7. Implements commonly used for crop production

7.1 Ards

Ards (*araire* in French) are sometimes known as "breaking plows" or "scratch plows". Different types of ard have been in use for thousands of years and numerically they are the most important animal-drawn implements in the world. Their development over the centuries and the different designs currently in use in different regions of the world have been well reviewed by Haudricourt and Delamarre (1955) and Hopfen (1969).

An ard plow is symmetrical on either side of its line of draft. As the share and plow body pass through the ground, the soil is fractured and disturbed equally on either side. Unlike a mouldboard plow, soil is not systematically inverted. Typically the ard comprises a long wooden beam that connects with the yoke. The plow body is made of wood to which an iron share is fitted. Many ards have a single wooden handle and the symmetry of design makes it easy to control the implement with one hand (Fig. 7-1, 7-2). Some ards, including those widely used in Egypt, have dual handles although one-hand control is common when soil conditions are favourable.

Some ard plows (including the Ethiopian *maresha* beam ard) till a narrow width at a shallow depth (hence the description scratch plow), leaving small and irregular ridges and furrows. Weed control and seedbed preparation are achieved through a series of cultivations (usually at least three) each at an angle to the others. By repeated cultivations most of the soil in a field becomes disturbed, with the later passes achieving a similar effect to that of a harrow. Weeds are not covered but are generally uprooted and remain with stones

Fig. 7-1: Maresha ard in use in Ethiopia Photo: Paul Starkey

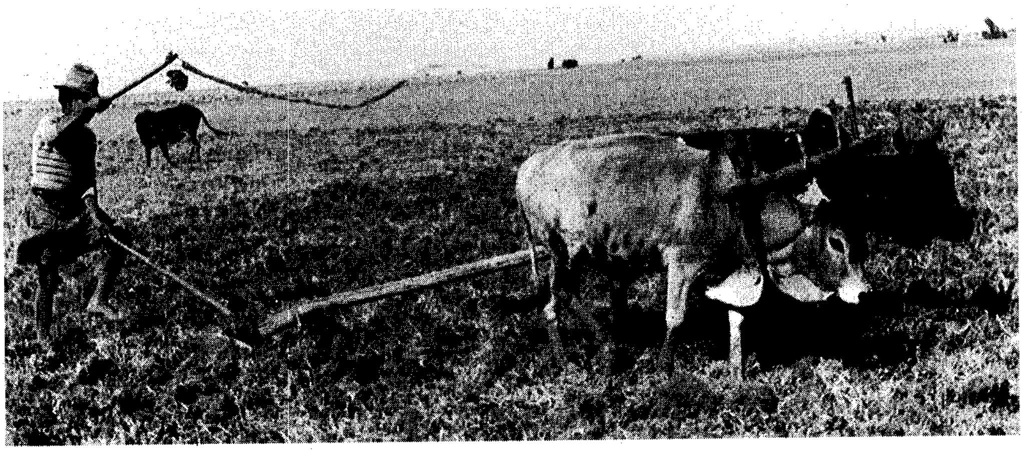


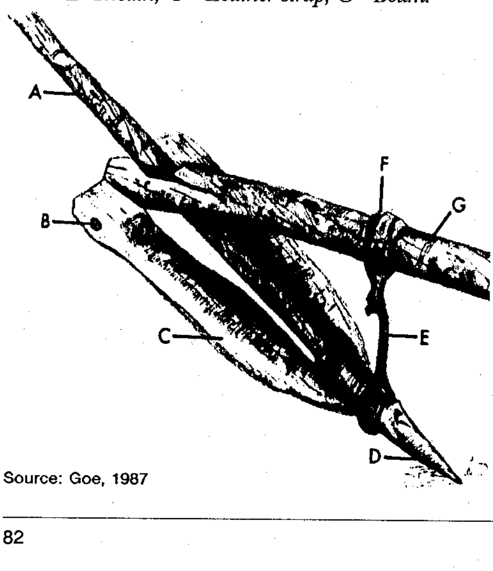
Photo: Paul Starkey

Fig. 7-2: Plowing with an ard in Egypt; in this case only one of the two handles is being used to control the plow.

and other trash at the surface, and in semi-arid areas this may result in quite effective weed control.

Other ard plows (including some body ards and sole ards in use in India and north Africa) have quite large wooden plow bodies (Fig. 7-5). These follow the steel share through the earth, breaking up relatively wide tracts of the soil (hence the description breaking plows). Although such ards do not fully invert the soil, they can often be used to systematically plow fields in a single pass, leaving most of the soil cultivated and weeds uprooted, buried or disturbed. This allows an appropriate seedbed to be rapidly achieved through subsequent harrowing using, for example, a blade harrow or ride-on levelling board.

Fig. 7-3: Ethiopian maresha and its parts.
A - Stilt; B - Sheath; C - Sole; D - Share;
E -Sheath; F - Leather strap; G - Beam.



Source: Goe, 1987

It has been argued that the symmetrical design of ard plows makes them unsuitable for use with soil and water conservation techniques that require soil to be thrown to one side, such as contour bunding and bed formation. In order to overcome such limitations, conventional ards have been fitted with wings or mouldboards. One recent research initiative involving such modifications in Ethiopia has been described by Jutzi, Anderson and Abiye Astatke (1986, 1988).

The *maresha* ard (Figs. 7-1, 7-3) is the main animal-drawn cultivation implement currently in use in Ethiopia, with around three million employed. The *maresha* has recently been studied in detail by ILCA scientists (Gryseels *et al.*, 1984; Goe, 1987). Ethiopian farmers

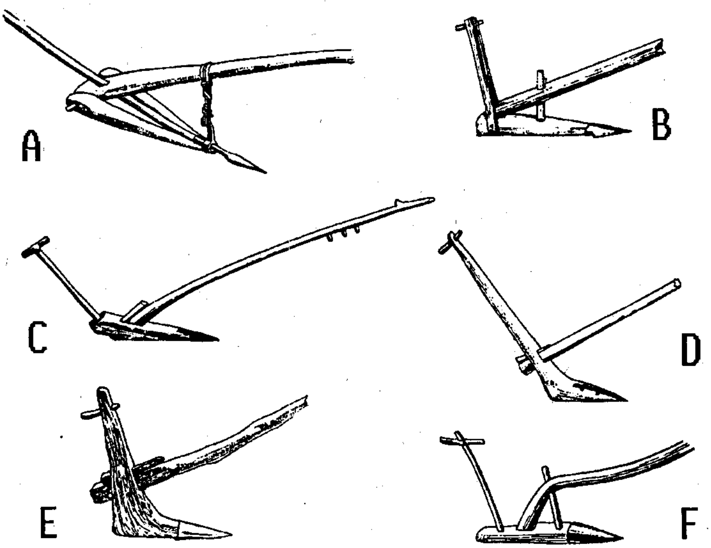


Fig. 7-4: Some ard designs
A- Ethiopian maresha;
B - Egyptian balady plow;
C - Nepal sole ard;
D - Indian body ard;
E - Afghanistan body ard;
F - Cyprus sole ard.
Source: after Hopfen, 1969

generally make their own implements from local timber and leather, but purchase their shares from local blacksmiths. For initial cultivations a share of 5 cm width is employed. Under typical farm conditions in the Ethiopian highlands a pair of indigenous oxen each weighing around 290 kg is used to plow at a depth of 9-15 cm with a draft force of about 1.0 kN. During the first four cultivations, a tillage rate of about 210 m^2 per hour can be achieved, representing 48 hours per hectare for each cultivation (Goe, 1987). Experimental trials have suggested that overall cultivation times could be reduced by 50% through the use of mouldboard plows (Abiye Astatke and Matthews, 1982, 1983, 1984). Nevertheless most attempts to introduce mouldboard plows at the smallholder level in Ethiopia have failed. Reasons for farmer rejection have included higher cost, heavier weight, limited durability and difficulties in obtaining spares and repair services from village artisans (Goe, 1987).

Ards are still commonly used for cultivation in north Africa, even in countries such as Morocco and Tunisia where animal-drawn steel mouldboard plows are widely available. In Morocco, ards can last for very many years, and can be passed down from one generation to another (Elbatnane, 1983).

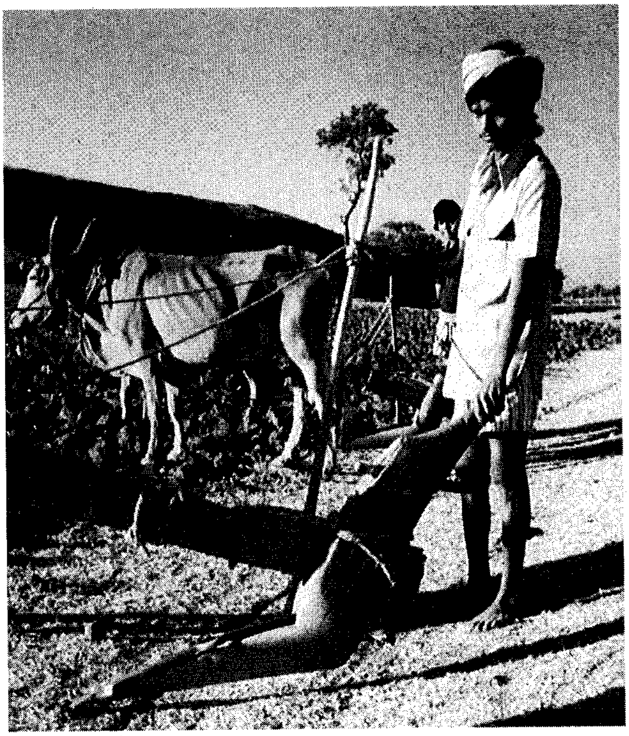
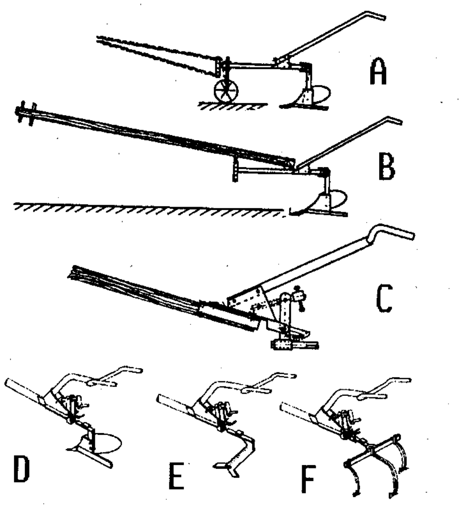


Fig. 7-5: An ard in central India. There are 30 million ards of many different designs in use in India. Photo: Paul Starkey



Source: after Nolle, 1986

Fig. 7-6: Evolution of the Kanol
A Houe Sine toolbar (A) was combined with the long pole of an ard (B) to form a prototype long-pole toolbar (C). A double handle was fitted and it was developed to take plow bodies (D), subsoiling sweeps (E), weeding tines (F) and other attachments. Although the Kanol has been widely evaluated it has not been widely adopted.

In recent years the government of Egypt has been advocating (and subsidizing) the promotion of motor-powered farm equipment, yet local artisans continue to make traditional ards to meet the significant demand from small farmers, the majority of whom use animal-drawn ards.

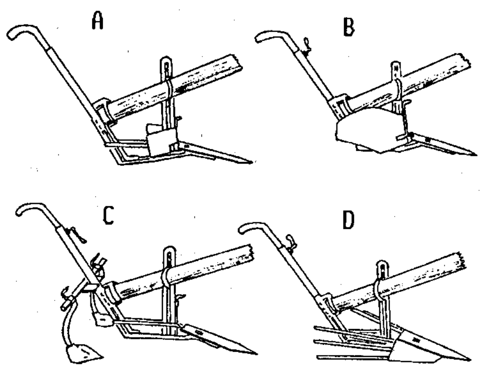
It is evident that, despite its antiquity, the ard should not be written off as a topic only for archaeologists and historians. The use of ard plows on a large scale has persisted in Asia, Africa and Latin America despite the promotion and spread of mouldboard plows. Ards are clearly well adapted to many present day farming systems. Their continued importance is well illustrated by the present situation in India. Western style mouldboard plows of good quality have been manufactured in India for several decades and are widely available at reasonable prices. Nevertheless their uptake has been quite slow. Between the years 1951 and 1972 the number of mouldboard plows increased from one to five million (Shanmugham, 1982). While this may appear to be a very significant expansion, it has to be seen in the context of an *increase* in traditional ards (from 32 to 39 million) and a major uptake of seed-drills and sowing devices (from less than one million to four million in this period).

Many aspects of ard design have evolved over centuries and have been proven by use by millions of farmers. Among the design features commonly found are:

- the use of a single, symmetrical share set at a fixed angle to the ground;
- use of a long beam (as opposed to a flexible chain) between the body of the implement and the yoke;
- provision of a single handle for control;
- use of materials and construction techniques that allow fabrication by village artisans.

It is clear from the great success of the ard, that when combined, these (and other) characteristics can result in very practical implements. However it is less clear which features are particularly critical, which might be changed, and which could be incorporated into other types of animal traction implement.

Fig. 7-7: Prototype toolbar based on traditional Peruvian ard.
A - Standard ard body; B - Earthing up body; C - Weeder; D - Potato lifter.



Source: after Herrandina, 1987

Source: ILCA, 1983

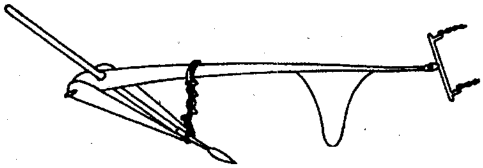
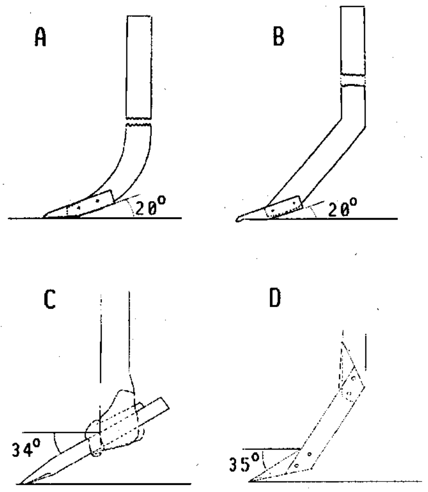


Fig. 7-8: A modified maresha ard.
It was developed in Ethiopia by the International Livestock Centre for Africa (ILCA) to allow use by a single animal. The beam was shortened and a skid and swingle tree were fitted. On-station trials were encouraging, but farmer uptake has been low.

Some recent and on-going research may eventually help to clarify these points.

Research being undertaken by CEEMAT involves the use of single symmetrical, angled tines for tillage in semi-arid conditions (Fig. 7-8). These have not been mounted on wooden beams (as is the case with ards), but onto steel beams or toolbars, as commonly used in sub-Saharan Africa. It is too early to know whether these tines will prove to be successful for primary cultivation, but the initial research reports of field trials seemed encouraging (Le Thiec and Bordet, 1989).

Fig. 7-9: Prototype single tines for primary cultivation tested by CEEMAT. Design D, ("RR"- réversible à ressort) made in abrasion-resistant manganese-silica steel performed best in trials.



Source: after Le Thiec and Bordet, 1989

In Peru, research is being carried out on combining many of the design features of traditional ards with the concept of multipurpose toolbars that can accept different steel attachments to assist ridging, weeding, potato lifting and inversion plowing (Fig. 7-7). While most of the principles of use remain the same, the complexity of manufacture, assembly and adjustment of the ard have been increased significantly. This ard has recently started to be marketed in Peru (Herrandina, 1987), and is being field tested in Niger (Projet Productivité de Niamey) but it has yet to pass the test of widespread adoption.

