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SESSION: THE USE OF DRAUGHT ANIMALS IN SEMI-ARID FARMING SYSTEMS

Aspects of Work Animal Use in Semi-arid Farming Systems

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Summary

Smallholder farmers in the semi-arid regions of many developing countries are faced with a multitude of problems including soil erosion and soil fertility decline, erratic rainfall and increasing risk. Semi-arid region farming systems incorporate animal and crop production. Oxen are usually the preferred work animals, but necessity may require the use of cows and equids. Harnesses and equipment for equids are often under-developed locally but programs of participatory technology development have produced viable options. The combination of high-lift harnesses and light-weight equipment has been a particularly successful example. The use of smaller animals as power units can add versatility to farming operations. Smaller animals consume less fodder and so may allow more widespread use of conservation farming practices, including direct seeding which requires soil cover. Hillside soil and water conservation can be achieved with the associated attraction of producing dry season fodder via the use of vegetative contour live-barriers. There remains an urgent need to reduce the cost, effort and drudgery demanded to care for semi-arid regions' fragile soils and scarce moisture. Draft animal use offers an opportunity to achieve this provided that the animals can be sustainably maintained and harnessed to purpose-designed equipment.

Keywords: animal breeds; draft capability; soil moisture, fertility and conservation; fodder; high-lift harness; light-weight tools; equids; live-barriers.

Introduction

Farm families struggling to secure a livelihood in the semi-arid regions of the World are often confronted by multiple difficulties which can make their situation particularly precarious when compared with that of small farm families working in more favorable climatic regimes.

By definition, moisture availability is a critical constraint and is fundamentally affected by soil manipulation and cover, and weed populations. Having the right amount of moisture available to crops at the critical times in their cycles can make the difference between harvest (and survival) and no harvest. Coupled with the scarcity of total moisture supply is the factor of the unpredictability of the rainfall. Without irrigation, semi-arid region farmers are at the mercy of the vagaries of the weather, which is frequently notoriously difficult to predict and so inhibits confident farm planning.

Soil fertility decline is a frequently expressed problem facing semi-arid region smallholder farmers. Crop yields decline year after year, more "thorough" cultivation increases organic matter oxidation resulting in the continuing downward slide in soil fertility and water-holding capacity. Regions with broken terrain, making it necessary to cultivate sloping land, have additional problems. Soil erosion resulting from heavy rainfall on cultivated soil bereft of vegetation will result in the preferential loss of the lighter soil particles which are also those richest in plant nutrients – or soil fertility.

Where animals are kept, either for production or for work (and often both), the pressure on the land is increased still further. Forage production will tend to be low *per se* and so will lead to the removal of all crop residues. Bare soil surfaces at the beginning of the rainy season exacerbate the erosion problem resulting in an accelerated loss of soil fertility.

As if these woes were not enough, semi-arid region small farmers are often forced to farm their marginal areas because of pressure on more fertile land by other sectors of society, sectors with more political muscle. The outcome is that small farmers, attempting to produce from marginal land in the first place, frequently find themselves marginalized politically, socially and economically as well. This can have a negative effect on access to markets, access to productivity enhancing inputs (seeds, fertilizer, crop-care products, etc), and still further marginalization.

These conditions constitute a challenge for the small farm family and the R&D community working to produce solutions to aid the families to farm sustainably whilst improving their prospects for better livelihoods. This paper examines some aspects of the work animal component of semi-arid farming systems, it looks at some of the problems associated with their use and suggests some solutions. We do not discuss the crucial issues of work animals' health and disease. This is not to say that they are not of paramount importance to the success of farming systems in semi-arid regions. It simply reflects the limitations of time. The paper considers and draws on the results of many years of work with small farmers in the semi-arid regions of Latin America and sub-Saharan Africa.

