversation with M. Jöel Meunier, ISRA, Section Arachidière Darou, Senegal. (June 19, 1979 at Bambey).

8. SRCVO, Rapport Synthetique (1977-78), "Etude de l'Influence de la date de Binage sur les Rendements du Sorgho, " p. 17, Cellule Techniques Culturales.

This type of experiment needs to be done for different types of weeding equipment and herbicides.

9. Essor Rurale, July 15, 1978, p. 16, Projet FAO/UPV/17/DANIDA, Upper Volta. This figure is in line with other sources of information on the subject.

10. Brady, Miles C., The Nature and Properties of Soils, 8th ed. 1974, pp. 538-540.

11. Pieri, C., "Fertilization of Rainfed Cereals, " ICRISAT reprint from Agronomie Tropicale, No. 8, 1973, pp. 751-766.

12. I was very impressed by my visit to the farm of M. Yacouba Dembélé, at Nampossèla near Koutiala, Mali. His two compost piles were each about 4m x 5m (walls of cereal stalks), filled with manure, litter, stover, ashes, weeds, and household sweepings. He plows the compost into his cotton fields.

13. ECIBEV is under the Ministère de Tutelle et des Sociétés d'Etat. I sold 482 farmer-fattened animals in 1977-78. Agents contacted volunteer farmers in October and the feeding period is January-April, using crop residues and cotton-seed. Average net return per head to labor and management is about 18,000 FM For details, see Larry Harms, USAID/Bamako, "ECIBEV Credit Activities: May 1975 to April 30, 1978" (Mimeo).

14. The nature of these contracts might be very relevant to the ability of farmers to repay equipment credit, and to their ability to purchase large equipment such as the Tropiculteur, Mopti-Nodet, rice seeder, and small tractors.

15. Charreau, C. (see footnote 2), p. 254.

16. Moisture is conserved two ways. First soil water loss from evapo-transpiration by weeds and grasses is reduced by plowing. Secondly, soil capillaries, through which water is transported to the surface during evaporation, are broken at the plow layer.

    For a detailed discussion, see Nicou, R. (footnote 4), pp.9-12.

    At CNRA/Bambey, Senegal, Dr. Claude Dancette, soil physicist, is carrying out very interesting research on this subject.

17. High grass may have to be cut first. If the fallow has good grass for hay-making, then plowing could follow cutting.

    The plow pattern "Labour a la Fellenberg" may facilitate incorporation of the grass.

    The burying of high grass can also be facilitated by the use of a strong wire attached to the vertical regulator of the tool bar, pulled into the crack between the moldboard and the plowshare, and attached somewhere behind the moldboard. The wire lays down the grass until the plowslice falls inverted.

18. Charreau, C. (footnote 2), p. 241.

19. The prototype is being tested at CEEMA, Samanko, by M. Jean-Marie Togo and M. Moustaph Touré.

20. See, Boyd, John L. and Ayok, E.A., "Report on Farm Equipment Development Project, Daudawa, N.C.S. Nigeria (Nov. 1971-Dec. 1973)". Intermediate Technology Development Group Ltd., 25 Wilton Road, London, SW IV IJS England.

This publication has pictures, diagrams, and test evaluations for many interesting weeding tools: a high clearance rotary hoe, a rotary hoe attached to the Ariana toolbar, ridger wings for scraping the sides of ridges, ridge scraping knives attached to the toolbar, and five tine expandable cultivator. Also of interest: the fertilizer applicator attached to the ARIANA, a variety of hand-pushed rotary hoes, and the single ox-yoke.

21. The Division of Machinisme Agricole is trying to adapt the Bajac B-4 plow to the ARIANA for rice growers. The B-4 is popular for plowing while the ARIANA is effective for weeding.

22. See, Wijewardene, R. "Appropriate Technology in Tropical Farming Systems," World Crops (May/June 1978), p. 128.

23. Primagram is used on cereals. Gesatene is used on peanuts (except variety 47-10 which is sensitive) Cotodon has shown good results on 47-10. Sorghoprim is now being tested against Primagram at varying levels of dosage. SRCVO, Rapport Synthetique 78-79, "Techniques Culturales", p. 32.

