Multipurpose use of work animals in smallholder farming systems

Jeroen Dijkman[1], A. GebreWold[2] and R. Anne Pearson[3]

[1]*Food and Agriculture Organisation of the United Nations, c/o International Livestock Research Institute, PO Box 5689, Addis Ababa, Ethiopia*
[2]*Ethiopian Agricultural Research Organisation, Holetta Research Centre, PO Box 2003, Addis Ababa, Ethiopia*
[3]*Centre for Tropical Veterinary Medicine, Easter Bush, Roslin, Midlothian, EH25 9RG, United Kingdom*

Abstract

Rapid increases in population densities and the associated environmental changes have meant increased problems for farmers in planning effective resource management strategies. In response to these driving forces and to improve the efficiency of the available work animal resources, many traditional systems of management will have to change. An obvious challenge in this respect lies in the application of new management strategies and the use of work animals for a number of different tasks and purposes. Opportunities exist in the use of female animals for tasks traditionally carried out by male animals and in changes of ownership patterns. This would enable farmers not only to make better use of the available resources but it would also increase the output and income generation from the work animal sub-system. In addition, improvements could be sought in the use of the different work animal species for a range of diversified tasks to reduce the idle time. Many other systems benefits could be derived through the better use of nutrient resources that smallholder farmers have at their disposal. These may consist of an improvement in the use of manure, the development of food / feed systems and the optimised use of available biomass production. The implementation of these types of strategies will depend on the use of methods that would enable both researchers and development workers to tackle the issues in a dynamic, integrated and system-oriented manner. There is also a clear need to improve the delivery of research results to extension workers and their client-farmers, and for materials and methodologies that reduce the complexity of these interactions and which allow farmers to take an active part in the evaluation of alternative strategies.

Introduction

The use of domestic animals to provide tractive power for cultivation predates recorded history. Indeed, the development of agriculture itself is closely linked to the development of the use of animal power for cultivation. Today work animals continue to make a significant contribution to the livelihoods of the poor in many rural and urban economies. Current estimates suggest that up to two billion people depend on work animals as the main source of energy for farm operations. However, environmental changes and rapid increases in population densities in many smallholder production systems around the globe, have meant increased problems for farmers in planning effective resource management strategies. The need to meet the associated demand for increased productivity from declining land holdings, with decreased access to common property resources, has also lead to changes in the traditional management of work animals in many farming systems. This paper highlights some of these changes and investigates the potential and requirements to improve the efficiency of use of the available work animal resources to meet the objectives of smallholder farmers into the next millennium.

A global view

Although data are scarce and unreliable, cursory estimates suggest that work animals provide the power for c. 52 % of the total cultivated area in the developing world (Table 1).

Table 1: Livestock as a source of agricultural power in developing and developed countries

Source of power	Developed countries		Developing countries	
	ha (million)	*% of total cultivated area*	*ha (million)*	*% of total cultivated area*
Tractors	528	82	105	22
Hand labour	45	7	125	26
Animal power	71	11	249	52

Source: Sansoucy, 1995

This is a paper is published in: Kaumbutho P G, Pearson R A and Simalenga T E (eds), 2000. Empowering Farmers with Animal Traction. Proceedings of the workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA) held 20-24 September 1999, Mpumalanga, South Africa. 344p. ISBN 0-907146-10-4. For full details of ATNESA and how to obtain this and other ATNESA publications, see http://www.atnesa.org

Numerically, cattle and buffalo provide the bulk of these farm inputs, although equids and camelids are also of importance. Although the cultivation of the soil is essential to the survival of millions of subsistence farmers, these figures fail to take account of the vital role that work animals play in the provision of transport. They also do not consider the many other contributions that work animals make and could make to a sustainable increase in household food security, income generation and the maintenance of the natural resource base (Dijkman and Chirgwin, 1997).