In 1974 the agricultural engineer Jean Nolle developed a multipurpose long-beamed toolbar in Nicaragua, by combining the principles of the local ard with the successful "Houe Sine" toolbar (Fig. 7-6). This implement was subsequently developed and marketed as the "Kanol" (Nolle, 1986). As it developed it lost all links with the ard except for the continued use of the long beam. It is a relatively sophisticated steel implement, guided by two (not one) steel handles, and a wide range of steel tools can be attached to it. In comparison to an ard it is (like other steel toolbars) complicated, expensive and difficult to manufacture. Although the Kanol has been tested in numerous countries, it has never achieved the same popular success as the traditional ard or the Houe Sine.

In Ethiopia, the International Livestock Centre for Africa (ILCA) modified the local *maresha* ard for use with a single animal (ILCA, 1983b). This involved replacing the traditional long beam with a shorter beam and skid, that connected to a swingle tree and traces. To date farmer acceptance has been negligible. Since the various changes (ard, single animal, different yoke design and use of traces) have all been brought together in one package (and so statistically confounded), it is difficult, at this stage, to judge whether it was the change in the beam length of the *maresha*, or some other factor(s), that were critical.

While the ard has been introduced by many migrants and settlers in historical times, leading to a worldwide diffusion, there seems little evidence of ards being introduced successfully in recent years. For at least fifty years, visits to Asia by officers responsible for animal traction programmes in sub-Saharan Africa have led to specific recommendations to evaluate traditional Asian wooden equipment in Africa. Only some of these suggestions were acted on, and to a very limited extent, but none led to significant adoption. The apparent lack of success of such initiatives may have been related either to perceived technical disadvantages relative to steel mouldboard plows, or to the difficulties experienced in training local artisans to fabricate wooden ards. At a national or project level the ordering of factory-manufactured steel implements may well have been administratively convenient and perhaps commercially expedient. However such influences should not have prevented smaller non-governmental organizations from developing the use of ard plows in Africa. While advocates for the use of ards argue that the absence of the ard south of the Sahara is simply due to lack of promotion, other people consider that lack of diffusion and farmer adoption is because the ards that have been tried have been rejected.

Thus while it is evident that ard plows can be highly effective in farming systems where they have been traditionally used, including North Africa and Ethiopia, it is not at all clear whether ards could prove to have an increasing role elsewhere in Africa. In conclusion:

- Ards should certainly not be dismissed merely because of their simplicity and their antiquity.
- Design features that have contributed to the widespread success of ards might well be incorporated into designs of other animal traction implements.

Fig. 7-10: Chinese single-handled, wooden "swing" plow with symmetrical cast-iron share.

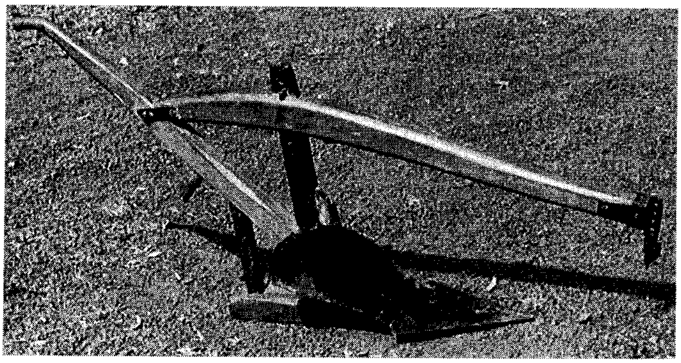


Photo: Paul Starkey

7.2 Mouldboard plows

Mouldboard plows are asymmetrical around their line of draft. They lift and turn the soil to one side, inverting it. The degree of inversion depends on the cohesion of the soil and the shape of the mouldboard. As it moves soil to one side, the mouldboard plow clears a distinct furrow. By continually turning soil into each previous furrow a farmer can systematically cultivate a field in one operation, covering both weeds and surface trash.

Historically mouldboard plows were developed mainly for swamp-rice production in humid climates and for rainfed crops in temperate climates. In these circumstances they provide quite rapid tillage that is combined with effective weed control and the incorporation of organic matter. Advantages of inversion in temperate climates are said to include improved aeration and drainage and the exposure of soil to the weather elements to accelerate the breakdown of soil into a fine tilth. In the tropics, and in particular in semi-arid areas, such soil inversion may not be desirable as it may increase the rates at which soil moisture is lost and humus is decomposed; in the tropics a fine tilth may be dangerously susceptible to both wind erosion and heavy rainstorms.

Single handled, mouldboard plows without any wheels have been used widely for more than two millennia in China, Japan and south-east Asia, mainly for rice production. Some modern plows from these countries are similar to very old designs, comprising a simple wooden or steel frame with one handle onto which fit symmetrical, cast-iron shares and mouldboards (Fig. 7-10).

In Europe mouldboard plows have been used for about two thousand years. Early designs were made mainly of wood and had flat wooden mouldboards with a two-wheeled forecarriage to support the plow beam. Over many centuries wood persisted as the main construction material, although iron components became increasingly used. It was only about a hundred years ago that steel of a suitable quality became available at an appropriate price to allow it to replace wood as the major component of the western plow. Steel mouldboard plows became standard tillage equipment in Europe, North America and temperate climates around the world. During the present century they have often become increasingly important in countries using traditional ard plows. Various designs of mouldboard plow have been introduced into the countries of sub-Saharan Africa, and often they have become the main implement for animal-drawn cultivation.

A wide range of mouldboard plow types has been evaluated in Africa this century, and from the numerous designs selected in different countries, a clear pattern has emerged. Most plow bodies comprise a shaped central element, or *frog*, to which are attached a *share* which cuts soil, a *mouldboard* which turns the soil and a trailing *landside* which provides stability against yawing and pitching. The end of the landside is known as the *heel*. The heel assists in controlling the depth and the pitching of the plow

Source: after Viebig, 1982

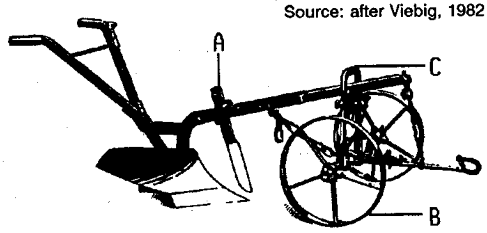
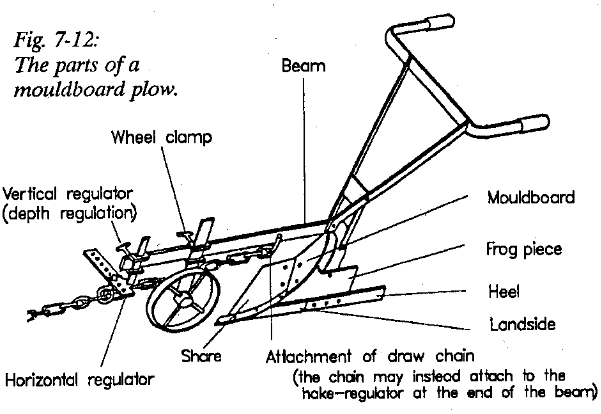


Fig. 7-11: Mouldboard plow of design used in Europe, but seldom seen in Africa. A - Knife coulter; B - Furrow wheel; C - Forecarriage.

and since it can be subject to rapid wear, it may be detachable to allow it to be replaced independently of the landside. The use of countersunk bolts has become standard to reduce wear and friction; these have square shanks to allow them to be tightened and slackened in the absence of a hexagonal head, and this means that spare parts such as shares must have square, countersunk holes of similar size. (Incidently, this feature causes problems for village blacksmiths and small-scale workshops, since punching a square hole is much more difficult than drilling a round one). The central frog is bolted to the main beam, usually a strong, J-shaped piece of steel of rectangular or "I" cross-section. The beam is usually about one metre in length, which is short compared with the old European plows. The attachment point of the traction chain may be along the length of the beam or at a terminal *hake*; in either case there is provision at the end of the beam for lateral and vertical

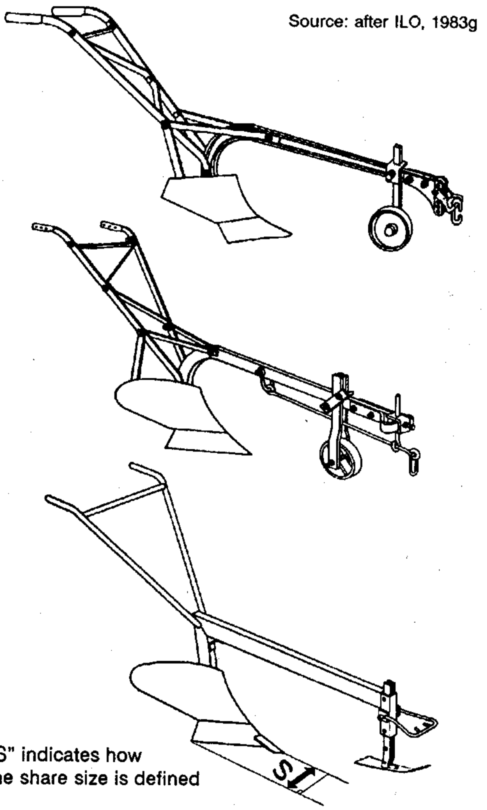
Fig. 7-12: The parts of a mouldboard plow.



Source: after Dibbits, 1987

Fig. 7-13: Mouldboard plows from southern and eastern Africa.
Top: *plow with chain attaching directly to hake manufactured on a large scale by UFI, Tanzania.*
Middle: *plow with draft rod manufactured on a medium scale by Northland, Zambia.*
Bottom: *Prototype plow with skid from Kenya.*

Source: after ILO, 1983g



"S" indicates how the share size is defined

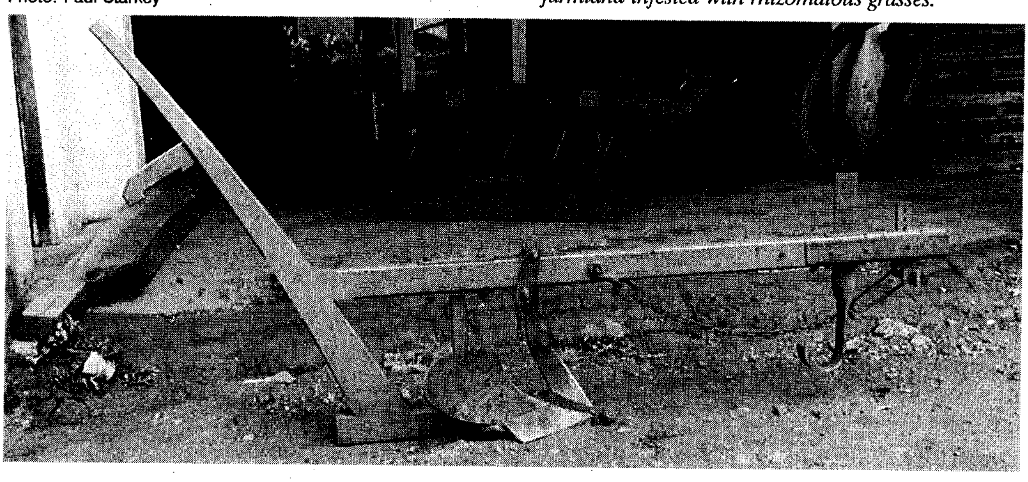
adjustment of the chain position. An adjustable *depth wheel* is attached towards the front of the beam, and this is used to restrict the depth of plowing and reduce pitching. Most steel plows in use in Africa have double handles. (Fig. 7-13).

These standard implements have arisen from the evaluation of a large range of possible plow designs. Such plows have evolved as an acceptable compromise between the requirements of low cost, simplicity, low weight and convenience, with those of technical excellence during work. Several features that have been valued in Europe, such as coulters, furrow wheels and reversible bodies have not been widely adopted. In most cases the rejected refinements had increased cost, complexity and draft requirements more than they increased efficiency.

Coulters were widely used on European plows and were considered particularly useful for plowing grassy land. In Africa they have seldom been used outside research stations. Knife coulters or disc coulters attach to a plow beam in front of the plow body and as-

Fig. 7-14 (below): Prototype plow developed by an NGO project in Zaïre, and subsequently made by village artisans. The plow has a wooden beam, coulter and skid. Coulters are seldom used in Africa, but this one was being evaluated for plowing farmland infested with rhizomatous grasses.

Photo: Paul Starkey



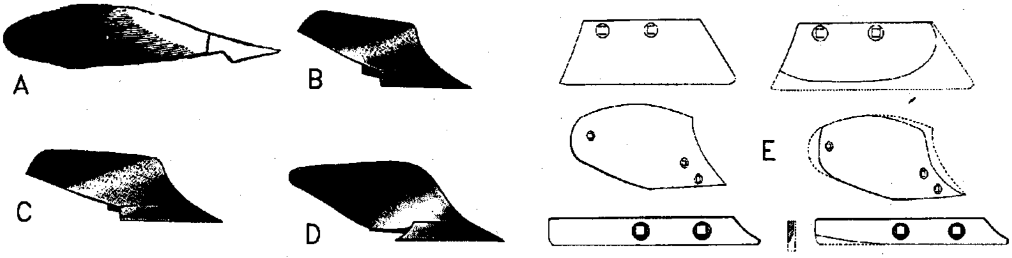
sist in obtaining a clean cut through vegetation and the soil. They also help in maintaining stability and straight furrows but they increase the draft of the implement and add to the price, weight and the number of adjustments. Disc coulters impose less draft than knife coulters, but are more expensive and in hard soils they tend to ride up, reducing penetration.

Although introduced and tested on many occasions, the carriage type of plow with a second and larger *furrow wheel* (Fig. 7-11) that was widely used in Europe has seldom been adopted in developing countries. A furrow wheel, as its name implies, runs in the furrow, increasing stability by reducing yawing and rolling. Adaptations of furrow wheel principles can be seen in intermediate toolframes, such as the *Ariana*, that have been adopted on a limited scale in certain countries. The second wheel makes it easier to hold the plow upright during work and the great stability of such implements can be convincingly illustrated during "hands off" plowing demonstrations (Fig. 7-15). Despite the advantages of the additional wheel, they have not been widely used in Africa, perhaps because farmers have found their increased cost, weight, draft and complexity too great to justify.

In contrast another plow refinement, the land wheel, has been almost universally adopted for the cultivation of rainfed crops. Land wheels are not essential and can be positively disadvantageous for swamp cultivation. Traditional Chinese and Japanese plows have not used land wheels. However a *swing plow*, one without a wheel, requires much more effort to control the working depth and the pitching tendency of the implement, particularly when the animals surge forward or slow down. A simple skid (Figs. 7-13, 7-14) made of wood or metal has the same effect as a wheel in providing stability and preventing the plow from digging too deeply. In very muddy conditions, or where there is much surface vegetation, a skid has less tendency to clog than does a wheel. Skids are easier and cheaper to make than wheels and require much less maintenance. An indication of the problems of wheel maintenance can be gathered by the number of times one sees (or hears!) wobbling depth wheels that have had their bearings, axles and even wheel centres worn away to almost nothing. Nevertheless a skid usually imposes more resistance than a wheel and is less convenient for the farmer during transport to the field and in turning at the ends of rows; consequently skids are not widely used.