Semi-arid Farming Systems

Semi-arid agricultural production systems can be conveniently characterized as having 400 – 1200 mm annual rainfall, a mean air temperature higher than 18 C and having at least one season when evapotranspiration exceeds precipitation (LPP, 2001). Such circumstances lead to a shortage of water, or moisture, which is a major constraint on production, particularly crop production. No particular type of soil is especially prominent in the semi-arid areas that are farmed but, with conditions not generally promoting the growth of large volumes of vegetation, the soils are not rich in organic matter. They, therefore, tend be infertile, degraded and have low water retention which, in many cases, exacerbates the shortage of rainfall.

Many, if not most, semi-arid farming systems depend on an integrated approach to crop and livestock production. With relatively poor soil, smallholder farmers being unable to achieve high levels of productivity need to cultivate fairly extensively to harvest sufficient for their family needs, and market if appropriate. It is attractive, therefore, for them to cultivate their plots using draft animal power (DAP) to reduce drudgery, rather than depending only on human labor to increase the area cultivated. (Tractors are very rarely an option for smallholders). However, more extensive cropping may introduce problems with the timeliness of planting and the demands of crop care. Yield is forfeited if late planting results in the scarce rainfall not being fully exploited or if the weed infestation is too severe. A surprisingly small proportion of smallholders, even those with access to DAP, enhance their weeding with draft animal technologies. Two of the more likely explanations are that seeds may have been broadcast (rather than planted in lines) and that weeding is regarded as a woman's job (men tend to control the draft animals and their use).

The basis of crop-livestock integration is that animals assist with crop production tasks (mainly land preparation) and transport, whilst the crop residues are used as fodder which, together with grazing, enable the animals to survive and provide organic fertilizer (manure). Animals, especially cattle, are important culturally in many semi-arid farming systems and their value provides a means of holding wealth with high liquidity.

Semi-arid farming, especially crop production, is risky primarily because of the combination of low rainfall and high temperatures creating crop moisture stress. Furthermore, semi-arid tropical climates tend to be characterized by erratic rainfall patterns leading to periods of water-logging and "mini-droughts", neither of which are conducive to prolific and healthy crop growth and reliable yields. As one means of managing, or ameliorating, these risks, smallholders may do their planting at different stages into the growing season and thereby hope to achieve a worthwhile total yield, although it may not be optimal in any given year or season. Other ways of reducing the risk of yield loss from mini-droughts include water conservation. These are generally fairly arduous soil and water management practices but they can be facilitated by the use of DAP. Many problems could also be overcome by the use of an irrigation system but conventional systems demand a good, stable water source and a significant investment well beyond the reach of typical smallholder farming families. Smallholder farming families often depend mainly on human labor but this is usually found wanting during periods of peak demand (planting, harvesting and especially weeding) and reliance on the extended family is a common solution. Households help each other out when tasks need to be done. Very little money changes hands and families are rewarded for their efforts by meals or reciprocal labor arrangements. Only the wealthier families can afford to hire labor, or draft power, for cash.

Solutions are urgently needed to enable smallholders to increase both their land and labor productivity whilst making more sustainable use of their natural resources for growing crops and raising livestock. A diversified use of draft animals, coupled with a move away from traditional land management to enhance water (rainfall) use and reverse declining soil fertility, would seem to offer a promising approach to reach a solution. For such an approach to succeed, there is a need for better information on the matching of draft animals, animal-drawn equipment, soil manipulation and moisture management within the context of the declining productivity of local farming systems and practices.

Work Animals

The are no major physical differences between draft animals and others of the same species, although certain breeds are more renowned for their draft capabilities. Almost any bovine (including buffaloes), equid or camelid can become a draft animal, provided that it is reasonably healthy, has an appropriate temperament, and responds to training. In general, the most important criterion for draft effort is body mass, or liveweight. This reflects the amount of muscle on a lean animal and, thus, its potential to exert a force or, more specifically, a pull which the farmer can utilize through soil-working implements. A basic guide is that an animal can pull about 10 to 15% of its weight for a working period of around four hours, although there is some variation between species, breeds and working conditions. Summaries of the approximate work capabilities of different species are given in Table 1.

Table 1. Draft capability and power outputs of various animals.