Dairy/draught

Although many farming systems throughout the developing world maintain draught oxen primarily for work purposes, increasing population and livestock pressure on the land in some areas may lead to scenarios where this will be no longer possible. The use of dairy cows to provide the power requirements could potentially benefit total farm output and incomes through increased milk production, while making it unnecessary to feed draught oxen year–round or to maintain a follower herd to supply replacement oxen (Matthewman *et. al*., 1993; Matthewman and Dijkman, 1993; Pearson and Dijkman, 1994). Additional benefits could accrue through the optimisation of the use of scarce feed resources, the sale of male offspring and a reduction in stocking rates.

The Ethiopian Agricultural Research Organisation (EARO) in collaboration with the International Livestock Research Institute (ILRI) have researched the different aspects of the use of dairy cows in a series of on-station and on-farm experiments. Results have indicated the following advantages and disadvantages (Zerbini *et. al*., 1993, 1998; Lawrence and Pearson, 1999; Pearson *et. al*., 1999):

The advantages

- A smaller herd is required if cows are replacing oxen for work.
- Male animals can be fattened more efficiently for meat and sold at a younger age if they are not needed for work.
- Feed to maintain work oxen is not needed, so feed can be used more efficiently.
- The working females produce their own replacements.

The disadvantages

- Cows are generally smaller and therefore less powerful than bulls or oxen.
- Working cows need more and better feeding to meet the requirements for work, reproduction and lactation.
- Work can reduce milk production.
- Work can reduce calving rate.
- Cows are not available for work about one month before and one month after calving.
- All the ‘eggs are in one basket’, i.e. if the cow is sick, dies or is stolen, then both draught and milk production are affected.

The project also looked at the influence of dairy / draught on income generation. Although farmers who adopted systems using crossbred cows generally increased their income through the sale of milk, these changes did not always coincide with an improvement of the nutritional status of the household. Although there could be some increase in actual milk and butter consumption, most of the increase in food consumption was in the form of cereals acquired with the proceeds of the sale of milk (Shapiro *et. al.*, 1994; 1998).

Most of the work carried out to investigate the opportunities for dairy/draught in different systems in Africa has been done by comparing the use of crossbred cows to a traditional system of using local oxen for work and local cows for milk production. It may be interesting to investigate the opportunities to use local cows for dairy / draught, especially since the introduction of these systems would be less dependent on the existence of a rather large peripheral support system in terms of feed supply and veterinary care.

Although these systems may be more efficient in biological terms, one also has to realise that their successful application is dependent on the existence of the appropriate enabling environment and farmer-felt necessities. In many systems, farmers are still dependent on the manure produced from a relatively large herd to collect and import the nutrients that enable them to sustain crop production. In addition, in many countries livestock is still one of the most secure forms of investment and, unless needs dictate otherwise, this may be another hurdle to the willingness of farmers to reduce herd size.

Nevertheless, changes in circumstances do lead to the adoption of radical changes in the systems and strategies used. There are, for instance, many examples of dairy/draught systems in Asia and Southeast Asia, which have been operating successfully for a considerable period of time.

Short-term ownership

Decreasing farm sizes and reduced availability and access to common property resources in other areas have led to the development of alternative coping strategies as well. In parts of Bolivia, for example, farmers who do not have enough resources to maintain a pair of work animals throughout the year, buy a young pair of oxen at the start of the cultivation season. These animals are than used for work for the duration of the cultivation period. During this season, farmers also take advantage of the relative abundance of feed resources and at the end of the working period the animals are sold fattened (Dijkman *et. al.*, 1999a; 1999b). Not only do farmers, in this manner, reduce their dependence on the hiring of work animals from other farmers or tractor services, that frequently reduce the timeliness of planting and are often prohibitively expensive, but they also optimise the income generation from their work animal and feed resource sub-systems. Although the quality of the work produced by these young animals may not be comparable to more experienced pairs of work animals, soil preparation techniques and cultivation systems are such that this reportedly has no negative effect on crop production. Similar systems exist in parts of West Africa, where meat prices are good (e.g. Reddy, 1988; Pearson *et. al.,* 1990). The practice of short-term ownership does, however, often depend on the importation of animals from other parts of the country, which could, potentially, lead to the establishment of exotic pathogens and vectors in these areas. Implementation of a system to prevent this would be called for. In addition, although much research has been done on the nutritional requirements and feeding systems of work animals, specific management and feeding recommendations to optimise the outputs of these types of systems of work animal use, are not commonly available (Dijkman and Sims, 1997).