The length and shape of the mouldboard has a great influence on the quality of work. Under one, largely outdated, system of plow classification in Europe a *general purpose* or *common* plow body was one with a long, gently curving mouldboard that kept cohesive soil intact in long continuous seams that were often inverted through 135° to lie at an angle of about 45° to the horizontal. Such plow bodies are seldom found in developing countries al-

Fig. 7-15: Ariana toolframe fitted with two wheels and a mouldboard plow being used in a "hands-off" plowing demonstration in Lesotho. (The designer of the Ariana, Jean Nolle, is walking beside the plow).
Photo: Peter Munzinger



Sources: after: LCC, 1984; Viebig, 1982; AETC, 1986

Fig. 7-16: Mouldboard plow bodies and wearing parts.
A. European style "common" or "general purpose" body, rarely seen in Africa.
B. "Continental" body. C. "General purpose" body. D. "Semi-digger" body.
E. Slip share, mouldboard and landside showing typical patterns of wear.

though some training manuals appear to have been based on the assumption that such implements were in common use. A *digger* body has a shorter mouldboard that causes the soil seam to break as it turns, and most plow types in use in Africa are of this *digger* or *semi-digger* type (Fig. 7-13). Semi-digger plows can have *cylindrical* or *semi-helicoidal* shaped mouldboards (Fig. 7-16), and these different shapes can make a major difference to the quality of land preparation. The choice of a suitable design depends not only on soil type but also on the time between plowing and sowing. For rapid cultivation in relatively light and sandy soils the action of a short, cylindrical mouldboard (which is particularly easy to manufacture) can assist the rapid breaking and loosening of soil for immediate light harrowing or direct planting. A semi-helicoidal shape produces a more gradual inversion which is suited to areas of high weed infestation in more humid climates, where complete burial of the weeds is important. Semi-helicoidal mouldboards are generally preferred for areas with cohesive soils and are often combined with the practice of thorough harrowing. If farmers have not had an opportunity to assess different plow bodies within their farming systems, providing them a chance to do so might well prove a valuable exercise.

The length and angle of a plowshare determines the width that the plow cuts. The quoted size does not actually refer to the dimensions of the share itself, but to the width it will cut (Fig. 7-13). Despite the widespread use of metric units, share sizes are often still expressed in inches (*pouces*), even in francophone countries. Small shares require less draft power but as each plow furrow is small it takes longer to cultivate each hectare. With a 6" (150mm) plowshare, the plow (and farmer) has to travel about 66 km to cultivate each hectare. With a 10" (250mm) share the distance is 40 km. Most mouldboard plows in use in Africa have shares of 7-9" (180-230mm) although in Botswana some plows have large 15" (380mm) shares which require the strength of several animals. Plowshares are usually of the slip share type (Fig. 7-16) and, as wearing parts, they are designed to be regularly sharpened, reworked or replaced. In abrasive soils a share may last for only 2-4 hectares, while in other soils a share can last for several seasons. A worn plowshare cuts a smaller furrow and can eventually lead to the plow body itself becoming worn which is much more difficult to repair. Lightly worn plowshares can be reworked into an acceptable condition by village blacksmiths and new ones can often be made from the leaf springs of old vehicles.

In addition to plowshares, the heels and landsides are wearing parts that need regular attention and repair or replacement. Although neither is essential (some Chinese or Japanese plows lack them) both greatly im-

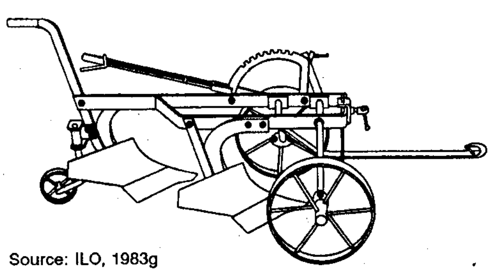
Photo: Paul Starkey

Fig. 7-17: Double furrow plow in Botswana. While this double plow (with a drawbar instead of a traction chain) is an experimental prototype, there are about 9000 double furrow plows with similar plow bodies in Botswana. They are pulled by teams of 8-16 animals.

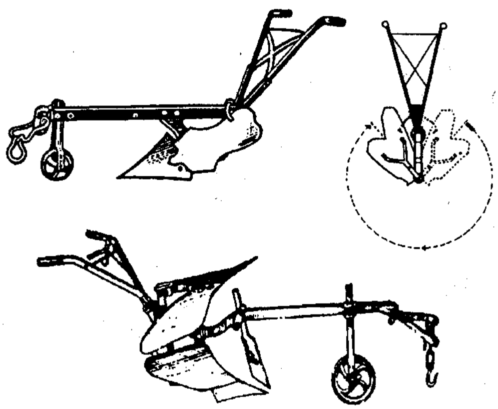
prove the handling characteristics of plows. A long landside which trails along the bottom of the furrow wall helps to absorb the lateral (yawing) forces associated with the asymmetrical shape of mouldboard plows, making it easier to plow a straight furrow. The heel assists in depth control by lightly scraping the bottom of the furrow, so reducing any tendency of the plow to pitch. If heels and landsides are not maintained, the ease of handling gradually deteriorates, and eventually the frog-piece starts to wear. Land wheels often wear rapidly as abrasive soil particles enter the wheel bearing. Preventive maintenance, notably regular cleaning, may preserve the life of a wheel but there is controversy as to whether greasing the axle of a wheel is desirable. Greasing reduces friction, but if a seal is absent, or worn, abrasive particles combine with the grease to form a grinding paste, which can actually accelerate wear. In such circumstances it may be better to keep unsealed bearings dry so that abrasive particles leave as easily as they enter. Although village blacksmiths can do remarkable repairs, it has frequently been observed that farmers find it particularly difficult to maintain wheels in good condition.

Double-furrow mouldboard plows may be used where draft animals are readily available but where time and human labour are in short supply. Inevitably the second plow body increases the draft requirement substantially compared with a single plow and this normally necessitates large teams of animals pulling the one implement. Large teams are less manoeuvrable than small teams and so more time is lost in turning. The main advantage of large teams is that a small number of people can control many animals. Double and even triple plows were widely used in North America in the first half of this century, and they were often used by one or two workers controlling teams of 4-12 large horses. Where labour is available, plowing may be achieved more quickly and more simply by harnessing the extra animals to a second single mouldboard plow. Investment in two single plows allows a farmer greater overall flexibility in resource management than does the purchase of a double mouldboard plow. Double plows are sometimes used in Botswana with teams

Fig. 7-18: Prototype double furrow plow built by CAMERTEC in Tanzania. In some parts of Tanzania farmers use teams of oxen, but few double-furrow plows are in use.



Source: ILO, 1983g



Sources: after: Hopfen, 1969; CEEMAT, 1971

Fig. 7-19: Reversible plows.
Top: Inexpensive reversible design that is quite widely used in India, showing the method of rotating the mouldboard to the other side at the end of a row.
Bottom: A more expensive design of plow with two bodies that are alternately swung into place. Designs such as this have been tested in several African countries, but have generally been found too heavy and expensive for use in the local farming systems.

of eight or more animals, but they are seldom seen elsewhere in Africa.

Reversible plows, sometimes known as *one-way* or *turn-wrest* (wrest = mouldboard) turn soil to the left or right depending on the setting. The standard mouldboard plow always turns the soil to the right, so that plowing is usually done by progressively moving around fields or parts of fields, with furrows facing opposite directions on either side of the plowed areas. This inevitably leads to some unfilled furrows or ridges wherever the two directions of plowing meet, although such effects can be minimized by technical skill. With a reversible plow a farmer can steadily move across a field, creating the seams and furrows in just one direction. This may be particularly useful for contour plowing in hilly areas or for maintaining the uniformity of level in irrigated or terraced land. In most circumstances, farmers feel the advantages do not sufficiently compensate for the additional weight and complexity. In the simpler forms of reversible plow the share is symmetrical (like that of an ard) and only the mouldboard is moved. In more expensive and heavier models a second plow body can be brought into use on alternate rows (Fig. 7-19, bottom). Significant numbers of simple reversible plows have been adopted in India (Fig. 7-19, top). In Angola about 45% of the estimated 150,000 plows in use are reported to be of a simple reversible design. Elsewhere in Africa, reversible plows are seldom seen outside research stations, although the use of heavy reversible plows pulled by teams of four to eight animals has been reported from certain rice cultivating areas of Madagascar (FAO/CEEMAT, 1972).

7.3 Ridging plows

Ridging plows are symmetrical around their line of draft and the two mouldboards turn soil to both sides (Fig. 7-22). In each pass through the soil a ridger makes one furrow and two small ridges. In normal use the furrows are so spaced that two small ridges are

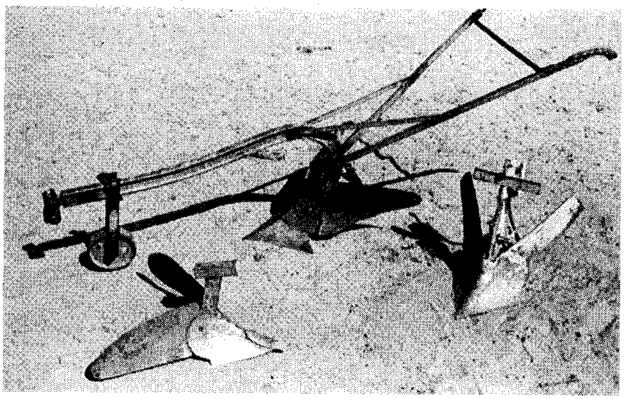


Fig. 7-20:
"Emcot" ridging plow in The Gambia. Beside it are ridging bodies designed to fit the Unibar/Pecotool (left) and the Houe Sine (right) multipurpose toolbars. The Houe Sine ridging body with high wings is designed for earthing up, rather than primary ridging.

Photo: AFRC-Engineering archives

Source: Bulawayo Steel, 1983

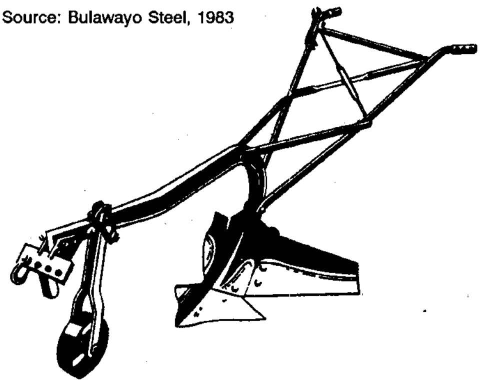


Fig. 7-21: "Inkunki" high wing ridger, manufactured in Zimbabwe.

combined to make one larger one. Thus on every pass the ridger completes one ridge and forms one half of the next one. Because of their wide working width ridgers have a high draft. In light soils or with heavy animals it is possible to form ridges on seasonally fallow land, but in other conditions soil may have to broken with tines or a mouldboard plow to make it light enough to ridge. Ridgers may have mouldboards (wings) that adjust in elevation or in the angle between the wings. This permits ridges to be made of different shapes and heights.

Ridging can be quite a fast system of soil cultivation. This is due both to the wide working width, and the fact that not all the land is tilled. The land under the ridges is not disturbed, and if ridges are spaced at 90 cm the ridger only travels 11 km per hectare (in comparison to 43 km/ha for a 9"/23 cm mouldboard plow). Permanent ridges may lead to the development of hard layers of soil difficult for roots to penetrate. This leads to the practice of ridge splitting which, if carried out in dry conditions, imposes a very heavy work load on animals (Stokes, 1963).

Ridging as a method of cultivation developed in many African countries before animal traction was introduced. Cropping on ridges is common in several areas including the savannah regions of Nigeria, in the west of The Gambia and in parts of Malawi and Zimbabwe. In certain climatic zones ridging may be valuable as a means of soil and water conservation, and some of the benefits may be attributable to the labour-intensive operation of ridge-tying (discussed in section 9.5). Planting using animal power is more difficult on the ridge than on the flat, and while animal-drawn ridge seeders have been developed in several countries, they have usually been less effective than seeders designed for level ground. Hand weeding with hoes along ridges is more time-consuming than within-row weeding on the flat, but inter-row weeding and re-ridging with a ridger can be effective and ridges are more easily followed than rows. In certain areas, notably northern Nigeria, the ridger is often the only animal traction implement, being used for primary cultivation, weeding and earthing up.

Fig. 7-22: Ridging in Nigeria.

Photo: Enoch Gwani

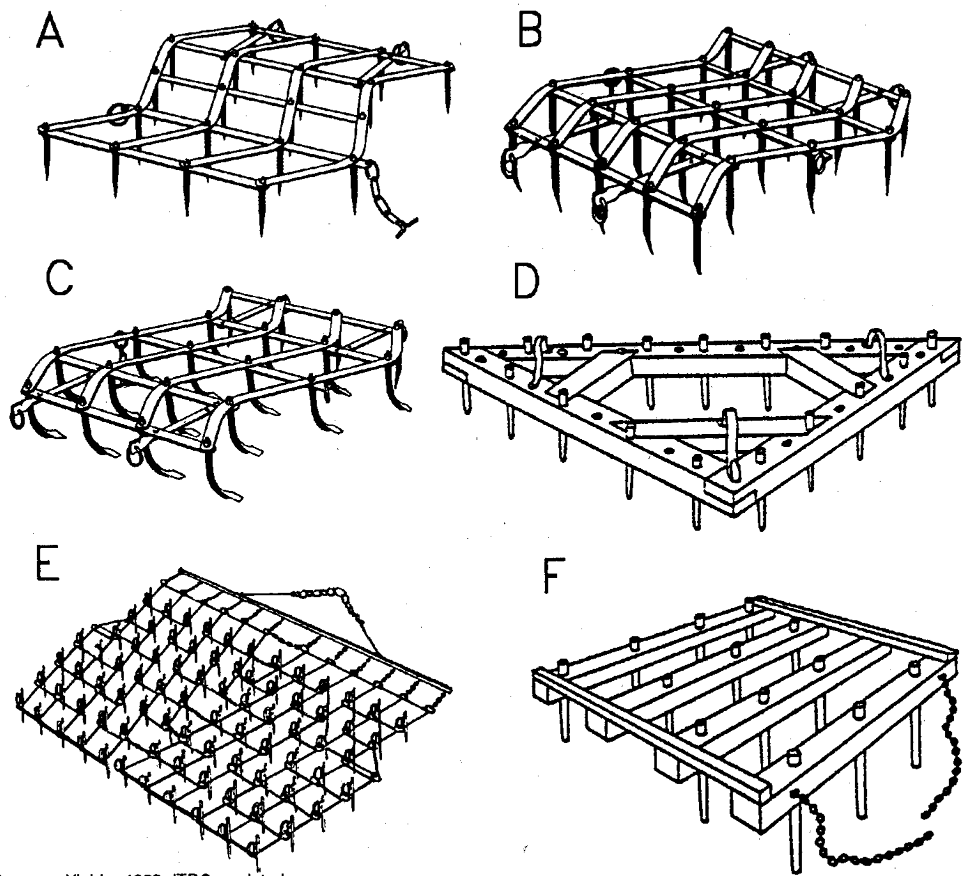
Ridging plows are seldom used for primary cultivation in francophone West Africa but "earthing-up" ridging implements may be used for weeding crops such as cotton and maize. Such earthing-up ridgers (*butteuses*) are designed primarily as secondary cultivation implements, and are often attached to a multipurpose toolbar. The shape, strength and wearing characteristics of such earthing-up ridging bodies have been designed for inter-row weeding and earthing-up, and so such implements are unlikely to be found ideal if used as ridging plows for primary cultivation.

7.4 Harrows

Harrows are mainly used to crush clods and to level a seedbed after plowing. They are also used to control weeds and to cover seed or fertilizer that has been broadcast. In temperate climates they are used to aerate pastures.