Animal	Average weight (kg)	Approximate draft capability (N)	Average speed (m/s)	Power developed (W)
Ox	500 - 900	600 - 800	0.56 -0.83	560
Cow	400 - 600	500 - 600	0.70	340
Water buffalo	400 - 900	500 - 800	0.80 - 0.90	560
Horse	400 - 700	600 - 800	1.0	750
Mule	350 - 500	500 - 600	0.9 - 1.0	520
Donkey	150 - 300	300 - 400	0.70	260
Camel	450 - 500	400 - 500	1.1	500
Man	60 - 90	300	0.28	75

Source: from Campbell, 1990

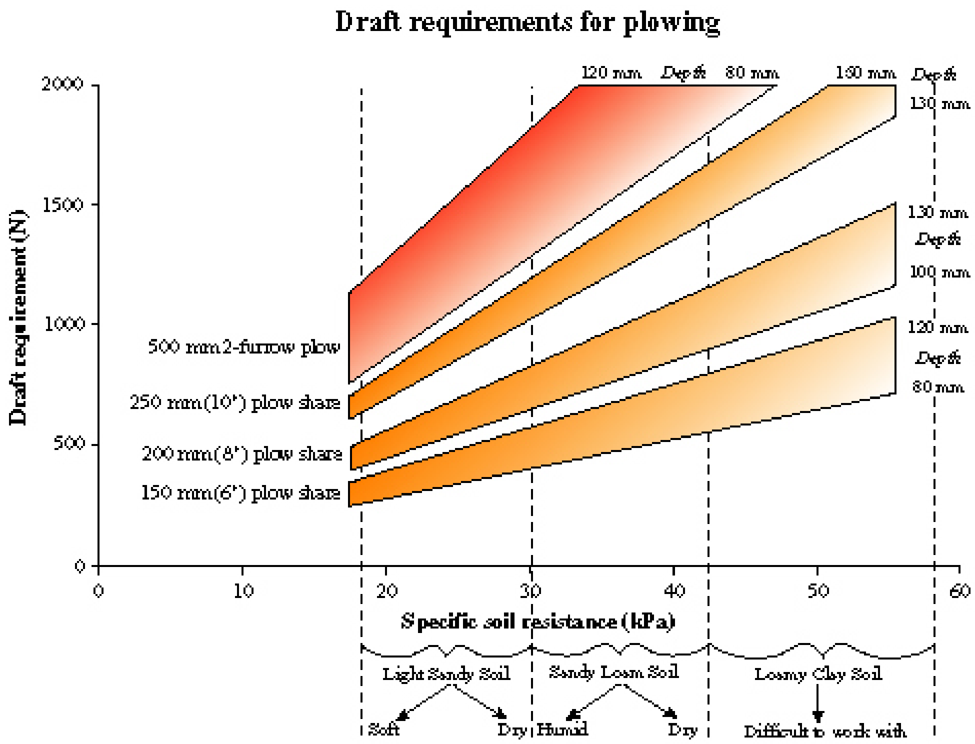
The total amount of work that can be done with a sustained pull depends on the animal's energy reserves and the onset of fatigue which, in turn, depend on the animal's condition and nutritional status. The energy cost of work can be found by measuring the animal's metabolic rate whilst working. The most direct determinant of metabolic rate is the animal's oxygen consumption, but this is not easily measured, especially in field conditions. A less direct but more accessible determinant is heart rate, which varies linearly with metabolic rate for a given animal.

Any large domestic animal may be used for draft and farmers will choose what fits in with their system of farming from what is available and affordable. For the crop / livestock farmers of sub-Saharan Africa who, typically, own cattle, oxen would be the first choice. But, in the areas of southern Africa which have been most seriously affected by droughts in the last decade where many cattle have perished, donkeys are increasingly being used for crop production because, for smallholders, they are becoming more available and affordable than cattle. In the drier Sahelian region, camels would be the first choice but for how much longer smallholder farmers will be able to afford them is questionable.

The draft requirements for plowing are summarized in Figure 1. The amount of pull that has to be provided (by an animal or a team of animals) can be roughly predicted from the soil type and quality (as represented by its "specific resistance" – one of the soil's physical parameters) and the design and setting of the plough. Figure 1 can be used in conjunction with Table 1 to assess ways of meeting an identified draft need. The draft requirements for ripping (see below) have not been documented but would be expected to be less than those for plowing, as the broken soil is not lifted and inverted.