24. M. Abdullai Sanogo, Chef de Modernisation at OACV, provided me with much information on weed control.

25. Based on CEEMAT estimates in Memento de l'Agronome (1974) Ministère de Cooperation Francaise, pp. 347-8.

26. The "Méré" is approximately half and half. The "méré-wolosso" is approximately three-quarters zebu. For interesting observations on cattle near Sikasso, see Rapport 4, Premières Observations sur l'Elevage, by Bakary Sanogo, Programme de Recherche Socio-Economique Appliquée dans la Zone de Production Cotonniere--Sikasso, IER/IRRT, April, 1979.

27. The CMDT has had trouble finding a convenient source of oxen for the Centre Saisonnier trainees. It is currently looking to the N'Dama ranch near Yanfolila (Medina-Djasso); the ranch is a project by ONDY to improve the N'Dama breed for traction and meat.

ECIBEV's cattle fattening program experienced difficulty obtaining feeder cattle.

Opération Haute Vallée will have to find a source of supply for several pairs per year.

28. By setting up a reserve fund with the farmers' payment of insurance premiums, an Opération can self-insure the oxen it sells on credit. The premium is paid by the farmer as an added percentage on his or her outstanding loan. In Senegal, the SO. DE. V.A. cattle fattening program uses auto-assurance. (Self-insurance).

A more complicated arrangement used by SO. DE. V.A. for traction animals is insurance through a private insurer "La Mutuelle Agricole" (Place de l'Independence, Dakar), and the participation of the Fonds Mutuelle du Developpement Rurale and the Caisse National de Péréquation.

29. "La Peste Bovine" (Rinderpest), "Peripneumonie" (Peripneumonia), "Pasteurellose", Charbon Symptomatique (Blackleg) and "Charbon Bacterigen" (Anthrax).

Isolated appearances are frequent and control depends on rapid vaccination of animals in the immediate area.

30. Dr. Modi Touré, Central Veterinary Laboratory, Bamako. Conversation 29.9.79. CVL is interested in a diagnostic survey unit, but financing is still pending.

30. A Zebus in southern Mali are more susceptible to tick-borne diseases and streptotricosis (skin infection).

31. Morrison, Frank B., Feeds and Feeding (9th ed. abridged) 1961, p. 85.

32. Conversation with M. Mahamane Cissé, Directeur Actions Elevage, OACV, Bamako, 11.9.79.

33. The UF data presented here is only approximate. Various sources conflict on UF values. I chose UF values in the middle range of divergent estimates. The sources were: Morrison, footnote 31; CEEMAT, Aide Moniteur, footnote 44; data from CNRZ/Mali (Centre Nat. Rech. Zoo.); Essor Rurale, June and July 1978, Projet FAO/UPV/17/DANIDA, Upper Volta; figures supplied by Mr. Joseph Howell, Animal Science, Oklahoma State University, Sillwater, Oklahoma, U.S.A.; and Memento de l'Agronome, Ministère de la Cooperation Francaise (1974) Chapitre 13.

34. In Senegal, ISRA/Bambey research has show large increases (up to 40%) in the consumption of millet stover by oxen when it is chopped.

The Appropriate Technology project of Peace Corps/Mali has a prototype bicycle powered chopper that can be built inexpensively by Malian blacksmiths. The bicycle is easily detachable from the chopper. (Built by Mr. Rob Martin)

35. ILCA/Mali is researching NaOK treatment of rice straw. In India, the treatment reportedly increased wheat straw digestibility from 17% to 45%. See, R.E. McDowell, "Are We Prepared to Help Small Farmers," Cornell University, Ithaca, N.Y. (1977).

36. The hay making procedure is based on: Morrison, footnote 31, pp. 178-181; my own experience making hay at Sotuba Research Station, Mali and interviews with many people but especially Mr. Larry Harms, USAID/Mali; M. Moustaph Coulibaly, CNRZ/Mali; and Dr. Moctar Traoré Action Elevage, CMDT, Bamako.

37. Conversation with M. Tidiani Sylla, Chef de Barouéli, 24.9.79.

38. Other frequently mentioned legumes are: Leucaena leucocephala (a tree); Phaseolus atropurpureus; Guar (Cyamopsis tetragonoloba); Clitoria ternatea; carob (tree).

Manioc (cassava) is not a legume but the leaves are nutritionally equivalent.

Some organizations working on forage legumes in Mali are ILCA, FAO/CILSS, CNRZ , and ICRISAT.