Diversification of use

In many smallholder farming systems, the activities carried out by the different types of work animals are often well-defined. There are, however, frequently opportunities to increase the efficiency of use by a reduction in the idle time of the available work animals through the diversification of the tasks that animals are being used for.

Cultivation

In various different cultivation systems across the developing world, apart from the primary cultivation, which is done by oxen, all other field operations are carried out by hand. However, in systems where equids are available, possibilities exist to employ equids (either single or paired) for low-draught tasks such as inter-row weeding (e.g. Betker, 1993; Emhardt, 1994). Similarly, oxen (either single or paired) could be used for secondary cultivation purposes, and equids for primary cultivation on light soils, as well as combinations of different species to provide the tractive power, as necessity determines. Unfortunately, appropriate implements for these types of operations are often not available. Nevertheless, there are distinct possibilities in many areas to adapt, manufacture and evaluate low-cost implements that have proved successful in other areas. One of the main stumbling blocks, that is often mentioned, to the spread of these types of technologies is the established cultural prejudice against the employment of animals for activities that deviate from the norm. However, recent evidence from Southern Africa, where farmers started employing donkeys for primary cultivation purposes following the loss of their work oxen in recent droughts, Bolivia and Mexico where the use of equids for activities other than pack transport is rapidly increasing, would suggest that this is dictated more through requirements than cultural taboos (Arriaga, *et. al.,* 1997; Sims *et. al.*, 1998; 1999).

Soil and water conservation

In semi-arid farming systems, the conservation of water is of vital interest to farmers. Coupled with the fact that often steep, fragile hillsides are cultivated for annual crops, soil conservation is also a priority concern with farmers. Reduced tillage techniques that are relevant answers to these concerns include contour and strip tillage to promote rainwater infiltration and to reduce the risk of soil loss through water and wind erosion. Equipment developed for these techniques has generally been of high draught requirement, but efforts have been made to design equipment suitable for low draught animals such as donkeys (Sims *et. al.,* 1996). Evidence from Nicaragua also suggest that work animals can be successfully employed for the establishment of hillside terraces that significantly improve soil and water conservation (FOMENTA, 1998), and many of these systems merit adaptation and evaluation under African conditions.

Carts

The introduction of carts would not only significantly increase the transport capacity and efficiency of animals traditionally used for pack only, but it could also provide a, potentially, low cost alternative to motorised transport. Whereas the introduction of animal-drawn carts has frequently proved to be prohibitively expensive, recent evidence suggests that a variety of good low-cost alternatives are feasible (Chadborn, 1991; Dennis and Anderson, 1994). Animal carts can allow farmers to diversify their income generating activities, providing transport for the building trade, road maintenance, and water distribution within communities.

Stationary equipment

One other way of optimising the use of the available work animals, is the introduction of stationary power devices for tasks such as water-lifting or milling. There are various examples of these types of implements that have been specifically designed or adapted to be driven by animal-energy (e.g. Starkey *et. al.*, 1989; Dippon, 1993). Most of these constructions and machines, however, are rather intricate and relatively expensive and although their investigation may warrant attention in the future it is not perceived to be an immediate priority, nor is their adoption in the current climate thought likely.

