



*The Society for engineering
in agricultural, food, and
biological systems*

*Paper Number: 021126
An ASAE Meeting Presentation*

Draft Animal Power for Soil and Water Conservation in Small-Holder Production Systems in the Inter-Andean Valleys of Bolivia

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**Written for presentation at the
2002 ASAE Annual International Meeting / CIGR XVth World Congress
Sponsored by ASAE and CIGR
Hyatt Regency Chicago
Chicago, Illinois, USA
July 28-July 31, 2002**

Abstract The inter-Andean valley region of Bolivia presents climatic characteristics which can be described as high, dry and cool. The prolonged dry season (up to eight months) can lead to severe forage shortages which affect working animals. The traditional draft animals are pairs of oxen which may have to be sold off at the end of the working season due to lack of feed. Production of forage and the possibility of using lighter, single animals are two ways to alleviate the situation. Natural resource management projects in the region, working in very close collaboration with farm families in programs of participatory development, have developed contour-planted live-barriers of grass / legume mixtures to stabilize steep hillsides and provide abundant and nutritious dry-season forage. The development of high-lift harnesses and lightweight equipment has enabled hitherto underutilized single equines (and bovines) to undertake draft work traditionally the exclusive domain of pairs of oxen.

Keywords. Live-barriers, forage production, high-lift harness, light-weight equipment, animal traction

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Introduction

The inter-Andean valley region of Bolivia lies to the East of the Andes mountain chain and is characterized by having a harsh climate and broken terrain with steep, cultivated slopes. Altitudes range from 1500 to 4000 masl; temperatures average around 12°C and rainfall 5-600 mm per year. Naturally there are wide variations in the climatic conditions with frosts and higher rainfall to be increasingly expected with increase in altitude. But, in general, the conditions can be described as high, dry and cool. The annual precipitation is not only low, but very seasonal and there can be a period of up to eight months (March to October) where rainfall is scarce if not absent.

Farmers in the region are obliged to plow steep slopes to gain their livelihoods. Whilst irrigated valley bottoms are always preferred, they are in scarce supply and slopes of 30-60% are commonly tilled by hand or with draft ox powered implements.

The situation gives rise to severe problems and needs. Soil degradation on the cropped hillsides is already severe and becoming critical. Farmers comment on falling yields which are a direct result of soil fertility loss due to soil erosion. Soil moisture becomes scarce as top soil is removed by the erosive processes of rain and wind, and so yield reliability is in jeopardy. The dramatic results of severe drought events (such as those produced by the *el Niño* phenomenon) serve to remind farmers that the productive potential of their hillside plots is on the decline. And they are desperately concerned. The prolonged dry season also limits the amount of forage available for livestock, including work animals. Farmers are obliged to use valuable cropping land to produce dry-season forage (usually oats) with the consequent opportunity cost of not producing cash or food crops for family subsistence.

Since 1996 a number of participatory research projects has been working with local communities jointly to overcome these constraints¹ and the purpose of this paper is to describe the major outcomes of the research. Two of the principal aims of research projects were:

- To develop the concept of establishing vegetative live-barriers on hillside contours in order to stabilize the soil, reduce erosion and provide dry-season forage.
- To diversify the use of draft animals through the development of appropriate equipment for different types of animal traction (e.g. single animals and equines).

The advances achieved are the result of an intensely participatory process whereby farming communities identified their own technical problems and worked with scientists to resolve them on their own plots and under their control. The research focus was also on the farming systems as a whole, with particular attention being paid to the interactions between system components (for example the feed value of erosion control measures and the mechanization requirements of stabilized hillsides).

¹ Projects funded by the UK Department for International Development

Forage production

Prior to the R&D work described in this paper, the universally used work-animals were pairs of oxen, or *yuntas*. These, and the traditional ard-type wooden plow, were introduced at the time of the Spanish Conquest (some 500 years ago) and have remained substantially the same ever since. Because of the difficulties of feeding the oxen through the dry season, they are frequently sold at the end of the peak work period (i.e. in the first quarter of the calendar year) and new animals are bought for the following season. Figure 1 shows the diversity of feed types used by farmers, and Figure 2 shows the metabolic energy balance for oxen through the year.

