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PROSPECTS FOR DEVELOPMENTS IN THE USE OF EQUINES FOR CROP PRODUCTION

Brian G Sims[1] *and Frank Inns*[2]

Abstract

Equines (horses, mules and donkeys) are numerous worldwide and represent a potential power source for small-holder farms. The use of equines as a crop production power source may be limited by competition from engine power and alternative work animal breeds. Other potential constraints include cultural, socio-economic, political, animal size and health and nutrition. Frequently oxen have been preferred but demographic and social pressures may make these increasingly non-viable. The paper discusses the constraints to the use of equines in general terms. The summaries, in italics, might be useful as a check list to help in identifying the viability of proposed development schemes. This is followed by examples, drawn predominantly from Latin America, examining the use of equines for primary and secondary tillage, seeding, weeding and ridging. There is further potential for equines to be used in conservation agriculture (specifically no-till seeding). Participatory research and local manufacture are needed to identify technical needs and to satisfy the market.

INTRODUCTION

The world population of equines has been estimated as 41 million donkeys, 15 million mules and 65 million horses (Fielding (1991). Population figures for animals are notoriously difficult to assemble, being based in many countries on estimates and extrapolations, but even allowing for a margin of error of 20% or so, it is obvious that these animals represent a vast power resource of which only a very small proportion is currently used to assist agricultural production.

This paper examines the constraints to increasing utilization of this store of power for agricultural purposes, how they might be overcome, the purposes to which the additional power might be applied and the potential for achieving sustainable ways of doing so. Examples are given drawing mainly from experiences in Latin America.

CONSTRAINTS TO THE USE OF EQUINES IN AGRICULTURAL PRODUCTION

Competition from other power sources

Engine power

In high income countries agricultural production depends almost exclusively on tractors and other engine-powered machines, usually benefiting from benevolent regimes of taxation and other subsidies. Despite a growing awareness of 'environmental issues' it must be accepted that practical politics will ensure that this situation does not change significantly.

[1] International Development Group, Silsoe Research Institute, Silsoe, Bedford MK45 4HS, UK. brian.sims@bbsrc.ac.uk
[2] 53 Alameda Road, Ampthill, Bedford MK45 2LA, UK. frank.inns@tesco.net

Tractors are also used in many less developed countries (LDCs) but capital and running costs are such that their use is usually restricted to wealthier farmers and government or aid sponsored projects. In general the costs of tractor ownership and use are beyond the reach of most farmers in the LDCs and is likely to remain so for some time to come. Tractor owning farmers or specialist contractors are sometimes available to undertake on-farm operations, usually plowing, harrowing and possibly seeding and harvesting of grain crops but availability of contractors may be erratic and the quality of their work variable.

> *The potential for the adoption of animal power may be restricted when farmers can rely on timely tractor-powered cultivations by competent contractors.*

Alternative animal power

The use of equines for personal transport and as pack animals is traditional in many regions. Equines tend to be used for draft more in temperate climate regions, including tropical countries at higher altitudes, but other animals, including oxen, buffaloes and camels, are more widely used as sources of farm power. They are generally stronger and more robust than equines (with the exception of mules) and, where their use is well established, it is unlikely that they will be substituted by equines unless in exceptional circumstances. Such circumstances may arise at times of drought or on the outbreak of diseases, specific to non-equines, which may be difficult or expensive to treat. Farmers may then look to any equines which might be available in the area, particularly donkeys which have good survival instincts and are often available at reasonable cost. They can be used for many field operations when fitted with suitable harness and implements.

> *It will probably be difficult to convert farmers to the use of equines when they are already using other animals (e.g. bovines) for field work, unless in exceptional circumstances.*

Cultural and social constraints

In many areas, particularly in tropical or hot dry regions, the ownership of horses is a symbol of wealth for an élite group who use them for riding or ceremonial purposes; while cattle ownership in other regions has a similar significance for many traditionally nomadic people. The status of such animals, and of their owners, would be undermined by using them for draft work in the field, creating a strong cultural barrier to their employment for this purpose.

Cultural constraints of this nature are not easily overcome in the short term and the trend to a more settled way of life, encouraged by some governments, is made more difficult. Of the other equines suitable for draft work, mules are often not acceptable culturally while donkeys tend to suffer from an insufficiently macho image, although they may be widely used as riding and pack animals. There is however a growing recognition that donkeys have a great deal to contribute to agricultural production. When well treated they are friendly and willing animals which respond readily to persuasion rather than force, a characteristic which makes them particularly amenable in the hands of women farmers. There are usually no cultural or social barriers to the use of donkeys by women, making their potential role as draft animals particularly helpful at a time when the empowerment of women is high on many political development agendas.