39. This 55 page book explains the fundamental principles of linking relevant research to effective extension. If the book is not already translated into French it should be. For copies: World Bank, 1818 H Street, N.W., Washington, D.C. 20433.

40. Benor, Daniel, and James Q. Harrison, Agricultural Extension: The Training and Visit System (World Bank, 1977, p. 16).

41. These booklets have been written by M. Mamadou Cissé and M. Derlon, Section Formation, CMDT Koutiala.

M. Cissé is both an agricultural technician and expert in functional literacy, and his work integrating the two is outstanding.

42. Memento No. 4, Actions de Developpement, CMDT, Bamako, 1979, pp. 27-28.

43. Sometimes the two years are shortened by the late arrival of the first year students who must wait past May for their entrance exam results. This year the results were issued in July. This considerably shortened first year experience in animal traction.

44. CEEMAT is Centre d'Etudes et Experimentations du Machinisme Agricole Tropicale. It publishes:
a) Manuel de Culture Avec Traction Animale, (1975) 336 pages. (An English version is the FAO edition sold by Editions Eyrolles, 61 Boulevard St. Germain, 75005, Paris). (64.50 F).

b) Aide Memoire du Moniteur de Culture Attelee (1974), 2 vols., 178 pages. (30.00 F).

Order address: Parc de Tourvoie, 92160 Antony, France.

45. SMECMA is the Société Malienne d'Etude et de Construction de Materiel Agricole. It is a joint venture of the government of Mali and the French company CODAMM In 1974 the factory was built and financed by FAC on the outskirts of Bamako. The Director is M. Boubacar Nantéguê Malle

The Chef d'Atelier is M. Diamanténé Sirtouma, who is very interested in equipment improvement and technical suggestions from the outside.

The factory has about 110 metal workers. The machinery is capital-intensive but incomplete so that importation of many parts is necessary (eg., plowshare, lister shovel, tines, wide sweeps, plow moldboard, wheel rims and hubs, and the seeder mechanism). Factory expansion, including an industrial forge, is now under study at CEPI (Centre d'Etudes et Promotion Industrielles).

Imported parts and stock steel is coordinated from Europe by CODAMM.

SMECMA wants to expand its product line in post-harvest equipment and accessory equipment for small tractors.

SMECMA collaborates with the Division Machinisme Agricole concerning the testing of equipment appropriate for Malian conditions.

SMECMA sells exclusively to SCAER.

46. SCAER is the Société de Credit Agricole et d'Equipment Rurale. It is the exclusive buyer of SMECMA equipment which it re-sells to the exptension Opérations.

It offers equipment on one to three year credit at low interest rates (3-6%). It subsidizes the interest rate because it borrows from the Banque de Developpement du Mali at higher interest rates. SCAER's operating funds come primarily from annual receipts from the price schedule (barene) on commercialized cotton and peanuts.

The credit terms are basically satisfactory, although many farmers would prefer a term of 4-5 years. Quantity and delivery of supplies can be a problem. SCAER is financially squeezed when the Opérations do not promptly transfer credit repayments. Also, coordination of transport with commercialization trucks has caused late deliveries of equipment.

The Government of Mali is considering the reorganization of SCAER into a supply agency. Credit functions would be located in a "Caisse Nationale du Credit Agricole.

47. Mouzon, S.A. 60250 Mouy, France. Important manufacturer of animal traction equipment. Good sales literature available on Houe Sine, Ariana, Tropiculteur and many versatile attachments.

48. SISCOMA is the Société Industrielle Senegalaise de Constructions Mecaniques et de Matériel Agricoles. B.P. 3214, Dakar, Senegal. Factory located at Pout. Bamako representative at SOMEA, Rue Mohammed V.

Used to be the major supplier of equipment for Mali, but now supplies only special, large equipment. Domestic sales account for 85% of SISCOMA's business.

49. M. Jean Nolle has developed the prototypes for some important animal traction equipment used in West Africa. His "four stages" of equipment advancement is Houe Sine/Houe Kolba/Ariana/Tropiculteur. Information on the "Systeme Nolle" is available from Mouzon, S.A.

50. The OACV and CMDT programs have been studied by SO. DE. V.A. which will have a program soon in Kaolack, Senegal.

The details of the OACV and CMDT programs are best obtained directly from those organizations. The content of the training, the lists of tools, and the types of credit contracts are constantly being improved.

