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ACIAR PROCEEDINGS

This series of publications includes the full proceedings of research workshops or symposia organised or supported by ACIAR. Numbers in this series are distributed internationally to selected individuals and scientific institutions. Recent numbers in the series are listed inside the back cover.

Pryor, W.J., ed., 1993. Draught animal power in the Asian–Australasian region.
A workshop held in conjunction with 6th Asian–Australasian Association of Animal Production Societies, Congress, 23–28 November 1992, Bangkok, Thailand.
ACIAR Proceedings No. 46, 135 p.

ISBN 1 86320 079 7

Editorial management: Peter Lynch

Typesetting and layout by CPN Publications, Canberra, Australia

Printed by Brown Prior Anderson Pty Ltd, Melbourne, Australia

Cover photo: Brian Lee

Draught Animal Power in the Asian-Australasian Region

A workshop held in conjunction with
6th Asian-Australasian Association of Animal Production Societies,
Congress, 23–28 November 1992,
Bangkok, Thailand

Editor: W.J. Pryor

Organising Committee
Dr Bill Pryor (Australia), Chairman
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Contents

Posters

Foreword

Following discussions held in May 1991 in Thailand between Dr Denis Hoffmann, ACIAR, and Professor Charan Chantalakhana, President of the Asian–Australasian Association of Animal Production Societies (AAAP), the decision was made to hold a Workshop on Draught Animal Power (DAP) sponsored by ACIAR during the Sixth AAAP Animal Science Congress, 23–28 November, 1992 at Sukhothai Thammatirat Open University, Bangkok, Thailand.

Over several years ACIAR has implemented multidisciplinary studies of DA systems in Southeast Asia, designed primarily to identify ways to increase farmer benefits from DA usage. Following the completion of an earlier project in 1990, a new project having a sharper focus, namely ACIAR Project PN 8908, 'Feeding and Management Strategies for Production and Draught Power in Large Ruminants', was implemented, the project leaders being Dr E. Teleni of Australia and Dr M. Sabrani of Indonesia. Previous studies had suggested that a focus on improved animal production efficiency of draught animals would be a fruitful research area. Socio-economic studies describing a range of different agro-ecosystems supported this view.

The present project, PN 8908, has been more specifically directed towards developing feeding and management strategies. This workshop had as its object the review of recent work with a regional focus. A range of speakers including some working on Project 8908 plus some from other countries within the AAAP region presented papers. These were designed to provide a background for informed panel discussion on:

a priorities of research and development within a farming systems context
b the organisation of international DA networks in research and development.

The Workshop was opened by Dr G.H.L. Rothschild, Director of ACIAR and chairman of the workshop sessions were Drs J. Copland, W.J. Pryor, M. Sabrani and E. Teleni.

Leaders of the discussion panel sessions were:
Prof. S. Watanabe (Japan), Drs M.R. de Guzman (Philippines) and C. Devendra (Singapore) for the first session and Drs M. Sasaki (FAO), P.S. Faylon (Philippines), M. Sabrani (Indonesia), C. Vajrabukka (Thailand) and N.S.L. Srivastava (India) for the second.

The Workshop is greatly indebted to them and also for the contributions of the following who acted as rapporteurs:

R.S.F. Campbell (Australia), N. Chaiyabutr (Thailand), P. Faylon (Philippines),
M. de Guzman (Philippines), J.P. Hogan (Australia), P.M. Kennedy (Australia),
J.B. Liang (Malaysia), A.R. Mohamed (Sri Lanka), R.J. Petheram (Australia),
J. Perkins (Australia), C.C. Sevilla (Philippines), E. Teleni (Australia),
R.C. Upadhyay (India), C. Vajrabukka (Thailand), M. Winugroho (Indonesia).

ACIAR sponsored the attendance of the large majority of the Workshop speakers. Support was also provided by the Australian International Development Assistance Bureau (AIDAB), Canberra which funded the attendance of Drs A.R. Mohamed and S.H. Hanjra. Grateful thanks are offered to AIDAB for this assistance.

To all of the above, and to Mrs Kim Taylor, ACIAR and to Mrs Ann Pryor who provided sustained office support, the most sincere thanks of the Workshop organising committee are offered.

W.J. Pryor
Workshop Chairman

Workshop Conclusions

Priorities for Research and Development (R&D) Within a Farming Systems Context

Importance of R&D for draught animals

DAP is, and will remain for many years, a critical part of sustainable agriculture in Asia and will require significant R&D contributions in the years to come. It is relevant and cost effective in the context of multi-purpose use of large ruminants in small farm systems.

There is currently inadequate research in the DAP sector to ensure its development for farmers in the context of other changes occurring within their agricultural systems. Very few national agricultural research services and international aid agencies support DAP now, and one is currently in the process of withdrawing. There is a need today to link DAP R&D to sustainable development policies.

There has been a concentration of effort at the diagnostic phase including the collecting of socioeconomic data, development of methodologies, and other field investigations. These provide a valuable entry point for more on-farm interventions which should now be submitted to test with policy support where required.

There is a good deal of variation between regions and much R&D will need to be region-specific. It was felt that upland agriculture needs more DAP research, though priorities will vary from region to region. Because of this it is not possible to suggest, in a simple listing, priorities for R&D.

Role of government policy

Government policy has a major impact on the manner in which DAP is used. Land reform programs, provision of subsidies for purchase of young animals, limitations on slaughter and bull supply programs are current examples.

The issue of whether these and other policy issues should be addresses before further on-farm R&D drew a range of views. Some argued that policy issues needed to be addressed first. Others argued that these issues and technological needs should be addressed simultaneously.

In some countries, at least, the reality is that DAP has lower government priority than projects which generate hard cash needed for national development. However, the Workshop was of the view that efforts to change policy for the DAP sector were worthwhile via rational discussion about policy alternatives. In the absence of quick returns from DA compared to say feeding dairy cattle for production government policies should be sought which encourage farmers to manage DAs for higher total productivity i.e. calves, work, meat, milk.

Systems study

The need for R&D on the wider use of draught animals in more intensive systems was identified. This would include investigation of methods to produce more meat and milk from draught animals. The sale of the calf is often a major income earner and effort should be focused on making outputs of DAP systems more diverse. The use of cows and single animals rather than pairs for work offers great potential for improving system efficiency.

The mechanisms through which ideas will be successfully transferred from farmers in one region to those in another need to be identified. Simple ideas transfer more readily than complex ones, particularly amongst resource-poor farming communities and this needs to be borne in mind.

DAP – mechanical power issues

Trends in DAP and mechanisation were discussed and it was pointed out that in some places such as northern India mechanical power is replacing draught power i.e. from two bullocks to one female buffalo and a mini-tractor. In Cuba following the loss of Soviet support (fuel and equipment) the trend was reversed with an increasing dependence on DAP.

It was concluded therefore that DAP and mechanisation should not be viewed as adversarial but that there was a need for research on their complementarity.

There was strong support for the continuation of the search for improved harnesses, implements and design of carts. It was claimed that a large amount of work on implements was not adopted. The role of India in this type research was recognised.

In some specific regions e.g. Bangladesh, where there is a very high incidence of harness sores, inter-disciplinary research (engineering, veterinary science) is needed.

Technological needs

Further research is needed on ways to produce animal power more efficiently. This includes production of stronger animals, better management and the development of better instrumentation to measure work output and physiological status of the DAs in the field. Equipment is needed that can be used in research conducted in flood irrigation systems. Practical management improvements are also need for whole systems e.g. bio-gas units and reduced tillage cropping.

A particular issue is the loss of weight of DAs during work reported to the Workshop. This is thought to be due to less time for feeding or feed collection, and the fact that work often coincides with the end of the dry period when only low quality feed is available. It may also occur when lands are occupied during the growing season.

This points to the importance of nutritional research including the possibility of feeding different feeds during different parts of the day during the work period.

Health, nutrition and reproduction

The poor health of draught animals is a specific barrier to efficiency in some regions. In Myanmar disease was listed as the biggest limitation to DAP, whereas in Bangladesh harness sores affect over 80% of working animals. In general, regional health problems are not well defined due to weak epidemiological data and the fact that disease differs widely from region to region in Asia. It is recognized that symptoms of nutritional deficiencies appear in DAs not only during work but off-work.

Some problems are known to be widespread e.g. infertility, gastro-intestinal parasitism in calves and fascioliasis. Even here sharper definition is required before comprehensive counter measures can be applied.

There are management strategies to reduce heat stress effects which are more prevalent in buffalo than in cattle. These include work early in the morning, rest periods during the day and access to wallows. Documentation to affirm these practices is needed as are measurements of DA reaction to working in water compared to dry land.

Nutrition of DAs was recognized to be a major limitation to their efficiency as work-capable animals. Technologies for pasture establishment and supplementary feeding systems are now well established and should be tested on-farm to a much greater degree. Improvements in the quality and quantity of forage available to animals was seen as a prerequisite for DAP improvement in many areas.

Effect of work

The consequences of work and work related stress on the reproductive performance of both female and male animals need to be better understood. This is particularly so to allow DAs to serve a multi-purpose function. Associated with this is the notion that nutrient demands (maintenance, reproduction and work) could be better estimated and hence nutritional needs better met. It became clear that this is not generally practical but may be so in particular locations and further research is warranted. Early warning of calves, for example, could improve the changes of good calf growth and also remove any adverse effect of suckling on oestrus on large ruminants.

Socioeconomic studies

As alluded to elsewhere the Workshop agreed that improvements are needed in extension/information systems to ensure a more rapid adoption of new techniques. Similarly better record keeping methods are needed as these would allow more effective comparative studies to be done within and between countries. It was recognized that such monitoring and survey data can be very expensive to collect and therefore alternative methods of acquiring and disseminating information should be developed.

Conclusions

The priority now is to shift R&D rapidly from the diagnostic phase into the intervention phase. Large-scale on-farm activities are necessary. The importance of farmer involvement at all stages including evaluation must be stressed. Such activities will require commitment at the national level and international donor support. The hope was expressed that ACIAR may play a critical role here.

Networking will be most important in such an approach. Overall closer scientist – farmer cooperation will be needed in R&D. A strong view emerged that an international group was needed to identify countries and scientists involved in DAP, the systems being used, the sources of funding available and the ways of improving contact and communication.

More generally it was considered that there needs to be wider recognition of the importance of DAP globally and work done to gain this recognition and to help governments avoid adopting policies which are detrimental to DAP being appropriately employed in sustainable agricultural systems.

It was agreed scientists involved in DAP need to maintain contact with farmers through established extension networks. These scientists also need to maintain contact with policy makers.

Organising International DAP Networks in Research and Development

Consideration of this issue requires views on the general concept of a DAP network, the means by which such a network might be formed, operate and be funded, and the actual desirability of forming such a network.

The need for a DAP network

In general a DA network was favoured. It was agreed such a network should be regional rather than worldwide. Strong linkages with other DA organisations e.g. Centre for Tropical Veterinary Medicine, Edinburgh and the West African network could be established also.

The need to form a network arises from:

- the indisputable importance of DA now, and in the future of the Asia – Southeast Asia region;
- the need to redress the past inadequacies of R&D related to DA;
- the need to expedite information dissemination and as a consequence maximise the use of existing knowledge amongst those with an interest in DAs;
- the benefits to be derived from sharing information and expertise i.e. to capitalise on the extensive experience of DA in countries like India
- the leverage to be gained in seeking recognition of the contribution of DAP and gaining funding support for R&D.

On a cautionary note it was pointed out that there was a risk that a network, centred on one location, may lead to imbalances in input and communication. This was claimed to have occurred to some extent in the Australian – Indonesian DA project network. The concept of a network with a central agency that rotates between member countries and institutions was considered a possibility. The value of seeking support for a network, as opposed to the establishment of a DA journal, was also queried.

Overall it was agreed that a normal network was need to maintain and strengthen the informal network which currently exists and the valuable contacts that have been made through the ACIAR – James Cook University – BPT Indonesia DA Project and its conferences and publications from 1985 to 1992, and through the more recent IDRC – sponsored Southeast Asia DA project.

Role and form of DA network

There was general agreement that a DA network would play a major role in promoting the 'exchange of ideas' on DAP. Some concern was expressed about the need to avoid duplication of information exchange, as might occur with the Buffalo Network and other livestock networks. Close links with other networks and their work would help avoid duplication, and yield information from other sources relevant to DA research and development.

A case was made for the establishment of a network with a centre in India, with advantages including support from the Government of India, and advice and training for member countries from national DA experts on various aspects of DA research and development.

Wherever the network was centred there would be a need, initially at least, for outside funding to allow establishment of the network and preparation and distribution of material to participants.

Funding a DA network

Any DA network should aim to be self-supporting in the long term, although this would be unrealistic for some less developed countries given the cost of paper, telephones, photocopying and access to communication media.

The ACIAR representatives clarified ACIARs mandate (of supporting international agricultural research) and indicated that this would not allow a large commitment to supporting networks.

There was general agreement about the need to seek funding from international and national agencies for the establishment of a DA network.

Conclusions

The Workshop recommended that a regional DA network should be formed with the hope that ACIAR would play a leading role. A request was made that ACIAR prepare a document entitled 'The Need for DA network' which would articulate the views of the meeting and appear in the Proceedings or be otherwise recorded.

Draught Animals in the AAAP Zone and Their Economic Future

R.S.F. Campbell*

Abstract

Draught Animal Power (DAP) is one of the oldest industries but it is still one of the most economically important. It is influenced by three levels of economic activity, namely, a) macroeconomic decisions such as transmigration policy made by central government, b) microeconomic factors at farm or village level, and c) intermediate areas of activity such as extension service support and agribusiness enterprises that use the output of DAP.

The present Asian systems are relatively efficient but capable of limited modification. Improved land tenure arrangements are urgently needed but politically difficult. Improved fertility and better health control can be valuable in selected areas where there are reliable data.

In the longer term, for example, 20–30 years, the economic base of rice and other crop production could be revolutionised by new, cheap forms of energy such as solar power. While animals would continue to be important as a source of protein, manure and income, political and economic emphasis would then pass to the employment of farmers, already a major problem and one that will increase in future. Consideration should be given now to the improved employment of rural populations in monocultures, integrated agriculture, agribusiness and other systems of work in the Asia of the future.

THE economic structure of draught animal power (DAP) in Asia is multilayered and varies from country to country according to national policy, social patterns and agricultural practices. In larger countries with diverse climates such as Indonesia significant variation in draught animal practices may occur between regions where wet and dry tropical conditions exist. Differences in agricultural systems influence the use of both human labour and animals. DAP in Asia, unlike parts of Africa, is well established and is a resource capable of improvement.

Prospective studies of the economic future of DAP are a dangerous pastime. Some analysts might be tempted to explore that territory through computer modelling but there are too many uncertainties. The urgency of the matter, however, cannot be denied because by the year 2050, 4.7 billion more people may exist on the planet, most of them in the tropical zone, and they must be fed and, if possible, employed.

It is clear that the influence of the draught animal farmer is a powerful one existing at three major economic and management levels (Table 1). Macroeconomic factors are the direct concern of central government; microeconomic factors are the day-to-day issues of the farmers; and intermediate functions link the other two levels.

Table 1. National and social implications of draught animal farming and crop production.

Macroeconomic	Key component of national economy for crop production, food and export Agricultural efficiency and land care Social stability
Intermediate	Factors operating vertically affecting DAP farmers, e.g. government, landowners, credit systems, extension services, agribusiness
Microeconomic	Day-to-day economic environment of farmers, families and cooperators
	Employment
	Food supply
	Human health

Macroeconomic Factors

The small farmer is a key component in the national economy of many countries. In the Asian region this situation has a strong influence on government policy not only because of its economic implications but also be-

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cause governments recognise that the farmer is a voter. That fact does not escape the governments of western Europe and the United States, with serious effects on international trade as a result.

The macroeconomic implications of DAP tend to be overlooked in the national statistical maze. Development assistance usually concentrates on the microeconomic level. Changes at the intermediate level can be critical but are often avoided as too vague, too difficult to operate in, or too sensitive politically. However, a major example of positive action at the intermediate level is the transmigration program of Indonesia which is significantly extending the geographic and economic impact of DAP. The scheme is unusual in that it is driven by demographic pressures as well as by economics.

Some of the quantitative aspects of DAP have been calculated by Ramaswamy (1985) who pointed out, for example, that at that time, 2 billion people in developing countries depended on the system in 100 million farm holdings of less than two hectares. He estimated that replacement of draught animals by petrol-based power could cost between $200 and $300 billion with annual running costs of $5 billion at 1985 prices. Investment of such magnitude would be unacceptable by any government at the present time.

The immensity of the farmer's influence on national economics can be roughly assessed by the population of large ruminants in Asia, mostly at the small farm and village level (Table 2). Even such simple figures help us to appreciate the impact of farmers and their animals on both the local and national economies. They also indicate possible shortfalls in livestock numbers in countries with burgeoning human populations and a need for increased agricultural production.

Table 2. Cattle and buffalo populations in the South and Eastern Asian regions.

	Cattle	Buffalo
	('000)	
Bangladesh	23 000	2 000
Myanmar	10 000	2 220
China	77 171	21 935
India	195 500	73 700
Indonesia	10 050	3 300
Japan	4 682	
Cambodia	2 000	730
Laos	805	1 050
Malaysia	639	220
Pakistan	17 363	14 349
Philippines	1 482	2 800
Thailand	5 285	5 443
Vietnam	3 026	2 907

(FAO 1990)

But governments, in implementing their policies, may damage the prospects for the small farmer. Excessive government spending on industry, for example, leads in effect to an inflation 'tax' on rural incomes and reduces resources such as agricultural extension services. Biases are most pronounced in parts of Africa where farmers may be implicitly taxed by as much as 50% (Anon. 1991a).

Farmers can respond positively to government policies and if these are beneficial through, for example, improved technology, research and extension services, secure land tenure arrangements and better education, major improvements in output are achievable. But technology transfer costs money; land tenure reforms cause social and political disturbance. As Professor Adam Smith, the founder of modern economics, wrote in 1776, 'Civil government is in reality instituted for the defence of the rich against the poor, or of those who have some property against those who have none at all!'. The situation has not changed at the rural level in many parts of the world in 1992. Only a determined government can impose improved land tenure conditions for the benefit of the farmer. Japan and Taiwan have shown that it can be done.

The national effects of the Asian draught animal system flow upward from crop production, mainly rice, which at one end of the economic chain is essential for local consumption and at the other end can be a buffer against imports by conserving foreign exchange. Through good DAP practices, agricultural land is also maintained productively. Properly supported by extension services, many livestock owners should be able to breed more animals, though evidence from some studies strongly suggests that this is one of the less successful parts of the system when it ought to be a major earner of income for small farmers (Sumanto et al. 1987). Cattle, unlike tractors, can reproduce if bull and cow or their genetic material are able to meet at the right time, not always an easy arrangement at village level where communications are often poor and extension services weak. A further advantage of the DAP system is that it is a source of social benefit and social stability essential to any modern state whatever its political structure may be. A seldom acknowledged effect of draught animals is that they ensure the availability of carbohydrate, protein and other essential food constituents at the local level and contribute to the general health of the human population. It is important that the total effects of DAP are fully appreciated as it is likely to be in use for a long time.

Intermediate Factors

The term 'intermediate' is used, for want of a better name. These factors are essentially links between higher political decision-making levels and the smallholder farmer. They may be of profound importance to his productivity and well-being and are of national importance. This layer of influence has been neglected for various reasons. Professionals concerned with development assistance often target the poor with the best of intentions while failing to recognise (or admit) that the weakness of the system lies elsewhere. The difficulty of achieving delivery of improved technology to the farmer has certainly been identified by Australia (Anon. 1991b).

Government influences this economic layer whether it operates through broad policy decisions, e.g. transmigration, or support activities, such as the extension services. Some powerful forces may act to weaken these links. In recent times the general economic downturn has reduced financial support at farm level where difficulties may be further compounded by inflation and low commodity prices (Table 3). Another potent factor that has received little attention is managerial inefficiency in government services which may be financial or administrative or both. They are not unique to Asia.

Land tenure can have a significant effect on agricultural productivity, as experience in the centralised economies has shown. Each country has had its own approach to this sensitive issue. Some, like Japan and Taiwan, made great progress with land reform after World War II under exceptional circumstances, while others still try to tackle the problem with limited success after 50 years or more (Hayami et al. 1990). On the one hand, the farmer cannot call the land his own and lacks the incentive to produce. On the other, the family farm may become smaller and less economic with each generation. Some way should be found to balance ownership with economic efficiency and lead to increased output.