> *The acceptability of using horses in agricultural operations varies widely from country to country, depending on cultural factors, but they are rarely available for use by women. The use of donkeys by women is socially acceptable in most countries and is desirable as a catalyst for women's empowerment.*

Size and conformation

European farm horses, as used for plowing in former times, were heavy (about 600 kg) and low set and were usually harnessed in teams of two or four, pulling a two furrow wheeled plow. This arrangement was rather difficult to adjust and maneuver so that a single horse pulling a lighter single furrow plow was sometimes used on farms with smaller fields.

In the LDCs the weight of a typical horse will probably be less than half that of a European farm horse and it will have longer legs and a finer bone structure, having been bred and selected for riding or carriage pulling. Terrain, and perhaps irrigation and soil conservation measures, often result in small field sizes and frequent turning will be necessary, so that use of a team of horses will be unwieldy and tiresome. European equipment, even that designed for single horse working, will generally be heavy and awkward to use and alternative designs of harnesses and plows are desirable for efficient single horse (or single donkey) working in these situations.

> *Horses available in developing countries are small for heavy cultivation work unless in teams, which are awkward to use in small fields. A single horse or donkey in fit state should be able to cope with lighter work such as weeding and for plowing in favorable soil conditions, with suitable equipment, but European harnesses and implements tend to be too heavy, complicated and tricky to adjust.*

Health and nutrition

Horses tend to be more healthy in cooler regions, precluding their use in a large part of the tropics unless at high altitude. Trypanosomiasis is a major problem in sub-Saharan Africa, in many parts of Asia and in some parts of tropical South America with severe effects on horses and mules, although donkeys are more resistant to the effects of the disease. Horses in central Africa are also highly susceptible to East Coast Fever, usually fatal, which precludes their use in that area.

Nutrition is always a problem with draft animals, particularly on small farms where livelihoods are marginal and the farmers' first priority is to feed the family. However, where horses are customarily kept for riding and as pack animals, basic nutritional know-how is likely to be reasonable and capable of development. It has to be emphasized that horses used extensively for high draft operations will need extra feed to compensate for the energy expended in their work output. Similar emphasis must be put on the need for supplementary feed for working donkeys, which are often left to forage for themselves.

> *The use of any animal power for draft work is always conditional on the availability of healthy, well nourished animals. Experienced management is also required, most particularly for equines. It would be unwise to introduce equines or develop their use specifically for draft work in areas where these requirements can not be met.*

Socio-economic-political factors

Farming practices are dynamic, emerging from a complex array of interacting factors and adapting continuously to changing circumstances, *e.g.* climatic, social, political, economic, environmental. Powerful political actions have been taken which impose change on farmers in the name of 'competition', 'specialization', 'free markets', 'globalization', 'reduction of subsidies', *etc,* with far-reaching consequences to less robust national economies, though not always the predicted ones. Farmers' livelihoods have been affected by consequential loss of markets, reduced crop prices, withdrawal of advisory and veterinary services and few identifiable compensating benefits. One result of these changes is the need to reduce the costs of animal power by using fewer animals or ones which are less costly to maintain. Perhaps no-till conservation agriculture, as widely used in engine powered farming, might dramatically reduce the energy required for field operations. Could efficient and reliable machines necessary for animal draft operations of this nature be developed? Would the per hectare subsidies available to engine powered farmers be available also to animal powered farmers?

Social change has also accelerated, notably in the advancement of the role and rights of women. In many countries this interacts with the spread of AIDS, affecting the responsibilities of the surviving members of a partnership and their dependents. Women must have a greater certainty in their capacity to deal with what has hitherto been regarded as 'men's work' which often includes work involving high physical effort for which any reduction in the effort required is to be welcomed: the operation of animal powered equipment is often thought of in this context.