Figure 1. Draft requirements for plowing in relation to soil type and width of cut.

The physical / physiological state of an animal, including its fitness for work, can be judged reasonably effectively by visual examination. Experienced farmers, who know their animals, have, of necessity, developed such a skill and now systems of



body condition scoring have been developed. These are mainly to help extension workers and researchers judge the condition of animals, and have the added advantage of providing a consistency of appraisal. The body condition score reflects, primarily, how healthy an animal appears and integrates its level of nourishment and the presence of any obvious disease or injury. One example is that proposed by Nicholson and Butterworth (1986), for oxen, which runs from 1 to 9, representing emaciated to obese. For work, body condition scores of between 4 and 6 would seem to be optimum. Oxen with a body condition of more than 6 may be too overweight to give optimum performance and may be more susceptible to heat stress than leaner animals.

A number of factors must be considered with regard to the feeding of working animals. Does the working animal have enough time to feed and take water? Is enough feed available and is it of sufficient quality in terms of both energy content and digestibility? Does work affect appetite and the passage of food through the body? If so, in what way and to what extent? For more details, see Pearson (1996). For horses, oxen and buffalo, most of the questions relating to feed and feeding practices can be answered, but, for donkeys and camelids, less research has been done and recommendations are less well defined. For camels, in particular, the issues are further complicated by the camel's ability to dehydrate and thereby modify its metabolic processes.

A particular concern with working animals is ensuring they have achieved and are able to maintain adequate body condition to meet their work needs. Only the better-resourced farmers are able to provide supplementary feeding to their animals (and milk animals usually receive priority in this respect), but it is still likely to be limited. The question is how to administer this limited supply to best effect. Research with oxen has indicated it would be preferable to supplement the diet during working periods rather than "building up" the animals in the period before work starts. Good management of working animals therefore requires regular monitoring and scoring of their body condition. Some weight loss during work is tolerable but can not be sustained over a long working period (Fall *et al.*, 1997). The feeding of supplements also raises issues which must be addressed, such as the nature and quality (concentrates would be preferred for several reasons but these are the most expensive) and the animals having the time available to consume them and for digestion / rumination. In summary, if an animal is maintained in reasonable body condition (say, at a score of between 3 and 6), its usefulness as a draft animal depends on its liveweight.

There is an almost universal complaint from smallholder farmers who rely on DAP that there is insufficient to meet everyone's needs. Traditionally, farmers who have used animals for draft work have kept some males specifically for this purpose, but increasing pressures on land and feed, together with the underlying costs of maintaining and maybe purchasing them, have prompted a change. This is particularly the case for farmers who own cattle, who have tried to economize by using cows for work. It is still rare to find a farmer spanning or yoking cows exclusively but it is not uncommon to find cows being spanned with oxen to make a team of two or four, where the farmer cannot afford to buy or maintain a complete team of males. This raises the question of how much work a female animal can do before her milk production or, more seriously, her fertility is affected. If a female draft animal is worked to the point of infertility, the outputs of milk and calves (or foals) are lost and the farmer has lost an asset of greater potential value than a working animal. Recently, research has been undertaken to evaluate the effects of using cows for draft but the results have not been conclusive (Zerbini and Alemu 1999; Zerbini, 1998). It is clear, however, that when milking cows are used for work supplementary feeding is essential.

Implements and Harnesses

The potential for using lighter, smaller animals for draft work on the farm means that less fodder needs to be consumed, with important implications for cropping systems and protection against land degradation. But it also raises challenges for making the use of the available, reduced, power source more efficient. In many semi-arid regions, oxen remain the preferred farm-power source. However their use for a few days a year, principally on tillage and transport work, imposes a heavy forage burden throughout the year, and this can be especially difficult to meet in the dry season. Figure 2 shows the metabolic energy balance for draft oxen in the semi-arid inter-

Andean valley region of Bolivia, and clearly indicates the period when energy demand exceeds the available supply.