Optimisation of available nutrient resources

Improving the contribution of work animals to soil fertility

For many of the less-advantaged farmers around the world, the problems of maintaining, let alone improving, soil fertility is significant. In the past, cropping has been sustained by the transfer of organic soil nutrients from forest and grazing land via the Fodder / bedding – Animal – Manure / compost (FAM) pathway. This pathway obliges farmers not only to keep large numbers of animals, but also requires access to a significant acreage of grazing and/or forest land to maintain the arable land (e.g. Wyatt-Smith, 1982; Pandey and Singh, 1984). While access to, and quality of, grazing and forest resources have declined, alternative options such as the use of costly inorganic fertilisers have not been available to poorer farmers. Under these circumstances, the most promising option for targeting the needs of the poorest farmers would appear to lie in reducing nutrient losses associated with inefficient organic matter management practices. Recent studies (e.g. Pilbeam *et. al.*, 1998) have indicated that these can be highly significant, with the FAM pathway potentially responsible for more than 70% of all N losses from the system. The role of the livestock component in regulating nutrient flows via the FAM pathway is, thus, clearly pivotal for the sustainability of the system as a whole in many areas.

Strategic studies on the impact of livestock and manure/compost management on nutrient flows, conducted in Kenya, suggests that, for a highly integrated system like that in Nepal, these factors must be taken into account if efficient nutrient management is to be used to enhance soil fertility. Key findings of this research include observations of small changes in types and quantities of feed supplements used resulting in large differences in the extent of net N mineralisation following manure incorporation (Delve, 1998; Lekasi *et al.*, 1998; Thorne and Cadish, 1998; Thorne *et al.*, 1998). Further research is needed, however, to examine specifically the scope for managing livestock to create more effective linkages between off-farm nutrient resources and arable land given a scenario of changing access and availability of common property nutrient resources.

Feed and fodder

When we discuss feed shortages of work animals, the first 'solution' we tend to think about is to plant more and better. It may indeed be true that this is the appropriate solution in a number of cases. However, competition for land to grow crops for human consumption may restrict the possibilities available to implement these type of strategies. It is also true that many elegant systems to cultivate fodder in association with other crops have been designed, but their success has been limited. Nevertheless, opportunities may exist within the current cropping systems to optimise the biomass available to work animals without jeopardising crop production. In many cereal cropping systems, for example, farmers plant three to four seeds per planting hole or use very high sowing densities. Following germination, the superfluous plants are thinned and disregarded. It would, however, be interesting to investigate if there are opportunities, without affecting crop production, to let these extra plants continue to grow for a given period to optimise their use as fodder. Other possibilities that optimise the production of animal feed from human food crops may lie in the stripping of leaves during crop growth. Experiences from countries around Africa would suggest that, if implemented properly, these methods do not harm crop production.

Weeding is a time consuming chore in the majority of cropping systems. The weeds that are removed, however, are often the forages utilised in natural pasture or on fallow land. What are the possibilities to use this voluntary production of biomass better? One obvious route would be to investigate the influence of these weeds during the different stages of crop growth on total crop production. It may well be possible to devise systems in which weeds in crops are managed to optimise feed and food production from the available land. In addressing the shortage of animal feed, some farmers, in Ethiopia, Mexico and Bolivia, for example, have developed an integrated food/feed system in which they allow specific weed species to flourish in the cereal crop to increase biomass production, forage palatability, digestibility and nutritional value, thus addressing several priority problems simultaneously. Comparison of these type of integrated systems with systems in which forages and human food crops are cultivated in mono-culture with respect to efficiency and total production would hence be of particular interest. Obviously there are many different permutations to the strategies mentioned above imaginable, but these would depend on the cropping systems currently in use.

Implications and needs

The various systems and options available to smallholder farmers described above have obvious implications for development and research initiatives. Although much research has been carried out in the past decades on the use and management of work animals, much of this has been done in isolation and without paying attention to the external driving forces that have caused, and are causing, significant changes in the existing farming systems. Any new initiatives will have to look beyond the conventional. Although the new possibilities and opportunities that may emerge may at first seem far-fetched, one has to realise that the changes driven by population increase and environmental modifications are inevitable. This is particularly in light of what has been called ' The Livestock Revolution', which predicts that in 2020 each person in the developing world is likely to demand about 29 kg of meat and 63 kg of milk a year, up from 21 kg and 41 kg, respectively, in 1993 (Delgado *et. al*., 1999), it is imperative that the efficiency of the current systems be dramatically improved. This not only requires a change in the training that future researchers and development workers around the world receive, but also a clear understanding of the external forces of change, to enable us to approach the problems in a dynamic, integrated and systems-oriented manner.