> *Social, political and economic factors are continually changing and close attention is necessary to detect trends which might affect existing systems and practices in farming. The use of draft animals must be considered in this context but is largely unpredictable. Perhaps the safest conclusion is that the trend will be towards fewer and less costly draft animals working with more efficient implements. The move towards greater use of donkeys, already proposed as a contributor to the empowerment of women but not yet widely practised, requires the greatest emphasis.*

Harnesses and implements

At present most harnesses and implements are based on traditional designs which have been developed over many decades at least. In recent years very considerable research efforts have been directed at the design of 'improved harnesses' directed mainly at alleviating discomfort associated with traditional designs, but no fundamental analysis of how harnesses work and how they affect implement draft has been made until lately (Inns, 1990). Reduction of draft will reduce the intensity of the loads at the various contact points between harness and animal as a fundamental and possibly more significant step towards minimizing discomfort at these locations.

Many current implements are based on old designs originating when materials and manufacturing techniques were less developed than those available today, resulting in large and heavy machines which then relied upon wheels, skids or other ground contacting surfaces to support them when they reached their working depth. The heavier the implement the greater the support forces and hence the greater the rolling or frictional resistance generated, causing the animal to work harder, tire more quickly, expend more energy and need more food to replace the extra energy used.

> *There is a need to improve working efficiency by the adoption of radical improvements to the design of harnesses and implements. This applies for all animals but will be particularly valuable in the case of smaller and lighter animals such as donkeys so as to extend the possibilities of using them for operations which have previously been considered 'too heavy' for them.*

DESIGNING HARNESSES AND IMPLEMENTS FOR REDUCED DRAFT

Frank Inns (1990; 1991) created a deal of fertile discussion in the First Equine Colloquium held in Edinburgh when he introduced the concept of light-weight implements with a high angle of pull as an effective method for reducing the draft of a chain (or rope) pulled implement. His analysis showed that implement draft can be reduced by reducing the effective vertical force on the implement (due, principally, to the implement weight and soil forces) and/or by pulling it a steeper angle (Figure 1). The theoretical analysis was validated by field experiment (Inns and Krause, 1995) and used to design a harness/implement combination matched to the pull of a single donkey (Inns, 1996). The field trials reported in these papers showed that implement draft is reduced by about 50% as the angle of pull is increased from 15º to 30º without noticeable reduction of working depth. This is of fundamental importance to lighter animals (which include equines, especially donkeys) as they are only able to sustain draft forces in the range of 10-15% of a rather low body-weight.

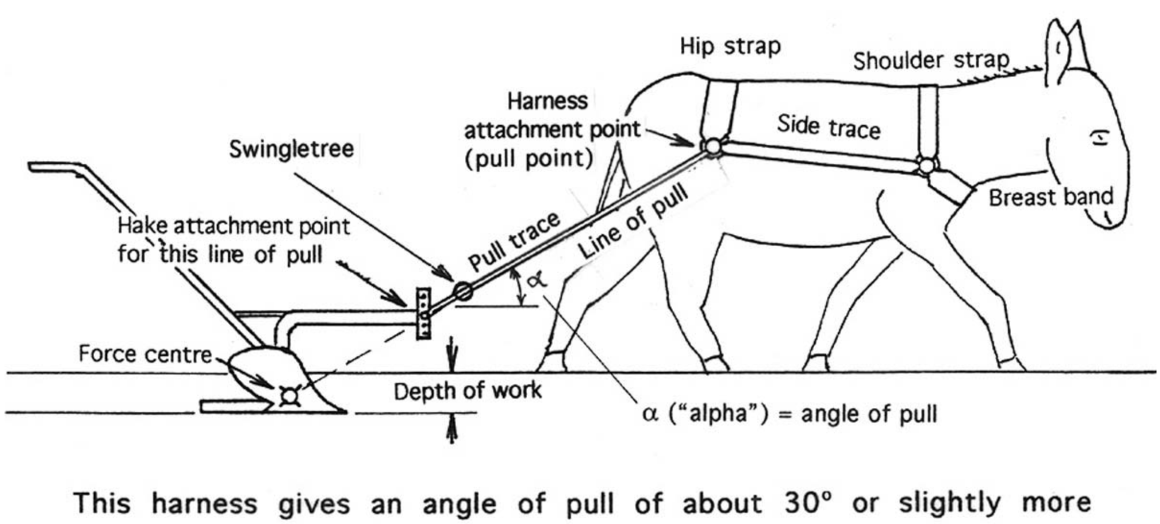

Figure 1. The force system acting on a draft animal. Increasing the angle of pull (α) will reduce the implement draft

Lightweight plow for the high-lift harness

The donkey harness/plow system has been used on-farm in Bolivia and Kenya, where it has been noted that "it operates with minimum effort and women and young persons can use it without fatigue" (Muckle, 2001). Desirable features of the system are: low draft; no depth wheels or skids, therefore lighter in weight; simple to adjust; easily transported and cheap; not so easily damaged as it tends to jump out of the ground if it hits an obstruction; less ground contact pressure reduces wear. It must be noted that the geometry of the implement plays an important part in achieving these benefits — it must be designed specifically to work with the 30º - 40º pull angle.