Research and development support by efficient extension services has been shown to be crucial for major advances. Increases in rice and maize production by improved cultivars are proven cases, but these require active support trickling down through the extension workers who must receive adequate funds for petrol, materials and subsistence costs if they are to carry out their tasks.

Microeconomic Factors

Most research in recent years in all continents has focused on the DAP unit and its local social impact. The present Conference reflects that approach. A mass of new information on work, animal health and nutrition, engineering and the farming system unit is now available to us through journals and bulletins published by research centres in Thailand, Indonesia, India and Australia as well as other continents. The relative advantages of cattle and buffalo are better understood. The influence of soil types, forages and crop by-products has been clarified. Constraints caused by disease are slowly being brought into perspective although data on incidence and geographic distribution of many infectious, parasitic and nutrition conditions are still far from complete in most countries. It is clear that the fertility of draught animals in many areas is poor and may constitute one of the main losses of farmer income.

Socioeconomic studies have opened up a vast store of knowledge about the forces that help or hinder the farmer, his family and his associates. The work of the DAP network has in fact given remarkable insights into Asian farming generally, showing some of the local and vertical influences affecting production. The chief aim of draught animal research to date has been to examine and identify those factors which can be modified to the advantage of the farmer and the economy of which he is a part (Sabrani and Perkins, these Proceedings).

On the debit side farmers may receive only a fraction of the value of their commodities while inputs and goods consumed become more expensive.

The Present Situation

Workers in Thailand, Indonesia, India, Australia, Ethiopia and elsewhere have now completed several years of integrated DAP research of a high quality. It is time to stand back and assess the current position and attempt a

Table 3. Economic indices relating to DAP production and agricultural investment, 1989.

	Population (million)	GNP growth rate (%) (1965–89)	Inflation rate (1980–89)	Agricultural growth rate (%) (1980–89)
Bangladesh	111	0.4	10.6	2.1
China	1 114	5.7	5.8	6.3
India	833	1.8	7.7	2.9
Indonesia	178	4.4	8.3	3.2
Korea, S.	42	7.0	5.0	3.3
Malaysia	17	4.0	1.5	3.9
Nepal	18	0.6	9.1	4.5
Pakistan	110	2.5	6.7	4.4
Philippines	60	1.6	14.8	2.0
Sri Lanka	17	3.0	10.9	2.2
Thailand	55	4.2	3.2	4.1

(Anon. 1991a)

projection for DAP research and the DAP system itself.

In 1961, Jawarharlal Nehru recognised the vital importance of draught animals but was greatly concerned at the lack of progress in improving the system. Yet the draught animal system has stood the test of time. In an inflationary world beset with unstable oil prices and rapidly rising rural populations it is a relatively efficient system producing nutritional and cash crops for local consumption and export year in and year out. People are fed and employment is provided. The DAP system is a lubricant on which the economies of many countries run.

DAP has taken part in some great leaps forward. The promotion of high-yielding strains of rice is one. The extension of agriculture through transmigration is another. These advances have originated outside the system. After examining DAP in detail at the farm level the research worker has not found any miraculous way to increase income or production. Indeed, one study claimed that Indonesian farmers were technically efficient in their production of rice and, to increase productivity, entirely new technologies were required (Esparon 1988).

Other workers have indicated ways to increase production in selected areas, for example, reproduction (Sumanto et al. 1987; Teleni and Murray 1991), calf health (Carmichael 1990), and mineral supplementation (Winugroho 1989). Any such advances will require active 'vertical' inputs by government through the extension services (which may include trained farmers) and emphasise the importance of the intermediate group of factors in developing the DAP system. Technical inputs inevitably involve costs which government may find difficult to meet but many types of delivery system may be available. Radio and television are now established at the village level in many parts of Asia and can be an efficient arm of the extension service. Individual countries must find their own solutions depending on finance, geography, government organisation, social structures and communications.

The Future of Draught Animal Power

In a previous paper I suggested some of the factors that would influence the draught animal society in Asia up to the year 2020 (Campbell 1989). Looking back, I still would not change a word. After the uncertainties created by the Gulf War of 1991, the international financial recession, a continuing inflationary trend in many countries and some decline in rice production, the role of the DA farmer in ensuring employment, social stability, food supply, human health and national productivity seems increasingly important.

Governments should therefore develop a greater sense of urgency and create conditions that allow the DA farmer to operate with maximum efficiency in the decades ahead. The DAP system represents a fundamental component in the social, agricultural and economic fabric of Asian countries. It is stable, productive, and underpins the economy of most of the states of south and east Asia. It is a source of employment for the population and has the potential for diversity at the microeconomic, that is, rural, level.

Can we therefore identify some of the economic factors that constrain the DAP system at present, and predict others still to emerge?

Land tenure and land reform

This paper is not the forum to analyse a complex topic that varies so much from country to country. The problem, using a Philippine model, has been discussed in detail by Hayami and co-workers (1990) and it is one of great social and agricultural importance. Land reform has been described as the age-old cry of the small Filipino farmer and farm worker; a promise all too often heard during an election campaign but sadly forgotten once the votes are cast (IBON 1988). The successes of Japan and Taiwan were achieved immediately after World War II under external pressure and are not applicable to other countries of the region but efforts continue to find an effective solution to the creation of socially acceptable landholdings capable of optimal productivity, with varying success. Great differences exist between countries. For example, in India and Nepal, hired labourers may be employed for a year or for a crop season, whereas, in the Philippines, contracts may be for the day or other short-term tasks (Hayami et al. 1990). Land tenure continues to be a constraint to maximum production in a number of countries.

The optimal size of holdings is debated. In fact, it may be the single most important factor for success. However, the lucky farmer who acquires a personal block of land has to cope with not only annual problems of climate, fertilizer costs, animal health, commodity net income, marketing and so on, but also debt repayments and the reduction in land holdings with each generation.

Some demographers question whether land reform is the only answer to social and agricultural problems, arguing that the basic aim should be to create a system that allows maximum sustainable social stability with assured economic agricultural production. One approach is to combine existing elements of the rural sector, including DA farmers, with other microeconomic or intermediate forces, e.g. farmer cooperatives or agribusiness (Chantalakhana 1980). This is the age of diversification. At the same time outputs must have guaranteed and stable markets with adequate returns at the farm level.

The size of farm under a reform policy receives great attention and it is interesting to note the situation as it exists (Table 4). A smallholding of only 1–3 ha does not imply inefficiency. Rice yields per ha in the Philippines are higher in smaller farms. If this finding is applicable generally in southeast Asia, the future of the small DAP animal power unit should be assured for the foreseeable future, since the petrol-driven tractor is unlikely to compete economically at that level.

Table 4. Size distribution of rice farms in the Philippines.

	Farms		Area	
	No. ('000)	(%)	(ha) ('000)	(%)
(ha)				
Under 1.0	415	22.2	272	7.5
1.0 – 2.99	916	49.1	1657	45.4
3.0 – 4.99	313	16.8	874	23.9
5.0 – 9.99	163	8.7	522	14.3
10.0 – 24.99	52	2.8	234	6.4
25 and above	7	0.4	91	2.5
Total	1866	100.0	3650	100.0

Source: (Hayami et al. 1990)

The result of genuine land reform can, however, be dramatic. In China, output accelerated in 1979 when prices were raised but households were given control over land and allowed to retain net income. Between 1965 and 1980 output increased 3% per year but between 1980 and 1988 it increased further to more than 6%. During the same period it is claimed that the number of extension service stations increased from a few hundred to more than 17 000 (Anon. 1991a), showing the interaction between intermediate and microeconomic levels of activity.

In most countries the area of land available for agriculture is diminishing with increased population and urbanisation. It is imperative therefore that the agricultural unit becomes more efficient and productive in the face of demographic pressure. Time is not on our side.

Transfer of technology

Effective extension services are an essential link in the use of new technology in tillage, crop rotation, animal health and other activities. They require active and substantial investment by government. It is also becoming apparent that the private sector could be used more extensively (Anon. 1991a). Agribusiness is slowly being recruited in Thailand and elsewhere to disseminate new technology, and may even employ farmers as extension personnel. A novel approach is seen in the recently formed Indonesia International Animal Science Research and Development Foundation, which is attracting contract funds for a wide range of educational, research, extension and other activities supporting the smallholder farmer.

The basic question is not whether the DAP system has a future, but rather in what industrial structure it is going to be most productive. The sociological implications of the chosen system are vital. If incomes rise as it is hoped, some DAP farmers may move into non-farm businesses and hire labour. If their children prefer to move into urban occupations, hired rather than family labour again becomes more significant. Analyses of such effects must be left in time to the sociologists. It is generally accepted that migration to the cities is a major trend and problem in all countries, a trend which depletes the rural areas of some of their most enterprising people.

Microeconomic factors

Previous workers have compared the relative economic and technical potential of DAP and tractors and generally concluded that in smaller holdings the place of livestock is assured (Javier 1980, Devendra 1985, Ramaswamy 1985, Campbell 1989). Mechanisation introduces capital investment, costs and maintenance problems whereas livestock may provide additional cost-free profits from calves, manure, rent and income from sales, all of which may be critical at the village level. In small-scale farming, animals can generate a greater net profit. The value of draught cows is almost universally acknowledged (Matthewman 1987) but in some areas, e.g. the Philippines, their numbers may be as low as 18% (Ranjhan 1983). Methods of synchronising breeding programs with the working season have been outlined by Teleni and Murray (1991).

New technology

Recent studies have indicated aspects of the DAP system that may be susceptible to technological change. These include improved livestock fertility and areas of disease control and nutrition which could be applied immediately with the support of government through the extension services if funds were made available. In the absence of adequate inputs from the intermediate levels of activity, however, the DAP system is inflexible and unlikely to change. Agriculturalists the world over, including draught animal farmers, are risk-minimisers (Lesueur 1985). Any innovations must be economic certainties.

Fundamental advances are unlikely in the near future but when they appear they will almost certainly be profound and in the area of new energy sources (Campbell 1989). Nuclear fusion, fuel cells, hydrogen, solar and wind power are active fields of research in many countries. Theoretically all are capable of being hooked up to agricultural engineering systems of some kind. The current intense interest of major car manufacturers in electric vehicles, some of them solar-powered, will probably come into practical use early next century, and one can predict with some confidence that they will generate a range of functional machines adaptable for agricultural use at relatively low cost. Increased efficiency in tillage, harvesting and land preparation can then follow. Climatically the tropics are ideal for solar machines. How to generate power economically for agriculture is the problem for the engineers.

If tillage is improved by mechanisation what role is left for cattle and buffalo in the rural areas? There will be a continuing need for fertilizer, animal protein and milk as well as draught, in the face of increasing human populations. The DA farmer should therefore be given an opportunity for diversification as agriculturalist and animal breeder which will fit into the economic needs of his country. Now is the time to consider integrated farming systems most suitable for the tropical countries of Asia. Dairy farmers have shown how cooperatives can work. Animal–crop–meat systems allied to marketing strategies have not yet been exploited to their potential limits. Ramaswamy (1985) has listed some of the sectoral systems to which DA may contribute, e.g. milk, meat, slaughter by-products, biogas, social forestry, rural industries and transportation. Alternative or multiple crops that can be integrated into the systems of the farming year should now be under consideration. In water–rice areas, aquaculture might be introduced as a component of the system in both fresh and brackish water.

With the invention of new power sources a dilemma will arise. Nehru's dream of an improved lifestyle for the farmer may be achievable but an improved standard of living will not follow unless the farmer can be part of a production system that yields an adequate economic return at existing price levels. Quality of life for the smallholder farmer has received too little attention while some of his brothers and children in the cities have prospered. But improvement cannot take place unless a satisfactory economic return is assured from crop production or other activities. Whether these are supported by draught animals or machines, new agricultural production sources and marketing systems will undoubtedly be needed in the next 20–30 years if social stability and justice are to be achieved (Hodder 1973).

The environmental background

Campbell (1989) made reference to emerging environmental problems and their impact on agricultural production in the tropics. Even in three years the situation has deteriorated. A complexity of environmental factors, coupled with rapid population expansion, has reduced the output of grain per person (Brown 1992). More people are hungry and incomes have fallen in more than 40 developing countries. A new approach to environmental control must be coordinated with improved technology to increase the output of agricultural systems including DAP. The first global environmental conference held in South America this year identified some of the problems, though not necessarily the solutions.

Conclusion

The future importance of the DAP system seems assured in the medium term, that is, until the first two decades of the next century, but it is probable that novel energy sources will become available because of new technology and diminishing reserves of fossil fuels. Agricultural production may be revolutionised as a result, with major impacts on rural populations, employment, commercial interactions and the political forces in individual countries. Governments should anticipate these developments which will have a profound effect on their peoples.

Despite significant progress in limiting population growth rates by some governments, alternative systems of employment must be devised to occupy the energies of expanding populations. Vertically integrated and diversified systems for the production and distribution of agricultural products seem desirable goals, but in most areas of Asia are undeveloped. Agribusiness in the United States is not necessarily the best model for Asia. The Indian dairy industry has illustrated what can be done for one commodity. It is now necessary to consider new options for the draught animal farmer (Table 5). In some

Table 5. Diversification opportunities for the DA farmer.

- Draught animals plus
    - calves
    - bulls
    - beef
    - milk
- Mixed crops
- Plantations
- Aquaculture
- Small business
- Crafts
- Transport
- Tourism
- Fishing
- Something entirely different

countries there is still an urgent need to establish fair land tenure conditions for farmers. These are essential if new technological advances are to have their full impact.

This session is about improving the productivity of draught power. It is about improving the living standards of the agricultural worker. It is about the economic health of nations.

There is perhaps a lead time of about 20 years to work on an improved Asian model before the next industrial revolution. The DAP Network should now begin to consider methods not only of improving the system, but also of creating new employment opportunities for the DA farmer and his family.

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Farming Systems and the Use of DAP in Support of Sustainable Agriculture

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Abstract

The importance of draught animal power (DAP) is increasing in the Southeast Asian region. Work animals are complementing motor power, or providing most of the power in a range of different farming systems. Research on DAP and its complementarity with cropping is now a priority area of research and development. Raising animals for work has added sustainability to farming, through tillage and cartage, increasing farm income from stock sales and rental, providing security and capital growth, utilising farm by-products, providing animal fertilizers, reducing farm risk and through its inherent self-replacing nature.

Draught animals contribute about seven per cent of the world's total methane emissions to the atmosphere. However, DAP uses a replaceable energy source and does not rely on burning fossil fuels. There are some risks of DAP misuse leading to land degradation in sensitive and steep areas, but in general DAP use makes a valuable contribution to the stability and viability of Asian systems.

Potential exists for improving the role of DAP in sustainable agriculture — through enhanced efficiency in feeding and through the adoption of more efficient implements and carts. However, as most users are resource-poor farmers, the most acceptable changes will be simple ones at present. Improved composting, biogas production and use of more sophisticated DAP equipment are improvements that will require major advances in our ability to influence farmer knowledge and organisations.

IN many areas of Southeast Asia DAP is increasing, while in others tractors have taken over much of the work, but DAP is complementing motor power in various ways. Governments, research institutions, aid agencies and development projects are committing substantial resources to DAP, in many areas for the first time. Raising work animals is complementary to sustainable agriculture because it utilises farm by-products, provides animal manures as fertilizer, represents family investment and security, and is self-replacing. The relative importance of all these aspects of rearing draught animals varies between countries, islands, villages, farming systems and farmers. The history of economic development shows that one country's success does not necessarily mean that the same system will succeed elsewhere.

Increased agricultural productivity to meet the demands of increasing human population has received international attention and support. More recently, the attainment of sustainable agricultural production and environmental preservation have become major global concerns, both in developed and less developed countries. The objectives of this paper are to identify some major farming systems, and to analyse the future role of DAP in supporting sustainable agriculture in the region. As sustainability is critical to the future welfare of farming families and whole rural areas, another aim is to suggest ways in which the contribution of DAP may be improved.

Definitions and Aims

While the term 'farming system' in the title may be defined quite simply as 'a group of farmers with similar practices and production and operating in a similar physical and economic environment', the definition of 'sustainable' is not as straightforward. For instance, one international definition of sustainable farming allows no use of inorganic chemicals, and to some 'organic' farming groups, a sustainable system is one that depends on no outside inputs to the system at all. Most Asian farmers would probably consider their farm system 'sustainable' if it has supported their family over many generations.

In Australia, the crop farmer's interpretation of 'sustainability' is a system that preserves land quality by reducing tillage to a minimum and returning most organic residues to the soil. Conway's (1986) definition of

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sustainability is related to the extent to which the system's long-term production potential is affected by major disturbances (e.g. drought).

Thus the definition of sustainability is culture-dependent, land-specific, and likely to change with human values and economic factors, over time. The one factor common to all definitions is the concept of 'maintaining or improving the quality of the land's resources', and it is this aspect that is adopted here as the major requirement for sustainability of farming systems.

With this broad definition in mind, one could attempt to classify all major farming systems as either sustainable, or unsustainable. One could also examine the role of DAP in each system in contributing to sustainability, or non-sustainability. Further, one could try to predict the potential role of DAP in improving or degrading the farming system (or the larger agricultural system) in the future.

The main questions that we were asked to answer are:
'What are the farming systems in which DAP plays a role in Southeast Asia?', and
'How does (or could) the use of DAP contribute to the sustainability (or non-sustainability) of Asian farming systems?'

While there is some information of a general nature available on the first topic, attempts to answer the second question are very subjective because of an almost complete lack of data on the condition of the land resources (and therefore sustainability). A third question, that cannot be ignored, is the contribution of draught animals (and farming systems) to the preservation (or destruction) of the global environment.

Major Farming Systems and Features of DAP used in Southeast Asian Countries

In Southeast Asia, one can distinguish numerous farming systems into which DAP has been integrated. We select from the literature a few major farming systems in selected countries and attempt to summarise some features of DAP use in these. The intention is to show the similarities and also the differences that occur in the way that DAP has been integrated into systems.

Thailand

In parts of Thailand there was a drastic decline in buffalo population from 1982 to 1987, particularly in southern, irrigated rice-producing areas. Here there has been a large increase in the use of small tractors, but these changes have been accompanied (in 10 years) by a doubling in the price of adult draught animals and of meat (Sukharomana 1991). The Cattle and Buffalo Bank was set up to reduce the shortage of draught animals (Chantalakhana 1985).

The same author reported that in Thailand:

Cattle were generally worked in pairs and buffalo as singles. Carting was mostly with animals in pairs. Inputs to DAP enterprises were minimal, with animals housed in simple stalls, and given mainly traditional health remedies. Breeding was mainly by random natural mating amongst the village herd. Most male cattle and buffalo were castrated, but with negative effect on breed improvement. Training of animals for work took 2–3 weeks.

In the northeast, where DAP use is prevalent, two major farming systems were described in 1991 by Chantalakhana and co-workers, (a) lowland rainfed rice, and (b) mixed upland crops and lowland rice. Some features of these rainfed systems follow

- Ploughing, raking or harrowing and carting were the main DAP operations in both systems. While the time spent on tillage operations was similar in each, animals in the lowland system pulled carts for longer (20 days) than those in the mixed farming system (5 days).
- Animals were worked for an average of 68 days (22–115) and 51 days (8–81) per year in the lowland rice and in the mixed system, respectively. The corresponding farm size was 4.5 and 3.8 ha.
- Although DAP was the major power source, there was an increasing tendency for farmers to employ small 2-wheel tractors to supplement DAP at busy times of year. Tractor loans were one stimulus for this trend.
- Rice straw was the main feed available almost all year round in the lowland system, and was stored by all farmers. There was a greater diversity of feeds available in the mixed farming system (many crop by-products) than in the lowland system.

Also in Northeast Thailand, Sukharomana (1991) found that:

main problems reported by farmers in rearing buffalo were disease and insects, feed shortage and lack of grazing area, labour shortage, theft, water supply, lack of capital, low genetic quality and buffalo housing;

main deterrents to DAP use were opportunity cost of labour for rearing, shortage of grazing, relative slowness of DAP compared to tractors, risk of loss of animals to theft, water supply (for wallowing) in the dry season;

farmers generally allocated about half a hectare of farm land for raising buffalo during the wet season, rice straw and weeds being the main feeds in the dry (some forests and public lands supplied grazing in dry periods, and 64% of farmers said that shortage of grazing was the main deterrent to rearing);

theft was an increasingly serious problem because of the increasing value of stock and the consequent need to allocate labour to protection; and

the advantages of DAP over tractors were calf sales and asset increase, and manure. (There was greater return from sale of offspring than from work itself.)