- At present OACV has trained 150 blacksmiths at the first level, 65 at the second; and 18 at the third. The respective credit packages are about 52,500 FM, 186,000 FM, and 400,000 FM. The major problems seem to be:

1) that the trainers are technically competent but often fail to use effective teaching techniques.
2) that repayment of credit has been slow where there was low demand for equipment, where metal supplies were inadequate, and where follow-up was not close enough. (One must realize that the OACV zone is huge).

Conservation with M. Sanogo, (footnote 24).

- At present CMDT has trained 162 blacksmiths at the first level, 48 at the second, and 28 at the third. The respective credit packages have been about 153,000 FM, 200,000 FM and 2 million FM. The major problems seem to be:

1) Maintenance and use of welding equipment.
2) Close follow-up and timely repayment of credit.
3) Supplies of steel.
4) Delays in receiving order of new tools and spare parts.

See: CMDT, Memento No. 4, Actions de Developpement (1979) pp 2-5; and CMDT Bilan 1977-8 Action de Formation et d'Equipement des Forgerons by M.R. Grimal.

51. SATEC*, 110 Rue de l'Université, 75340 Paris, France. SATEC has available very good literature on other animal traction equipment that it has developed. There is the "Porte-Outil Automoteur" walking tractor (four horsepower, 331 kgs). Also interesting is the two oxen forage mower with a 0.8 m or 1.37 m swath.

SATEC's model is not in production but a similar model is produced in Poland.