High-lift harness for equines

The 'high-lift' harness with steep 30º to 40º pull angle can be adapted from either a conventional equine collar harness or a breast-band harness by adding a simple and cheap 'hip-strap' over the hind legs to carry the small vertical forces from the plow traces — the full draft force is transmitted through to the breast band or collar. A breast band harness, allowing the animals to pull from their strong chests, is preferred because it is simple and easy to make, with low weight and low cost. The hip strap has to be adjustable to set the angle of pull, which should be in the range of 30-45º. It is interesting to note that the steep angle of pull from the harness to the implement is a feature of the Latin-American 'saddle harness' shown in Figure 2, which has been arrived at independently, presumably by farmers using trial and error techniques. No doubt there are other examples of empirical development along these lines.

Figure 2. A seeder pulled from a donkey saddle. This arrangement provides the high angle of pull required to reduce the implement draft.

The combination of 'high-lift harness plus lightweight plow' accords with the farmers' view-point, expressed in many farmer-researcher participatory draft-animal R&D programs that many implements are "too heavy for equines to use". The theoretical analysis justifies this opinion.

THE USE OF EQUINES IN AGRICULTURAL PRODUCTION: EXAMPLES FROM LATIN AMERICA

HISTORICAL BACKGROUND

Equines (particularly horses) have been, and are being, used in many Latin American countries as a power source for crop production and transport work. Traditionally, the power source used in small-scale Latin American agriculture has been oxen, usually employed as pairs called *yuntas*. Land degradation, demographic pressures and constrained forage supplies have led to a re-examination of the role of draft animals in Latin American agriculture and to greater R&D efforts to employ single animals, be they bovines or equines.

Equines tend to be used more in regions which are cool, that is the higher areas of tropical countries (e.g. Mexico) and the temperate regions of Southern Cone countries like Chile and Argentina. In warmer, more humid areas the ox still holds sway as it has done since the Spanish Conquest of the 16th century.

Equines are predominantly used for transport and riding. Mules and donkeys are especially important as pack animals in rough and less accessible terrain (e.g. mountain regions). The imposition of adverse economic conditions may make equines particularly useful for carrying people, as is the case at the moment in Cuba that has been hit by a fuel scarcity since 1989 (Figure 3). However equines do have a traditional role and a huge potential in crop production activities, and it is on this area that the bulk of this section will concentrate.

Figure 3. Equine use is dynamic. There has been an upsurge during the 1990s in Cuba as a result of externally imposed economic conditions.

Light draft jobs, such as weeding and chain-harrowing have been the horse's domain even before it superseded the ox in other, higher draft, jobs in Europe (Chivers, 1988). This situation remains true today in many developing countries, humans, tractors, equines and bovines can all play productive and profitable roles as appropriate powers sources under different agro-ecological and socio-economic sets of circumstances. However, equines need not be confined to the traditionally light-draft operations if suitable equipment is designed and made widely available. A moldboard plow designed to work (at the rate of one acre [0.4 ha] per horse per day) behind a pair of 800 kg heavy horses in Europe will not be a possibility for a 300 kg horse with an inadequate diet in the high Andes of South America (Figure 4).

Figure 4. Typically equines used for pack transport are much lighter than the heavy breeds bred for draft. Their potential can only be realized with the provision of suitable harnesses and implements.

Possible solutions to the problem are to use a greater number of animals to produce sufficient draft force for large, heavy implements (Figure 5); or to reduce the draft requirement by making equipment smaller and more light weight, and by choosing harnessing arrangements that use the available power most efficiently.

Figure 5. Heavy implements, designed for oxen, can be used by equines if sufficient numbers of animals are employed.