In addition, delivery of the results of work animal research to front-line extension staff in a comprehensible and useable form, has often been neglected. As a result a gap, not a link, exists between the two in many areas. Without the effective implementation of a link, it is difficult to see how extension services (public, co-operative and private) can promote improved management and new strategies amongst their client farmers in a way that is flexible enough to meet the individual needs and that accounts for the dynamics of smallholder systems. Paper-based extension literature (in tabular or other formats) is not always effective and although some new approaches are currently being tested (Thorne, 1998), these new methods still rely heavily on frequent contact between extension systems, that are often poorly functioning, and farmers. Deficiencies in this process may mean that these approaches will not always be sufficiently responsive to changing seasons, resource endowments, local markets and production objectives, compromising the extent to which farmers can base their management decisions on these and other factors. There is, therefore, a need to generate information in a form that reduces the complexity of the interaction between extension services and farmers and that allows the farmer to take a more active part in the evaluation of alternative strategies.

References

Arriaga J. C., Gonzalez D. J., Gonzalez E. C., Nava B. G. and Velazquez B. L. 1997. Caracterizacion de los sistemas de produccion campesinos en dos zonas del municipio de San Felipe del progreso, Mexico: Estrategias contrastantes. pp. 171-197. in: Rivera H.J., Arellano H. A., Gonzalez D. L and Arriaga J C. (eds), Investigacion para el desarrollo rural. Diez anos de experiencia del CICA. Centro de Investogacion en Cencias Agropecuarias, Universidad Autonoma del Estado de Mexico, Toluca, Mexico.

Betker, J. 1993. Research on the mechanization of weeding with animal-drawn implements. pp. 99-103. in: Lawrence P R, Lawrence K, Dijkman J T and Starkey P H (eds), *Research for Development of Animal Traction in West Africa*. Proceedings of the fourth workshop of the West Africa Animal Traction Network held 9-13 July, 1990, Kano. Nigeria. Published on behalf of the West Africa Animal Traction Network by International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

Chadborn, A. 1991. Some designs for donkey carts and animal powered engines. pp. 251-257. in: Fielding D and Pearson R A (eds), *Donkeys, Mules and Horses in Tropical Agricultural Development*. Proceedings of a colloquium held 3-6 September 1990 at Edinburgh, Scotland. University of Edinburgh, Scotland, UK.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Courbois, C. 1999. *Livestock to 2020. The Next Food Revolution*. IFPRI/FAO/ILRI. Food, Agriculture and the Environment Discussion Paper 28.

Delve, R. 1998 *Implications of Livestock Feeding Management on Soil Fertility in Smallholder Farming Systems*. Unpublished PhD Thesis. Department of Biological Sciences, Wye College, University of London

Dennis, R. and Anderson, M. 1994. Improving animal-based transport: technical aspects of cart design. pp. 396-404. in: Starkey P H, Mwenya E and Stares J (eds), *Improving Animal Traction Technology*. Proceedings of the first workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA) held 18-23 January 1992, Lusaka, Zambia. Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, The Netherlands.

Dijkman, J.T. and Chirgwin, J.C. 1997. Animal energy: an undervalued and under-utilised resource. *Paper presented at the first Caribbean Workshop on Energy and Environment*. Cienfuegos, Cuba, 26 - 28 March 1997.

Dijkman, J.T. and Sims, B. G. 1997. From beast of burden to multi-purpose power source: challenges for the utilization of equids in Bolivia. *Paper presented at the International Workshop on Improving donkey utilisation and management*. Debre Zeit, Ethiopia, 5 - 9 May 1997.