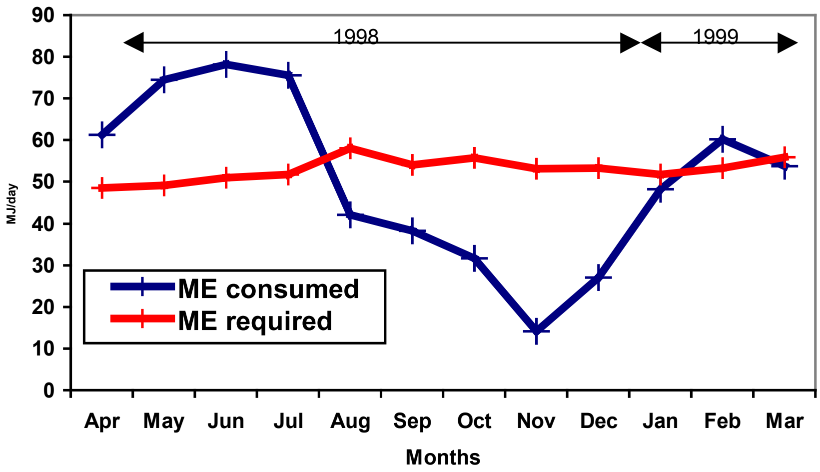


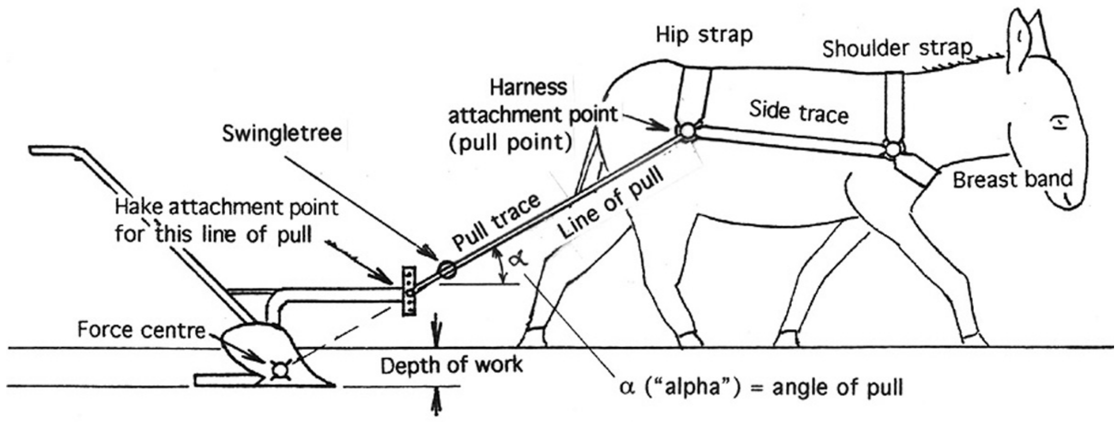
Figure 2. Metabolic energy balance (MJ day^{-1}) for oxen during the year.

The consequences of seasonal forage shortage on farming systems and livelihoods can be quite dramatic. It is frequently necessary for farmers to sell their animals after the main soil cultivation season, and to buy new animals the following year. This involves journeys to the markets, uncertain prices, training new draft animals and risk.

Conversations with farm families has led to the suggestion that other, lighter, animals could possibly fulfil the functions of the heavier oxen. Equids (donkeys, mules and horses) are frequently already available as a transport option (although in some cultures horses are reserved for men to use for riding and sport). However, appropriate harnesses and light-weight equipment have not often been sufficiently developed. Whereas research can quite easily provide technical solutions, the existence of a manufacturing infrastructure is a vital ingredient in the process of successful development of adoptable technologies.