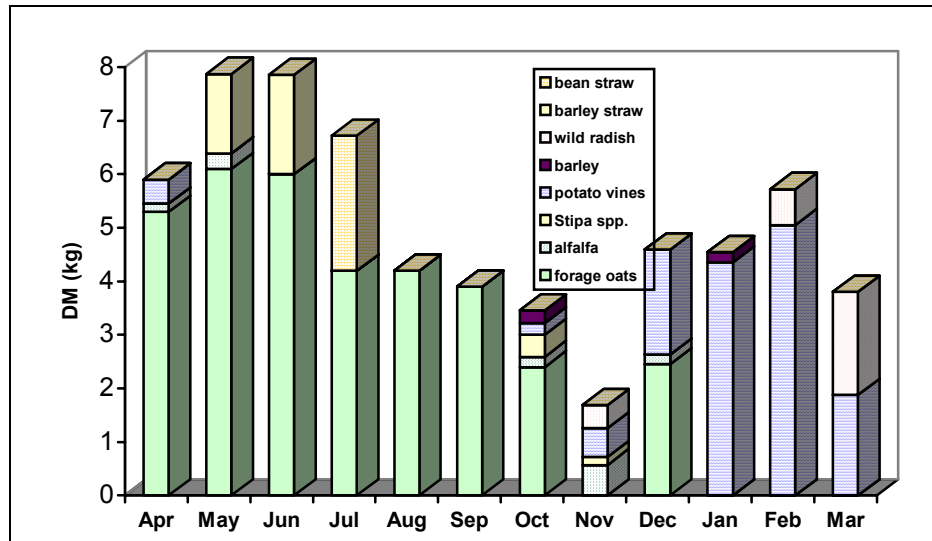


Figure 1. Fodder consumption by oxen. Whilst forage oats is the single most important fodder source, other sources, including weeds, are seasonally important.

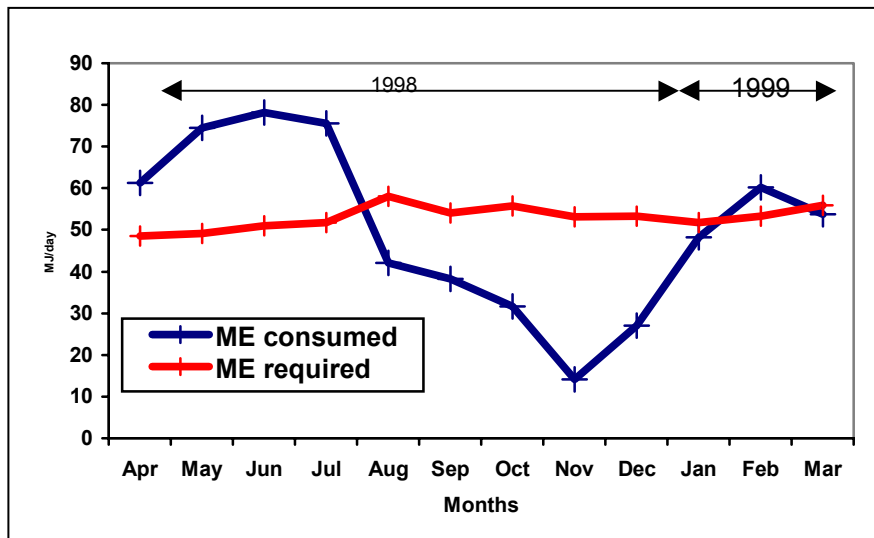


Figure 2. Metabolic energy balance (MJ day^{-1}) for oxen during the year.

Figures 1 and 2 clearly show the impact of the dry season, forage is in short supply and the work animals have an energy shortfall which results in severe weight loss. Generally, however, the work animals suffer no lasting damage and soon regain weight as the rainy season produces abundant green fodder.

The concept of hillside stabilization with live barriers planted on the contour is not new in the world, but it was a novel concept in the Bolivian inter-Andean valleys. Initial research evaluated a wide range of grass and shrub species (Sims *et al.*, 1999) in a range of agro-ecological niches in the valleys. The outstanding winner from the points of view of adaptability and forage production, was phalaris grass (*Phalaris tuberoarundinacea*). Farm families immediately appreciated the value of this grass which can be grazed to ground level in the dry season and comes back vigorously with the onset of the rains. Women, especially, praised the practice as it afforded them close access to high quality fodder for their sheep flocks and so freed up time for them to devote to other, more productive, activities. Phalaris yields depend on a number of factors (such as available moisture, soil fertility, number of cuts per year) but most importantly altitude above sea level. Thus yields equivalent to 16 tonnes dry matter per hectare are possible at 2500 masl, this will fall to 3 tonnes per hectare at 4000 masl. The grass is, of course, grown in strips, typically 0.5 m wide, and farmers will cut them three or four times a year before leaving them to grazing livestock. The protein content is highly dependent on the stage of growth and soil fertility, but values of crude protein of 16% DM and 10% metabolizable energy (MJ/kg DM) are normal for phalaris at the pre-flowering stage (Sims *et al.*, 2000).