Table 1. Days and value of work on and off farm, per animal per year, by farming system and by operation.

	Farming system					
	Rice-based	Corn-based	Coconut-based	Sugarcane-based	Hilly land	All farming systems
On-farm			Days/animal/year			
Ploughing	11	22	5	26	16	16
Harrowing	10	13	7	19	8	12
Furrowing	1	10	1	9	5	5
Levelling	6	7	4	13	–	6
Cultivating	2	19	1	29	10	12
Hauling	2	5	10	9	1	5
All operations	32	76	28	105	40	56
Value (P)	1 120	2 090	980	2 100	800	1 418
Days/ha	15	20	10	35	21	20
Off-farm						
Ploughing	10	16	12	18	8	13
Harrowing	9	11	14	2	–	7
Furrowing	1	2	–	–	1	1
Levelling	[a]	–	6	–	–	1
Cultivating	[a]	2	–	22	–	5
Hauling	1	2	14	[a]	–	4
All operations	22	33	46	42	9	31
Value (P)	770	908	1 610	840	180	862
Total days	54	109	74	147	49	87
Total value (P)	1 890	2 998	2 590	2 940	980	2 280

[a] Less than one half–day

Source: Alviar and Elauria 1991, p. 136.

Rearing DAs reduced income instability from crops due to climatic risks and market uncertainty. Buffalo were used as security and also as a heritage. The lower capital price than tractors was also a major attraction.

Chantalakhana (1985) stressed the need to develop technology to enhance the complementarity of DAP and mechanisation in farming systems.

Philippines

In the Philippines, Alviar and Elauria (1991) reported on DAP use in five major farming systems, i.e. rice-based, corn-based, coconut-based, sugarcane-based, and a 'hilly land' system. The systems were significantly different in numerous respects, including their proportional utilisation of DAP on different activities.

Average farm size was 2.4 ha for rice-based farms, 2.6 ha for corn-based farms, 3.9 ha for coconut-based farms, 8.0 for sugar farms and 1.5 ha for hilly land. Corn farmers had an effective crop area of 6.4 ha/year. Over all systems, the average farm size was 3.7 ha and the effective crop area 5.2 ha, meaning that over 40% of land was planted twice per year.

The total number of days worked by animals, on and off the farm, was 54 (rice), 109 (corn), 74 (coconut), 147 (sugar) and 49 (hilly), and the average per year was 87 days.

The DAP operations carried out in all systems were ploughing, harrowing and cultivating, with some hauling in rice, corn and coconut systems. The time spent on each operation, and for on- and off-farm work is shown in Table 1.

Many (45–50%) farmers had only one animal but combined with other farmers for work in pairs. The requirement for work per ha was 10 days (coconuts) to 35 days for sugar cane.

Hilly land farmers, in particular, felt that a reduction in quantity or quality of buffalo would seriously delay planting dates and reduce the area ploughed.

Main problems in rearing were a lack of grazing areas, and animal ill-health. Tractor power was more available in some systems than others, but regarded as expensive.

DAP use was seasonal, although there was considerable use of animals off the farm out of the cropping season (see Table 1).

Although animals were said to be raised mainly for work, they provided income also as a source of meat, milk and by-products.

The authors made recommendations for a 'massive campaign' to produce, large, strong and healthy buffalo for multipurpose use (Alviar and Elauria 1991).

De Guzman and Allo (1975) described a cattle–coconut farming system that:

> had advantages of more efficient use of coconut land, weed control, increased income and more efficient labour use, nutrient recycling through return of manure, and additional returns from meat and milk, and made best use of sunlight, water and nutrients in a multistorey canopy, by planting a combination of crops of different height and root pattern, e.g. coconut palms over coffee, bananas, papayas and an understorey of vegetables and other annuals (Cosico et al. 1984).

Sri Lanka

Siriweera (1989) reported that in Sri Lanka, the tractor subsidisation policy had failed and the cost of mechanisation was prohibitive. There is now a return to animal power. Ranawana (1991) stated that the number of buffalo did not meet the demand, and that:

> Nearly all buffalo were kept on holdings of 0.5 to 2.0 ha and used for draught in rice production. Most rice farmers reared one or two animals, but in the dry zone some farmers owned up to 40 head.
>
> Animals were grazed on pastures with no feed supplementation.
>
> Average period worked was 52 days/year and 7 hours per day. The main operations were ploughing (12 days/year/ha), puddling (33), levelling (7) and threshing (22).
>
> Animals were used in pairs for ploughing and levelling, but in groups of four to eight for puddling. Nearly all farmers used animals for riceland cultivation (and puddling), but only some used their animals for threshing.
>
> The number of buffalo days used per ha was about 12 days ploughing, 33 days puddling, 7 days levelling and 22 days threshing.
>
> Neglect of grazing and wallowing needs in some projects has led to a drastic reduction in animals kept.

Ranawana (1991) saw a need to develop more intensive buffalo systems, where milk as well as work is produced. He believed that breeding should be planned so peak lactation does not clash with the work season, and that total health-care schemes are needed. Forage improvement is a prerequisite for DAP development in many areas (Siriweera 1989).

Bangladesh

Most farm power in Bangladesh is supplied by cattle and buffalo. The agriculture is characterised by a rice monoculture and animal tillage, with three crops per year (Barton 1988). Some interesting mixed farming systems have been described by Saadullah (1991) in Bangladesh, where multipurpose (milk–work–meat) enterprises are a main feature of DAP use. The integrated farming systems mentioned were crop–cattle–poultry (33% of farms), crop–cattle–goat–poultry (18.5% of farms), and cattle with goats, poultry or both (6.5% of farms).

The use of milk cows for draught was a comparatively recent phenomenon, but was increasing particularly on farms under 0.8 ha. In some areas, over 80% of farms used cows for work.

Animals were worked in pairs, and the use of single animals was very rare, although being recommended at present.

There was a shortage of DAP, particularly among farmers who do not own animals, but also on larger farms.

The feed available for draught animals was only about 2 kg of rice straw and 88 g concentrates per day, barely enough for maintenance, without any work, milk or reproduction demands. There was little space for an increase in fodder production.

Saadullah (1991) recommended that the work capacity of existing DAP herds should be increased (rather than increasing animal numbers) by improving feed quality (e.g. treated straw) and introducing improved implements and harnessing systems.

Indonesia

In Indonesia, the role of draught animals has been described in lowland rice-farming systems (Sumanto et al. 1987), medium-altitude mixed gardens and rice systems (Santoso et al. 1987), low-altitude rice and medium-altitude mixed gardens (Yusran and Yudi 1991), and for Timorese lowland rice and upland maize systems (Liem et al. 1988, Petheram and Liem 1990). Santoso and Sumanto (1992) also described DAP use in soybean production in a transmigration village in Sumatra. A summary of selected characteristics of some Indonesian DAP subsystems is shown in Table 2.

DAP is most important in farming systems that are isolated from infrastructure and have a high ratio of land to population. The newer transmigration areas are thus very dependent on DAP, but so too are numerous villages, even on densely populated Java, where the land is steep or field sizes are small or irrigation water scarce.

In the larger irrigation schemes, where there is a need for rapid turnaround between crops, hand-tractors are playing an increasing role. On the other extreme, in parts of Java where the human population density is very high and fields very steep and small in size, human labour is a major competitor with DAP as a power source for tillage.

A main contrast illustrated in Table 2 is the wide variation in period of work per year. Cartage is the enterprise that makes best use of the work capabilities of animals, although some tillage rental operators work for 200 days per year. Some other features of Indonesian DAP use are discussed below.

- The cost of hiring DAP is lower in East Java, where livestock husbandry is much more important in the local culture and large ruminant population density is much higher, than in West Java. In East Java, too, the

use of metal in implements is common, while in West Java wooden implements are the norm.
- The use of single animals in lowland rice systems in parts of West Java and Sumatera was standard, although in other lowland rice systems throughout Java, paired animals were the norm.

These interactions with local culture make it difficult to attribute differences in DAP to farming systems alone. Cattle were more prevalent in drier East Java than in West Java, where swamp buffalo were the traditional animals used.

Natural forage was the main feedstuff in most farming systems, although rice straw and maize stover were major components of diet in East and Central Java. Grazing was the main feeding system in most systems in the dry season, and hand-feeding in the wet season. In West Java, rice was fed only while green and was not stored, while in East Java storage was the norm. In East Java, forage was sold at dry times of year, and some farmers used ricebran as a feed supplement. In certain Madura villages, grazing has been prohibited by local authorities, and this has led to new opportunities for improving local forage supplies; some farmers even fertilise natural pasture there.

Labour for forage collection or grazing was a major constraint in many areas to rearing cattle or buffalo.

Most families made more out of sales of calves than from draught itself, although some landless rearers made their main living from contracting for animal work.

Table 2. Work output for swamp buffalo in six selected farming systems in Indonesia.

Farming system	Days work/year	Hours work/day Average load
Rainfed rice and/or other crop production (1 crop/year)	10–30 days Ploughing, harrowing, levelling	3–5 hours 40–70 kg
Irrigated rice production (2 crops/year)	25–60 days Ploughing, harrowing, levelling	3–6 hours 40–60 kg
Irrigated rice production (3 crops/year)	60–90 days (mainly own land) Ploughing, harrowing, levelling	3–5 hours 30–70 kg
	100–200 days (mainly rented out for tillage)	3–4 hours 30– 60 kg
Haulage of carts	200–300 days Cartage of bricks and other loads up to 30 km/day	8 hours walking 400 kg start 30 kg moving

Source: Petheram 1991.

The practice of using mainly cows for draught has led to a serious shortage of bulls in many villages, and a complete lack of good breeding bulls in some areas. This was particularly serious in low-density, isolated areas, and posed a major problem for DAP development.

In West Timor, there was no DAP use in upland areas, and in the rice systems the traditional practice of 'trampling' to prepare fields is likely to give way to implement tillage, as has occurred in Lombok (Perkins and Sarwono 1987). The use of carts in Java was still very common in many areas, but there was strong competition with small petrol-driven vehicles. Some sugarcane factories hire cattle to cart cane to the mills, but other estate crops use little DAP. The potential for DAP use by oil palm smallholders seems to be high, given their poor road conditions and isolation.

Role of DAP in Sustaining Asian Farming Systems

The discussion so far suggests that draught animals have had a major 'co-evolutionary' role with farmers in the development and maintenance of Asian farming systems. In some systems DAP has been partly or largely replaced or complemented by hand tractors, but in general, DAP remains a vital power source in Southeast Asia, despite considerable efforts by governments (and tractor manufacturers) to promote mechanisation. Even though tractors do have advantages in some farming systems, it appears that a vast majority of farmers in Southeast Asia do not have the resources to replace DAP with tractors.

The complementary use of tractors and DAP is evolving in many farming systems, but until the terms of trade of farmers improve markedly, DAP is likely to remain the major element. However, farmers are attracted to large ruminant enterprises not only for reasons of draught power and financial inability to purchase machine power.

Crop residues and by-products are a major source of feed for draught animals. Where animals do not consume (and break down) these by-products, they must be cleared from fields or disposed of in suitable ways. The production of manure and its use as a fertilizer is one example of the interdependence between crops and DAP.

The use of animal manure has sustained yields of rice in countries such as Thailand at levels of 1.5–2 t/ha for four or five decades, with the use of very little other fertilizer.

The environmental benefits and economic savings to nations through DAP use have been stressed by Ramaswamy (1985), who estimated that it would take 30 million tractors to replace the 300 million draught animals used on small farms in Asia. DAP carts provide transport for millions of people in towns and rural areas.

The use of (renewable) animal power instead of (non-renewable) fossil fuels and tractors has saved millions of dollars in foreign exchange and has also reduced CO_2 and CO emissions to the atmosphere.

Ruminants are thought to account for about 15–25% of the total world's total methane emission into the atmosphere (Crutzen et al. 1986). Draught animals produce about one-third of this methane and may thus be seen as a threat to the environment. However, more work is needed on greenhouse gas equations, as ruminants also depend on forages which consume CO_2 from the atmosphere.

Methane production from the world's ruminants has quadrupled over the last century and is about twice the amount produced by all coalmining and natural gas leaks worldwide. It is, however, lower than methane production from rice paddies and wetlands (Crutzen et al. 1986).

Although methane production per unit of feed is generally lower for animals on high-energy diets than on high-fibre diets, the average amount of methane emitted per head is higher (55 kg/year) in developed nations than in the rest of the world including Asia (35 kg/year). This is because the daily feed intake in ruminants in Europe and North America is much higher than in 'developing' regions (Crutzen et al. 1986).

It is relevant to note that while most draught animals consume only fibrous roughages, about 40% of the world's grain is consumed by ruminants in 'developed' countries — production systems that are hardly sustainable for the global environment.

In tropical agro-ecosystems, soil resources are generally fragile and subject to erosive or other degrading forces of nature. Draught animals, as part of these systems, have generally assisted farmers to keep ahead of nature to protect the land. For instance, hill slopes are levelled into terraces for ricefields initially, and are then re-levelled using animal power each year to ensure even spread of water and meticulous redistribution of rainwater to lower paddies. Without such systems, the erosion of ricefields would make farming unsustainable within a few years. Animals play an important joint role with farmers in such processes, and hence in ensuring long-term productivity and economic viability.

While hand-tractors have successfully replaced DAP in many intensive rice-farming areas, there are also areas where the loss of animals from farming systems has resulted in greater risk and instability and a decline in long-term income for farmers (e.g. Sinaga and Bernsten 1981).

As animals are so integral a part of the farmers' economy, the animal enterprise cannot be valued in terms of draught alone. The benefits that farmers obtain from animals range from tillage and cartage work to reduction of risks in cropping, accumulation of capital (banking), income from sales or rental or milk, security and insurance, to recreation use and prestige — which all add up to making economically viable and biologically sustainable systems (Devendra 1983).

Improving the Role of DAP in Sustainable Agriculture

Where farming systems are already sustainable, the scope for improving systems lies in enhancing the efficiency of DAP, e.g. in terms of farmer returns per labour or other input. Thus most technology designed to reduce animal time or effort spent on tillage or cartage, or farmer time spent in feeding or guarding animals, would enhance total sustainability, unless that technology results in soil degradation, through structural breakdown or erosion. A more efficient plough in wetland rice systems could increase permeability and hence result in less efficient water use.

Thus some DAP technology may require careful screening for suitability. The introduction of animal-drawn sledges in steep or sandy areas has caused vast soil losses in parts of Africa. Yet the same sledges used in flat fields in Asia can be a boon to farm transport in rice systems. Some farming systems could benefit greatly from a reduction in the amount of tillage, or by using implements which do less damage to the soil structure.

There may be scope for altering the DAP subsystem to improve the sustainability of some threatened farming systems. For example, in many upland mixed cropping systems there is evidence of serious fertility decline. This has led to reduced crop yields, weed invasions and serious soil erosion in some areas. Improved use of animal manures, terracing of steep slopes and construction of contour banks with animal-powered scoops are possible solutions. In Timor, where no animal power is currently used on upland maize systems despite serious weed problems, it may be irresponsible to introduce DAP without introducing contour banks as well.

The replacement of paired animal use with single animals for work purposes could have significant impact in improving the efficiency of use of feed resources, as the output from one animal eating the same feedstuff as the pair could be more than twice that of the two animals (in meat, milk, work and/or calves). The use of suitable supplements with low-quality forages could further improve efficiency, and could also give rise to a 60% reduction in methane emissions (Leng 1989).

Improving the diets of ruminants through supplementation with selected feeds and strategic feeding could raise the dietary level from little more than maintenance into the productive zone (Teleni and Hogan 1989). The main improvement sought would not be in work output, but in the production of meat, calves and milk, and hence in the income and total-system viability. The efficiency of utilisation of farm and village forage resources could be vastly improved through even small increases in feeding levels.

The Javanese farmers' preference for female working animals is another logical improvement to efficiency, in producing calves, work and other family benefits, from a minimum capital and input system.

Better utilisation of animal by-products is an area which could yield vast improvements in nutrient cycling in Asian farming systems. At present, most of the fertilizer value of animal by-products (e.g. urine) is usually wasted, and even contributes to pollution of housing areas. Matsuzaki (1989) developed a continuous composting system for animal wastes, that produced good fertilizer with excellent handling properties. This fermented compost was superior to compost produced by high temperatures. Suitable composting processes can be developed for particular animal manures, and for the prevailing conditions of climate and labour availability.

A further step in improving the integration of systems and resource-use efficiency would be in the production of biogas from wastes of draught animals, for home fuel supplies. While the potential is theoretically vast, numerous attempts to develop village-based biogas units in Southeast Asia have so far failed. Considering the predicted population growth and energy shortage, further effort to promote appropriate biogas units is important.

The scope for improvements in DAP implements, carts and harnessing seems large, through transfer of ideas from one system to similar systems elsewhere. In Java, for instance, use of DAP for cultivation of weeds is almost unknown, yet in African countries new to DAP it is standard practice. Carts and sledges are unheard of in certain systems where transport of products requires backbreaking labour. However, there appear to be strict limits to the complexity of DAP technology that resource-poor farmers can accept, so careful choice of technology to suit local materials and crafts is imperative. If farmers are affluent enough to adopt complex changes to their systems, they are likely to opt for tractors or machine-driven equipment. A good example is water-pumping, which is generally much more practical with an engine and pump than an animal-driven device.

Machine power and even electricity are likely to remain out of reach for the foreseeable future for vast segments of the Asian population. A vital need is to develop technology transfer processes that facilitate the spread of existing simple DAP technology from other DAP systems among poor farmers. An even greater challenge is to develop 'human organisational systems' (e.g. farmer information groups and cooperatives) that could allow access of more complex technology, such as DAP watermills and tool-carriers, or village biogas units and communal grazing improvement schemes, to resource-poor farmers.

Conclusions

The challenge that faces planners and scientists now is not just to raise productivity or farmer profit, but to do this by rational use of their 'national' resources, and in ways that are sustainable in the long term. The development of DAP technology to fit in with other changes in farming and technology will be a key to success in many Asian systems. Poor planning could result in the loss of livestock from previously integrated systems, and consequent reduction in stability and other substantial family benefits.

The achievement of these aims requires that scientists seek much greater understanding of systems and develop skills in collaborative work with farmers. This approach is much more important to developing sustainable systems for the future than sophisticated research on the physiology of work or implement engineering. Immediate requirements for technology in most DAP systems exist in other farming systems, and the main needs are careful adaptation and transfer to fit local situations.

Once scientists have developed the necessary skills and links with farmers for effective adaptation and transfer of technology, and suitable farmer organisations are established, the potential for the adoption of composting, biogas, and other technology important to future system sustainability will improve.

Acknowledgments

The assistance of the Australian Centre for International Agricultural Research for supporting travel to the conference is gratefully acknowledged.

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Government Policies and Socioeconomic Factors Affecting Future Use of DAP in Countries of AAAP Region

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Abstract

Some government policies and socioeconomic factors affecting the future use of DAP in the AAAP region were reviewed. Evaluation of these policies was related to the effort to improve future adoption for better DAP supply and implementation in integrated livestock–plant interaction. The need to increase the DA population as a consequence of food self-sufficiency, the resettlement program and land reforms was discussed to develop the appropriate direction of DA development.

THE structure of agricultural production in most AAAP countries is that of small diversified farming, with limited resources and multiple farm objectives (Sabrani et al. 1989; Anonymous 1990). Most of these activities are complementary in nature and maintain the biomass recycling process.

As the population grows and economic conditions improve, demand for food increases. This pressure challenges governments in the AAAP region to improve farm productivity and to increase food crop production (Anonymous 1981). The issue of food self-sufficiency has become the main political objective to achieve national stability.

To meet this challenge, labour as well as land productivity should be improved and better and appropriate technologies should be introduced and developed. Land preparation techniques, soil management and harvest technologies should be able to improve yield and work efficiency.

To achieve this target, mixed farming involving draught animals has to be developed. The role of draught animals is to provide the necessary power for cultivation, the formation of a stock of assets and the production of manure (Anonymous 1991). In most of the AAAP region, draught animals are one of the existing energy sources. However, the objective of this paper is to compile information on the use of draught animals as related to government policies and factors affecting their use.

DAP to Improve Cultivation Capacity and Soil Management

To cope with the increasing demand for food and food self-sufficiency, governments have evolved an agricultural development plan which involves extensification, intensification and diversification. Resettlement programs have created new production areas and land reforms increased the status of land ownership.