Tine harrows are characterised by a wide working width and many small cultivating points, generally made of steel. *Disc* harrows usually comprise two gangs of steel discs which pulverise clods into a fine tilth. Because of their rolling design, animal-drawn disc har-

Fig. 7-23: Tine harrows
A and B. Steel zigzag harrows ("seed harrows"). C. Chisel-tine harrow.
D. Triangular wooden harrow with steel tines. E. Chain harrow (rarely used in Africa).
F. Wooden rectangular peg-tooth harrow with rigid construction.



Sources: Viebig, 1982; ITDG, undated.

Source: ITP, 1985

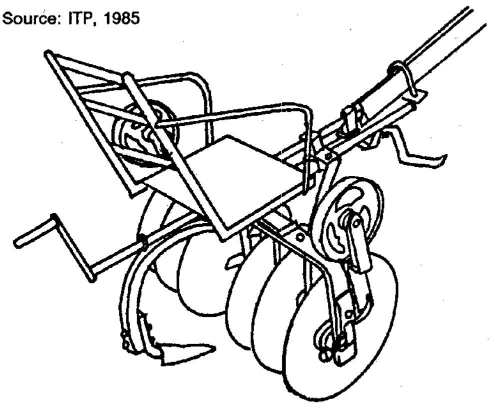
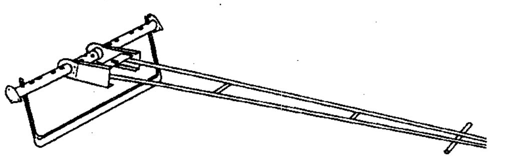


Fig. 7-24: Ride-on disc harrow
Such implements are commonly employed in India, but seldom used in Africa.

rows are often ride-on implements, with the weight of the operator increasing the effectiveness of work (Fig. 7-24). Although animal-drawn disc harrows are quite widely used in India, they are rarely seen in Africa. They are expensive, heavy to transport to a field and their high working draft requires strong animals. Some rotary implements may be used for rice production (see section 7.9).

Tine harrows may have rigid or flexible frames and the cultivating points may be rigid *peg teeth* or *spring tines*. Rigid harrows often have a triangular or rectangular wooden frame and 15-30 steel tines (Fig. 7-23D, F). These can be easily manufactured by village artisans (MacPherson, 1975; Starkey, 1981). Wooden pegs can be used instead of steel tines, but these are less durable. Peg-tooth harrows are quite heavy and one reason for their limited adoption in Africa is the difficulty of transporting them to a field in the absence of carts. A second disadvantage can be the speed at which normal timber can rot or become infested with insects, so causing the tines to loosen or the wooden frame to break during work. The use of local varieties of very hard, resistant timber reduces this problem, but at the cost of greater manufacturing difficulty.

Fig. 7-25: A prototype multipurpose tool developed in India that is designed to function in the same way as the traditional blade harrow.



Source: Basant, 1987

Steel *zigzag* or *diamond* harrows (Fig. 7-23A-C)are more widely used and last longer than wooden harrows. These are generally manufactured in small factories and are more expensive than wooden framed harrows. The draft of peg-tooth harrows depends on soil conditions, the weight of the harrow (and any logs added to increase penetration) and the number, angle and sharpness of the tines. Tines angled towards the direction of travel increase both penetration and draft. In general terms, a 15-20 tine peg-tooth harrow is likely to have a comparable draft requirement to that of a 9"/230mm mouldboard plow.

One disadvantage of a harrow with a large, rigid frame is that the implement is not capable of responding to minor undulations in the surface of a field. This problem can be reduced if two, or more, smaller harrows in parallel replace one large harrow, or through the use of a *flexible* or a *chain harrow*. Animal drawn chain harrows pulled by teams of large horses were widely used for pasture management in temperate climates. Such harrows usually have more than 60 points and the draft is excessive for normal tropical applications. With an assumed draft resistance of 10-60 N per tine, harrows designed to be pulled by pairs of oxen should not normally exceed 15-30 points (CEEMAT, 1968).

In India *blade harrows* are very widely used, particularly in semi-arid areas. The sharp metal blades about 400-600mm long are attached to a wooden frame, and are pulled through the soil about 50mm below the surface (Fig. 7-26). They loosen the soil and cut roots without disturbing the trash on the soil surface. By not turning or mixing the soil surface

Photo: Paul Starkey

Fig. 7-26: Blade harrow being used in India.

they cause less moisture loss than a tine harrow. There appear few records of simple blade harrows being used in Africa. However wide sweeps fitted to toolbars and wheeled toolcarriers that may have been functionally comparable to blade harrows have been tested in several countries. These have seldom been found satisfactory, with problems of trash clogging the implements, very high draft, and disappointing weed control for the work involved (EFSAIP, 1984).

Animal-drawn *rollers* were commonly used to crush soil clods in temperate agriculture, but they have not been adopted in the tropics; this seems largely attributable to their heavy weight, high draft requirement and cost.

Cultivators may be used to achieve the same effect as harrowing and these are discussed in section 7.6.

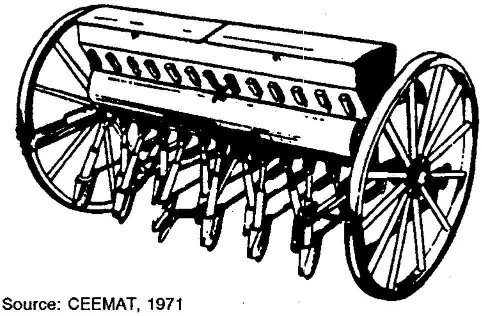
7.5 Seeders and planters

With the notable exception of Senegal and Mali in West Africa, animal-drawn seeders have seldom had the same degree of success as have plows and cultivators. This is because seeding can often be done quickly and effectively by hand while mechanical sowing devices are usually expensive and often require ideal working conditions.

The objective of sowing is to place seeds at an appropriate depth in the soil with an optimal spacing between seeds. It has repeatedly been shown by comparative trials that accurate planting produces higher and more reliable average yields than random seed placement. The object of a seeder is to obtain such *accurate* and *reliable* seed placement *conveniently* and at an *acceptable cost*. In the past twenty years many organizations and projects in developing countries have invested time and money in trying to achieve these goals. Most initiatives have failed. In some cases the mechanism was simply not effective; in others the implements worked perfectly on research stations, but could not cope with the variable seed size and soil conditions of real farms; finally there were those that met all the technical requirements, but which were not cost-effective in the prevailing farming systems.

The main manual techniques for sowing are broadcasting, dibbling and drilling. Broadcasting involves the scattering of seeds over the soil surface followed by some mixing of the topsoil. Dibbling necessitates the making of a small hole into which are dropped one or more seeds. Drilling is the process of making a narrow furrow into which seeds are placed at regular intervals after which the furrow is covered with top soil and loosely compressed. The various manual processes may be either combined with, or replaced by, animal traction techniques.

Broadcasting has historically been the major method of seeding grasses and small cereals such as wheat, teff and rice. When broadcasting is combined with animal traction, soil is generally plowed several times to obtain a satisfactory seedbed, or plowed once and then

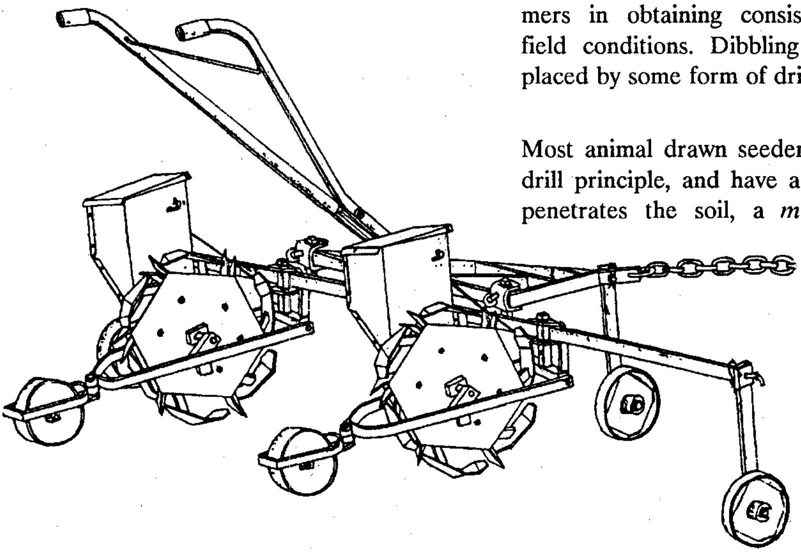


Source: CEEMAT, 1971

Fig. 7-27: Multi-row cereal seeder.

harrowed. The seed is scattered by hand and then a light *seed harrowing* (or seed plowing with an ard) ensures that seed is incorporated into the topsoil. Once seed is distributed in this way, further animal traction operations are virtually impossible without damaging the crop. Very light harrowing as a means of early weeding is technically possible but seldom practised in the tropics. The broadcasting of wheat and rice may be replaced by animal-drawn single-row seeders or multi-row seed drills. The narrow inter-row spacing favours multi-row seeders, and designs of these are commercially available (Fig. 7-27). Dibbling has traditionally involved the use of a simple hoe or stick to make holes into which seeds are dropped; the holes are then covered with soil using a foot. Although the work is tedious, fast rates can be achieved. Further, while seeders are designed for uniform areas, farmers' fields are highly variable, and with dibbling a skilled farmer can adjust population density very accurately to the micro-relief or fertility patterns of a field. Hand dibbling can be on ridges or on the flat, can be in rows or evenly spaced and can involve single seeds or groups of seeds (hill planting). Dibbling is therefore a very flexible system of planting that is difficult to mechanize effectively. Rolling injection planters, such as those developed by IITA in Nigeria and widely evaluated elsewhere, are based on the dibbling principle. These seeders can be made as multi-row units to be pulled by animals, and prototype animal-drawn rolling injection planters have been built by appropriate technology organizations in several countries. Small numbers have been manufactured by the UPROMA factory in Togo (UPROMA, 1984 & 1986; Fig. 7-28). To date the uptake of these has been minimal and reasons for this may be associated with the high cost of these implements and the problems experienced by farmers in obtaining consistent results under field conditions. Dibbling can often be replaced by some form of drilling.

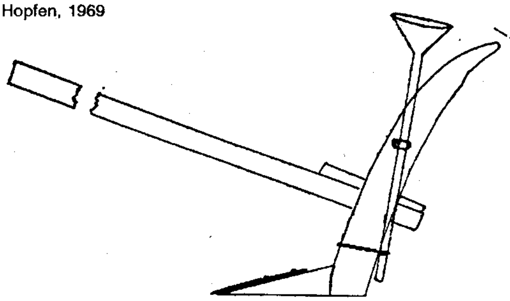
Most animal drawn seeders are based on the drill principle, and have a *furrow opener* that penetrates the soil, a *metering* mechanism,

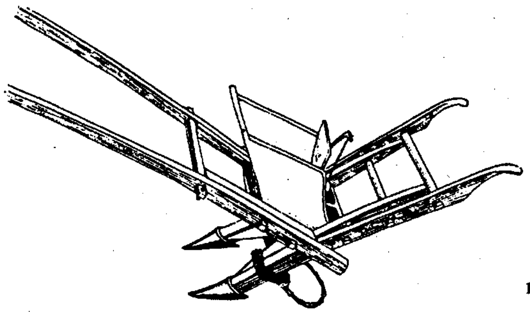


Source: UPROMA, 1986

Fig. 7-28: Prototype animal-drawn rolling injection planter. Planters such as this, based on seeder units developed by IITA, have been evaluated in several countries, but have yet to be widely adopted.

Sources:
Gite and Patra, 1981
Silsoe, 1986
Hopfen, 1969





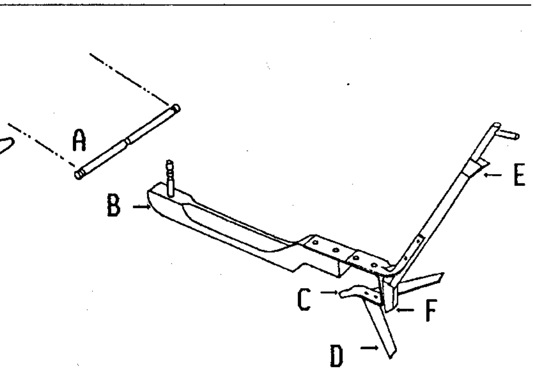


Fig. 7-29: Simple hand-metred tube seeders.
Above right:
Prototype simple seeder-weeder developed by a development project in Sudan.
A. Traces to donkey. B. Wooden ground beam. C. Chisel point. D. Sweep. E. Seed chute. F. Seed box.
Left:
***Top:** "Nari" single-row seeder used in India.*
***Bottom:** Chinese two-row seeder.*

that determines seed rate, and some form of seed tube that transports the seed to the furrow. There is generally some system for covering the seeds in the furrow and lightly compacting the soil.

The simplest systems do not require separate implements. Row seeding can be achieved using a plow (ard or mouldboard) as a furrow opener and hand-metering by dropping the seeds into the furrow. If furrow depth is not constant there will be seed wastage, but with no capital outlay, this may be acceptable. The problem of accurately aiming the dropped seeds can be overcome by the provision of a plastic seed tube that drops the seed behind the plow (Fig. 7-29). This elegantly simple design can be adapted into a two, three or four row planter. The seeds are hand-metered into a small wooden bowl and pass down plastic tubes to simple furrow openers. A second bowl and series of tubes can be used to make the implement into a combined seeder and fertilizer distributer. Such seeders are commonly used in India, but not in Africa. It does not seem clear whether this lack of uptake has been because of inherent problems with these implements or because they have been overlooked. Certainly the majority of research and development workers involved with the testing and adaptation of seeders in Africa have concentrated on precision seeders.

Precision seeders use the forward movement of a ground wheel to drive some mechanism that causes seeds to drop behind the furrow opener. Covering is ensured by a simple device such as a loop of chain dragging the surface or the action of two tines mounted in parallel behind the seed placement position. Compaction is often achieved by a small trailing roller. The simplest mechanisms involve a wooden roller driven directly by a ground wheel. As the implement moves forward, the roller rotates and seeds drop into holes or slots and are transferred to the seed tube. Seed rate may be determined by the size of an adjustable aperture at the bottom of the seed hopper and spacing depends on the shape of the roller. Different rollers are used for different crops. More complex seeders involve

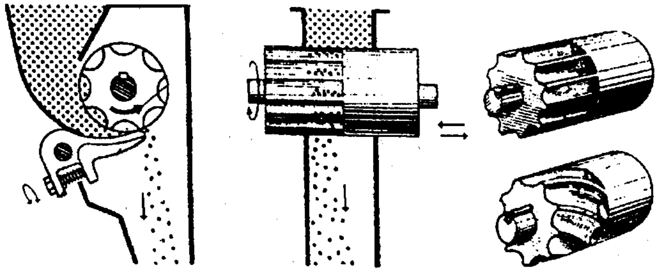


Fig. 7-30: Basic roller seeder mechanism, used in multi-row cereal seeders. Metering can be controlled by regulating the orifice (far left) and moving the roller in or out to determine how much of the fluted (seed-metering) portion is actually in operation (centre). The fluted rollers (right) can be straight or spiral.