* SATEC (Société d'Aide Technique et de Cooperation

APPENDIX

1. KORO RAINFALL TABLE
2. SINGLE OX YOKE
3. WEED CONTROL ON RIDGE
4. FIELD OBSERVATION FORM

IRREGULARITY OF RAINFALL DURING SOIL PREPARATION

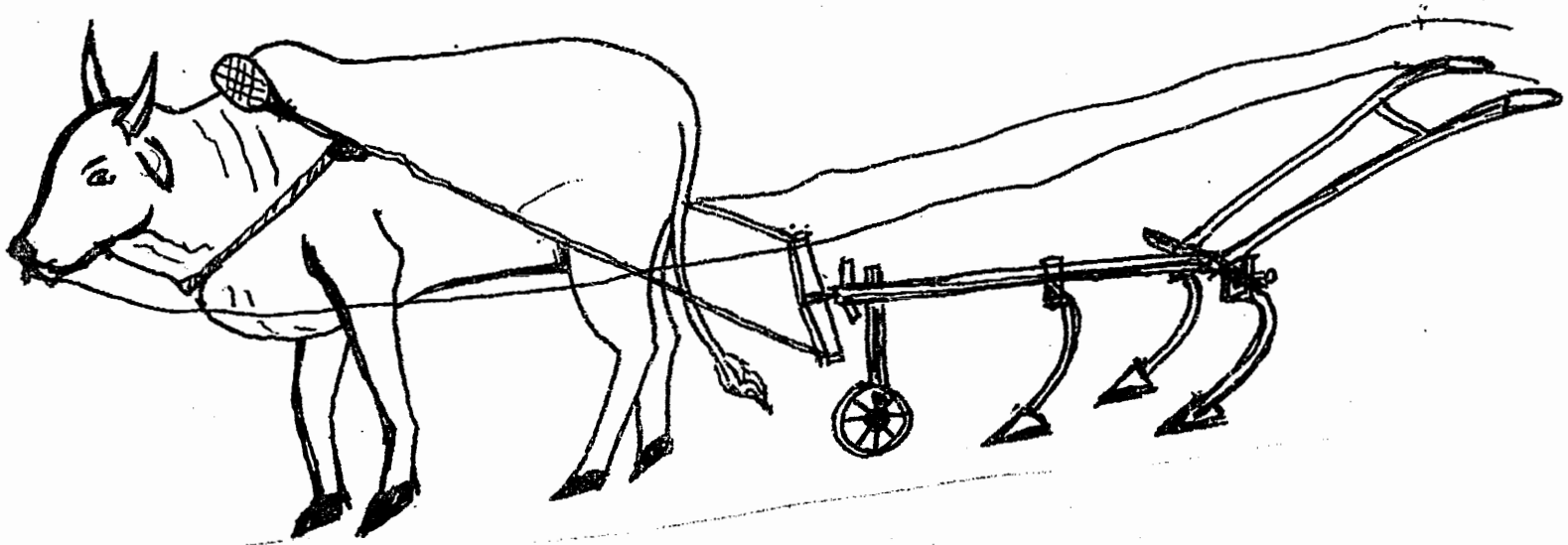
AT KORO ZER CENTRAL

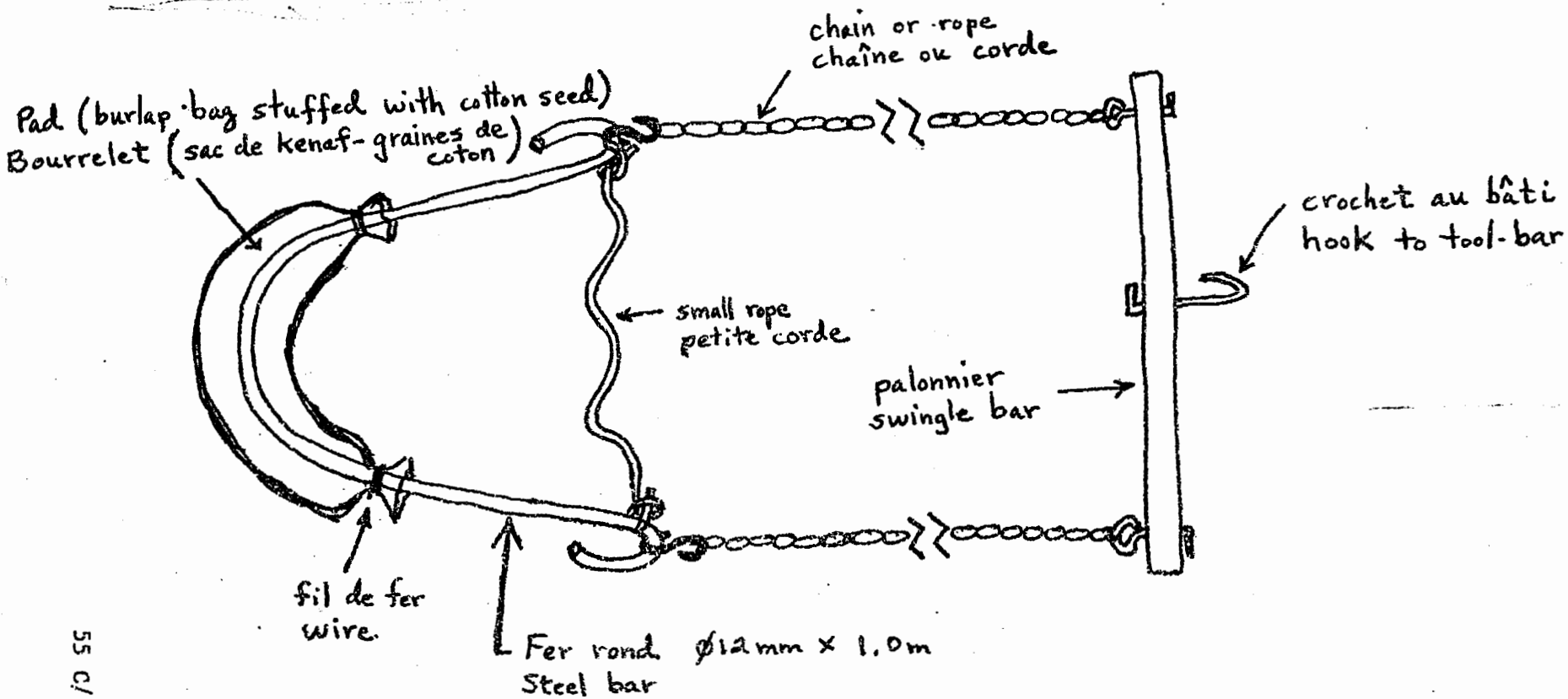
(Data From Opération Mils Mopti, Secteur of Koro)