To improve the farmer's cultivation capacity and soil management, the role of DAP in food production systems has been examined. Today there are three energy systems developed, namely:

- farmer + manual tools,
- farmer + animal power, and
- farmer + machine.

The majority of farmers in developing countries work with manual tools in food-crop production. About 15% of farmers use animal power (Bodet 1987). In advanced countries most farmers use machines. However, the three energy systems have been used side-by-side and influenced by ecological conditions and their importance. In this connection governments are selective in introducing the farmer + machine system to avoid competition in the power market, especially in areas of low wages and small land-ownership. Binswanger (1978) pointed out that the introduction of mechanical power could replace human labour with large farms being developed at the cost of small farms.

DAP is still considered the most appropriate technology to improve the cultivation capacity of the small farmer and also to improve soil management for better crop production. The importance of DAP was described

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by Shrestha and Sherchand (1988), Esparon (1990) and Anonymous (1992) in terms of power and land area cultivated by farmers. Ploughing farmers showed higher land cultivation capacity. In this case, land is one of the most significant factors in food crop production.

Manure is one of the draught animal outputs which supports the improvement of soil condition. The average daily production of cow manure is 15 kg and of buffalo, 17 kg.

The content of N, P and K in cow manure is 0.92%, 0.56% and 0.83% while in buffalo it is 1.22%, 0.04% and 0.45%, respectively (Oli 1990). Manure production management is a very important aspect of tropical livestock production.

Through the use of draught animals in an agricultural production system, the farmer's land cultivation capacity can be increased up to 48% (Anonymous 1992) while farm income can increase up to 55%. The extensification program of food production and the implementation of land reforms require more labour. The farmer + animal power energy system seems to be the appropriate means of improving the small farmer's capability to cultivate land.

Government Policies which Affect the Use of Draught Animals

Realising the important role of draught animals in a food production system, governments have developed programs to intensify the use of draught animals in agricultural systems. In most of the AAAP region, governments are encouraging small-scale livestock development by providing credit with assistance from IFAD, EEC and other agencies (Anonymous 1990). This program is intended to meet the demand for draught animals by increasing their number and improving distribution. The problems faced by governments in the region are stagnation or decline in the number of draught animals, and the problem faced by farmers is that the investment is relatively high. Reproduction, feed availability and management are the dominant constraints to animal production.

To support the use of draught animals policies have developed designed to increase animal population and draught quality.

Prohibition on the slaughter of productive animals

Indonesia and the Philippines have prohibited the slaughter of productive large ruminants. This effort is intended to improve the supply of draught power and the herd structure for better reproduction (de Guzman Jr 1990). The absence of culling and selection for better productivity, high calf mortality, in-breeding and slaughtering of productive females are some causes of large ruminant population decline or stagnation. The implementation of the policy has faced constraints such as ineffective enforcement and forced sale by the farmer due to cash need and weakness of control.

Large ruminant distribution scheme

Government projects to distribute draught animals exist in some AAAP countries, supported by IFAD, ADB, EEC and other credit agencies. The motivation is that draught animal power has been considered the most appropriate means of mechanising agriculture for small farmers for very little cash outlay (Soejoto and McEvoy 1989). Governments are introducing credit programs (mainly in kind) to improve livestock production to satisfy the growing demand for power and meat.

An integrated draught animal improvement project indicated the economic importance of draught animals over mechanised agriculture for small farmers (Kasrino et al. 1984).

Land reforms, resettlement programs and public land for forage production

Land reforms and resettlement which encourage smallholding land ownership increase the demand for draught animals for cultivation. The limited capacity of farmers to plough their land should be improved by animal labour. The use of public land as a source of feed encourages the increase of animal production.

Use of feed resources under tree-cropping plantation areas

The integration of animals into plantation areas improves the availability of feed and expands animal production. The model of a cattle – coconut base is widely developed.

Food self-sufficiency

To improve national stability, some governments have developed food self-sufficiency policies, each related to meeting national food needs. This long-term national development objective is supported by land reform and new settlement policies which expand cultivated land for food production and activate landless farmers to operate their own land. To achieve this objective, an adequate animal labour supply should be available, hence the role of draught animals is critical. The need for animal labour is enhanced by other policies such as cattle credit and distribution schemes.

Institutional support program

The development of institutional support programs encourages the improvement of draught animal performance such as reproduction and body weight, lower mortality rate and new draught equipment. Institutional support is concerned with animal health, animal production, artificial insemination, extension and research. Low reproduction, slow growth rate and high mortality in young animals are basic causes of low productivity and are linked to poor animal nutrition and management and inappropriate equipment.

Socioeconomic Factors Affecting DA Use

The development of policies for DA use must include consideration of both technical issues and socioeconomic constraints. The technical policies concern issues such as breeding, land policy for feed production, and animal health. The economic policies include issues such as price structure, cost of production and consumer preference. These together will determine the technology used and what research should be developed.

Rising beef prices and production costs

The rapid increase in beef demand in the AAAP region has been influenced by four major factors: (1) population increase, (2) increase in income, (3) great income elasticity in the demand for beef, and (4) nutrition improvement campaign.

The development of a price incentive as shown by the beef price increase has encouraged farmers to sell their animals at a very young age. This phenomenon shortens the period of draught animal service to produce power. The high extraction of young animals reduces their availability for draught use (Sabrani and Semali, unpublished).

The higher cost of production created by difficulty in getting feed during the dry season forces farmers to sell animals. The same applies if the opportunity cost of family labour to keep the animal increases because some alternative employment such as off-farm or in the non-agricultural sector is available, when farmers reduce the labour allocation for keeping animals. In other words, the number of animals should be reduced (Anonymous 1992). In most AAAP livestock production systems fluctuation in the opportunity cost of production is related to such characteristics as large seasonal variation in feed supply, family and hired labour availability, and seasonal variation in draught animal use. However, the key features of the animal production system in most of the AAAP region are linkages, interactions, seasonality and the complementary use of resources. One farm activity affects the development of other activities. The dynamics of the system are described by research into farming systems (Camoens 1985).

Shift from draught to meat

The rising price of meat causes a shift in draught use to meat production to meet domestic market needs. The conflicting issue of the decline or stagnation of draught power supply is the high extraction of young animals (Sabrani and Semali unpublished). The animal market age is determined not only by biological factors but also socioeconomic factors such as farm price, the value of draught service, and the value of sociocultural considerations.

The development of cattle-fattening which requires calves increases calf price and hence stimulates farmers to sell their calves (de Guzman Jr 1990). To meet these changes, efforts should be directed to improving reproduction rates and growth rates, and to reducing mortality through better nutrition management.

Economic structural changes

Economic development in the AAAP region has created non-farm employment. Farm labour movement away from the agricultural sector has been observed. The relative contribution of agriculture to National Gross Domestic Product (in terms of percentage) has declined. This movement of farm labour, especially to developing industrial areas, has created shortages of farm labour supply during peak farm activities. The same phenomenon has been identified in new settlement areas such as transmigration areas. To face this structural change, strategies of draught animal development must be directed to more appropriate objectives such as increases in livestock population and draught quality. In some areas mechanisation has been introduced, but in others, draught animal power is being developed and expanded (Kasrino et al. 1989). The livestock (subsector) position has been improved to increase livestock population, with the special purpose of overcoming animal labour scarcity.

Conclusions

In developing nations of the AAAP region, draught animals as an integrated production activity of small farms are still an important component in improving farm productivity, soil management and as a source of income. Its development should be supported by appropriate government policies and economic structural adjustment. The issues of agricultural sustainability of small-farm development and food self-sufficiency support strongly an increase in draught animal use. The increase in demand for meat, however, may affect the availability of draught power. Improving the breed so that it is valuable for both draught power and meat develops a dual-purpose animal for farmers to take advantage of better market access to increase income.

Reproduction, growth and survival of the animal should be improved. Feed, management and reforming credit and marketing systems would be the focus of policy considerations.

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Power from Draught Animals

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Abstract

Cattle and buffalo are used widely in land preparation for agricultural work in most developing countries. They are worked in wet and dry lands which have different types of soils. Few studies have aimed at the optimal use of animal power. Studies are needed on factors affecting the draught capacity of animals during work under different field conditions as well as simple methods to measure these in the field. This paper discusses the type of implements drawn in farm operations and the methods available to assess work performance. An attempt is made to simplify the method of measuring DAP in the field through measurement of soil strength, and to establish the relationship between these two variables.

VARIOUS species of animals provide draught power for agricultural operations in developing countries (DCs). Among them cattle and buffalo are the two species most used, horses, donkeys or camels used in only a few countries. Cattle and buffalo seem to be better suited for agricultural work, especially for tillage operations. Cattle are used in both wet and dryland, whereas buffalo are preferred for work only in wetland cultivation. This may be related to the high power required for the work as well as to the physiology of the buffalo, which, because they possess few sweat glands, require water to keep cool during work.

The role of draught animals in DCs is important and will be so for many years to come. The increase in human population in these countries is usually faster than the increase in the animal population. The need to increase the animal population is not only for the provision of more power but also for more meat for human consumption. There are no reliable data on the exact numbers of draught animals available for agricultural work and some countries do not even have records of the total number of large ruminants. This could be due to the fact that farmers in DCs do not rear animals for draught purposes only but primarily for meat. Numbers of draught animals available in Indonesia, for example, are considered to make up about 52% of the total cattle and buffalo population (Kasrino et al. 1989).

The increased requirement of food for human consumption may be overcome by either opening new areas for cultivation or using available land more intensively. Both methods require extra working animals. Providing sufficient animal power for land preparation would be a problem in rainfall-dependent areas, where more animal power is required at the same time as the short period when water is available. Tractors have been introduced as alternative sources of power in agriculture, but their sustainability at the village level is doubtful for reasons such as increases in oil prices and the difficulties faced by smallholder farmers in maintaining tractors (Campbell 1989).

Studies of ways to optimise uses of animal power are few and more research is required, for example, on factors affecting the draught capacity of animals, and on a simple and easy method of measuring it in the field. Such information is necessary to improve the draught performance of working animals for agricultural work in DCs.

Animal-drawn Implements in Farm Operations

The types of implements drawn by animals during work have been reviewed by Bansal and Thierstein (1987) and Starkey and Sims (1989). Implements in various countries and even from region to region vary. Such variations could be due to cultural practices, animals used, soil types, etc. However, the basic functional structure of the

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implements is similar. There are no distinct differences between those used for similar operations.

Farm operations include such activities as tillage (land preparation), cultivation, harvesting and threshing, and the implements used are ploughs, levellers/harrowers, planters, harvesters and wheeled tool-carriers. Worldwide, the plough and the leveller are the two most important implements in agricultural work involving animals.

Normally ploughing takes place before levelling, and each activity is repeated in the same order. However, the combination of these two activities is not always the same from one region to another. Ploughing may be done one or more times, followed by levelling one or more times (Sumanto et al. 1987). Furthermore, there are also variations between wet and dryland operations. Ploughing and levelling are usually done more often in wet than in dryland. Levelling sometimes is not required in dryland cropping, for example, in the transmigration area of South Sumatera, Indonesia (Bakrie 1990). Ploughing represents harder work and is more time-consuming than levelling, because it is carried out after harvest time, when the soil is hard, as it has been settled during the growing period of the crop.

Ploughs are divided into two basic types according to their use, i.e. the breaking plough and the turning plough. The former is usually called the *Ard* plough, or in Ethiopia the *Maresha* (Starkey and Sims 1989), in India the *Country* plough (Bansal and Thierstein 1987) and in East Java, Indonesia it is called the *Brujul*. It is a narrow plough made from hard wood, with a metal tip, which breaks open the soil and leaves the vegetation on the surface. It is used mainly for dryland ploughing where soil moisture is minimal. The turning or mouldboard plough inverts soil to the side, effectively burying weeds in the process. It is usually made of metal, but in some areas in Indonesia, it is made of wood with metal tips and is known as the *Singkal*. The mouldboard plough has a cutting width of 15–25 cm and a usual ploughing depth of 3–25 cm. It is most suitable for wetland cultivation, such as in flooded rice fields. It may also be successfully used in dryland cultivation when there is adequate moisture content, e.g. in the soyabean-growing areas of South Sumatera, Indonesia (Bakrie 1990). In Africa, trials have been made to replace the *Maresha* with the mouldboard plough and it is reported that the overall cultivation time is reduced by 50% by so doing (Starkey and Sims 1989).

Levelling may vary from heavy tasks, involving the movement of a large volume of soil from the lower to upper side of a terrace, to light cultivation which is to make the soil level. There are also two types of implements used in Indonesia, one the *Garu*, a 2–m–wide boom with vertical spikes for transferring large volumes of soil, the other the *Bugis*, which is smaller than the *Garu* and is for light tasks (Sumanto et al. 1987).

Studies on the force required and the walking speed and power output of animals during ploughing are considered to be more important than studies on levelling. To measure the draught force during ploughing is also relatively easier to carry out. Measuring that involved in levelling is rather difficult, as the operator needs to push down the leveller by hand or sit on the handle, which could lead to an underestimation of the values recorded.

Work Performance of Draught Animals

The performance of animals during work needs to be assessed to obtain the optimal use of these animals. The dominant factor in assessing the work of draught animals is the draught force. If the force required to move an implement is greater than the force that the animals can produce, the task cannot be carried out, and if the force required is unacceptably high, the work cannot be sustained. Other factors used to assess performance are walking speed and changes in physiological parameters during and after work.

There is a relationship between draught force and walking speed of animals during work. Animals appear to have an ability to regulate their walking speed according to the amount of pull required. They tend to move faster when working on tasks requiring light force and slower on heavy ones. If the increase in speed is faster on tasks requiring greater draught force, then animals would not be able to work for as long on heavier loads as they could on light ones. During continuous work for a given force the walking speed will usually decrease as the work progresses.

Power output of working animals is expressed as the product of draught force and walking speed:

Power (hp) = Force (kN) x Speed (m/sec) x 1.36.

Following any increase in draught force, which results in a decrease in speed, power would be expected to increase. Conversely a decrease in force would substantially lower the power output. Power output would increase with an increase in force to a certain level when it would start to decrease with further increases in draught force and reductions in walking speed (Kebede and Pathak 1987). At a given force power output tends to decrease as work progresses due to the progressive reduction in walking speed (Rautaray and Srivastava 1982). When the draught force varies greatly during work, due to the nature of the working conditions or animal movement, animals seem to regulate their effort to compensate those variations by varying their walking speed, thereby producing a relatively constant power output (O'Neill et al. 1989).

Changes in physiological parameters of an animal can be used to assess the animal's ability to perform the work. Such parameters include the breathing rate, body temperature and the heart rate. All are expected to increase as the work progresses. The degree of increase would reflect the animal's ability to cope with the work. A more rapid change in these parameters would mean that the animal would not be able to work for a long period, and vice versa. Many studies have been carried out on the effect of work on these parameters (for example, Singh et al. 1968).

To obtain optimal working capacity, one needs to work the animal at a sustainable level of draught force. Achieving this requires a knowledge of the level of acceptable force, which depends on such factors as the animal itself and the working conditions. Few workers have used animal size to estimate the draught capacity of working animals. A heavy animal possesses a greater pulling capacity than a light animal, so it is likely to generate more power during work. Since the heavier animal is better able to perform work requiring a large tractive effort, it can pull larger implements and walk faster, thus reducing the time required to undertake operations.

The draught capacity of working animals has been estimated based on their liveweight. The different values reported by different workers are due mainly to the differences in the type of work and in the speed at which the animal walks during work. Maurya (1985) reported large variations in the draught force (7.5–24.5% of liveweight) exerted by the animals walking at speeds varying from 1.91–4.95 km/h. Goe (1983) estimated the force to be only 10–14% of liveweight of the animal when working at speeds of 2.5–4.0 km/h. Martin and Teleni (1989) suggested that the optimum draught load for cattle and buffalo working continuously for 3–4 h, at a walking speed of 2.5 km/h in ambient temperatures 27–33°C or more, is 11% of liveweight.

Certain agricultural work requires more force than a single animal can provide, thus a pair must be used. However, when animals are worked as pairs, their draught capacity is only 1.85 times the capacity when they are worked as singles (Marks 1951). Despite this, working with a pair of animals can save 10–30% time compared to working with a single animal (Gryseels et al. 1984), since when working single animals, one needs to rest them more frequently. The position of each animal during work in pairs also has an important effect on the amount of power produced by them during work, as reported by Bakrie et al. (1992) in that the animal which was placed on the right produced more power due to the extra force required every time they turned at the end of the pass.

The types and conditions of the soil are very important factors contributing to the variation in the amount of draught power produced by animals during work (Rapte 1982). The draught power required for ploughing increases from sandy loam to clay soils. There is also a certain soil moisture content required during work. Randolph and Reed (1928) found that an increase in moisture content from 9.1–11.7% reduced the power required in fine sandy loam by 15–35%. Moisture level above 35% and below 23% increased the draught of the plough (Rapte 1982). Therefore the draught force required to plough dryland will not be the same as in wetland.

Measurement of Draught Power in the Field

Measurement of the walking speed of animals during work is rather easier to perform. It is carried out by recording the time taken to travel a given distance. The amount of draught force required during work, however, is quite difficult to measure as it requires a dynamometer or a load cell which needs to be placed in the proper position to be able to record all the forces generated during work. The AFRC-Engineering Institute in Silsoe (UK) has developed a data logger which modifies and records three mechanical (draught force, angle force and speed) and four physiological (heart rate, breathing rate, body temperature and stepping rate) data sets during work under field conditions. The CTVM in Edinburgh (UK) has developed an advance system which gives a more complete account of the work done by draught animals (Lawrence and Pearson 1985). It consists of a load cell, a timing device and an odometer which are all connected to a digital logger. A simpler method of predicting draught force or power output using the relationship between these variables and soil shear strength was investigated by Bakrie and Komarudin-Ma'sum (1992).

Soil shear strength is measured using a vane tester (Serota and Jangle 1972), which consists of a torque head with a direct reading scale which is turned by hand, and a vane of 19 mm diameter, mounted on an extension rod and screwed into the rear of the torque head. Measurements are taken at normal ploughing depths of 10–15 cm. A pair of Madura cattle is worked to plough six blocks of 4 m x 40 m medium clay land, with different strengths as a result of varied moisture content. The draught force is measured using a load cell which is hooked to the rope

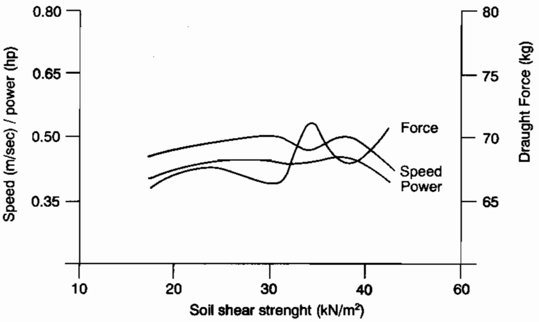

Figure 1. The relationship between soil shear strength and draught force, speed of walk and power output of a pair of Madura cattle ploughing on a medium clay soil.

connecting the draw bar to the yoke. The relationships between the soil shear strength and draught force, walking speed and power output are shown in Figure 1. Although the relationships between the variables measured and the soil shear strength were not linear, there was a tendency that draught force and power output increased as the soil shear strength increased. Further studies are needed to develop the concept into a practical method of predicting draught force and power output from values of soil shear strength.

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Draught Performance of Water Buffalo and Cattle in the Philippines

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Abstract

While buffalo and cattle provide the bulk of power input for all farming systems in the Philippines, little attention, in terms of research and development, has been given to understanding and improving the draught capacity of these animals. In this paper, results of a number of research trials on the draught capacity and physiological response of the Philippine water buffalo or the carabao and their grades of Murrah and Nili-Ravi are summarised, and those of the first studies to be conducted on Philippine draught cattle in a lowland rice-based system are reported. In general, the carabao and their crossbreds are comparable in terms of resistance to work stress and docility. Cattle and carabao can generate the same draught power equivalent to 15% of bodyweight, but were found to be physiologically more comfortable with draught output equivalent to 11% of bodyweight.

Introduction

WATER buffalo and cattle are recognised as indispensable allies of small farmers in Asian countries, being the main source of farm power. In the Philippines, the carabao, followed by cattle, are normally used to plough, harrow, level and puddle fields, thresh rice, transport cane, coconut and other farm produce, extract cane juice and for many other uses. Of about 2.7 million water buffaloes, 99% are in the hands of small farmers (Momongan et al. 1990) as are about 80% of the 1.7 million cattle. Together, these animals are estimated to provide 3×10^6 hp for farm use.