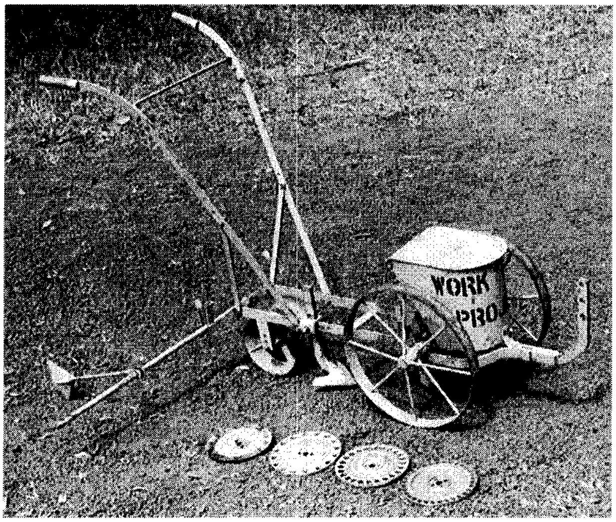
Source: CEEMAT, 1971

some form of cog or chain gearing mechanism that indirectly takes power from the axle of the ground wheel(s) and drives metering wheels or plates. The *"Super Eco"* type of seeder (probably the most successful in Africa to date) uses a sealed gear mechanism to drive seed wheels at an inclined plane. The number of holes in a wheel determines inter-plant spacing and seed wheels with different sizes and patterns of holes are available for maize, sorghum, millet, groundnuts, cowpeas and rice. A separate hopper and seeding mechanism are required for cotton seed that has not been delinted. A clear and well illustrated description of the use of *Super Eco* seeders may be found in a manual prepared for use in The Gambia by Matthews and Pullen (1976).

A simple but important aspect of seeder design is the "next-furrow" marker. This is a bar with an adjustable tine that draws a line on the ground parallel to the furrow being created. This mark is then followed to ensure the next and subsequent rows have constant inter-row spacing. This is particularly important to allow effective animal-drawn inter-row cultivation. Two (or more) separate seeder bodies

*Fig. 7-31: Super Eco seeder. **Below:** Seeder with various distribution plates and next-row marker extended. **Right:** Seeder in action showing back of distribution plate and seeds falling into seed tube. The furrow opener, press wheel and row marker are just distinguishable. The ground wheels turn a sealed gear mechanism that drives the distribution plate.*

Photos: Paul Starkey



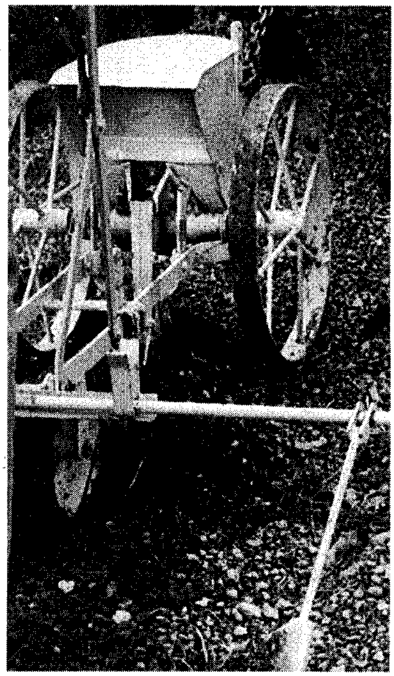
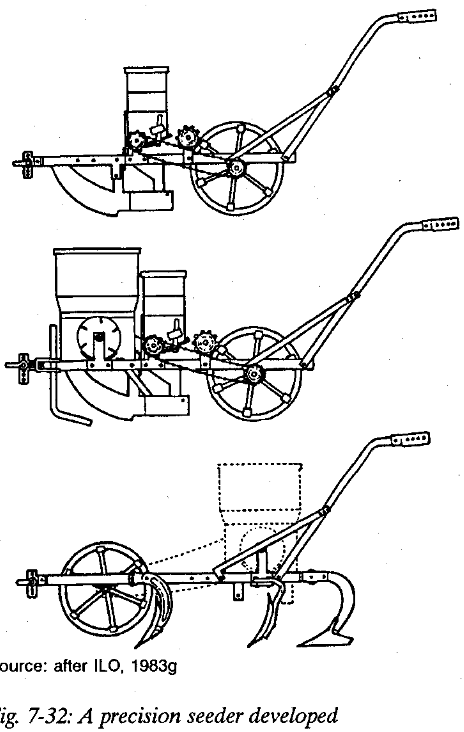


Photo: Paul Starkey

Fig. 7-33: Horses are commonly used to pull Super Eco seeders for planting groundnuts in Senegal.



Source: after ILO, 1983g

Fig. 7-32: A precision seeder developed experimentally in Botswana from a general design quite widely used in Southern Africa. The ground wheel turns a chain that drives the metering mechanism comprising an agitator over a fixed, gravity-fed metering plate. It was intended that the chassis could be used as a simple seeder (top), fertilizer-planter (middle) or cultivator (bottom).

may be used together, for example on an intermediate toolframe. However despite many attempts to encourage multi-row seeding using two or more precision seeder bodies, farmers in West Africa have shown a clear preference for single-row seeding (Bordet, 1987).

Well-adjusted seeders operating in good conditions can save working time. They can also save seed by sowing at the depth and spacing considered optimal for germination and survival. On the other hand poorly-designed or badly-adjusted seeders working uneven seedbeds can waste time, waste seed and result in irregular and low plant populations. Surface trash or sticky soil can clog seeders; metering wheels may slip, thereby changing seed spacing; planting depth will not be constant on uneven ground; metering mechanisms may physically damage seeds, thereby reducing the proportion that germinate; seeds of unusual shapes may become stuck in seed-holes and require removing (it is actually quite difficult to detect during seeding that seed-holes have become blocked, but it shows clearly at germination time!). Seeding on ridges generally has

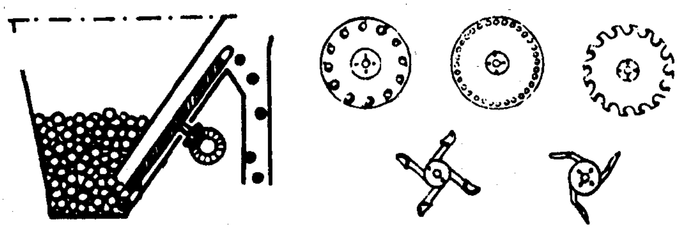


Fig. 7-34: Basic mechanism of the inclined-plate seeder, widely used in West Africa for groundnuts. The ground wheel drives the plate, which carries seed up to fall into the seed tube. Metering depends on the size and number of holes in the plates.

Source: CEEMAT, 1971

additional problems due to inevitable variations in their height and surface. Many an agricultural engineer can testify to the frustrations of trying to obtain optimal seed rates with seeders on the excellent seedbeds of research stations, while many a farmer can further amplify the problems of use under normal field conditions. In southern Mali, some farmers who own and use animal-drawn seeders still opt to hand-plant *some* of their fields and crops. They use long cords with knots in them to ensure straight rows and constant plant spacing. They argue that although cord-planting is slower, the resulting rows are more parallel, the plant population is more uniform, and the efficiency of weeding is improved.

Problems of cost, complexity and unreliability have restricted the spread of seeders in Africa. In most Sub-Saharan countries in Africa the number of animal-drawn seeders in use is below 5000. The main exception to this generalization is Senegal where there are about 145,000 *Super-Eco* seeders in use (Havard, 1985). In neighbouring Mali another 45,000 similar seeders are employed. The *Super Eco* was first introduced in Senegal in the 1930s, and has been locally manufactured since 1963. The diffusion of seeders in Senegal has been well reviewed by Havard (1986) and Bordet (1987). Several other seeder designs have been tested and sold, but none had the same combination of efficiency, durability, adaptability and availability. The single-row seeders were successful in the semi-arid areas where the number of days a year suitable for planting are few, and time is of the essence. In such conditions there may be no time for conventional seedbed preparation and in very light soils, seeders such as the *Super Eco* can be used for direct planting. Thus in parts of Senegal and The Gambia some farmers have purchased seeders (to be pulled by a single donkey or a horse) even when they did not own plows or cultivators, and the seeder is second only to the multipurpose cultivator (*Houe Sine*) in terms of number of animal-drawn implements in service.

The *Super Eco* and similar seeders use a system of interchangeable discs to determine spacing (Fig. 7-34). This metering system is well adapted to the single planting of relatively large seeds that are more or less spherical in shape, such as groundnuts, maize, cowpeas, soya beans and delinted cotton. It is less suitable for smaller or less spherical seeds such as sorghum, millet, rice or raw cotton. Although there have been attempts to modify the *Super Eco* (and other seeders) for ridge cultivation in Senegambia, these have not led to adoption. Problems with seeding on ridges include the positioning of the operator and animal (a single animal pulling a ridge seeder would walk on the ridge) and the stability of the seeder on the ridges.

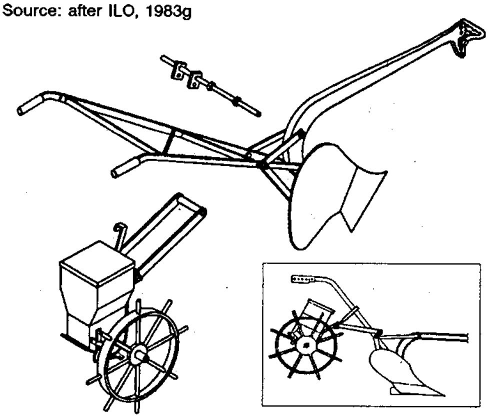
The success of the *Super Eco* can be usefully contrasted with the failure of some other seeders in Senegal. There have been several attempts to introduce dual-row and multi-row seeders. These were not adopted by farmers, mainly because the increases in cost and weight and decrease in manoeuvrability were not considered to be justified. While a single-row seeder could be pulled speedily by a single horse, the dual- and multi-row seeders required extra draft, and were normally pulled by a pair of oxen, which walk more slowly than horses (Havard, 1986; Bordet, 1987).

Seeders seem most likely to be adopted in semi-arid areas where planting time is particularly critical. As already noted, one means of achieving very rapid seeding is to plant manually at the same time as plowing. Alternatively a precision planter can be attached to the plow (Fig. 7-35). The advantages of such rapid, direct seeding systems may be offset by heavy weeding requirements, but in very marginal areas the fact that a crop even reaches the weeding stage may be an achievement in itself. Plow planters have been developed in several southern African countries, including Botswana (EFSAIP, 1984; Horspool, 1987).

One of the main benefits of seeders is the ease of producing parallel rows and the resulting time-savings achieved with animal-drawn inter-row weeders. However as noted earlier, some farmers in southern Mali have found planting using a long cord can be more efficient than planting with a seeder. In other situations where the disadvantages of seeders outweigh their advantages, simple parallel row markers (*rayonneurs*) may be used to identify clear rows for hand-placement of seed (Fig. 7-36). Such systems may allow the very significant benefits of inter-row weeding to be obtained without the technical and financial problems sometimes associated with seeders. While row-markers are intrinsically very simple, they are certainly not without their problems, for while they are very effective on flat, clear surfaces, they cannot cope effectively with surface trash or with mounds and depressions. The wider they are, the more difficult they are to use under normal farm conditions, and few farmers actually make use of them.

Fig. 7-35: A simple plow planter developed experimentally in Botswana. The unit attaches to the standard plow. The ground wheel drives the metering mechanism comprising a "wavy edge" disc agitator over a fixed, gravity-fed metering plate. Different seed plates can be fitted for various crop and seedrate combinations.

Source: after ILO, 1983g



Source: UPROMA, 1986

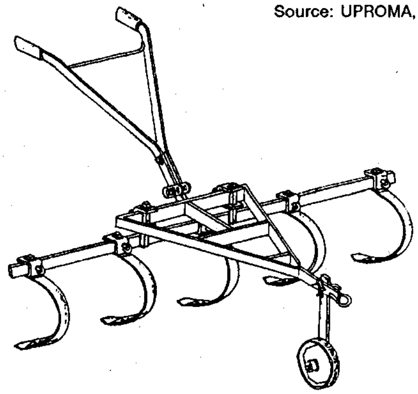
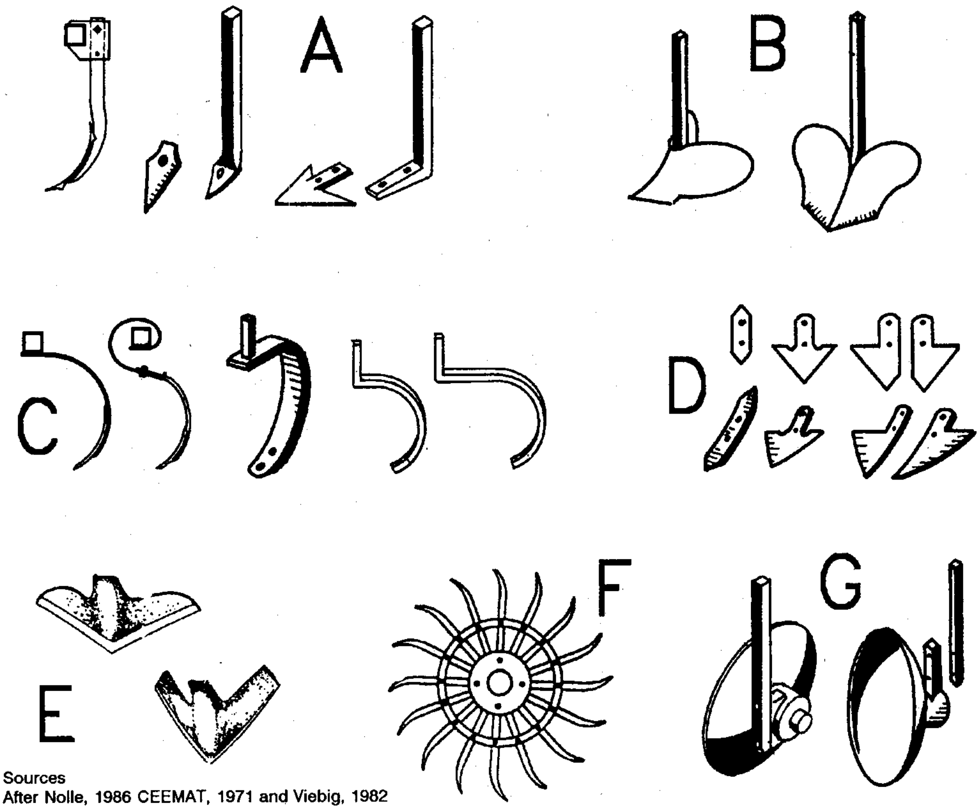


Fig. 7-36: An adjustable row marking device using standard cultivation tines (reversed, mounted on a triangular multipurpose toolbar in Togo.