A process of participatory technology development in Bolivia (LPP, undated) worked with farm families on this theme and in conjunction with a local draft animal implement factory. Farmers recognized the untapped potential of their equines, but pointed out that existing draft animal tillage equipment was too heavy for use with lighter animals as it had been designed for use with pairs of oxen. Taking as a starting point Frank Inns' work on high-lift harnesses for reducing the draft of chain or rope-pulled implements (Inns, 1990 and 1991)[1] we were able to demonstrate that increasing the pull angle of the harness results in the reduction of the effective vertical force on the implement (by reducing parasitic soil/implement friction forces, and the effective implement weight). As a rule of thumb, by increasing the angle of pull from 15° to 30° it is possible to reduce the implement draft by up to 50% (Figure 3). But there is the risk of reducing maximum depth of work by increasing the vertical component of the pull force.

[1] And, in fact, incorporating Frank Inns into the R&D team



This harness gives an angle of pull of about 30° or slightly more

Figure 3. The force system acting on a draft animal. Increasing the angle of pull (α) will reduce the implement draft.

The materials used should be non-abrasive and padded where load is applied (i.e. the hip and shoulder straps and, especially, the breast band). Local materials should be used and, once the principles have been well understood, local adaptation will be expected (Figure 4).

Figure 4. A horse using a high-lift harness made from fertilizer sacks. Capinota, Bolivia

The sustainable pull that an equid can produce will depend on its disposition, nutrition, health and physical condition, but also, crucially on its body weight. Equids can typically sustain pulls in the region of 10-15% of body weight which, for a 150 kg donkey translates to a pull force of 150–220 Newtons. This will usually still not be a high enough value for sustained pulling of equipment designed for pairs of draft oxen, and so lighter equipment needs to be designed and tested to ensure that it is within the capacity of the work animals. In the case of moldboard plows, for instance, we have found that a fit donkey can handle a plow with a share width of some 115 mm and this increases for a single horse to 150 mm width. Clearly, this would require more passes and a longer period of work compared with cultivating the same area with a wider cut plow.

However, although one important aspect of work animal use in semi-arid regions is the requirement to use less fodder, another is to reduce the amount of tillage and to increase rainwater infiltration.

Work in sub-Saharan Africa (Sims and Twomlow, 2000) has shown that the major problems associated with conservation tillage approaches currently promoted to the smallholder farmer are crop establishment, weed control, and the associated shortages of adequate draft power. To date little work has been carried out to assess the interaction of different conservation tillage options with different weeding regimes on maize yield and soil-water regimes. Therefore, it is essential that conservation tillage practices are developed that both conserve water, reduce draft animal power requirements, encourage timely crop establishment and weed control systems that take into account the resourcefulness of smallholder farmers.

The advantages have been shown of establishing a crop within either a rip line (with a narrow tine) or a planting furrow opened with a plow on winter or previously spring plowed land (Muza *et al*., 1996). Although these techniques of crop establishment can reduce energy inputs for seedbed preparation and allow timely planting, a heavier and earlier weed burden results, compared with that for overall plowing and planting together (the prevailing practice in sub-Saharan Africa [Mabasa *et al*., 1999]). If combined with weeding with a plow (or a cultivator with ridging blades), timely planting, better soil water conservation, weed control and labor reduction could all be achieved.

Recent work in Zimbabwe has focussed on developing weed control strategies that complement primary tillage techniques for the majority of communal area farmers who cannot afford purchased inputs, including herbicides. Because of poor returns to cropping and an acute shortage of labor in many households, tillage / weed control systems need to be based on low cost, labor saving technologies (Ellis-Jones and Mudhara, 1997). Riches *et al.*, (1997) reported that the use of the moldboard plow with body attached during weeding allows the creation of a ridge and furrow landform that can enhance soil water retention. The soil thrown towards the crop row smothers weeds and reduces the need for subsequent labor-intensive inter-plant weeding. Labor productivity, in terms of grain harvested, can be considerably higher with this technique than the use of existing hand-hoe or cultivator followed by hoe systems. While the vast majority of households own a plow in southern Zimbabwe, less than a quarter own a cultivator, so "plow-weeding" provides an opportunity for increasing the timeliness of weed control, for farmers who currently weed by hand, without the need for additional capital investment, if they have access to work animals.