Dijkman, J.T., Sims, B.G. and Zambrana, L. 1999a. Availability and use of work animals in the middle Andean hill-farming systems of Bolivia. *Livestock Research for Rural Development*, Vol. 11, Number 2.

Dijkman, J.T., Sims, B.G. y Zambrana, L. 1999b. Mejoramiento de tracción animal: Temas y opciones no tradicionales. Memorias del Primer Seminario Taller del Proyecto Mejoramiento Tracción Animal (PROMETA). Cochabamba, Bolivia, 3 - 5 febrero, 1999. pp. 119-125

Dippon. K. 1993. The development of an animal-powered rice-huller. pp. 49-55. in: Lawrence P R, Lawrence K, Dijkman J T and Starkey P H (eds), *Research for Development of Animal Traction in West Africa*. Proceedings of the fourth workshop of the West Africa Animal Traction Network held 9-13 July, 1990, Kano. Nigeria. Published on behalf of the

This is a paper is published in: Kaumbutho P G, Pearson R A and Simalenga T E (eds), 2000. Empowering Farmers with Animal Traction. Proceedings of the workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA) held 20-24 September 1999, Mpumalanga, South Africa. 344p. ISBN 0-907146-10-4. For full details of ATNESA and how to obtain this and other ATNESA publications, see **http://www.atnesa.org**

West Africa Animal Traction Network by International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

Emhardt, F. 1994. Improving the Hata donkey-drawn weeder in Niger: experiences and results. pp. 210-213. in: Starkey P H, Mwenya E and Stares J (eds), *Improving Animal Traction Technology*. Proceedings of the first workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA) held 18-23 January 1992, Lusaka, Zambia. Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, The Netherlands.

FOMENTA, 1998. *Manual de Conservacion de Suelos y Agua con Traccion Animal: Dar de Beber al Suelo Sediento*. FOMENTA Serie Tecnica # 1. FOMENTA, Nicaragua.

Lawrence, P.R. and Pearson, R.A. 1999. *Feeding Standards for Cattle used for Work*. Centre for Tropical Veterinary Medicine, University of Edinburgh, Scotland.

Lekasi, J.K., Tanner J.C. Kimani S.K. and Harris P.J.C. 1998, Manure management in the Kenya Highlands: Practices and Potential. HDRA Publications, UK ISBN: 0-905343-25 5.

Matthewman, R.W. and Dijkman, J.T. 1993. The nutrition of ruminant draught animals. *Journal of Agricultural Science, Cambridge*, **121**, 297-306.

Matthewman, R.W., Dijkman, J.T. and Zerbini, E. 1993. The management and husbandry of male and female draught animals: research achievements and needs. In: Lawrence, P.R., Lawrence, K., Dijkman, J.T. and Starkey, P.H. (eds.) *Research for Development of Animal Traction in West Africa*. pp. 125-136. Proceedings of the Fourth Workshop of the West Africa Animal Traction Network held in Kano, Nigeria, 9-13 July 1990. ILCA, Addis Ababa.

Pandey, U. and Singh, J.S. 1984. Energy flow relationships between agro- and forest ecosystems in central Himalaya. *Environmental Conservation*, **11**: 45 – 53.

Pearson, R.A., Zerbini, E. and Lawrence, P.R. 1999. Recent advances in research on draught ruminants. *Animal Science,* **68**: 1-17.

Pearson, R.A. and Dijkman, J.T. 1994. Nutritional implications of work in draught animals. *Proceedings of the Nutrition Society*, **53**, 169-179.

Pearson, R.A., Lawrence, P.R. and Jansen, H.G.P. 1990. Ani8mal traction in Niger, prospects for the futire, International Livestock Centre for Africa, ICRISAT Sahelian Centre, B.P. 12404, Niamey, Niger.

Pilbeam, C.J., Tripathi, B.P., Sherchan, D.P., Gregory, P.J. and Gaunt, J. 1998. Nitrogen balances for households in the mid-hills of Nepal. *Agriculture, Ecosystems and Environment*. Submitted.