Collars for equines have proved their worth over many centuries (even though their modern versions are expensive, innovation can produce locally cheap alternatives [Starkey, 1989]). Versions currently used in Latin America are often roughly constructed of not very durable materials. Nevertheless, breast-band type harnesses are the cheaper, more widely adopted design adopted throughout much of the world (Pearson, 1998). Developing country harnessing arrangements must, above all, be cheap if they are to be adopted (Figure 6). Simple designs using readily available but appropriate materials are likely to indicate the route to success. The use of inappropriate materials liable to frequent breakages and abrasions are to be avoided, as are running repairs using wire, nails or bolts which are also likely to damage the animals.

Figure 6. A simple breast-band harness is the most appropriate arrangement for transmitting energy to the implement.

Although the first animals brought to Latin America by the Spanish conquistadors were horses, donkeys and mules soon followed. However, for agricultural field work the *yunta* and the steel-shared wooden plow were the technology option, as they had been in Spain.

This option is perfectly well adapted to lowland flat areas where relatively high rates of work are required and soil erosion is not a problem. It is also a viable option where population rates are low and forage supplies are adequate throughout the year. However with global population predictions are set to take us from our current 6 billion to 9 billion by the year 2050, the trends are clear and persuasive.

Draft animal users have usually been near to the bottom of the social hierarchy in Latin America, their political clout has been limited and they have been at the whim and mercy of the more powerful political élites (Duncan and Rutledge, 1977). The result has been that small farmers have been increasingly consigned to the more marginal agricultural areas, away from the more fertile valley bottoms. The outcome has been the cultivation of more fragile lands, steep slopes in semi-arid conditions, for example, with the increasingly inappropriate technology imported by the conquistadors and virtually unchanged since then (Figure 7).

Figure 7. Cultivating steep slopes with inappropriate technology can lead to land degradation and impoverished livelihoods.

These regions require a more delicate approach if they are to yield rural livelihoods on a sustainable basis. Repeated plowing with the wooden plow, or its successor, the steel moldboard plow, can lead to rapid deterioration of soil structure and fertility unless protective measures are taken. Keeping a pair of oxen throughout the year, when it is probably only used for a few days during times of peak demand, can also present a serious problem of forage supply. Integrating the use of a resource that already exists for riding and pack-transport (the equine) into the farming system through the development of appropriate harnesses and equipment, and adding concepts of natural resource conservation, can help to overcome these constraints to sustainable production.

CURRENT PERSPECTIVE: EXTRACTING THE POTENTIAL

This section looks at the present and possible future role of equines in traditional and potential crop production systems.

Primary tillage

Primary soil tillage is, generally speaking, the highest-draft job on the farm. Where oxen or tractors are available they will be used for this work and can then leave subsequent jobs to the lower-cost alternative of lighter animals. Nevertheless, equines are quite capable of primary cultivation, implement options include moldboard plows, which invert the soil prism, and chisel tined implements which effect vertical tillage without soil inversion. Extensive, farmer-participatory field testing under different, but typical, soil conditions and with a variety of animals will be the best way to arrive at a satisfactory configuration and weight. As a guide, a moldboard plow with a weight of 10-15 kgf and a width of cut from 10 – 15 cm would be within the pulling capabilities of a healthy equine.

For non-inverting tillage there are several options. One (Figure 8) 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.

Figure 8. Scaled-down *arado combinado* from Bolivia, designed initially for ox-draft but now within the capability 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 (i.e. disturb a greater volume of soil per unit of energy input), fitting inclined wings to the rear of the chisel point has been found to be effective (Spoor and Godwin. 1978). Figure 9.

Figure 9. Wing-tined chisel plow for more efficient soil bursting during vertical tillage.

Weeders

Weeding, if done when the weeds are small enough (less then 5 cm tall) and when the soil is in the right condition (friable) is a light draft job well suited to the draft forces available from equines. There is a series of design characteristics which should be adhered to for optimum results (Emhardt and Kutzbach, 1993). These include light weight, low draft; good tine overlap; low angle of attack; good under-frame clearance for trash flow. These characteristics are discussed in detail in Sims (1993). One particularly successful design, commercially available in Bolivia, is shown in Figure 10.

Figure 10. A three-tined cultivator designed for single-equine draft.

Ridgers

Forming ridges and furrows can be a pre-planting operation, and the same implement can be used to earth-up the growing crop as part of weed control in the growing crop (Figure 11). Important design aspects are: a long, narrow, slightly inclined share to ensure penetration and stability; a heel for depth control; concave moldboards which are adjustable for width of work. Experience has shown that farmers' criteria are vital. They will have very specific requirements for moldboard size and furrow width for each of their ridging operations.