7.6 Cultivation tines

Cultivation tines may be used for primary land preparation, secondary cultivation (harrowing) and weeding. In present times, as well as in previous centuries, cultivators have often been designed as multipurpose implements, capable of being used in various configurations and with a range of different tines. For weeding purposes large triangular sweeps up to 500mm wide may be used, which have a similar effect to an Indian blade harrow. More common are intermediate triangular *duckfoot* points which are about 150 mm wide. For primary tillage and harrowing, as well as some



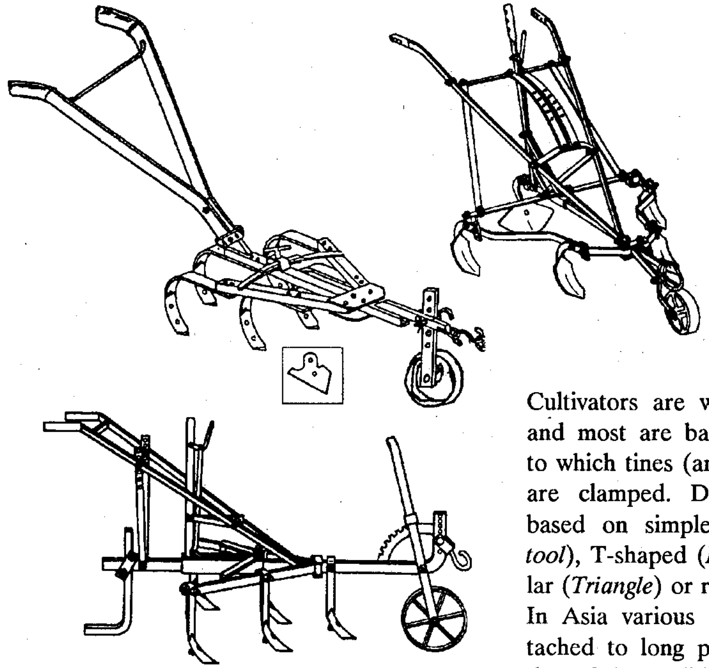
Sources
After Nolle, 1986 CEEMAT, 1971 and Viebig, 1982

Fig. 7-37: Some cultivation tine options.
A. Rigid tines with points or duckfoot shares. B. Earthing-up (ridging) cultivation tines.
C. Spring tines (favoured for weeding). D. Cultivation shares: reversible, duckfoot and half-duckfoot.
E. Wide sweeps. F. Rotary tines. G. Disc tines.

weeding operations, narrower 50 mm points are more usual (Fig. 7-36). Such points are often designed to be reversed when worn, to allow further usage. For primary tillage the effect of each point is similar to that of a small ard plow, although the working width and depth are much smaller.

The tines on a cultivator may be rigid or flexible. Rigid tines act at a constant depth relative to the cultivator frame and wide sweeps are always mounted on rigid stalks. *Spring tines* are designed to bend backwards and spring forward, so varying the depth and increasing the pulverisation of the soil. The speed at which oxen walk is seldom sufficient to obtain the intense shattering effect of vibration seen on tractor-mounted spring-tine cultivators. Very springy tines are seldom used with draft animals, but most are designed to have some flexibility. This is particularly useful for reducing damage to the animals and implement should the cultivating tine meet an obstruction.

Inter-row cultivators should be capable of adjustment for different row widths. Angular expansion cultivators are sometimes used in India, Latin America and some countries in Southern Africa. These have an adjustment handle that varies the angle at which the lateral bars hinge onto the central frame, so changing the effective working width (Fig. 7-38). This allows quick and accurate adjust-



Sources: after ILO, 1983g and UPROMA, 1986

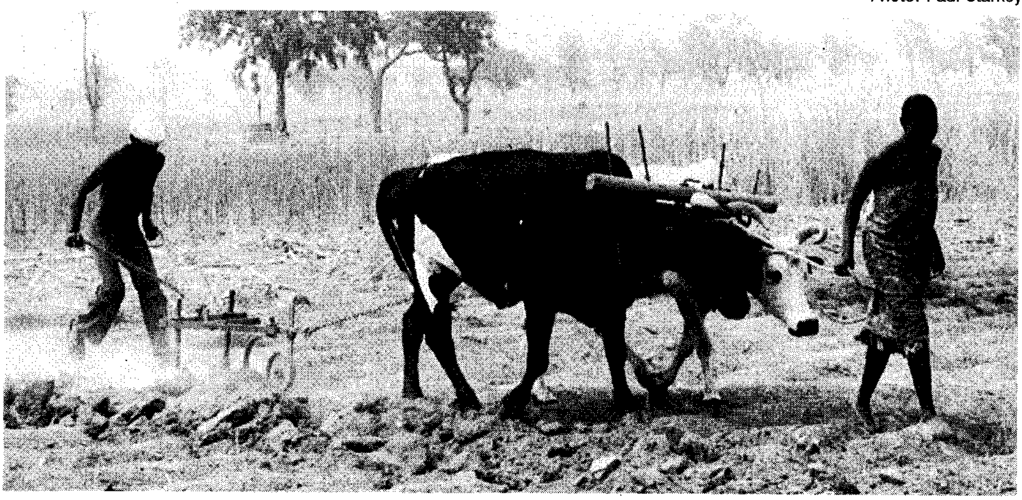
Fig. 7-38: Expandable cultivators.
Top left: *"Houe Manga" manufactured by UPROMA, Togo.*
Top right: *"Rhino" cultivator manufactured by Northland Engineering, Zambia.*
Lower left: *Interrow cultivator developed by CAMERTEC, Tanzania*

ment in the field, but adds to the implement cost. In Burkina Faso the Houe-Manga operates on a similar principle, but being designed for use with a donkey, it is significantly smaller than the cultivators of southern Africa which are usually pulled by large oxen.

Cultivators are widely used in West Africa, and most are based on multipurpose frames to which tines (and sometimes extension bars) are clamped. Different designs have been based on simple longitudinal (*Arara; Peco-tool*), T-shaped (*Houe Sine; Ciwara*), triangular (*Triangle*) or rectangular (*Ariana*) toolbars. In Asia various cultivating tools may be attached to long poles in a manner similar to that of the traditional ard plows. Such cultivators may be multipoint implements or 250-400mm blade harrows.

The effectiveness of cultivation depends on the adjustment of the cultivator for depth and width. Weeding should normally be shallow

Fig. 7-39: Tine tillage in dry conditions in Togo, using a "Triangle" toolbar fitted with rigid tines and points.
Photo: Paul Starkey



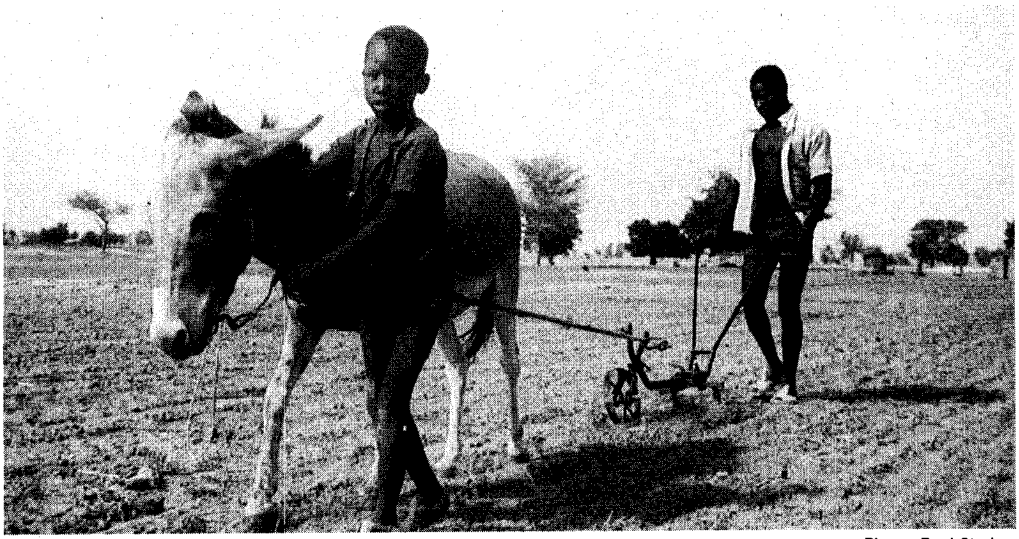


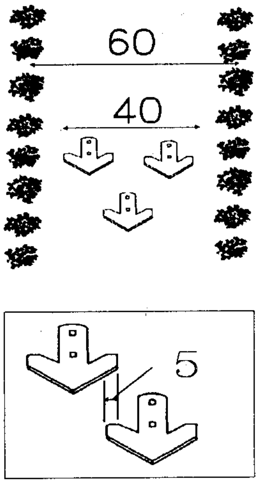
Photo: Paul Starkey

Fig. 7-40: Very early weeding (between seeding and crop emergence) with Houe Occidentale fitted with duckfoot tines in Senegal.

(50mm). Depth control is often obtained both by a depth wheel on the toolframe and clamps on individual tines. In the horizontal plane, it is usual for adjacent weeding tines to be spatially offset, but for their paths to overlap. Duckfoot tines should overlap by about 25-50mm (Fig. 7-41).

Naturally the draft of cultivators will depend on soil characteristics and the depth and width of working. Nevertheless the work load can be high, and a three tine cultivator may have a similar draft to that of a 8"(200mm) mouldboard plow. Unless soil conditions are very light, cultivators fitted with five duckfoot tines are likely to prove too heavy for donkeys or pairs of light oxen.

Inter-row cultivators are best suited to crops grown on the flat with inter-row spacings of about 450-650mm. With significantly larger inter-row spacings, the number of duckfoot tines required to weed becomes excessive in terms of draft and convenience in use. Smaller spacings make it difficult for the animals and operator to walk between the rows without damaging the plants. Inter-row weeding of rainfed rice or wheat at 300mm spacing using an animal-drawn sweep or blade harrow is possible but seldom practised. Cultivating tines tend to break down ridges rapidly, so that weeding of crops grown on ridges generally



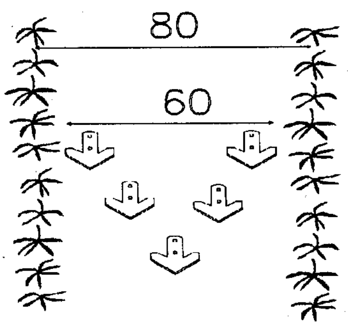


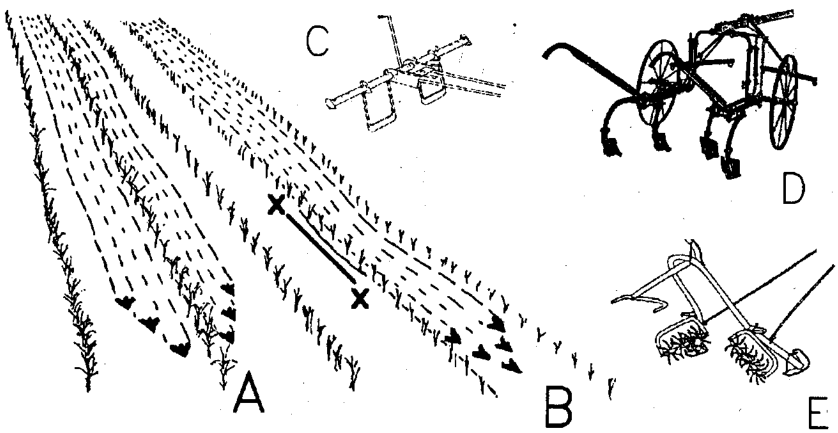
Fig. 7-41: Examples of recommended spacing of duckfoot tines for weeding groundnuts (left) and maize (below) (dimensions in cm).

Source: after FAO, 1983

involves an earthing-up ridger.

Multi-row cultivators that weed two or more interlines were widely used in Europe and North America. Multi-row cultivators have been designed or evaluated in many countries in Africa and in recent years several have been based on wheeled toolcarriers or intermediate toolframes. Multi-row cultivators have been shown to be effective on research stations, yet their adoption by farmers has been minimal. The problems centre on manoeuvrability and crop damage. While single-row weeders can be lifted easily by the operator in cases of field obstruction or temporarily converging crop-rows, multi-row weeders are much more difficult to lift and manoeuvre. Consequently in the uneven fields of most African farms, crops are much more likely to be ripped out of the ground by a multi-row cultivator than by a single-row weeder. However Roosenberg (1987) argued that damage could actually be reduced through the use of single-line over-the-row weeders that weed either side of a single row, weeding only half of each of the two adjacent inter-rows. He argued that low adoption of weeders was associated with the fear of crop damage and that this is almost inevitable using weeders which are set to weed almost all (80%) of the inter-row space. Variation in row spacing and operator error when having to judge implement proximity to two rows simultaneously are likely to bring the weeder into contact with the crops quite frequently. To avoid this there is the time-consuming, but otherwise inexpensive, option of setting the weeder to half the interline, and passing down each row twice. Alternatively the farmer could use a single over-the-row implement. In both cases the farmer only has to concentrate on a single row at a time, but using an over-the-row cultivator the equivalent of a complete interline is weeded in each pass. Single-line, over-the-row weeders enable animals to be yoked closely, they do not require exactly parallel rows and, because they cultivate close to each side of a row, they can throw up soil to inhibit the weeds within the rows (Roosenberg, 1987). Unfortunately it is difficult to design an efficient yet affordable single-row over-the-row weeder. They tend to have high centres of gravity (associated with the clearance needed to avoid damage to growing crops) and the operator either has to straddle the crop or to control the implement from only one side. Such problems can be solved by wheeled ride-on implements, but these have

Fig. 7-42: Over-the-row weeding.
While single-row over-the-row weeders do not depend on crop rows being exactly parallel (A), normal inter-row weeders (B) may remove plants (X-X) when the rows converge.



Some implement options:
C. Prototype, all-steel version of the traditional and simple Indian double-blade hoe.
D. An old North American design of over-the-row weeder: expensive.
E. Prototype straddle cultivator from Nigeria: expensive and difficult to manoeuvre.

Sources: after Roosenberg, 1987; Basant, 1987; ITDG, undated the major disadvantages of higher cost and weight and reduced manoeuvrability.

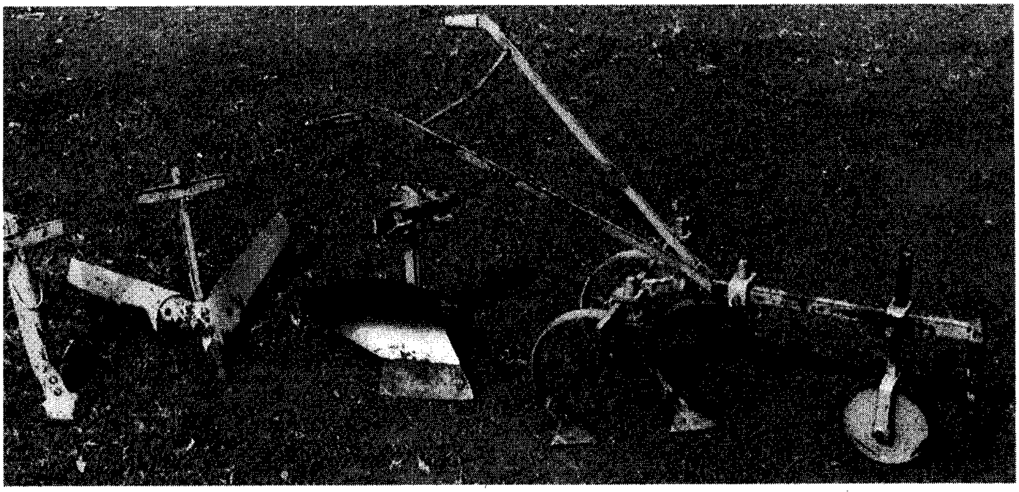
The "Strad" over-the-row rolling weeder (Fig. 7-42) developed and marketed in Nigeria proved technically effective in experimental prototypes (ITDG, undated; Gwani, 1989). The Strad is a heavy walk-beside or ride-on cultivator with two or four gangs of tines that rotate as the implement moves forward. The rotating tines are effective for weeding crops grown on ridges, but the adoption of the Strad has been low, perhaps because of its high cost. Prototype animal-drawn weeders using steel discs as tines have been developed. The angled discs rotate as the implement moves forward, and they can be used with great precision close to plants. However weeding discs and suitable bearings are expensive to manufacture or buy, and implements fitted with discs have generally been heavier than alternative implements. Their diffusion has been very limited.