In spite of research and extension effort by government agencies to attain a level of agricultural mechanistion technology higher than that of human and animal power, draught animal power (DAP) will remain and continue to be the major source of energy in small farms in the foreseeable future. The alternative, that of pursuing mechanised farming involving massive importation of engines and spare parts, will drain foreign exchange reserves, deprive rural workers of agricultural employment and subject farmers to continued poverty. The low purchasing power of the small farmers, the shrinking farm holdings, the lack of farmer technical abilities and the seasonality of draught usage are hindrances to mechanised farming in most developing countries. In 1980, FAO estimated that agricultural production should be doubled by the year 2000. Consequently, the small farms of the developing countries must substantially increase energy inputs if this goal is to be met. It seems that even with massive government effort to increase the level of mechanisation, the transition will be a slow process considering the financial and social implications of replacing DAP. Furthermore, DAP will have its own niche in the farming systems in terms of economic, technical and social features, as does mechanised farming in other circumstances. Finally, the farmers themselves perceive the decrease in DAP will result in delay in farming operations and decrease in area cultivated (Alviar and Elauria 1990). Hence DAP will remain for a long while to be the mainstay of energy sources in small farms in the Philippines and Asia in general.

DAP Research in the Philippines

Carabao

There is a paucity of information on the draught ability of

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the carabao and more so on cattle. Of the many factors that affect the maximum pulling capacity of draught animals, liveweight and therefore genotype has the greatest influence. Normally, the continuous drawbar pull capacity of an animal is directly proportional to its liveweight and corresponds to about 1/10 of the liveweight (Chang Cheu-Shang 1964; Hopfen 1960). In 1964, Lantin conducted the first bioenergetic study of the carabao with liveweight ranging from 495 to 511 kg. He reported that the carabao could generate 0.48 hp at 40 kgforce (kgf) pulling load to 1.38 hp at 100 kg pulling load over soil covered with moist grass. No marked changes in power output were noted during the 2-hr work period. It was then concluded that the efficient working horsepower rating of the carabao ranged from 0.8–1.2 hp. Speed ranged 3.64–4.00 km/hr and was not affected by loads varying 40–100 kgf. In another study conducted under actual ploughing of wet and dry land, the draught performance of mature Philippine carabaos and Philippine carabao-Murrah crossbred steers (520 kg, 4–7 years old) was determined (Garillo et al. 1987). The type of land ploughed and genotype of draught animals used had no significant effect on the draught force developed which ranged 49–54 kg and drawbar horsepower generated ranging 0.34–0.40 hp. The same animals required 7.14–8.89 hours to work 1/4 ha at a depth of ploughing of 12 cm and width of 18 cm. In Kwangsi, China as reported by Chantalakhana (1980), swamp buffalo had a draughting power of 65.0 kgf while that of Murrah was 88.6 kgf. However, these draught power ratings were equivalent to 16.0 and 16.5% of the liveweight, respectively. While carabao x Murrah or Nili-Ravi crosses are heavier by 22.7% at birth and 40% at two years of age than the Philippine carabao (Parker et al. 1986), the draught performance, in terms of resistance to work stress and docility, was found to be comparable between the two genotypes (Momongan et al. 1989).

The physiological responses between the carabao and its crossbreds, in terms of pulse rate, respiration rate and body temperature (PRT), did not differ significantly before, during and after ploughing (Garillo et al. 1987). Similarly, PRT values were not significantly different between the carabao and its crossbreds of Murrah and Nili-Ravi when used as pack animals carrying a load equivalent to 20% of the bodyweight over 6 km. The provision of wallow resulted in lower initial and final respiration and body temperature of the buffaloes and, likewise, stimulated the animals to walk faster (de los Santos and Momongan 1989). Similar results were reported when carabaos and their grades were made to pull a sledge with a dead load equivalent to 50% of the bodyweight over a distance of 1.6 km.

Cattle versus carabao

Draught usage and feeding management

While cattle, mostly Zebu upgrades, are typically used for draught in the upland, there are no available data on the draught capacity of these animals. The first attempt to investigate cattle for draught in the Philippines was started in 1988, involving survey and intervention trials to determine the feeding management and draught usage of typical grade cattle and carabao and to compare their draught performance under a rainfed lowland condition in the village of Carosucan, Sta. Barbara, Pangasinan. The cropping pattern at the test site is rice–mungbean. Draught animals are used heavily in July for the rice crop and in October and November during rice harvest and land preparation for mungbean. Cattle and carabao holdings average 1.4 animals/farm or a stocking rate of 1 animal unit/ha for the whole village. This site was ideal for DAP study since both cattle and carabao are used by the farmers for lowland rice and mungbean production. A preliminary study conducted during the 1988 crop season showed that cattle, more specifically bulls, were used at an average of 341 and 42 hours for rice and after rice crops, respectively, whereas carabao were used for 417 and 59.

In a subsequent study during the crop season of 1989, the feeding regime, liveweight change and draught usage of six each of cattle and carabao were monitored. Results showed the draught animals lost weight in July and September and then again in November and December. Since grass was in abundant supply in July, the loss in liveweight during this period could be mainly attributed to the heavy work demand for rice cultivation (Figure 1). On the other hand, the liveweight loss recorded in November and December could be due to both the effects of work and the low quality of feed supply. During this period, rice straw constituted as high as 86% of the total feed offered. The daily duration of tethering ranged 0–6 hr for cattle and 0.4–5.6 hr for carabao and was influenced more by availability of tethering area rather than that of forage.

This was followed by the testing and refinement of a methodology for draught measurement using a sledge coupled to a dynamometer attached to a single tree. The procedure was described in detail by de Luna and colleagues (1990). From this experiment, the following factors or constraints were encountered and adequate measures that are practical under farm conditions were taken into consideration for the succeeding study.

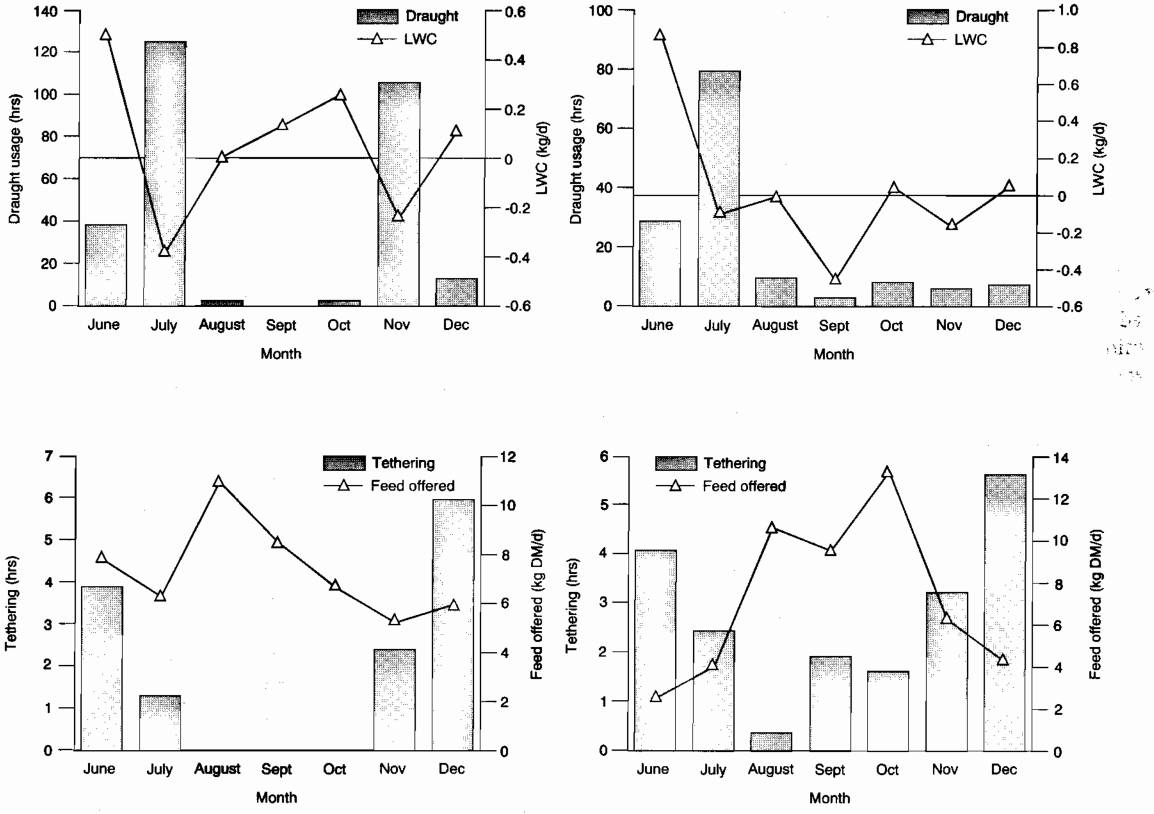

Figure 1. The average monthly draught usuage, liveweight change, feed offered and tethering of cattle (a) and carabao (b) in upland rice-basedsystems of Carosucan, Sta. Barbara, Pangasinan, Philippines.

Factors	**Variables**	**Considerations**
Weather/climate condition	temperature; humidity	conduct test in shortest possible time
Field condition	soil texture; amount of soil moisture	use of oval tract
Test animal	management practices; body physique; work experience	strict selection of experimental animals
Operator/farmer	experience in DAP use; attitude	selection of motivated cooperators
Implement	type of implement type of operation	use of sledge

Table 1. Mean pull, draught, speed, and power of cattle and carabao.[a]

	Pull (kg)	Draught (kg)	Speed (m/sec)	Power (hp)	Draught (% of BW)
Cattle	81.8±0.8	74.7±0.8[b]	0.97±.01	0.69±.01	15
Carabao	82.2±0.9	77.6±0.8[c]	0.97±.01	0.72±.01	16

[a] Least square means ± least square SE.
[bc] $p < 0.02$

Draught capacity and physiological response

In a study conducted in the wet season of 1990, the draught capacity and physiological response of four each of farmer-owned grade cattle (421–578 kg LW) and carabao (437–532 kg LW) were compared in a 2 x 5 factorial experiment in completely randomised design, with species and draught loads as the main factors. The animals were allowed to continuously pull dead loads from 50, 100, 200, 250 and 300 kg for 10 minutes each in an oval tract. However, the animals resisted pulling the 300-kg load. Each animal was tested both in the morning and afternoon from 0600–1000 and 1500–1800 hours, respectively, for all loads. The average relative humidity and temperature were 80% and 26.8°C in the morning and 49% and 34°C in the afternoon. PRT measurements were taken after each test run, except at 150-kg load. The data were analysed using a General Linear Model Procedure.

Table 1 shows the mean pull, draught, speed and power of cattle and carabao. While the carabao developed significantly higher draught than cattle, the power generated by both animals was not significantly different. Computed as a percentage of the liveweight, draught was equivalent to 15 and 16% for cattle and carabao, respectively, and ranged from 5% at 50-kg load to 30% at 250 kg. These values are within the range of values given by Swami Rao (1964), as cited by Pathak (1985), for cattle and by Goe and McDowell (1980) and Lantin (1964) for water buffalo. Increasing dead loads correlated positively with pull, draught and power but inversely with speed (Figure 2). Also, results of this study did not show significant differences in speed between cattle and carabao. This explains the similar draught power output of cattle and carabao, since speed is equally important as draught in power measurement (Pathak 1985). Further, it was observed that the carabao appeared to be more docile and to behave and work more consistently than cattle. This may be attributed partly to the more uniform body conformation, probably due to genotype, of the carabao than cattle. While the cattle used in the experiment were all Zebu grades, based on physical features, their body conformation and build were different from each other as there exists a bigger pool of genotypes for cattle than carabao. There were no species x load interaction effects.

Table 2 shows the mean pulse rate, respiration rate and body temperature of cattle and carabao. Respiration rate was significantly faster for carabao than cattle when subjected to work stress. This is in agreement with the general observation that carabao are physiologically more susceptible to heat stress, whether associated with solar radiation or work (Mason 1974; Chaiyabutr 1990). Bhatnagar and Upadhyay (1991) also reported that cows subjected to work stress exhibited only a slight rise in pulmonary ventilation. Furthermore, our carabao were not provided access to a wallow, which is a major compensatory mechanism for heat dissipation.

All PRT values increased with increasing draught at varying rates (Figure 3). Pulse rate increased by 34% from 50 to 100-kg loads and by 40% and 20% from 100 to 200 and 200 to 250 kg, respectively. Respiration rate increased by 66% from 50 to 100 kg load and by 80% from 100 to 200 kg. Table 3 shows that the animals exhibited a significantly faster pulse rate and respiration rate when pulling 200 and 250 kg loads compared with 50 and 100 kg loads. The animals resisted pulling loads of 300 kg. The 200-kg-load resulted in a draught force of

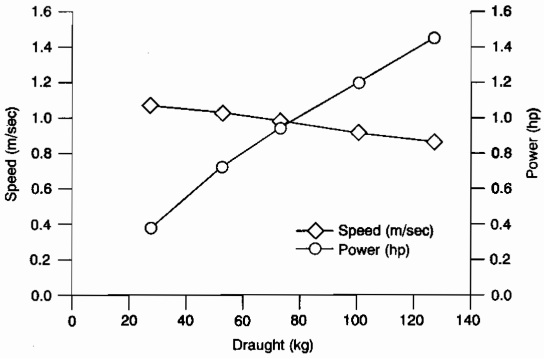

Figure 2. The mean speed and power developed by cattle and carabao with increasing draught force.

Table 2. Mean pulse rate, respiration rate and body temperature of cattle and carabao[a].

Species	Pulse (beat/min)	Respiration (blow/min)	Temperature (°C)
Cattle	77.8±4.1	43.4 ± 3.9^{b}	38.8±0.1
Carabao	85.8±4.3	58.8 ± 4.0^{c}	38.5±0.1

[a] Least square means ± least square SE.
[bc] $p < 0.01$

100 kg or 20% of the bodyweight and 0.91 hp, whereas a 100-kg-load generated draught of 52 kg or 10.8% of the bodyweight and power equivalent to 0.53 hp. It was observed also that the animals tend to become uncooperative and temperamental when required to pull dead loads of 200 and 250 kg, resulting in poor animal–handler coordination. Physiologically, the animals seem to be more comfortable with loads less than 200 kg. Considering the average body weight of the carabao at 470 kg (de Guzman 1982) and draught cattle at 490 kg, the equivalent draught power generated is 52 and 54 kg, respectively. This is more than the required draught force of 30 kg to plough rice fields (Chantalakhana et al. 1990).

A total of six each of farmer-owned grade cattle and carabao were used in an experiment to determine the effect of rice bran supplementation on the draught response of cattle and carabao. All the animals were managed similarly except that three each of the cattle and carabao were given rice bran as a supplement at 0.5%of the bodyweight and the others served as control animals for six months. Measurement of PRT was taken before and after the animals were allowed to plough the paddy soil for 20 minutes.

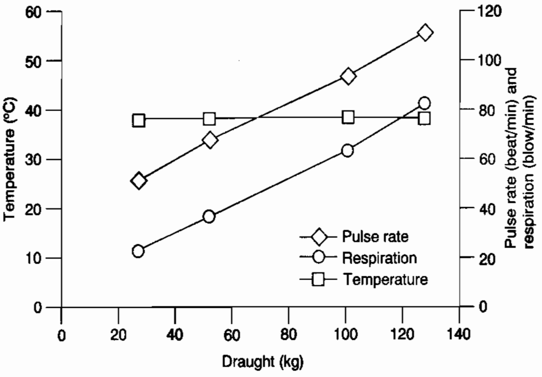

Figure 3. The mean pulse rate, respiration rate and temperature of both cattle and carabao as affected by increasing draught force.

Table 3. Mean pulse, respiration and body temperature of cattle and carabao at different draught loads.[1]

Load (kg)	Pulse (beat/min)	Respiration (blow/min)	Temperature (°C)
50	50.9 ± 5.9^{a}	21.5 ± 5.5^{a}	38.2 ± 0.2^{a}
100	68.0 ± 5.9^{a}	35.8 ± 5.5^{a}	38.5 ± 0.2^{ab}
200	94.6 ± 5.9^{b}	63.5 ± 5.5^{b}	38.9 ± 0.2^{b}
250	113.6 ± 6.3^{c}	83.6 ± 6.0^{c}	39.0 ± 0.2^{b}

[1] Column means with different superscripts are significantly different ($P < 0.05$).

Supplementation with rice bran had no significant effect on the liveweight of either cattle or the carabao. Table 4 shows the PRT values taken before and after work and their differences. There were significant animal x treatment interaction effects on differences in pulse rate, respiration rate taken after work and difference in respiration. The increase in pulse rate and respiration rate was lower in carabao given supplement when subjected to work stress compared with cattle. This may be partly attributed to the ability of the carabao to utilise low-quality feeds more efficiently than cattle (Kennedy 1988) and when the animals were working (Ffoulkes et al. 1986). There is also evidence to show that draught buffaloes in good body condition resulting from better nutrition utilise metabolisable energy more efficiently than those in unfit condition (Teleni and Hogan 1989).

Research considerations

With reference to draught measurements, DAP experiments when conducted on-farm or on-station differ in many ways, making it almost impossible for results to be compared. Based on our experience, the following observations, among others, are deemed important considerations in the interpretation of results of DAP studies done on-station and on-farm: 1) difference in the parameters used by the researcher and the farmer in the selection of draught animals for testing, 2) lack of control over experiments in terms of time and degree of draught usage when farmer-owned animals are used, and 3) variation in the level of training of animals and of animal–handler association. Since on-farm animal research is probably the best means by which a certain technology can be ascertained acceptable to the farmers, as it subjects the prospective technology to actual farm conditions, there is a need to develop an appropriate in-field draught methodology to hasten the transfer of draught technology from research stations to the small farms.

Table 4. Mean pulse rate, respiration rate and body temperature of cattle and carabao taken pre-and post-work[a].

	Pulse rate			Respiration			Temperature		
	Pre-work	Post-work	Difference[b]	Pre-work	Post-work[c]	Difference[d]	Pre-work	Post-work	Difference
Cattle									
Control	50.7	57.3	6.6	26.7	44.0	17.3	37.8	39.0	1.16
Intervention	44.7	58.0	13.3	26.7	49.3	22.6	38.2	38.6	0.5
Carabao									
Control	42.6	60.0	17.4	28.0	62.6	34.6	38.0	38.7	0.7
Intervention	45.3	55.3	10.0	22.0	31.3	9.3	38.3	38.7	0.4
SE	2.1	2.2	2.4	3.0	6.3	5.6	0.3	0.4	0.5

[a] Least square means

[b] Animal x treatment interaction ($P< 0.02$)

[c] Animal x treatment interaction ($P< 0.02$)

[d] Animal x treatment interaction ($P< 0.03$)

Conclusions

Results of these studies suggest that at the same liveweight, cattle and carabao are capable of generating the same power output, although the latter may require more intermittent rest periods to allow them to dissipate accumulated body heat. Furthermore, the results indicate that both cattle and carabao can generate draught equivalent to 11% of the bodyweight without reaching the maximum work stress condition.

Acknowledgments

The authors gratefully acknowledge the International Development Research Centre (Canada) for financial support in the conduct of research on draught cattle and carabao at Sta. Barbara, Pangasinan, Philippines. We also knowledge the assistance of Ms A. S. Sarabia in the preparation of this paper.

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Finding a Way Through a Maze of Methods for Evaluating DAP: an example of the use of FSR techniques for DAP research in Indonesia

John Perkins* and Neil Sturgess†

Tactical research is conducted for many reasons — to seek solutions for expressed or perceived problems or to find appropriate means to achieve a desired outcome. This paper follows the development of one research project charged with analysing the role of draught animals in Indonesian smallholder farming systems. It concentrates on research into the economic aspects of these systems and, in particular, methods used to collect the information needed to answer economic questions.

All research is driven by some 'need to know'. Objectives are set and raise researchable questions. The information required to explore these questions is defined and researchers plan a program of activities which, it is hoped, will yield data that contribute to some resolution. Most research is diffusive. Seeking information to answer one set of questions usually raises more points which require further lines of investigation and different methods of study. Researchers work with limited resource time, in particular, and must make decisions to allocate these resources to meet changing information needs. At the end of a project it is possible and useful to question what happened. Did the research methods yield profitable results, i.e. was the value of information gained worth the effort expended? What was learnt? Could it have been done better or differently?