Reddy, S.K. 1988. Use of animal power in West African farming systems: farm level problems and implications for research: perspectives from Mali. pp.182-190. in: Starkey, P.H. and Hdiame, F. (eds), *Animal power in farming systems*. GATE, Vieweg, Germany

Sansoucy, R. 1995. Livestock – a driving force for food security and sustainable development. World Animal Review, **84/85**: 5-17.

Shapiro, B., Jemal Haider, Alemu GebreWold, Abebe Misgina and Mengistu Alemayehu. 1998. Impact of market-oriented dairy production on women and children: Evidence from the Ethiopian Highlands. *Women and Animal Production; Proceedings of the Sixth Annual Conference of the Ethiopian Society of Animal Production*, 14-15 May 1998, Addis Ababa, Ethiopia.

Shapiro, B., Zerbini, E. and Gemeda, T. 1994. The returns to investment in dual use of crossbred cows for milk production and draught work in the Ethiopian Highlands. First workshop of the Animal Traction Network for Ethiopia. Addis Ababa, 27-28 January, 1994.

Sims, B. G., Ellis-Jones, J., Uresti G., J., Francisco N., 1996. On-farm evaluation of soil and water conservation practices in Mexico, Nicaragua and Honduras. *Agricultural Mechanization in Africa, Asia and Latin America*. (Japan). 27(2):18-24.

Sims, B.G., Inns, F., Dijkman, J.T. and Zambrana, L. 1998. Equines in the farming systems of Bolivian Inter-Andean valleys: meeting the challenges. Paper presented at *the Third International Colloquium on Working Equines*. Mexico City, Mexico, 5-9 October 1998.

Sims, B.G., Zambrana, L. y Dijkman, J.T. 1999. PROMETA: El proyecto de mejoramiento de tracción animal en Bolivia. Logros y perspectivas. Memorias del *Primer Seminario Taller del Proyecto Mejoramiento Tracción Animal (PROMETA)*. Cochabamba, Bolivia, 3 - 5 Febrero, 1999. pp.1-10

Starkey P.H., Abiye Astatke and Goe M.R., 1989. Alternative applications of animal power. pp. 231-241. in: Hoffman D, Nari J and Petheram R J (eds), *Draught animals in Rural Development*. Proceedings of an international research symposium held 3-7 July 1989, Cipanas, Indonesia. ACIAR Proceedings No. 27.

Thorne, P.J. 1998. *DRASTIC-A Dairy Rationing System for the Tropics. Evaluation Version for Windows 3.1*. Chatham, UK, Natural Resources Institute.

Thorne, P.J. and Cadisch, G. 1998. *ANORAC. Allocation of Nitrogen in Organic Resources for Animals and Crops*. Chatham, United Kingdom, Natural Resources Institute. 32pp.

Thorne, P.J., Delve, R., Cadisch, G., Tanner, J.C., Giller, K.E., Kimani, S., Thorpe, W. and Thomas, D. 1998. *Implications of Livestock Feeding Management for Long-term Soil Fertility in Smallholder Mixed Farming Systems. A Final Technical Report on a Research Project Funded by the Department for International Development's Livestock Production Research Programme*. Chatham, UK. Natural Resources Institute. Unpublished Report. 68pp

Wyatt-Smith, J. 1982. *The agriculture system in the hills of Nepal. The ratio of agricultural land and the problem of animal fodder*. APROSC Occasional Paper 1, Kathmandu, Nepal.

Zerbini, E, Alemu Gebre Wold and Shapiro, B. 1998. Development of cow traction technologies and implications for adoption in the eastern African highlands. In: *Meeting the challenges of animal traction. Proceedings of an ATNESA workshop*, 4-8 December 1995, Karen, Ngong Hills, Kenya.

Zerbini, E., Gemeda, T., Franceschini, R. Sherington, J. and Alemu Gebre Wold. 1993. Reproductive performance of F1 crossbred dairy cows used for draught: effect of work and diet supplementation. *Animal Production* **57**: 361-368.