7.7 Simple multipurpose toolbars

Cultivators (*houes* in French) have long been multipurpose implements and during the last thirty years multipurpose toolbars have become quite widely used in West Africa. One of the most successful designs has been the *Houe Sine* developed by the French engineer Jean Nolle in Senegal in the late 1950s. This comprised a T-frame with depth wheel, onto which clamped a variety of cultivating implements, including duckfoot tines, groundnut lifters, earthing-up bodies and plows (Fig. 7-43). The design has proved very popular, and its derivatives have included the Ciwara in Mali and the Policultor 300 in Brazil. The lighter *Houe Occidentale*, that can be pulled by a single donkey, has also been popular in Senegal, and might have spread more if subsidies had not made the *Houe Sine* better value for money (Havard, 1986; Bordet, 1987). The heavier *Unibar* (Fig. 9-11) with a Y-shaped frame and straight-beam toolbars such as the *Anglebar, Arara* and *Pecotool* and their derivatives (Fig. 7-44, 7-47) have also been used in several countries in Africa and elsewhere but have not caught on to the same extent. These have tended to be promoted in regions where plowing and/or ridging is important (such as cotton-growing zones), and in contrast to the *Houes*, the cultivation tines on

Fig. 7-43: The Houe Sine multipurpose toolbar and its derivatives have been widely manufactured in many countries. This example was made in Senegal and shows the toolbar fitted with three duckfoot tines. Beside it are a groundnut lifter, an earthing-up ridger and a mouldboard plow body.

Photo: Paul Starkey



these toolbars have often been of secondary importance.

In Burkina Faso and Togo the multipurpose *Triangle* cultivator with a single depth wheel is used in conjunction with conventional plows and ridgers.

Heavier, rectangular toolframes such as the *Ariana* and its derivatives have been developed from Jean Nolle's *Houe Saloum*, designed in Senegal in the late 1950s. These intermediate toolframes generally have two depth wheels, one on either side of the frame which gives great stability. For single-row weeding one wheel can be used in a central, forward position. The rectangular design of toolframes provides more space for additional implements, and thus a greater potential working width. However since the limiting factor on small farms is often animal draft power, additional implements cannot be easily pulled, and the potential for the extra working width is seldom used. These intermediate toolframes are about twice the weight and cost of simple toolbars and their weight

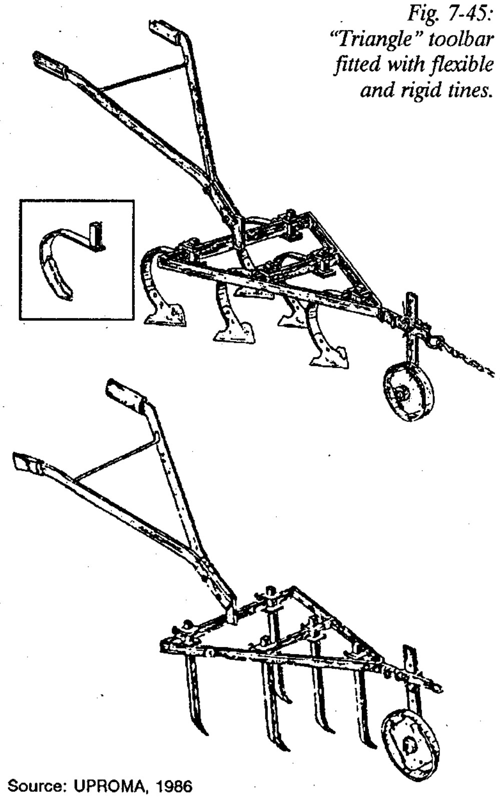
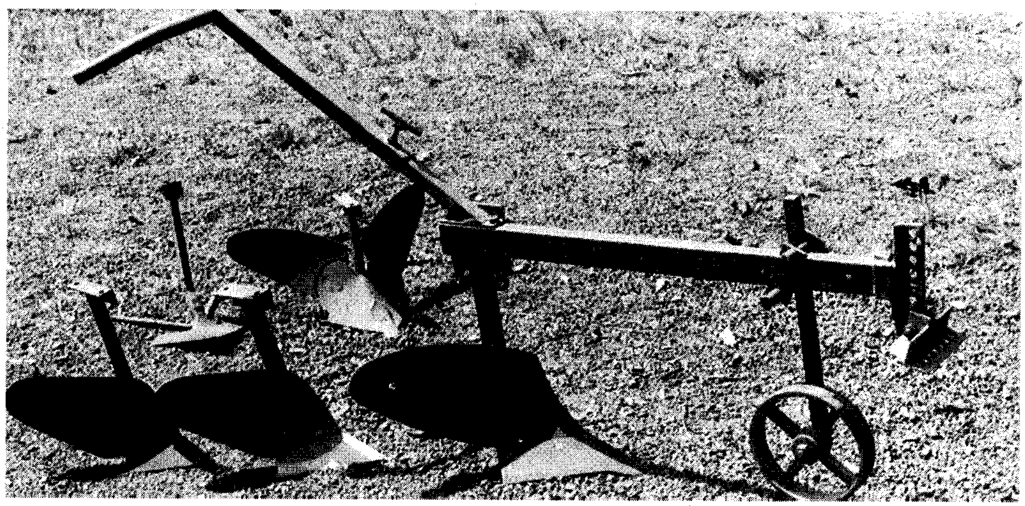


Fig. 7-45: "Triangle" toolbar fitted with flexible and rigid tines.

Source: UPROMA, 1986

Fig. 7-44: Pecotool multipurpose toolbar, showing three sizes of plow body, groundnut lifter and ridger. Small numbers of Pecotools (and similar Anglebars/Multibarras and Unibars) have been made in several countries including Sierra Leone and Tanzania. Photo: Paul Starkey



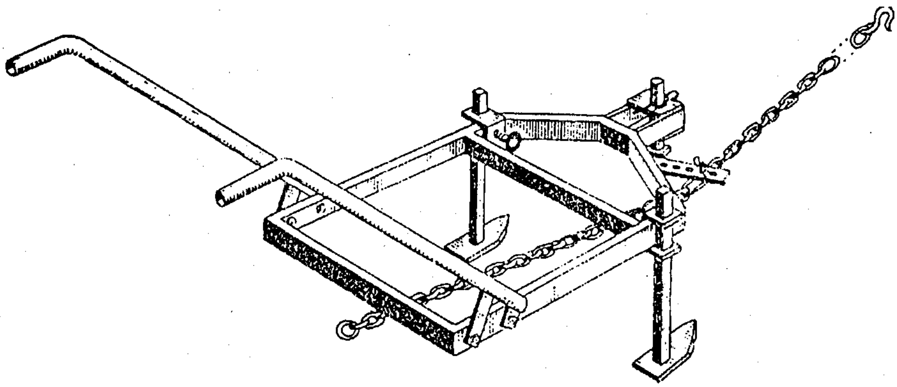
makes them less easy to transport or manoeuvre. Although they have received much acclaim when evaluated on research stations, they have never been adopted on the scale of simple toolbars. For example in Senegal, where they have been available for twenty-five years, sales in the period 1958-80 were about 8500 (the majority being sold during one scheme in the early 1960s). This represents less than 3% of the 340,000 simple toolbars (*Houes*) sold in the same period (Havard, 1985).

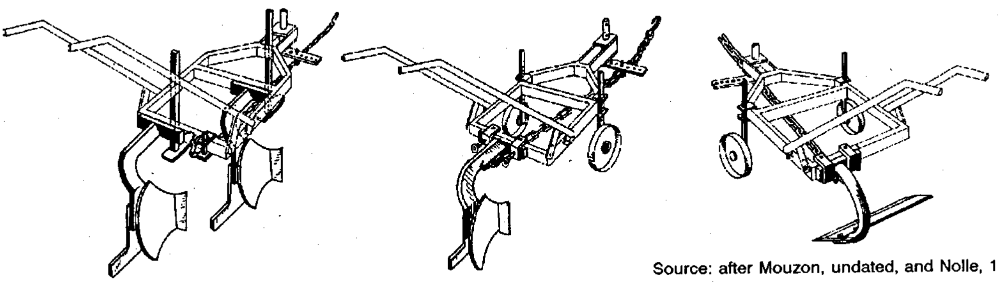
The larger wheeled toolcarriers first developed in Senegal at the same time have never enjoyed sustained farmer adoption, and reasons for their rejection are discussed in section 9.2.

Although undoubtedly successful in some areas, toolbars should not be seen as panaceas of universal application. Even in Senegal and Mali where they are most popular, they have not completely replaced single purpose implements such as plows. While Jean Nolle has developed the concept of multipurpose use into an effective design philosophy (Nolle, 1986), there are limits to its application. As has been made clear in previous sections, most equipment design involves compromise between incompatible features, and the more different uses an implement has, the greater will be the number and extent of the compromises.

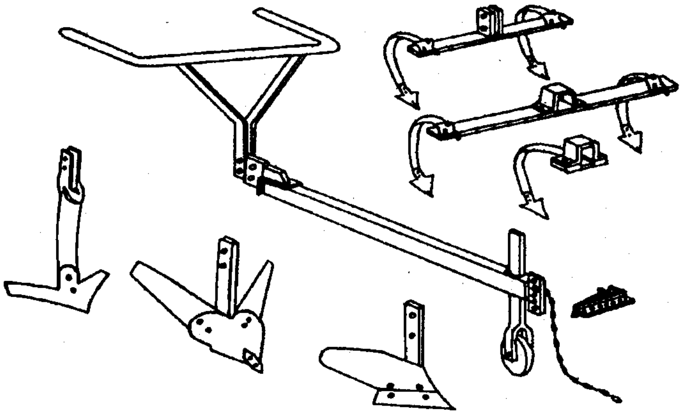
The main advantage of multipurpose design is to reduce overall material requirements and thus costs by using common elements for several purposes. Other possible advantages such as reduced storage space are seldom of great importance in rural locations. However the requirement to change between the different

Fig. 7-46: Ariana "intermediate" toolframe. The Ariana and its derivatives have been evaluated in numerous countries, and manufactured in several of these, but they have not achieved the same success as the Houe Sine.
Top: basic frame fitted with two skids.
Bottom: frames fitted with double furrow plow, single plow and groundnut lifter.





Source: after Mouzon, undated, and Nolle, 1986



Source: Mignolet *et al.*, 1987

Fig. 7-47: The Arara toolbar has been manufactured in several West African countries including Niger, Benin and Senegal. The package illustrated contains a groundnut lifter, earthing-up ridger, plow and cultivation tines.

modes leads to increased costs as removable clamps are more expensive than permanent welds or semi-permanent nuts and bolts. In addition the common elements (such as the frame) must always be designed for the most demanding of all the various applications. Thus a multipurpose implement is always likely to be more expensive than any one single-purpose tool. For similar reasons total cost savings over a full range of single-purpose tools are more modest than might be expected since the additional work involved in forming standard mountings and clamps partially offsets the savings of using a common frame and handles. In addition, a multipurpose tool inevitably involves some loss in convenience in changing between modes and readjusting the tools, in comparison with single-purpose implements that can often be left ready for use in an appropriate setting. Finally a multipurpose tool maximises risk. As all tool options depend on the common elements it is an illustration of the expression "all the eggs in one basket". To take a common example: if a bolt of a plow clamp breaks inside the clamp, the toolbar is unusable for all operations until it can be removed and repaired. A single-purpose plow would be less likely to break as it does not have such clamps, but should it do so, the farmer's other equipment (cultivator, ridger etc.) would not be affected.

Where multipurpose toolbars have been successful, it has been in countries where they have been mainly used as *cultivators.* In Senegal the *Houe Sine* is used more often for tine-tillage, weeding, groundnut-lifting and earthing-up than for plowing. Where mouldboard plowing or ridging are major characteristics of the farming systems, it is quite likely that the combination of single-purpose plows/ridgers and a *multipurpose cultivator* may be found preferable to trying to combine all implements into one tool. This may explain the noticeable lack of uptake of toolbars in Eastern and Southern Africa (Ahmed and Kinsey, 1984). Some development workers have advocated the promotion of multipurpose toolbars as one means to encourage and facilitate row-cropping techniques in the longer term (Mettrick, 1978; Starkey, 1981). However in such circumstances farmers may well be encouraged to purchase implements that are unnecessarily expensive for their short-term requirements. There has been a similar tendency to promote (through credit) comprehensive toolbar packages with a wide range of attachments, when only one or two of these proved to be of real value to the farmers. Finally many of the undoubted benefits of toolbars have arisen not only from the *multipurpose* characteristics of the designs, but from the simultaneous application of another of Jean Nolle's design philosophies: standardization and interchangeability. These characteristics have been elegantly combined in designs such as the Houe Sine and they could also be usefully applied to ranges of single-purpose implements.

Sources: after CEEMAT, 1971, Mouzon, undated and ITDG undated

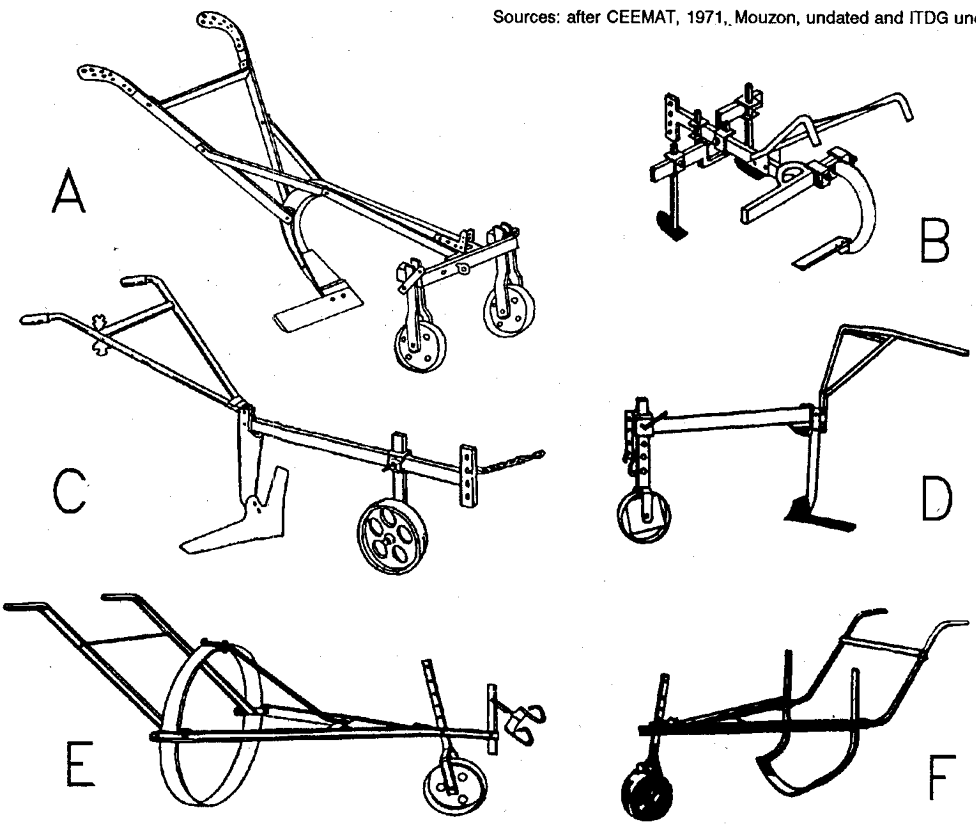


Fig. 7-48: Some designs of groundnut lifter.
A. Sidesweep lifting share fitted to Emcot ridger frame. B. Houe Sine fitted with sidesweep lifter. C and D. V-sweep lifters attached to toolbars. E. Hoop lifter. F. Curved blade lifter.