Reduced vertical tillage has also been a feature of participatory technology development efforts in Latin America. Chisel plows to improve run-off infiltration on hillsides have been developed to be more efficient in terms of volume of soil moved per unit of energy imparted. One is a scaled-down version of a plow designed for oxen and drawing heavily on the design of the traditional ard-type plow. Reducing the width of the pointed share, and the width of the twin moldboards, will bring the implement to within the capacity of equines.

Narrow tines with a low rake angle have long been used for bursting and mixing soil in a limited width of work (Spoor, 1969), and in fact this is the basic principle on which ard plows function. To increase the efficiency of a chisel plow, fitting inclined wings to the rear of the chisel point has been found to be effective (Spoor and Godwin. 1978). Figure 5 illustrates a design to achieve this.

Figure 5. Wing-tined chisel plow for more efficient soil bursting during vertical tillage.

Surface cover is one of the best soil conservers and improvers that can easily be adopted by semi-arid region farmers. A problem arises, of course, over the competing demands for animal fodder, but the value and potential of mulch-based no-till agriculture has been well demonstrated (Wall *et al.,* 2001). Although no-till planting with animals is common practice in several Southern Cone countries, light weight, multi-row equipment for small grains was not available in the semi-arid valleys of the Andean region. Figure 6 shows a late prototype that has been developed for small cereals and is on trial in semi-arid regions of Bolivia, Mexico and India.

Figure 6. Direct seeder for small cereals designed to be pulled by a pair of oxen. Bolivia.

CHALLENGES FOR THE FUTURE

The principal aim of research and development efforts expended on semi-arid agriculture is to contribute to the resilience and viability of the farming systems and to contribute to improved sustainability. This in turn will add to the farm families' capital stock and contribute to an improvement in livelihoods.

Crop production is more uniform and less risky if soil is conserved and fertility maintained or improved. Capturing and directing run-off is a fundamental requirement for crop production in this hostile environment. We have seen some efforts that have been made to reduce tillage and promote vertical tillage, other approaches include using micro-relief for water capture. The direct seeder shown in Figure 6, for example, can be adapted to furrow-bottom planting of small grains with remarkable yield increases. Larger scale physical works and micro-catchments (earth dams and so forth) are also possible to construct with the aid of animal power and can provide sufficient supplementary irrigation in dry years to prevent total crop loss (Pacey and Cullis, 1986).

Domesticated animals are an integral part of most semi-arid farming systems, but they are also a source of land degradation and threaten the cropping area, or rangelands, if the demand for dry-season fodder exceeds supply. Keeping fewer, lighter working animals may go some way towards ameliorating this situation and so an increase in the design, manufacture and supply of lightweight implements is a probable future development. The challenge is to develop this equipment in close collaboration with potential users and to produce prototype designs as a result of participatory (scientist and farmer) technology development.

Soil and water conservation, generally will be a priority for the future. With our present program of World environmental destruction, forest devastation and population growth set to reach 9 billion (from the present 6 billion) in less than 50 years, and the seeming lack of worldwide concern for the damage that we are perpetrating, the situation is bound to get worse. Conservation tillage (including direct planting) will clearly have a role to play in conserving soil and water in semi-arid regions, but so, also, will conservation measures which respond to farm families' needs by, for instance, producing useful products whilst protecting the soil.

Recent work in the Bolivian semi-arid region (Rodríguez, and Sims, 2001) has produced, in collaboration with farm families, a variety of suitable species for contour-planted, soil and water conserving, vegetative live barriers which produce abundant dry season fodder whilst conserving fragile hillsides (Figure 7).

*Figure 7. Contour barriers of phalaris grass (*Phalaris tuberoarundinacea*) and woolly-pod vetch (*Vicia sativa *ssp.* dasycarpa*) for soil conservation and forage production.*

There remains an urgent need to reduce the cost, effort and drudgery demanded to care of our semi-arid regions fragile soils and scarce moisture. Draft animal use offers an opportunity to achieve this, provided that the animals can be sustainably maintained (within the natural resource base) and harnessed to purpose-designed equipment that will deliver the required results. This is a combined challenge to farmers and livestock technology specialists.

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