Every technique used in this project worked. Data were collected and analysed; papers were published. Total understanding of the role of draught animals expanded and deepened. With the value of hindsight it is also apparent that some techniques proved cumbersome and expensive and that some of the most useful outcomes came from intuitive flashes based largely on informal and anecdotal evidence. Little of this could have been predicted at the outset.

There is no one best method to research draught animals and their place in farming systems. The paper summarises the methodologies used in the many studies that were undertaken, comments on their results and effectiveness and indicates where they next led the participants. The Appendix lists some key areas for which any researcher in draught animal systems should seek information. The techniques to gain such information are infinite in variety. What we found, above all, is that nothing beats the requirement to think hard on the real question, 'Why am I doing this?' Better resolutions of that question lead to better work.

First Steps

The decision whether one is assessing just draught work or all aspects of animal management is a critical choice. To address only those factors affecting work in the field severely limits the scope for research. The main factor limiting draught work is the (total) weight of animal(s) involved : working animals can overcome a draught force equivalent to some 11–14% of their body weight(s). Heavier (or more) animals can pull heavier implements. The ideal draught team would thus comprise large mature male cattle or buffalo. Nutritionists would concentrate on the diets required to raise and sustain such animals in peak condition; engineers could try different types of equipment to test the transfer of force from the animal through to the ground; economists could tinker at the edges, looking at least-cost diet formulations or pricing alternative harnessing systems.

Limiting ourselves to draught matters alone would have distorted the picture. To give just one example, most draught work in Indonesia is done by cows. Bulls or bullocks are used but the majority will have been slaughtered at two years or younger — why?

The Indonesian-Australian DAP Project was committed to a Farming Systems approach: draught animals

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within smallholder systems. Collaborators came from a range of disciplines and there was genuine group participation in the discussions that shaped the direction of total research activity. Those involved in economic aspects chose to address the question 'Which activities relating to total utilisation of cattle and buffalo will offer the greatest potential for increasing farmers' net income?'

Defining the Scope of the Study

As with any research study time must be spent on developing a picture of how things work. All participants had conducted some research work in Indonesian villages and knew something about DAP, but none had studied the subject to any depth. Building a background followed typical paths : locating and reading published

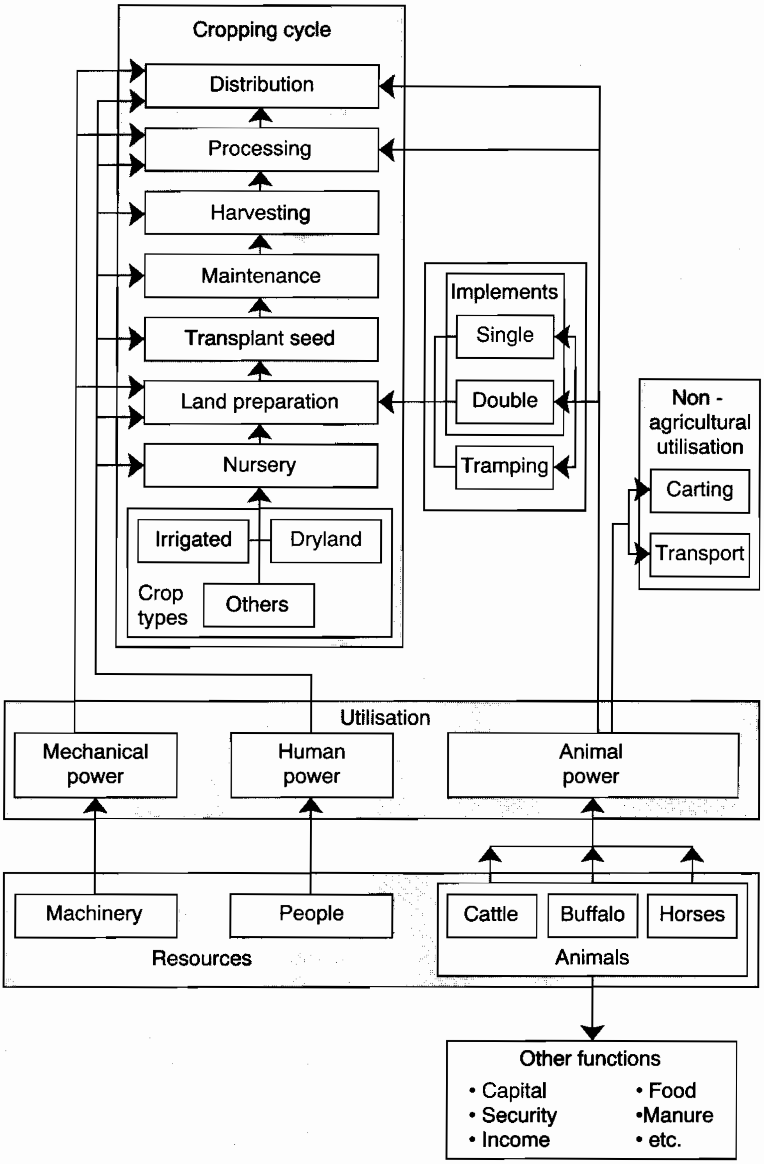


Figure 1. Sources and utilisation of power in Indonesian agriculture.
Source: Basuno (1991)

data and pooling experiences for discussion. Most useful were field visits to farms and villages, simply to observe what farmers did with their draught animals, ask basic questions on management and become familiar with equipment and tillage practices.

The value of simple, accurate and unbiased observation should never be underestimated. As Chambers (1983) suggested, such first impressions are usually the strongest and provide the basis for much analysis regardless of what follows. In our case we decided to make an informal video record of one day's work for a DAP team. With the help of Pak Mardi and Pak Santo, two village ploughmen from Pandansari village, West Java, we recorded the whole tillage sequence from starting for work at 0600 hours through harnessing, ploughing, levelling and cleaning-up. Following these activities introduced us to types of implements, the use of hired labour for hoeing, relationships between the owner of the field and the hired ploughmen and estimates of approximate rates of work. All this was done in seven hours with a sample of two ploughmen working two measured fields. As an introduction to the topic it was the cheapest, least formal part of the whole study and we never again learnt so many valuable things so quickly and so easily. Certainly, the sequence or type of tillage operations would vary or price levels change in different locations but many of the important patterns of events and relationships between animals and other parts of the system can be established by sitting on the edge of a field, watching people do their work and chatting with them when they have finished.

The background work led to a better understanding of draught animals in the farming system but also highlighted the diversity that exists at every point.

The major sources of power for Indonesian agriculture are summarised in Figure 1.

Locating power within the Indonesian systems directed the first research decisions. At the outset it was felt that any work would need to incorporate the study of variables listed in Table 1.

Table 1. First impressions of information requirements.

Area	Justification
Irrigated crops (mainly rice)	Most areas use DAP to prepare at least some of their ground for flooded (either irrigated or rainfed) rice production. DAP for land preparation of dryland crops certainly occurs and can be common at some locations. Given the wider cropping of rice and the particular requirements of tillage in flooded soils, rice production must be represented. To pick up dryland cropping would be a bonus.
Cattle and buffalo	Both are used for DAP. Horses are also used but only at a few locations. There is some argument whether cattle or buffalo are 'better' — neither can be excluded.
Single animal and double animal units	Some farmers plough with one animal, others use teams of two — why? Are there differences in terms of work rate, coverage? From an economist's viewpoint one cow or buffalo is half the investment cost of a double animal unit. Are there economic grounds which underpin the farmers' choices?
Equipment types	There are a few basic types of DAP implements but many varieties of each type — are these differences significant?
Animal power and hand labour	Much land for flooded rice production is prepared by hand labour alone — why do some farmers not use animals? Mechanical power is also used but is not yet an important power source for most villages.
Animals or no animals	Many farmers obviously prefer not to raise cattle and buffalo at all—why ? What are they loosing; what are they gaining?

Site Selection

Site selection was a joint exercise involving all disciplines in the study. The economists hoped to have the factors listed in Table 1 represented at the site and to these were added requirements covering nutrition, reproduction and more. The selection process has been described by Santoso, Sumanto, Rusastra et al. (1987). In terms of methodology it inevitably relied on secondary published material supplemented by visits to possible sites and interviews with local village leaders, farmers and extension staff (see Table 2).

Table 2. Site selection process.

Secondary	Agroclimatic classification using maps and published data; livestock population densities and distribution; farming systems classification; irrigation systems; topography.
Additional	Visits to possible sites; farm and village walks; discussions with farmers, extension officers and others.

Final site selection is both a quantitative and qualitative process which must include expressed willingness to participate by farmers and the village community. The main requirement is that the site, or sites, be reasonably representative of some commonly-occurring farming systems. This was particularly important for those concentrating on the economic aspects as circumstances would limit our study to one main site. It was already apparent that the draught component of most farming systems was relatively small. The evaluation of this component within the whole farm would require the collection of specific and detailed data, which is an expensive and lengthy process.

Site Description

Once sites are selected the next step is the construction of more detailed agroeconomic profiles. This follows the typical pattern of FSR work, building a first profile that becomes modified, broadened and deepened as research progresses.

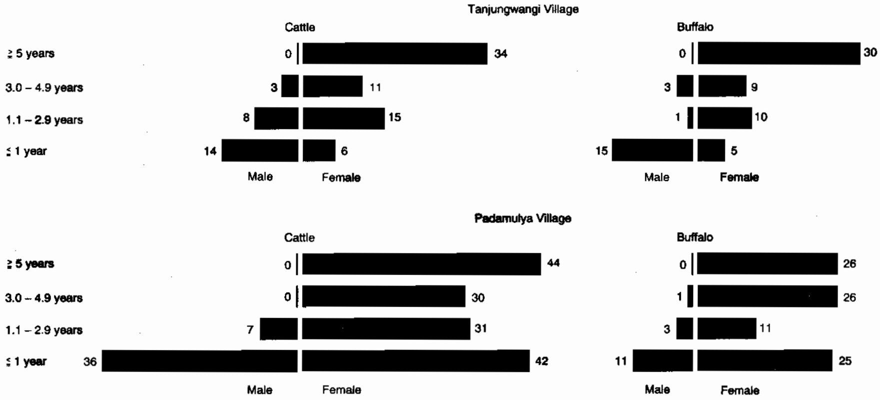
All participants again contributed to a common pool of information, using existing data supplemented by field observation and discussions with farmers, extension staff and key personnel. One study commissioned by the economists was a census of all ruminant-rearers in the two selected villages. The village office maintained statistics on cattle and buffalo populations but there was a belief that these overstated the numbers. Conducting a quick census would improve baseline statistics of obvious importance (Table 3).

The census was very effective. Few questions were asked, allowing quick administration and tabulation. An example of the results is given in Figure 2. The most useful results included the points that:

- cattle and buffalo populations were some 40% less than indicated by 'official' village statistics;
- households with large ruminants reared two or three head; none reared more than four;

Table 3. Census of ruminant-rearers.

Objective	Collect appropriate data from all households currently rearing cattle and buffalo.
Data types	Household size; number, sex and estimated ages of all cattle or buffalo reared by the household.
Respondents	c.200 households.
Enumerators	Four.
Length	About four weeks to visit all households; part-time — a part of all site description activities.



Source: Santoso, Sumanto, Perkins et al. (1987). Sumanto et al. (1987)

Figure 2. Distribution of cattle population by sex and age in two villages, 1988.

- the village cattle and buffalo populations were dominated by mature females (very few mature males were kept in either village and had restricted access to females, which has obvious implications for breeding and replacement); and
- most households operated a total of less than 0.5 ha of irrigated and dryland fields, and the distribution for non-rearers was similar (not much land needed ploughing by any one farmer).

When combined with other results from the compilation process a challenging profile for research developed. Only 6% of households in one village and 11% in the other reared cattle or buffalo. Most farmers preferred not to have large ruminants on their farm yet many would use them for land preparation. Those farmers with draught animals estimated that they used them for some 30–40 days of the year : 365 days maintenance for 35 days of work. This reinforced the benefit of examining draught animals within the system and led to two hypotheses for examination.

- For most farmers the net income from large animal management is lower than the net income available from other enterprises. Cattle and buffalo may well be 'profitable' but appeared relatively less profitable than other options.
- Most farmers prefer to rent-in animals for draught work, leaving the business of livestock management to others. It might pay to rent but not to rear.

The final lesson worth highlighting was the variability found in most factors examined — inputs, outputs, quantities and management. The farming systems within each of the two villages, for example, were similar in terms of crops grown and cropping patterns. But the means of achieving results could vary widely, even on adjacent fields. One example was farmer-stated preference for land tillage practices. Three main implements were used in the villages (the plough 'bajak', harrow 'bugis', and leveller 'garuh') but there was no standard pattern of use, either of implement type or frequency (Table 4).

The first parts of the project brought up more questions than could be answered with available resources. Some very promising avenues were never fully researched, e.g. access to irrigation water was probably the single greatest constraint to individual household incomes within the site. For the economic issues surrounding draught animals, these objective-seeking studies threw up the research areas discussed in the rest of the paper, these being: technical efficiency (two studies), farm modelling, the markets for meat and muscle, valuations of cattle and buffalo, livestock inventories and calf models.

Technical Efficiency Study, Java

The impression gained in the preliminary work was that farmers were generally efficient in the use of their resources, including DAP. This was obviously worth testing. But, might some be better at the job than their peers? If a more efficient group existed within the one farming system they might be utilising proven techniques that, through extension, could be made known to others and increase the efficiency of all through local technology transfer.

Table 4. DAP tillage practices for flooded rice production, Tanjungwangi village.

Usual pattern of DAP operations	**First wet season planting** (Nov–Dec)	**Second wet season planting** (Apr–May)	**Dry season planting** (Jul–Aug)
		All DAP rearers (%)	
Plough twice, level twice	42	33	–
Plough twice, level once	20	22	–
Plough once, level once	38	42	15
Plough twice	–	–	5
Plough once	–	3	25
Total	100	100	45

Source: Santoso, Sumanto, Perkins et al. (1987)

Frontier production functions were used to test these hypotheses. The technique is to look at the outputs achieved (production of irrigated rice, in this case) from a given bundle of measured inputs (such as labour, fertilizer and DAP) for a group of farmers operating within a similar set of resource constraints. 'Efficient' farmers will be those achieving the maximum output level from these inputs; 'inefficient' farmers are those whose input-output performance falls behind (Esparon 1989; Esparon and Sturgess 1989).

The technique requires detailed data which can be expensive to collect. A very large study had been recently completed in Indonesia, collecting farm management data from a panel of more than 2000 farmers. The data had already been entered and stored on tape at the Centre for Agro-Economic Research in Bogor. It looked appropriate for the task and offered the prospect of cutting time and collection costs. Analysis started with data from four West Java villages and was later extended to four sites in East Java (Table 5).

Table 5. Methods used for technical efficiency study, Java.

Objective	Estimate frontier production functions for irrigated rice production by village farmers, including DAP usage as one of the selected bundle of inputs.
Date	Secondary — collected previously for the National Panel of Farmers (PATANAS); farm management data; questionnaire-based data; 3–6 months recall required of farmer respondents.
Sample	Total PATANAS sample >2000 respondents; subsamples of 60–80 respondents from each of four selected villages in West Java and four villages in East Java.
Benefits	Zero collection costs for the DAP project; standard collection format.
Problems	Examples of missing, erroneous or inappropriate data; extensive checking, editing and treatment to convert data to required format.
Length	12–18 months (part-time) for data treatment, entry and checking.

The study provided analyses of great value and interest but at a much greater cost than originally anticipated. As with any third-party data the figures were never exactly as required. Months of work were needed to convert the original data to a format suitable for analysis. Problems were raised in data checks — missing data, erroneous data, mispunched data and data recorded in different formats for different villages. Tracing these problems required, in many cases, going back to the original questionnaires and even back to the original enumerators.

Such an exhaustive editing process inevitably brings other problems to light. The original questionnaires, administered through enumerators, were extremely long, detailed and exhaustive. Completion would have been a tiring process for both respondent and enumerator, which predisposes haste and error. They also covered a 3–6 month recall period, adequate for major tasks and activities but less accurate for the profusion of detail that was requested.

The whole process did not prove as quick or cheap as originally expected. There were certainly no costs of collection but these benefits must be set against the massive use of time. As with any third-party data the advice must be to use it for background but, for detailed analysis, use it only if it really fits the bill.

As stated, the major conclusions were of great value, in particular, that:

- all farmers were judged to be technically efficient within their environment and given their level of technology; and
- no particular group of farmers could be identified as operating at a significantly higher plane of efficiency, which appeared to limit the scope for technology transfer within the peer group but left open the options of transferring technology between systems or introducing new technologies.

Technical Efficiency Study, Lombok Island

Technical efficiency analyses were used for a supplementary study at another location on Lombok Island, east of Bali. Land in the southern part of the island had traditionally been prepared for rice cultivation through *merancah*, walking or running groups of buffalo around flooded fields until the land is sufficiently trampled and softened to transplant rice. The use of DAP (cattle, plus implements) had originally been introduced by Balinese farmers in the north of the island and was becoming more widespread. In some southern villages it was possible to see *merancah* and DAP used on adjacent fields and often on the same field. Research questions of obvious interest were raised. Was there any evidence of greater technical efficiency for either system (measured as rice yield) or different costs for tillage?

The study was conducted by a postgraduate student, thus both funds and time were limiting factors. Neither prolonged nor extensive monitoring was possible. One important decision was the choice of the basic sampling unit. In the PATANAS surveys farmers (or farms) were compared; for the Lombok study the ricefields were selected as the items for comparison. Early experience with PATANAS had indicated data problems. Most information was based on recall and, apparently, few items were physically measured. This is a completely acceptable method if 'close enough is good enough' is the standard of accuracy required. For the Lombok study the objective was to compare efficiency and costs on a standard unit which, in this case, was determined as land area. The student measured each selected ricefield with tape and compass and then tallied inputs entering those fields and outputs leaving them. By such means it was hoped that the per ha estimates would be of reasonable accuracy and compensate for the small sample size (Table 6). The study produced four interesting results.

Variability

The level of each measured item varied, from field to field, by large amounts (Table 7). The minimum labour input was one-third of the maximum recorded; animal power inputs varied by a factor of four; fertilizers by a factor of ten (after converting fertilizer inputs to monetary values to cover the cocktails of varieties that were applied). The highest yield recorded was more than six times greater than the minimum of 1.26 t/ha.

All plots were sown with one of two modern rice cultivars, many fields shared common boundaries, all were rainfed, and variations in the physical environment were negligible. Recordings were timely, accurate and yielded reliable data. The differences observed were 'real' differences and extremely difficult to explain.

There was evidence of response to fertilizer (but the most-fertilised field yielded 4t, only half the level of the maximum recorded) and a weaker response to total animal power. There were obviously other important explanatory variables including the depth and availability of water, which could not be measured.

Table 6. Methods used for technical efficiency study, Lombok.

Objective	Compare use of DAP (with implements) with trampling, in flooded rice production systems.
Data	Primary; estimates of defined inputs and outputs in measured ricefield areas; one complete rice production cycle; maximum recall period of one week for respondents.
Sample	Total of 21 ricefields in three locations; maximum of one km between locations.
Enumerators	One researcher; two assistants; part-time work which matches activity cycles.
Length	Data collection, editing and computer entry — five months.
Benefits	Reliable data of high accuracy; rapid data collection; limited range of data facilitates editing, correction and computer entry; quick reporting possible.
Problems	Small sample size – inappropriate for tests of statistical significance.

Table 7. Maximum and minimum input and output levels recorded, Lombok survey.

	Minimum recorded (per ha)	(yield)[a]	**Maximum recorded** (per ha)	(yield)[a]
Inputs				
Animal use (animal hours)	187	(1.3)	730	(5.5)
Human labour (hours	608	(5.3)	2 025	(4.0)
Fertilisers (rupiah)	10 000	(2.1)	101 700	(4.0)
Chemicals (rupiah)	0	(2.7)	25 000	(1.8)
Output				
Unhusked rice (kg)	1 255		8 375	

Source: Sarwono (1988)

[a] Figures in parentheses show the yield (t/ha) obtained from the ricefield on which this variable was recorded.

Technical efficiency

The Lombok data were subjected to the frontier production function analysis used with the Java data. Not surprisingly, no 'frontier of efficiency' was established because the inherent variability swamped the technique with 'noise'. Some points were of great interest, however. Although there was some response to total animal power (more animal hours preparing land was positively associated with higher yield) there was no relationship to technique. DAP and *merancah* were completely substitutable with respect to power input and final yield.