In conclusion multipurpose toolbars have proved very effective and popular in some countries, while in others uptake has been minimal. They have tended to be fashionable within development circles so that alternative equipment combinations have sometimes been overlooked. The advantages and disadvantages of multipurpose toolbars should be carefully considered, alongside other options.

7.8 Groundnut lifters

Animal-drawn harvesting implements are not common, but groundnut lifters have had some success. Lifters are quite simple implements based on one wide sweep blade. This passes through the soil at a depth of 50-100mm severing the deeper roots and leaving the plants, to which the groundnuts are still attached, lying on the soil surface from where they can be easily collected and piled. The implement share may be:

- a V-shaped sweep attached centrally to a rigid stalk;
- a long, broad, straight share supported at one end;
- a steel arc supported at either end (like a curved blade harrow);
- a complete hoop, the lower part of which acts like an arc-share.

The stalks supporting the shares are often rounded in order that they can pass easily through the groundnut foliage without frequent blockages. Rising rods may be added to

Photo: Paul Starkey

Fig. 7-49: Triangular harrow being used for swamp rice production in Sierra Leone.

aid the turning of the groundnut plants. Turning aids rapid drying, and therefore reduces the risk of poisonous aflatoxins building up in the plants. Groundnut lifters can be single-purpose implements, but are more commonly attachments on multipurpose cultivators or standard plowbeams. Implements designed for other operations may make quite satisfactory improvisations; for example ridger bodies with the wings removed have been used in northern Nigeria. Single weeding sweeps may be effective, but multiple sweeps rapidly become clogged with haulms and weeds. Various design options have been reviewed in detail by FAO/CEEMAT (1972) and the results of some comparative trials in The Gambia were provided by Matthews and Pullen (1974).

Groundnut lifters are generally simple implements and relatively easy to use. Their effectiveness is largely determined by soil conditions and the extent to which plants impede progress. If the soil becomes too hard before harvesting, the effort required to pull the large share can be high and plant breakage will lead to a higher proportion of the crop being left in the soil. Because of their highly specialized application they are only common in areas where groundnuts are widely grown; in Senegal numbers of groundnut lifters in use increased from less than 1000 in 1960 to 70,000 in 1983 (Havard, 1985).

7.9 Equipment for irrigated rice cultivation

For the cultivation of rainfed (upland) rice, equipment requirements are similar to other

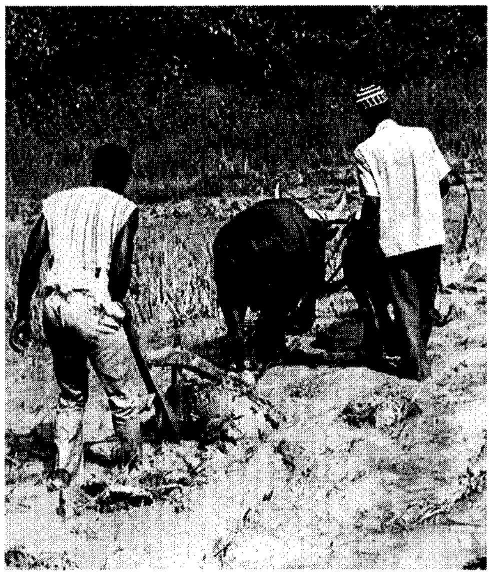


Fig. 7-50: Cultivating a flooded swamp with Chinese plow. Although the design was well proven in China, it was not considered suitable for use with N'Dama work oxen in Sierra Leone. Photo: Paul Starkey

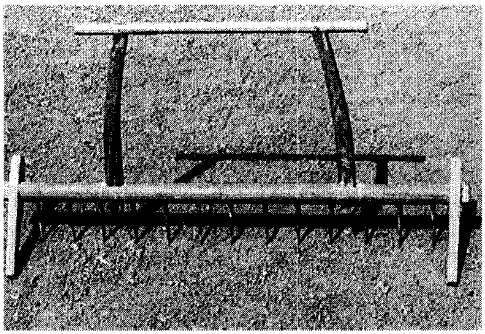


Photo: Paul Starkey

Fig. 7-51: Chinese comb harrow.

crops. However swamp rice cultivation often involves more specialized equipment. Many equipment designs originated in those parts of Asia where draft animals are widely used for swamp rice production. Where paddy fields have not been developed, major bunding and levelling may be required, and the use of scoops and bund-formers is discussed in section 9.7.

Working in flooded swamps is not pleasant for either humans or animals. For this reason the preferred system of swamp rice cultivation involves the initial plowing of the land without superficial water. In this case the tillage implements discussed earlier in this chapter (ards, plows and harrows) are generally used perhaps in association with specialized land-levelling tools (section 9.7). Nevertheless when water cannot be controlled (as in natural swamps) plowing in flooded fields may be necessary to obtain a second (or third) crop. "Standard" plows, whether ards or mouldboard plows, can be used for plowing in either dry or flooded swamps. Plowing in dry swamps is little different from upland plowing although the eventual requirement for level fields makes the use of reversible plows more attractive. In flooded swamps a depth wheel becomes easily clogged and causes unnecessary resistance and a simple, narrow skid may achieve the required depth control with less draft requirement. The shorter and lighter Japanese and Chinese type of plows (Fig. 7-50, 7-10) have been developed mainly for swamp rice production. Some have simple reversible mouldboards and some slatted mouldboards to reduce draft and obtain greater mixing. Without any wheel, skid or long landside the tendency to pitch can only be counteracted by pressures on the handle, and considerable practise is required to obtain accurate depth control. In unskilled hands such plows often alternate between very deep and very shallow plowing, causing discomfort to both animals and farmer (Starkey, 1981). This may partly explain why such plows have not been widely adopted even in the rice

Fig. 7-52: Evaluation of Chinese comb harrow for swamp rice production in Sierra Leone.

Photo: Paul Starkey

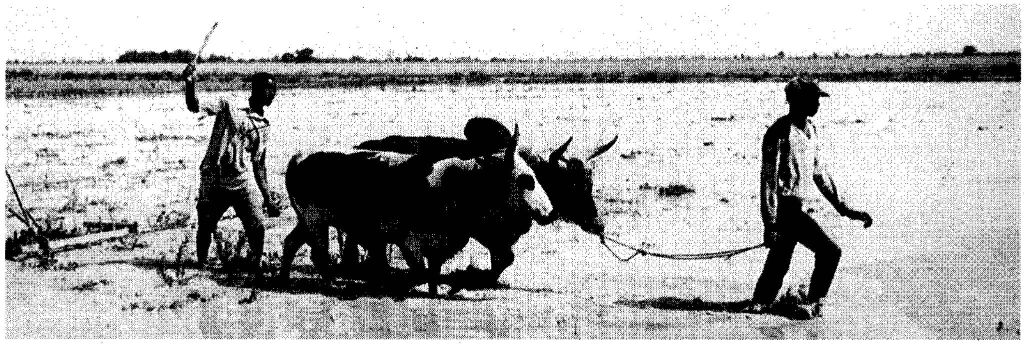


Photo: Paul Starkey

Fig. 7-53: Evaluation of an IRRI conical puddler at the large ARPON rice development project in Mali.

growing areas of Africa; farmers have generally preferred mouldboard plows with depth wheels (or skids) that can more easily be used for the favoured practice of plowing dry swamps, as well as for the cultivation of upland crops.

Following plowing, swamps are *puddled* and *levelled*, operations designed to create a smooth and level environment for transplanting the rice. While initial harrowing and levelling may be carried out prior to flooding, final puddling and levelling must be carried out with surface water present. The cheapest and most common system used in flooded fields involves several passes of wide comb harrows (Fig. 7-52) or levelling boards (which may, or may not, have handles such as those in Fig 7-51). These are made mainly of wood, although the harrow tines may be made of metal. They are commonly used in Asia, but less so in Africa. Their width makes them effective but quite difficult to control and manoeuvre. Similar results may be achieved from wooden triangular spike-tooth harrows (Fig. 7-49) and from Spanish harrows that have corrugated tines rather than points (Fig. 7-55). All these implements can be made and maintained locally.

Equipment with rolling discs, tines or blades can be particularly effective for achieving satisfactory soil mix in rice swamps. In dry swamps disc harrows provide useful pulverisation, while in flooded swamps long-toothed rolling puddlers (similar to those of power-tillers) can achieve good results, particularly if the animals can manage to walk quickly while

Fig. 7-54: Prototype conical puddler for rice production developed by IRRI, Philippines.

Photo: Paul Starkey

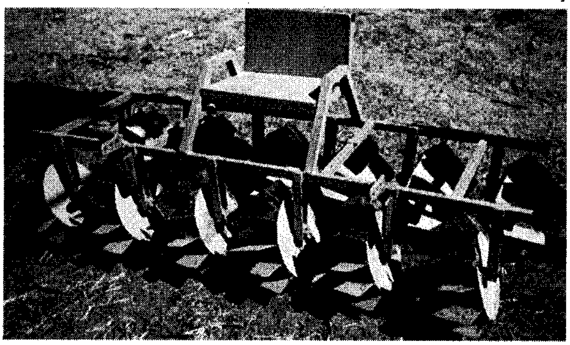
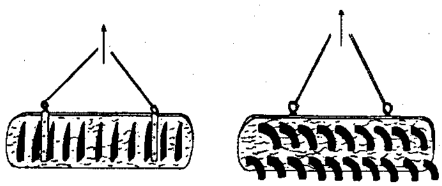


Fig. 7-55: "Spanish" harrows/levellers comprise boards mounted with a series flat steel teeth/shares which are used for swamp preparation in Asia and southern Europe.



Source: CEEMAT, 1971

Sources: Hopfen, 1969 and CEEMAT, 1971

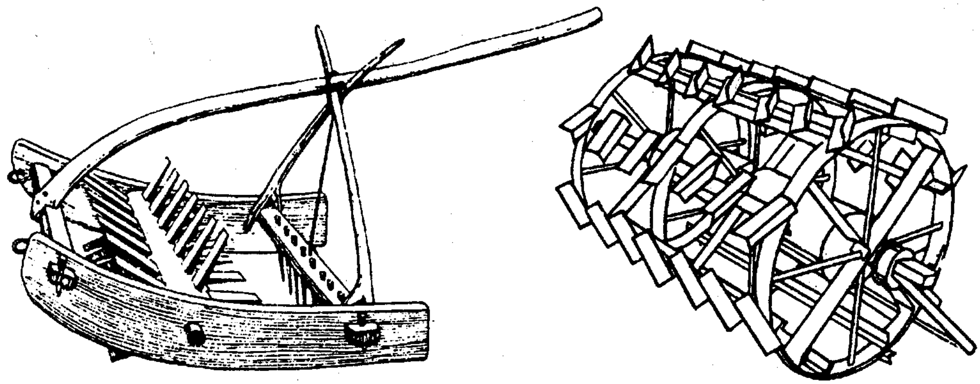


Fig. 7-56: Swamp puddling devices.
Left: a traditional design of wooden rotary puddler used in Asia.
Right: a very large rotary puddler made of steel weighed down with concrete that was developed as an alternative to the traditional method of puddling using herds of cattle in Madagascar.

pulling them. The major problems with such implements are their high draft requirements and their expense. In Madagascar large cattle herds have traditionally been used to trample round and round rice swamps to obtain a puddling effect. This system is effective but requires considerable effort from the cattle and those encouraging them (van Nhieu, 1982). As an alternative to this, large and heavy (160kg) rolling puddling wheels made of angle-iron have been developed (CEEMAT, 1984). These have proved technically effective but quite expensive and awkward to manoeuvre. More recently the International Rice Research Institute in the Philippines has developed an animal-drawn conical puddler (IRRI, 1986), but it is too early to say whether this will be regarded by farmers as cost-effective.

In both Asia and Africa, rice transplanting is normally performed by hand. Hand-pulled transplanters and motorized implements have been developed but, despite research efforts, there have not yet been any successful designs of animal-drawn rice transplanters (Biswas, 1981). In flooded swamps weeding may not be necessary, and the narrow inter-row spacing precludes the effective use of animals for such purposes. Harvesting of rice is performed manually or with motorized equipment, and there are few, if any, examples of animal power being used for rice harvesting.

7.10 Further sources of information

The reference works of Hopfen (1969), CEEMAT (1974), CEEMAT/FAO (1972), Munzinger (1982) and Poitrineau (1990) contain much helpful information on the range of animal-drawn crop production implements and their use. Useful training material on the adjustment and operation of conventional crop production equipment used with draft animals has been produced in Burkina Faso (FAO, 1983), The Gambia (Matthews and Pullen, 1974), Niger (Mignolet et al., 1987), Sierra Leone (Starkey, 1981), Swaziland (Seubert, 1986), Zambia (Dibbits, 1987), and Zimbabwe (AETC, 1986a, 1986b, 1987). Case history studies on the adoption of different types of animal-drawn crop production equipment in Africa have been written by Bordet (1987, 1989), Bordet, Lhoste, Le Moigne and Le Thiec (1988), Havard (1985, 1986, 1987), Kinsey (1984 a-d), Kline, Green, Donahue and Stout (1969), Le Moigne (1980), Robinson (1987) and Uzureau (1984).

Anyone intending to test, design or develop different or "improved" animal-drawn crop production implements would be wise to start by reviewing previous experiences. The brochures of manufacturers can be a useful starting point, although these should be treated with caution for they will not be objective publications. Just because designs are offered by commercial manufacturers does not guarantee they have *ever* been proven in farmers' fields or are appropriate. Bearing this in mind the ITDG book on agricultural implements (ITP, 1985) gives a good idea of the range of available equipment and some of the suppliers. Very many papers have been written describing implement prototypes and adaptations, and some of these have been published in journals such as *Agricultural Mechanization in Asia, Africa and Latin America, Appropriate Technology, GATE Questions-Answers-Information, Machinisme Agricole Tropical* and *RNAM Newsletter*. Not surprisingly the great majority of these articles are very optimistic, and readers should naturally treat their conclusions with caution and if possible attempt to trace a "second opinion" from someone else working in the same area. The work of Jean Nolle (1986) provides many ideas on design considerations for animal-drawn crop production implements.

Many organizations in Africa working on the development of "conventional" animal traction implements including plows, cultivators and seeders are mentioned in the GATE Animal Traction Directory: Africa (Starkey, 1988). These include: FMDU, Botswana; CNEA, Burkina Faso; CMDT-DRSPR, Mali; Projet FAO and Projet Productivité Niamey, Niger; ISRA and SISMAR, Senegal; WOP, Sierra Leone; WSDC, Sudan; Mbeya Oxenization/ZZK, Tanzania; UPROMA, Togo; Animal Draft Project and AMRDU, Zambia; and IAE and Bulowayo Steel, Zimbabwe. Other organizations with significant interest and experience in this field in Africa include CEEMAT, France; Agricultural Services Division (AGS) of FAO, Rome and AFRC-Engineering, UK.

A great deal of information on Indian designs of crop production equipment is available at the Central Institute of Agricultural Engineering (CIAE), Bhopal, India. IRRI, in the Philippines, has information on the use of draft animals for swamp rice production, derived from its own Agricultural Engineering Department, and also from its coordination of the Rice Farming Systems Network. Further information on Asian experience is available from the Draught Animal Power Project, coordinated from Townsville, Australia.