The live barrier concept, and especially the use of phalaris grass is now widespread in the valley region and is being promoted via NGOs and international development projects. Since initiating the dissemination process in 1999, over 2000 farm families have benefited from training, planting stock and family nurseries. Continued feedback from farm families emphasized the value of the live barriers as high value fodder, and this seemed to be more important, at least in the short term, than the soil and water conservation aspects. And so in 2000 new participatory research was initiated to increase the feed value of the barrier fodder.

The concept of associated live-barriers involves the use of phalaris and legumes combined. Again a range of legumes was tested and again one was outstandingly successful. Woolly-pod vetch (*Vicia villosa* subspecies *dasycarpa*) was introduced to Bolivia from Iran via an associated multinational project (Keatinge *et al.*, 1999). When it is established together with phalaris the two species produce abundant forage with a high protein content. At five months after sowing, the mixture had a crude protein level of 18% DM. The value of the associated live-barriers is very high for farm families with livestock enterprises. Not only are work and dairy cattle better fed, but other enterprises, (like keeping guinea pigs as a protein source) become viable throughout the year.

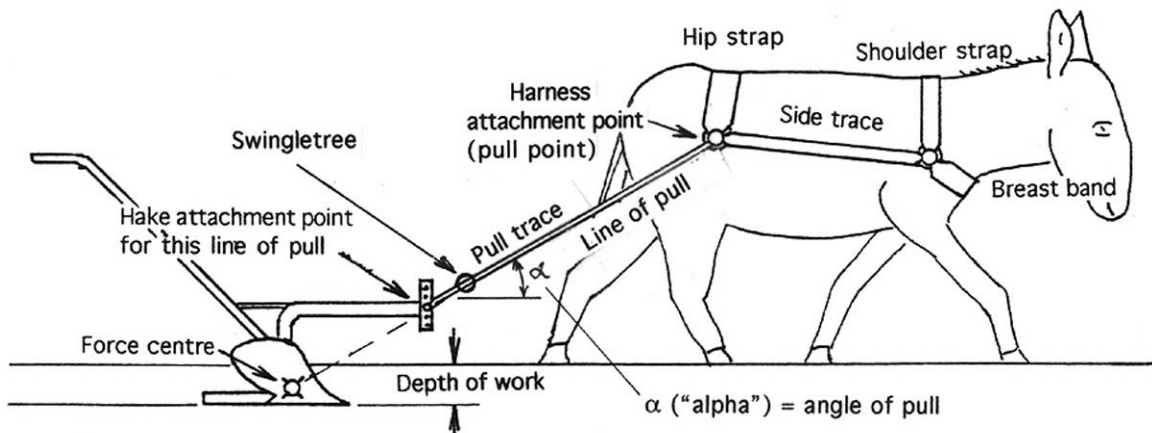
Work animals

It has previously been pointed out that the traditional work animals used for draft are pairs of oxen. And the traditional tool that they use is the steel-tipped wooden ard-type plow. Donkeys and horses were used almost exclusively for pack transport. The participatory research workshops and subsequent discussions highlighted the problems of feeding the work oxen

throughout the dry season, and the fact that the equines were not used for draft work because no suitable harnesses or equipment were available. However there was a desire to use the equine population more profitably as, although they needed to be fed every day, they were not able to work to earn their keep. Consequently a joint participatory technology development program was drawn up with the following results.

High-lift harness and light implements for equines

Light-weight implements with a high angle of pull provide an effective method for reducing the draft of chain (or rope) pulled implement (Inns, 1990, 1991). The analysis shows 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 3). The theoretical analysis has been validated by field experiment 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 15° to 30° 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. The concept was evaluated with farmers in Bolivia and proved to be a solution to the problem of how to make use of the power-producing potential of lighter animals.



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.

Based on this principle, and in close collaboration with the commercial draft animal implement factory associated with the Project in Bolivia, we have developed a line of lightweight equipment which has answered specific problems raised by the farming community.

Moldboard plows for donkeys and horses

Several designs of moldboard plow were designed and subjected to on-farm testing in the hands of experienced farmers. One-way plows, with widths of cut of 115 mm and 150 mm and weighing 8 and 11.8 kg respectively for a single donkey and a single horse. Tests (Figure 4)