Economic efficiency

The two techniques proved both technical and economic substitutes. There was no real difference in rental costs between DAP and *merancah*. This confirmed the growing suspicion of a general market for power. Land could be prepared by a number of means and market forces would tend to produce a similar level of costs for using any alternative source of power.

Factors off the field

The data indicated technical and economic substitutability for the two techniques under study. Yet the researcher's forecast was that *merancah* would eventually be replaced by the use of DAP. The reasons came from less definable factors that are never easy to measure. A *merancah* group comprises some 8–25 buffalo (and farmers recalled that, in previous years, the groups were larger) which are maintained on 'spare' land areas which are progressively being converted to cropping. Spare land was now more distant from the villages and buffalo were becoming more time-consuming and costly to maintain for *merancah*. The market for power kept them competitive on the field but the total costs of maintenance foreshadow the demise of the system.

These propositions again underscored the value of keen listening and good observation. Informal methods of gathering information may be derided by purists but are capable of yielding very significant insights.

Farm Modelling

Farm modelling involved the largest data collection exercise of the whole project. Preliminary work at the selected West Java site had confirmed that DAP was a relatively small component of the whole system but cattle and buffalo, in total, fitted into other, related subsystems. To test the effects of proposed changes throughout these systems required accurate data of high definition, covering all the farm's economic activities (Table 8).

Table 8. Data collection for farm models.

Objective	Collect data appropriate for use in linear programming models to simulate (a) farms with cattle or buffalo; and (b) farms without cattle or buffalo.
Data	Primary; detailed classification of quantities and prices for all major inputs and outputs: (a) on agricultural land under the household's management; (b) for activities on land under other farmers' management; and (c) for activities outside the agricultural sector.
Sample	A total of 80 farms; 40 each in the two selected villages, of which 30 were farms without large ruminants and 10 with large ruminants.
Enumerators	Four hired staff; one supervising researcher; occasional assistance.
Method	Farmers completed a short daily diary listing inputs used, outputs gained and the monetary values of each. Collected weekly by enumerators for transcription and coding onto weekly farm summary sheets.
Length	Fourteen months of data collection; approximately eight more months to complete checking, editing and entry of data into a computerised database for analysis.
Advantages	Very detailed data of reasonable accuracy; full picture of the complete farm system for each respondent; derivation of good average figures for simulation work; rapid simulation possible once the models are in place.
Problems	Data handling — quantity, editing, entry, management. Lengthy process; heavy use of research time and resources. Constructing and tuning of linear program also time-consuming. Retaining interest of respondents and enumerators.

The study was very well conducted and managed, given the size of the undertaking. The most positive outcome, with regard to methodology, was the use of daily diaries. These were completed by respondent farmers or, frequently, their school-age children. Scepticism is often expressed on the abilities of 'illiterate' peasant farmers to record information. However, the spread of literacy among their children provides an effective alternative. The diaries were short (two pages) and few items required on any day. Some problems were inevitably encountered as to what should be included. These were resolved through discussion and the weekly visit program meant that no problems remain undetected for too long (Basuno and Perkins1988).

The main purpose of the diary was to minimise recall length. There are inevitable losses and distortion of data as the gap lengthens between event and recall. Many long-term recall responses are a 'set' answer — what yield should be; the presumed level of fertilizer; the recommended rate of insecticide. As with the Lombok study the data from the diaries displayed the much greater range of variations that typically occurs in practice.

The main drawbacks to any large-scale long-term monitoring studies are the total consumption of research resources and the mountain of data that is assembled. This exercise took months to reach conclusions (of great value, it must be said) relating both to DAP and general farm management (for example, see Basuno 1989). But other approaches had leapfrogged to similar final conclusions well within that time.

- Changes to DAP field technology (e.g. improving the design of a plough) will have very small positive income effects.
- Changes to the management of inputs required to rear cattle and buffalo (e.g. reducing labour to collect forages) will have larger income effects.
- Increasing the frequency of calving would have the largest income effect. Of course, the models cannot explore how this can be done in systems where most of the males are sold before reaching sexual maturity and females may have intermittent access to those males which remain.

Markets for Meat and Muscle

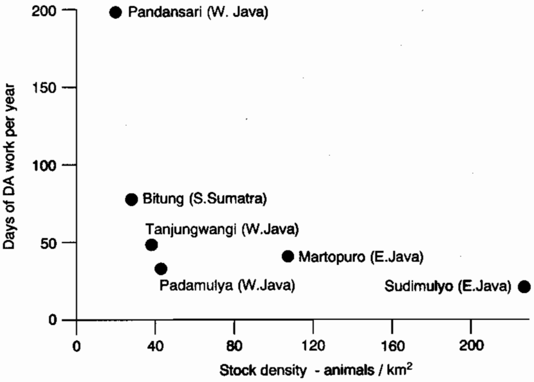
This section is a slight cheat as it involved no methodology or data collection. However, it is important because, early in the piece, it was becoming apparent that the scope for income benefits from changes to the DAP systems was very limited. Observing how people did things, talking to farmers, walking over fields, poking around animal pens, chatting to colleagues, reviewing statistics, conducting studies, assessing early returns, slew of activities (mostly informal) was flooding participants with impressions and ideas. Parts of the jigsaw were starting to fall into place.

The 'meat or muscle' hypotheses can be summarised thus:

- animal power, human power and mechanical power are substitutes for preparing land;
- as substitutes, they are also competitors in the market for power;
- competitive pressures in the market will lead to a set of prices for each alternative method which results in a similar cost of land preparation, whatever method is used;
- increasing the technical efficiency of one power source, e.g. DAP, will reduce the number of animals required at any particular location, for example, a 10% increase in efficiency will reduce by 10% the number of animals required to do the same amount of ploughing.
- the result will be a reduction in the local population of cattle and buffalo required for DAP, though total population numbers may stay unchanged because of the continuing demand for meat. The least likely outcome will be any increase in the population of cattle or buffalo.

This argument indicated that an increase in stock numbers would be achieved only by working DAP animals less efficiently (which is retrograde and unacceptable) or concentrating on non-draught aspects. If cattle and buffalo could be reared more profitably for sale (as 'meat') then the total numbers would increase and more would become available for use in draught work, if so needed.

This analysis was not testable through research: time and resources obviously would not permit a village to be converted to a giant research laboratory for the measurement of such changes. However, data gathered by other participants in the project suggested one hypothesis — the number of days worked per year would be lower at



Source: Petheram et al. (1989)

Figure 3. Average days of work and stocking densities at six sites in Indonesia.

sites with higher densities of cattle and buffalo (Figure 3). In other words, increasing the number of stock on a given land area (with some maximum number of tillage days available each year) reduces the opportunity for any animal to work on the land.

This still left unanswered the question as to which parts of total management were amenable to profitable change but the most significant effect was on the direction of economic research. The monitoring study which at that point had only just started continued to run and came up with similar conclusions, albeit much later. But no further specific draught-related economic studies were conducted. Everything was to concentrate on factors other than draught.

Valuations of Cattle and Buffalo

If we were to determine the management value of cattle and buffalo to farmers it was first necessary to improve information about their market worth. This is not an easy task. Everybody in rural Indonesia has an opinion on the rupiah value of livestock but very few would have counted the banknotes after making a sale.

Indonesian ruminant marketing systems are shrouded in secrecy. There are recognised cattle or buffalo markets and designated days on which animals will be bought and sold. But there are no scales, no auctions and no public declaration of prices. Buyers and sellers (usually traders, rarely farmers) appraise animals by looking, slapping and squeezing. Negotiations are person-to-person; exchange of money is done privately and often elsewhere. We had to put sale values on livestock — which ones were correct?

A study was conducted at Purwodadi market, West Java, counting all animals offered, weighing as many as possible and, for those sold, enquiring after the price paid from both buyer and seller (Table 9).

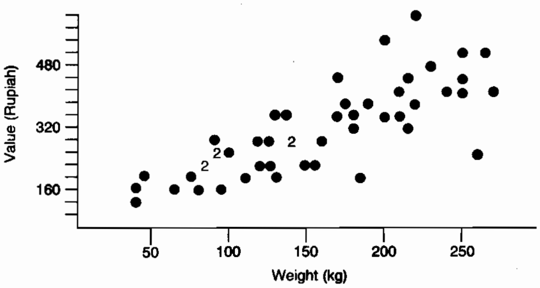
The main advantage of any survey with a limited range of data is the speed with which information becomes available for use. The study ran for three months but analysis was underway within the first four weeks. It was easy to choose the point at which collection could stop — as later data largely confirmed relationships displayed early — and thus save research resources for new work.

The most important outcome was, again, the enormous range in key variables. Asking both participants to each transaction provided some averaging of individual prices per animal, but this did not reduce the variation between individuals.

Figure 4 charts the prices given for 51 female cattle sold in the first few weeks of the study. There is a reasonably strong (and expected) relationship between price and weight : older, heavier cattle are generally worth more than younger, lighter cattle. Running a regression line through the points produces an R^2 value of 63%, thus weight (and age) explain part of the price variation. However, at any weight the value per animal varied by a factor of two; at heavier weights this extended to a factor of three.

Table 9. Cattle and buffalo valuation study, Purwodadi market.

Objectives	Explore weight, price and age relationships for cattle and buffalo at public market close to the DAP survey site.
Data	Primary; livestock weighed on portable electronic cattle scales; sex, condition and estimated age; buyer's and seller's accounts of price paid for cattle sold.
Sample	more than 700 cattle and buffalo offered for sale during study period; 95 'officially' sold.
Enumerators	Two staff, visiting market once per week.
Length	Data collection and editing—three months.
Benefits	Quick study; limited data range to collect; weight, sex and condition information accurate; straightforward analysis.
Problems	Impossible to authenticate price estimates; age estimates useful although obviously impossible to verify.



Source: Semali and Perkins (1989)

Figure 4. Price–weight relationships, female cattle, Purwodadi market.

Many explanations can be offered for such large differences in value — condition, training, pregnancy. Added to these must be the skills of the traders conducting the negotiations and the secrecy with which all such negotiations are conducted.

It was a simple, successful and useful study. Data was accurate for weight but less accurate for price. However, the overall accuracy was better than informal estimates made before. The study indicated that any economic valuation of animals in the system has to allow for variable price outcomes. Budgets should incorporate ±50% liveweight prices when estimating overall returns to cattle and buffalo management. And, finally, uncertainty on final sale price may be an important clue to the reluctance of many farmers to rear cattle or buffalo.

Inventory Study

One problem associated with monitoring studies is the relatively static picture that they portray. A few animals are purchased or sold, two or three are born and there may be an occasional death. The overall impression is of low inputs and low vigour. Indeed, that was our first interpretation of general animal management at the study site. Accepting such a model would point research towards cost-saving, low maintenance aspects of animal husbandry.

It was decided that this informal model needed testing. After all, calves were born — where did they go? Were they retained as future replacements or sold? Were mature animals ever bought? Did farmers keep mature females until they had reached the end of their reproductive life?

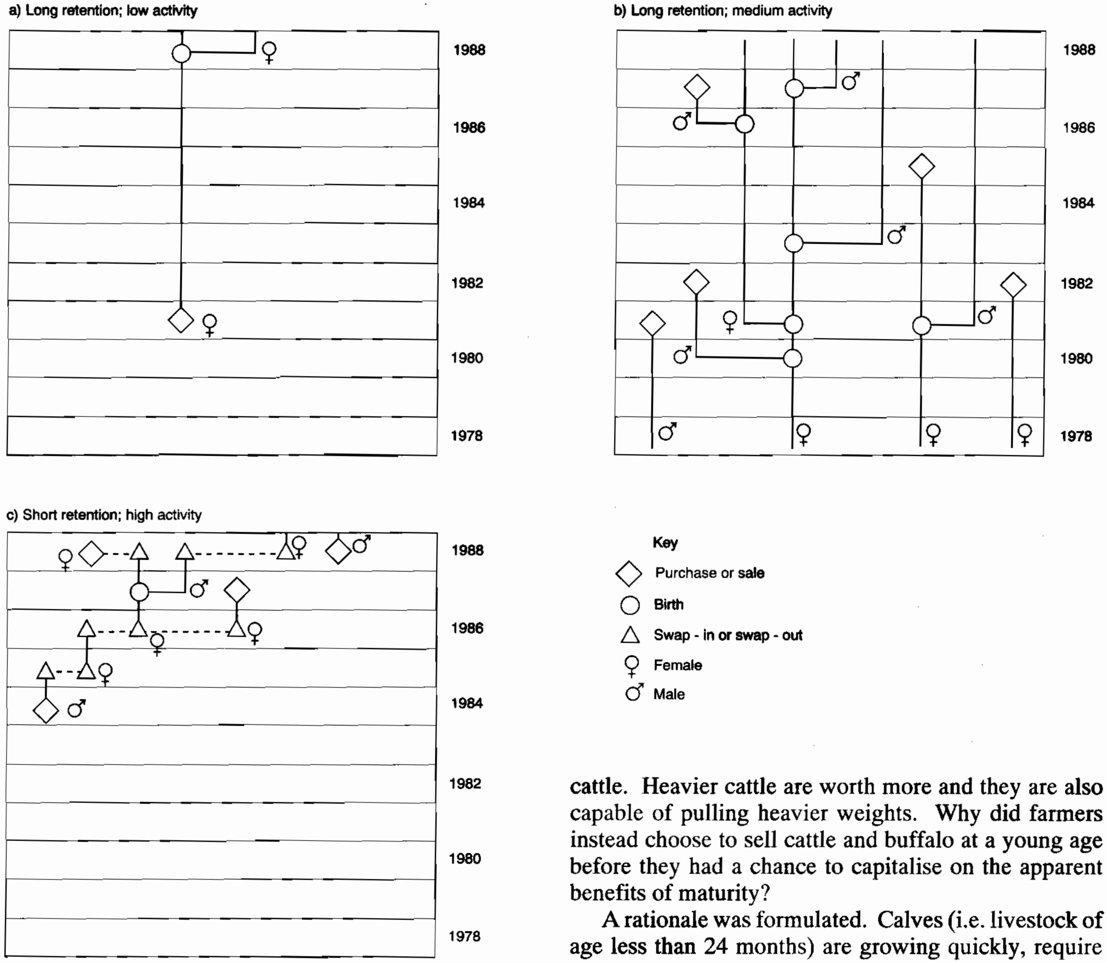
The method of test was a ten-year livestock inventory (Table 10). Each farmer currently raising cattle and buffalo in the two villages was asked to recall all animals that had come into, or left, that farm through birth, purchase, or renting-in, and sale, death or renting-out. A ten-year recall was felt to be an achievable target as farmers usually rear only 1–5 cattle or buffalo at any one time. These are major capital assets. The inventory was akin to asking Australians, for example, to list the cars that they have owned in the last ten years.

The results were reliable and proved a strong challenge to our original assumptions — the pleasure of being proved wrong! Problems with early recall for some farmers were expected and accepted. Farmers did not find this a taxing study. Long-term data was available quickly, covering a span not possible in a monitoring project.

The main results are detailed elsewhere (Perkins and Semali 1989). Most noticeable was the relatively vigorous trading conducted by many farmers. Three examples of individual farmers' inventories are given in Figure 5.

Table 10. Ten-year livestock inventory, two survey villages, 1988.

Objective	Look at patterns of livestock-rearing over time.
Data	Primary; farmers asked to recall all cattle or buffalo entering (birth, purchase, rent-in, swap-in) and leaving (sale, death, consumption, rent-out, swap-out) from 1978 to 1988.
Sample	c.180 farmers in two DAP survey villages.
Enumerators	Four staff, part-time.
Length	Data collection, editing onto transcription sheets — three months.
Benefits	Reasonably quick and cheap; very usable data, especially for previous five to seven years; no easier way to get long-term indicative data.
Problems	Poorer recall for earliest years; no checks possible on accuracy; previous rearers not covered.



Source: Perkins and Semali (1989)

Figure 5. Individual examples of ten-year livestock inventories, 1988.

We had forecast that most would resemble the types shown in (a) and (b), i.e., long retention on farm of female animals, calving interval of 3-5 years. In fact, most lay in a position somewhere between examples (b) and (c), the latter a very vigorous trader and swapper of cattle. The other major result was the frequent sale of calves born on the farm. This was not a system characterised by self-replacement of cattle and buffalo. Most calves were sold and most were sold within twelve months of birth.

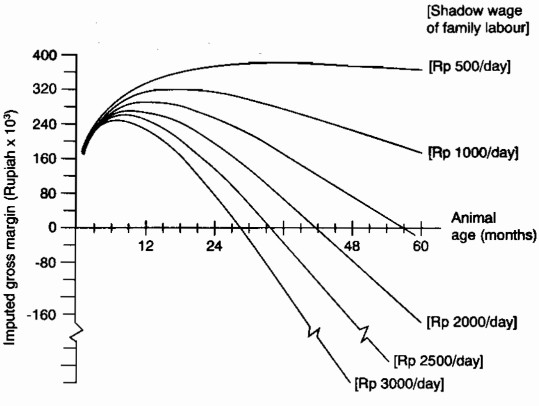
Calf Models

By the final stages of the project the economists had moved away completely from studying draught animals to exploring farmers' apparent preferences to sell young cattle. Heavier cattle are worth more and they are also capable of pulling heavier weights. Why did farmers instead choose to sell cattle and buffalo at a young age before they had a chance to capitalise on the apparent benefits of maturity?

A rationale was formulated. Calves (i.e. livestock of age less than 24 months) are growing quickly, require fewer inputs and to sell them young is to maximise on returns to effort. To test this hypothesis we required an 'all-of-life' growth curve, in which we could examine the relationships between age, weight and sale value, and set these against the labour required for management which, largely, involves labour for feeding. Information from the Purwodadi market study included only a few examples of calf age, weight and value relationships. A study was mounted to gain the maximum cross-sectional data for cattle weights and ages in the minimum of time and then use these cross-sectional data as a proxy for growth (Table 11).

This study was one of the more satisfying of those undertaken : quick data collection; good data; simultaneous answers to a number of fascinating points. It provided some basic information on cattle raised in Indonesian villages, such as weight–girth, weight–age and weight–dentition relationships. It also provided a good answer to the original question, i.e. the period of maximum profitability is, indeed, relatively early in the animal's life (Perkins1992).

As always, 'profit' is a relative term. In this case, profit was based on any farmer's self-assessment of the 'worth' of his work, i.e. the value of one day's labour. For those farmers with high opportunity costs of labour (i.e. richer, younger, active, landowners) there was good economic sense in selling young animals. For those with relatively few income-earning opportunities (e.g. poorer, older, less active, landless) the incentive would be to maintain the animals for a long period to achieve the greater weights and higher values associated with increasing age (Figure 6).



Perkins - fig 6

Source: Perkins and Semali (1992)

Figure 6. Estimated gross margins[a] for cattle-rearing at different daily labour wage rates,

[a] Gross margin defined here as total revenue (animal weight x rupiah/kg liveweight price) minus feeding costs (number of days labour to collect feed x cost of one day's labour).

What Did We Learn?

Draught animals in the farming system

The original objective set by the economists was to identify those parts of the management of cattle and buffalo which might make the greatest impact on farmers' net income.

- Indonesian farmers are competent managers of DAP and technically efficient in the use of the resources at their disposal, including DAP, for rice production. Research into draught-specific matters such as equipment, working methods, feeds, training and fitness for purpose can make some impact on income for animal rearers, but such impact will be small. The impact on income of non-rearers (who might rent-in DAP for land preparation) will be negligible. This statement applies largely to the production of flooded rice crops. There may be scope for increasing the use of animal power on dryland crops.
- Returns to research on reducing the costs of animal management are greater than research into draught work. In particular, research into the reduction of labour associated with feeding may have an impact as, potentially, this can release labour to work in other, more lucrative occupations.
- The greatest impact on farmers' net income would come through reducing current calving intervals, commonly three years or longer. This does not address the problem of *how* to reduce the calving interval, which is largely determined by the relative scarcity of mature bulls in many villages and infrequent opportunities for mating.
- Under current conditions of animal production, farmers could increase net income through concentrating on feeding strategies for the dam at the latter stages of pregnancy (to promote early lactation) and for the young calf (to promote early growth).

Table 11. Age, weight, value and labour relationships in cattle management, East Java, 1990.