YEAR	TOTAL FOR YEAR mm	FIRST RAINFALL ACCUM.	mm	PERIOD OF SOIL HARDENING	mm	SECOND RAINFALL ACCUM.	mm	PERIOD OF SOIL HARDENING	mm	THIRD RAINFALL ACCUM.	mm	PERIOD OF SOIL HARDENING	mm
1972	591	23/5-5/6 13 days	91	6/6-17/6 11 days	0	18/6 1 day	48	19/6-14/7 25 days	0	15/7-18/7 3 days	55	None	
1973	632	30/5 1 day	29	31/5-11/6 13 days	0	12/6-17/6 6 days	21	18/6-30/6 13 days	0	1/7-2/7 2 days	45	None	
1974	674	6/6-4/7 28 days	112	5/7-20/7 15 days	12	21/7 1 day	49	None					
1975	406	7/6-13/6 6 days	59	14/6-6/7 22 days	10	7/7-12/7 5 days	39	13/7-23/7 11 days	10	24/7 1 day	35	25/7-3/8 10 days	0
1976	496	14/6-27/6 7 days	84	28/6-12/7 14 days	0	13/7-18/7 5 days	36	None					
1977	684	16/5 1 day	40	17/5-30/5 13 days	0	31/5 1 day	33	1/6-17/6 17 days	14	18/6- 1 day	65	19/6-2/7 13 days	19
1978	473	No Data											
1979	No data	15/5 1 day	24	16/5-2/6 16 days	0	3/6-9/6 7 days	42	10/6-19/6 10 days	0	20/6-26/6 7 days	43	27/6-12/7 16 days	4

Dates (8/6 equals June 8)
"Rainfall Accumulation" equals more than 20 mm accumulation within 10 days.
"Period of Soil Hardening" equals less than 20 mm accumulation DURING AT LEAST 10 days.