Figure 11. Ridging the potato crop, either as a complete weed control and earthing-up operation; or following a weeder.

Seeders
Seeders for equines have been notoriously difficult to disseminate in large numbers, this is not difficult to understand when it is realized that the lower cost alternative is the planting stick, or the hand with a foot used to cover the seed. However, conversations with farm families about their machinery needs usually include a request for seeders. Seeders need to compete with the human eye, hand and foot and so must space the seeds accurately and cover them at the required depth.

Seeders with vertical cell-plates have been successful in Central America (Relata, 2002). However, experience with a wide range of grains under farmer-participatory evaluation, has led to the development and diffusion of horizontal rotating cell-plates for seed metering (Prometa, 2002) which produce fewer broken grains and improved seed spacing (Figure 12). Farmers are more content with this design when offered the choice.

Figure 12. A horizontal plate seed metering mechanism gives more uniform seed spacing and fewer broken grains.

Conservation agriculture
Conservation agriculture involves the maintenance of soil cover to improve structure, conserve moisture, increase organic matter and reduce costs over the medium term. It therefore includes direct, or no-till, seeding (FAO, 2002). No till seeders for animal traction have been developed in Brazil (Monegat, 1991) and the lighter models can be pulled by equines (Figure 13). These generally have a vertical wavy disc to cut through the surface vegetation, followed by a furrow opener (double disc or narrow tine), a horizontal rotating disc seed metering system delivering to the narrow furrow which is closed by press wheels.

Figure 13. Horse-drawn no-till seeder. Source: FAO, 2002.

Simplified no-till seeders can be made by coupling existing seeder units behind chisel plow for single-row working through surface cover

The use of equines for limited soil tillage on fragile hillsides has preoccupied researchers and interested hillside farmers for some time. Work in Central America (Almendares, 1999 and Relata, 2002) has resulted in the development of techniques for practicing safe tillage on hillsides with up to 40% slopes. In this process a single horse is used to plow 30 cm wide strips on the contour at a vertical interval of approximately one metre. Over time these strips form horizontal terraces which can be planted with horse-drawn implements (Figure 14).

Figure 14. Using a modified wooden plow on mini terraces. Source: Relata, 2002.

FINAL THOUGHTS AND FUTURE TRENDS

Equines are capable of performing all the tasks required for conventional crop production. The constraint has often been the lack of suitable harnesses and light-weight equipment designed with the limited draft force potential of the animals in mind. However with due care and attention paid to implement design, tools can be produced for primary and secondary soil cultivation, weeding and ridging. There is (almost) no limit to other applications of this power source according to the requirements of a particular crop or agro-ecological region.

Oxen, whilst generally being able to produce more draft force than equines, are increasingly facing another constraint. Animals need forage year 'round and in marginal regions, especially those with a prolonged dry season, this is not always possible. Work in the Andean valleys (Rodríguez and Sims, 2001) has shown the technical and economic viability of establishing grass / legume contour barriers on hillsides for soil protection and forage production (Figure 15). The terraces between these barriers are well suited to being cultivated by equine-powered implements, particularly reversible moldboard plows.

Figure 15. Contour barriers of phalaris grass (*Phalaris tuberoarundinacea*) and woolly-pod vetch (*Vicia sativa* ssp. *dasycarpa*) for soil conservation and forage production.

Where it is not an economic option to keep an underutilized ox throughout the year, it is possible that a market will develop for cheap, light-weight implements specifically designed for equines. Research and development work should be intensely farmer participatory from the outset. If potential users are part of the development process, and are "owners" of the technology, then it is far more likely that research effort will be expended on solving problems that are a priority for farm families, and that adoption will ensue once the products are on the market.

Local manufacture of high-quality implements and harnesses is a vital ingredient in assuring successful adoption. The design of implements for draft animals is not always such a straightforward process as many non-engineers imagine. Many times have non-experts (principally social scientists) opined that manufacture of animal-powered implements should be entrusted to rural blacksmiths, so that "local needs can be addressed". Long experience has shown this to be a fallacious view. Equipment users are looking for quality and durability which can only come about by standardizing manufacturing procedures and materials. Whereas local artisans can be charged with implement repair, the initial manufacture, and the production of standard replacement parts, is the domain of a centralized commercial manufacturing facility operating a policy of strict quality control.

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