Jougnet de garrot pour un boeuf
Single ox yoke



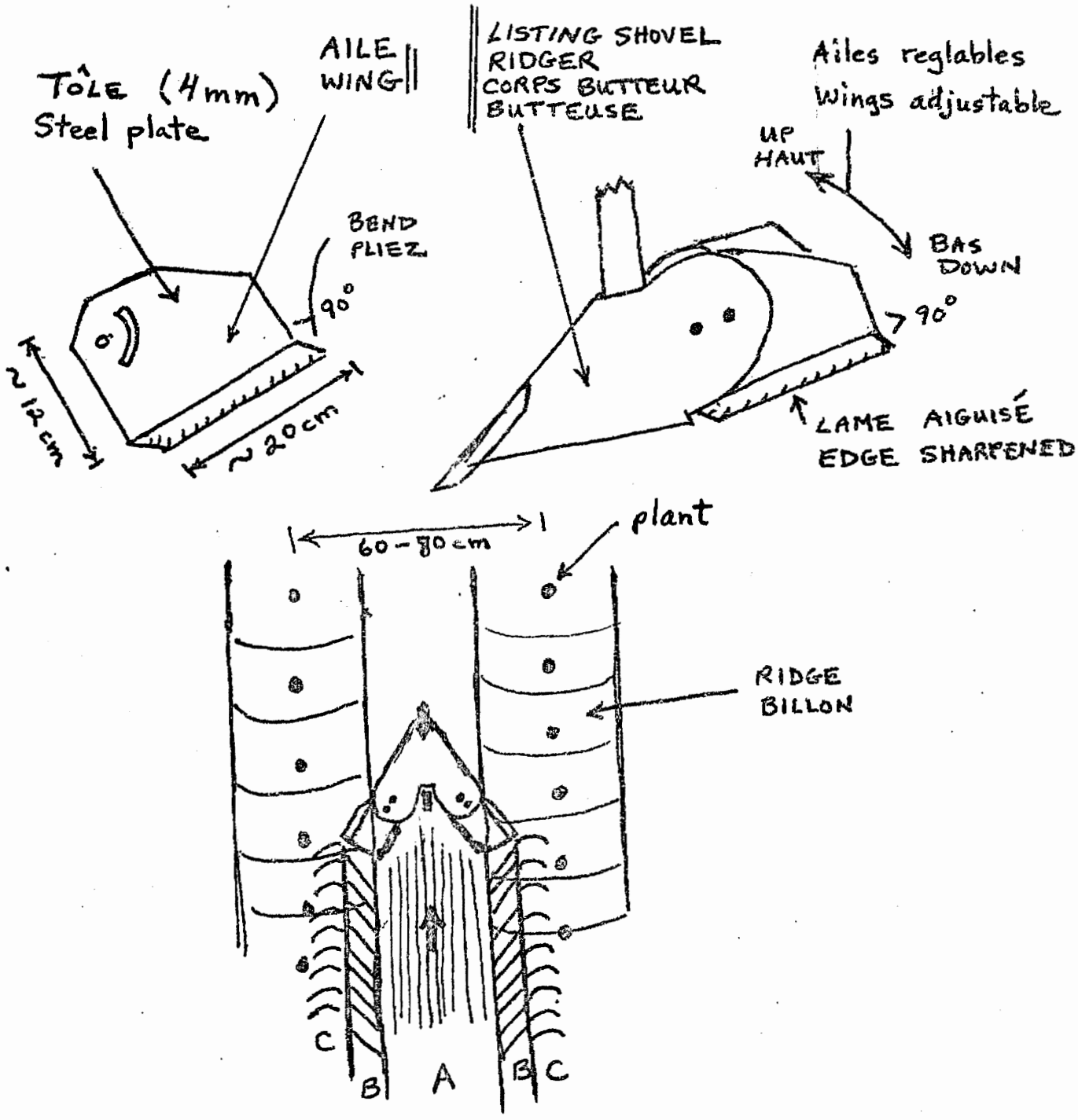


TECHNIQUE FOR WEED CONTROL ON SIDES OF RIDGE

TECHNIQUE DE DESHERBAGE DES COTÉS DU BILLON

"SCRAPING WINGS" (FOR LIGHT SOILS)

"AILES - RASETTES" (POUR DES SOLS LEGERS)



A - Sillon desherbé par le corps butteur
Furrow weeded by ridger bottom

B - Coté de sillon gratté
Side of ridge scraped

C - Terre poussée vers le plant
Soil pushed close to the plant

FIELD OBSERVATION DATA FOR EVALUATION OF MECHANIZED CULTURAL PRACTICES

Year: Name of Agent:

Village: Secteur

Name of Farmer: ZER:

SB:

1. Field Area: _____ ha.
   Number of trees in field: _____
   Number of predominant trees in field: _____
   Number of termite mounds _____
   Soil Texture: _____

2. Preceding Crops in the field:

Year	Crop	Chem. Fertilizer		Manure	Compost
		Yes/No	Type/kgs.	Yes/No	Est. kgs.

3. Name of crop: _____
   Familiar varietal name (local language: _____
   Familiar varietal name (French): _____
   Scientific Identification: _____
   Intercropping--Name of associated crop:
   Local: _____
   French:
   Scientific:

4. Seedbed Preparation
   Description of animals and their condition:

Dates	Soil Preparation Technique	Hours of work	Name of equipment	Depth of Tillage(cm)
	Scarification (dry soil)			
	(Moist soil)			
	Plowing (dry soil)			
	Plowing (wet soil)			
	Harrowing			
	Ridging without plowing			
	Ridging after plowing			

FIELD OBSERVATION FORM (PAGE 2)

5. Fertilization Program

Date	Chemical Fertilizer Kgs.	Formula	Date	Manure compost Est. Kgs.	Degree of Decomposition

6. Seeding

Dates	Equipment	Seed Treatment	Desired Spacing
	Hand rope Hand tracer Mechanical tracer Mechanical seeder Type:		

Germination problems: (birds, dryness, bad seed, erosion etc.)

Date of re-seeding:_____

% of area:_____

% of plants_____

Date of thinning if any:_____

7. First Weeding (or cultivation)

Condition of field:

Soil moist or dry:

Height of weeds:

Density of weeds: (per m^2)

Names of dominant weeds--local:

--scientific:

Manual Operation Completely:
Total man-hours (est.):

Date	Mechanized Operation: Equipment	Animal team hours	Number of operators	Man-hours of complemen- hand weeding

8. Second Weeding
9. Third Weeding
10. Fourth Weeding — Same information as No. 7

12. Actual Plant Density

FIELD OBSERVATION FORM (Page 3)

Est. Plants/ha:_____

Describe major variation in field appearance:

13. Harvest

Dates:

Observations: (birds, mildew, striga etc.)

Yield in kgs./ha
Grain or heads (spikes):
Method of estimation:
Type of scale (eg., "Roberval", roman etc.):