Objectives	Test the proposition that maximum 'profit' for cattle is achieved at relatively early stages of growth. Improve existing data.
Data	Primary; weight, girth, sex, condition, dentition and estimates of age and sale value recorded for each animal; questionnaire on farmers' estimates of daily labour inputs for feed management.
Sample	More than 300 village cattle (two breeds) weighed, etc., at two locations in East Java. About 60 farmers provided estimates of labour use.
Enumerators	Six staff.
Length	Data recording, three weeks; editing and checking, 5–6 weeks.
Benefits	Quick study; accurate data; rapid results and reporting possible.
Problems	Age and sale value were only estimates; survey conducted in dry period, thus 'all-of-life' growth curve could be an underestimate.

- There are few additional returns to be won from 'better' feeding strategies at the time of land tillage unless the farmer is a professional ploughman and his animals work on many days of the year.
- Lastly, to reiterate an earlier conclusion (Perkins and Semali 1989) most farmers rear draught-capable animals, not draught animals. Cattle and buffalo (and their operators) require time, labour and skill for training and application. But for most farmers the greatest economic return comes at the point of sale.

Methods of gaining information

The principles of gaining information on draught animals from farmers and others in the rural system are no different, in general, from collecting data on any part of that system. However, the following points are worth emphasising.

- Never underestimate the value of accurate observation and careful listening. Most of what you need to know can be gained quickly, informally and cheaply.
- Never leave farmers out of the process of collecting and analysing information. It is worth maintaining a healthy scepticism (check what they say with what they do) but do not rely completely on the interpretation of the system by those who are not farmers.
- Short, specific surveys (or experiments) to quantify the fuzzy areas that remain after observation, discussion and reviews of published material are the best uses of research resources.
- Long-term monitoring or analytical studies should be avoided unless absolutely necessary. They absorb enormous quantities of valuable skills and time; almost invariably they provide more data than is needed, can be managed or analysed. The goal of research shifts to completion of the study rather than evaluation of its worth.
- Detailed case studies of two or three farmers can be completed more quickly and will be just as effective as a large sample. Many of the 'what if.....' questions can be answered simply by adjusting the appropriate values determined in the case studies.
- Use secondary data with great discretion. Do not bend data that does not fit research needs. It is usually quicker and cheaper to mount a short, specific study than dredge through material collected for some other purpose.

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Appendix

Fifteen essential questions for DAP researchers

A. Draught-related

1. Is there any evidence of a shortage of power for land preparation?
   Are fields left untilled during the peak cropping period? If so, why? If not, total power for tillage may be sufficient but not necessarily abundant or cheap.

2. How is power supplied?
   Hand labour; DAP; mechanical power; all or some? Any indication of changes in recent times.

3. When is power supplied?
   Trace power through the annual cropping cycles — is it DAP for this and hand labour for that? Land preparation; seeding/transplanting; weeding; fertilizer application; spraying; harvesting; processing; transport. Who, or what, does what? Is there substitution of different power sources for the same task?

4. How is DAP applied?
   Equipment — what types? Harnessing systems? How much do these items cost? Are they made, purchased or both? What's their working life? Do they do the job well? How can you answer that? Are the same animals used for ploughing and carting?

5. Is there a market for land preparation?
   What are the values (hourly, daily, per ha) for the different types of power? What is the cost for the 'average' farmer to prepare his land using the options available?

6. How much do draught animals work?
   How many days each year, on the farmer's land, on other people's land? What is the typical working day? How much land is covered in a day's work — flooded land or dry land; by task; by equipment type.

7. What animals are used?
   Males or females? How many animals in a team? At what age do they first start to work? Are they trained, and how?

B. General management

8. How are they fed?
   Cut-and-carry; herded grazing; tethered grazing; free grazing — how much of each during the year? Who looks after feeding? Any evidence of supplementary feeds?

9. What are they fed?
   Grasses; crop residues; weeds; leaves. Where does it come from? Whose land? Is there a cost?

10. Who looks after them?
    Family labour and hired labour. What are the costs? What is the current wage rate — daily, weekly? Are there other rewards?

11. What is the tenure system?
    How many people own the animals that they raise? Are there renting or sharing schemes? How are the costs and returns divided?

12. What is the breeding system?
    Calving intervals; bull supply. Are there charges for serving cows?

13. What is their condition?
    General condition; fat cover; coat? Any evidence of harness sores? What is the usual calf survival rate? Do farmers identify common health or disease problems?

14. What are the animals worth?
    As calves, as sexually mature and older animals. By how much can this price change?

15. How are values set for the animals?
    Marketing and trading systems. What drives these markets? How do farmers value their animals?

An Overview of Methodology Development for Biological Measurements for Draught Power

R.C. Upadhyay*

Abstract

Draught power estimates from biological measurements are possible only to a limited extent. Physiological measurements in working animals have been made by conventional methods used in climatic or physiological studies, and research methodologies for field measurements are limited. Some of the routine techniques for biological measurements are described in the paper. Study of heart rate changes appears to be the most direct, simple and often the only method for evaluating the load and work stress. Oxygen consumption, though reflecting energy expenditure accurately, has limitations for field use. Rate of adjustment to work and rest has been correlated to level of work and stress in animals.

In draught animal research, instrumentation for the purpose of quantification is not available and the major task yet to be accomplished is to develop suitable tools and technology for solving problems of detection and quantitative measurement of biological events and change occurring at rest and during work. Most physiological functions may be measured by making use of transducers, piezoelectric crystals, ultrasonic devices and body-imaging systems commonly available for humans. Some of the physiological functions of vital importance for work in animals may be monitored at a distance using radiotelemetric systems.

How can we evaluate the work performance capacity of an animal and the intensity of work performed by animals under field conditions in natural environments? Most of the evaluation systems used on animals involve physiological measurements which have been studied using laboratory methods: measurement of oxygen consumption, pulmonary ventilation, cardiac output, stroke volume, muscle energy and substrates, blood gases, metabolites and body temperature changes. Research on animals is limited by the methods that can be used without impairing the animal's performance and this consideration often restricts the number of direct measurements possible for evaluating performance during work in large animals, particularly under field conditions. Numerous factors need to be considered for biological evaluation of work for prediction of work capacity. Some important aspects related to work output and assessment systems used by various investigators have been reviewed in order to discuss different possible methods for capacity prediction. Not all systems used on draught animals have been included in this review, mainly due to the vast range of methods which could be used for capacity prediction. However, attempts have been made to include as much relevant information as possible to stimulate discussion on animal capacity measurements.

Prediction of Working Capacity

Attempts have been made in the past to predict the working capacity of animals on the basis of physiological and haematological parameters at rest and during work. The chief aim of these studies has been to obtain a standard for an objective selection of animals most suitable for special type of work performed (Brody 1945; Engelhardt 1977). Oxygen consumption has been used as an index of work capacity and formed a basis for prediction of capacity, particularly where performance considerations are of prime importance. Blood biochemicals and other haematological parameters have also been studied in equine species and it has been observed that animals with markedly deviating values for these vari-

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ables usually showed signs of reduced working capacity and stamina (Persson 1967). Often the results of haematological, blood biochemicals and energy substrate levels in oxen during load-pulling did not reveal anything conclusive and these variables could not be used as a measure of physical working capacity, either individually or as an average for cattle (Upadhyay and Madan 1988, Singh et al. 1968a).

The information with which to evaluate the draught animal (DA) for power output has to be gathered from visual assessment of the body dimensions, signs of dehydration, hyperthermia and distress symptoms exhibited. The respiratory frequency and heart rate have been used for objective assessment to relate work output and distress. A better understanding of the metabolic changes that take place during work may be obtained by blood analysis, but sophisticated laboratory equipment is required and most analytical procedures for important biochemicals are too long and complicated to provide important correlates to work output in field conditions. There have been many reports concerning the metabolic responses to work of bullocks and buffalo but the results have not always been consistent, although some studies have been made of the relationship between the respiration rate, heart rate and blood biochemicals for meaningful correlates to work output under different environmental conditions (Upadhyay and Madan 1985; Martin and Teleni 1989). Work capacity estimates, to a limited extent, are possible from visual assessment of body dimensions, state of body condition and some specialised tests related to body activity and functional assessments. Some are reviewed here to relate them to work capacity.

Body Dimensions and Draught Power

The draught power of an animal largely depends upon its structure, conformation and coordination in various physiological capacities related to work. The body dimensions and morphology of large animals differ from small animals. Large bovine animals, though able to pull heavy loads, are not as manoeuvrable as small compact ones, and hence move slowly (Upadhyay 1989b). Body dimensions and geometric proportions of temperate-adapted cattle (Holstein, Red Dane, Brown Swiss) differ from small-sized Zebus (Hallikar, Nagore, Haryana) which are well adapted to tropical climatic conditions. The large-sized temperate animals possess, out of fundamental necessity, thick, straight and short legs for supporting a large body mass. Draught Zebu animals have long slender legs and a balanced proportional body for swift movement. These typical draught characteristics are not generally found in the crossbreds. In general, temperament, body conformations, symmetric body, leg structure, placement and well-set joints are looked for in animals for better draught power. Gait, conformation and leg defects which may influence the movement and speed at work need to be considered if higher speed is the main consideration. But as load-carrying capacity is related to body mass, body weight needs greater consideration if animals are to be selected for heavy load-pulling or carting work. General considerations related to selection of oxen (Upadhyay 1984) and buffalo (Upadhyay 1988) have been described. Farmers, in practice, while selecting oxen and/or buffalo, often look for a symmetric and balanced body with well-set and stout joints in fore - and hindlegs. Other important points considered are temperament, basic conformation, leg defects and training.

Cardiovascular Functions

Work intensity may be evaluated from cardiovascular adjustments and reaction during work. It is difficult to record blood pressure during work except by expensive automatic devices such as telemetric systems. Measuring cardiac output would be ideal but the present available methods are obviously impossible to use under field conditions. The simplest and most extensively used method has been to determine the heart rate (HR) during or after work. From heart rate not only the circulatory capacity has been evaluated but energy expenditure estimates have also been made (Richards and Lawrence 1984; Lawrence and Pearson 1989). Oxygen transporting capacity assessments are based on linear increase in heart rate with increasing oxygen uptake or work load (Rometsch and Becker 1991). On the other hand it has been shown that heart rate changes quite accurately reflect the physiological state during work in animals (Upadhyay and Madan 1986; Rometsch and Becker 1991). Consequently, for field use, study of the heart rate changes is direct, simple and often the only method available.

The heart rate maximum (HR_{max}) in animals has been tested limitedly as a possible measure of muscular work. The HR_{max} on a treadmill which we have observed is 200 ±10 bpm for Zebu and 150 ±15 bpm in crossbreds. Heart rate response on the treadmill varied within narrow limits and the average HR at a particular submaximal work load/exercise was similar for animals of the same age and state of training within an age range of 2.5–7 years. Other factors which often affect the HR response to work are body condition, state of dehydration and environmental conditions. Heart rate response at a single submaximal load often does not reveal anything specific about the animal capacity or state of training. An animal may have a low rate on some particular farm work and a well-trained animal may exhibit a higher rate during a particular work regimen. Our experience with animals shows that continued use of animals improves circulatory capacity and reduces heart rate both at rest and during work. The reduction in tropically-adapted animals (Zebu and buffalo) is greater than in crossbreds.

The cardiovascular phenomena of vital importance for understanding work effects include blood pressure, cardiac output, heart rate, ECG and capillary perfusion and dynamics. Most can be transduced for successful monitoring. Blood pressure in animals has been measured by direct puncture of the blood vessels, and fluid-filled manometric systems have been employed (Sporri 1965; Bergsten 1974); and lately microtip transducers (Brown and Holmes 1978) have been in use for pressure measurements on animals. Heart rate in animals has been measured by auscultation, use of coccygeal pulse, electrocardiography (Upadhyay and Madan 1986) and counting air bubble pulses in a jugular venous catheter (Teleni et al. 1991).

Pulmonary Functions and Capacities

Evaluating the work load by measuring oxygen consumption is reasonably accurate and has been used extensively in humans and equine and other large animals. Nevertheless, the method has several drawbacks in practical field applications. The equipment for collecting the expired air needed for oxygen consumption measurement is rather clumsy and uncomfortable. It impairs the animal's freedom of movement and affects performance. Furthermore, additional factors affecting performance like thermal heat and radiant heat cannot be evaluated by changes in oxygen consumption. The result is that in many field conditions, measuring oxygen consumption alone gives only a partial picture of the total physiological cost and may even, on occasion, lead to an erroneous estimate of stress involved.

Oxygen pulse — a measure of aerobic power

A number of different variables measured during submaximal work have been used to assess draught animal fitness or to predict the aerobic power (Brody 1945). Usually heart rate is the variable chosen. The work capacity of the animal is limited by the oxygen-transport capacity of the heart and related cardiorespiratory organs. Oxygen transport capacity has been related to the pulse, oxygen pulse and oxygen pulse per kg body weight in horses (Kibler and Brody 1943) and in bovidae (Upadhyay 1982). The oxygen pulse per kg body weight has been used as an index of muscular work capacity (Kibler and Brody 1943). Analysis of the oxygen pulse in our animals of varying body sizes and training showed that the volume of oxygen carried is widely variable, even at a single load and under similar conditions, and this variation is not due simply to differences in body size (Upadhyay 1982). We have therefore measured oxygen pulse at different loads during similar conditions and on treadmill. In a separate incremental test we assessed the maximal oxygen uptake on the same animals to see whether oxygen pulse may be used to indicate animal fitness and assess sustained work capacity. Our observations on oxygen pulse indicated that it increased at different hours of work in Zebu (Haryana) and crossbreds. The increase was of higher magnitude during heavy working than during walking or light load-pulling. Considerable variations were observed in some of the animals particularly during hot dry and hot humid conditions.

Maximal oxygen uptake ($VO_{2\,max}$)

The maximal steady-state oxygen uptake under highest aerobic metabolic activity is abbreviated as $VO_{2\,max}$. An enormous increase in maximal oxygen uptake occurs and can reach 35 times the resting value in horses (Detweiler 1984), about 10-fold in dogs, up to 20-fold in humans (Brody 1945) and about 5 times in ruminants. The $VO_{2\,max}$ has a practical utility for identifying limitations in terms of work capacity and could probably be used to predict capacity of animals for work similar to human subjects.

Generally, in laboratory experiments, only running on a treadmill has been applied to draught animals (Lawrence and Pearson 1989; Martin and Teleni 1989, Bhatnagar and Upadhyay 1991). The general methodological criteria include the requirements that large muscle groups should be involved and measurements of the O_2 uptake should be started when the work has lasted a few minutes to ensure that there is no oxygen debt, and that oxygen consumption, CO_2 production, heart rate, respiration rate and pulmonary ventilation have reached a steady state.

The experiments conducted to assess DA on treadmill and ergometer represent in many ways artificial situations. However, such procedures have a distinct advantage when studying physiology of work since these methods provide standardised conditions and permit comparisons to be made on repeated occasions. They often simulate the demands placed on the body in work conditions in the field. However, because they differ from the real situation in the field it is of the utmost importance to study the effect of such a situation in the field under typical weather conditions.

Pulmonary ventilation

Pulmonary ventilation volume (VE) increases during transition from rest to work. The pattern of the immediate ventilatory responses and its determinants remains of considerable interest in large animals. Pulmonary ventilation increase during work in large animals is brought about mainly by an increase in respiratory frequency, and tidal volume change plays a limited role except in the situation of changed breathing patterns. This is seen primarily during high ambient temperature conditions or over prolonged hours of work in animals with restricted capacity to dissipate heat. The maximal increase in respiratory frequency that can occur in the field is about 10–15-fold. The ventilation increase under field circumstances is 4–5-fold only. In many types of farm work the respiratory rate (RR) tends to become fixed to the work type and rise in VE is limited to about 2–3-fold only and such a rise keeps the O_2 and CO_2 pressure in the blood. The higher level of pulmonary ventilation during work is mainly regulated to provide the gaseous exchange required for aerobic metabolic processing. Since the rate of VE is proportional to the rate of oxygen consumption, the VE or work to rest ratio of VE may be taken as an index of work capacity.

The measurement of RR and function in DAs provides information on the stress experience during work. Various methods are available to measure both frequency and volume in large animals (Brody 1945; Findlay 1950). Some of these methods have been used in animal experiments (Upadhay and Madan 1985; Kartiarso et al. 1987; Lawrence and Pearson 1989). Observation of expired air at the nostrils of the animal over the fingers for a period to obtain RR has been used for field studies. Other methods, though suitable for laboratory experiments, make use of the stethograph. Chest plethysmographs connected to a sensitive recording spirometer have also been used for RR measurements in animals. Another method applied to animals working in the field makes use of a thermistor sensor which is held in the middle of the nostril to sense the temperature of ingoing and outgoing air (O'Neill et al. 1989).

Body Temperature and Work Performance

Increasing body temperature is one of the important factors affecting work performance, particularly during stressful climatic conditions, and has been shown in earlier studies (Upadhyay and Madan 1985; Pietersen and Ffoulkes 1988). Animals performing work at low ambient temperature show a limited increase in body temperature. Studies on farm animals, both cattle and buffalo, have revealed that trained animals have lower heart rate, respiration rate, metabolic rate and body temperature. The biological significance of such a lower body temperature due to set point shift can be seen in a decreased starting temperature that increases the margin to the critical limiting body temperature. This author has emphasised repeatedly that for sustaining work over prolonged hours animal body temperatures should be at a lower level, as a higher body temperature limits work performance (Upadhyay 1987, 1988). Zebu animals having lower body temperatures at the start exhibited fatigue at much later stages than either crossbreds or buffalo having higher temperatures. Crossbreds, due to their higher metabolic rate at rest, have both a higher heart rate and body temperature than Zebus, which becomes a serious limitation particularly during hot humid and hot dry conditions, when the ambient heat load is higher and heat flow is towards the animal. Under such situations the Zebu, a profusely sweating animal, is at an advantage over other animals such as crossbreds or buffalo, which have a limited reliance on sweating and thus have to store a great deal of heat of work for later dissipation (Upadhyay 1989).

Rectal temperature of animals often gives an indication of the thermal state and it is conveniently recorded in animals by means of a clinical thermometer inserted to a depth of about 10–12 cm. To record rectal temperature with a clinical thermometer is difficult in animals working in the field, therefore suitable devices are required for monitoring body temperature. Flexible probes containing either thermistors or thermocouples with long leadwires may be conveniently attached for monitoring body temperature of large animals while working, and small-sized LC displays could be used as indicators.

Temperature-sensitive radiotelemetric capsules have been used for the measurement of core temperature. The capsules are specifically designed for temperature measurement and the transmitting frequency is adjusted so that it can pass through body tissues and be received with optimum response and good accuracy in the field (Folk 1968). These capsules may be used for monitoring thermal balance of and work response to body temperature in working animals in the field.

Cellular Metabolic Changes

Studies on cellular metabolism are particularly important for determining the extent and rate of adjustment during work. Pre-work and post-work analysis of muscle tissue biopsy provide data on muscle metabolic changes and the level of fatigue (Upadhyay and Madan 1985). Such muscle biopsy study can also reveal the extent of muscle tissue involvement in aerobic and anaerobic processes.

Uptake of substrates in muscle has been measured in draught animals (Teleni and Hogan 1989) with the objective of studying the metabolic pathways of various energy substrates in the blood and muscle. Since these studies often involve catheterisation of deep-seated arteries and/or veins and therefore are not suitable for field experiments, they are of academic interest only. However, important findings from these studies may be utilised for improvement of work output and to regulate the energy supply of working muscles (Petheram et al. 1989).

Blood Biochemical Changes

There have been many reports concerning the blood metabolic responses of working animals, but the results have not always been consistent. Studies have also been made on the relationship between physiological reactions, namely, HR, RR and RT and blood biochemistry (Singh et al. 1968a,b). Haematology and blood biochemical measurements are commonly used as aids in the assessment of horses in relationship to their performance (Sloet van Oldruitenborgh-Oosterbaan et al. 1991). Limited studies have been made on the relationship between work output and blood biochemistry in oxen (Upadhyay and Madan 1988) and buffalo (Singh et al. 1979). Light work-loads significantly reduced total volatile fatty acids (VFA) in animals but an increased load level in oxen indicated no consistent results under field experimentation. Studies on utilisation of body fat reserves in cattle and buffalo (Kartiarso et al. 1989) revealed that plasma free fatty acids (FFA) level increased during work and the increase was more in thin animals than in fat animals, and greater in cattle than in buffalo. The study further revealed that uptake of FFA by muscle in fat animals was greater than in thin animals, and muscle of buffalo used more FFA fuel than in cattle. In the near future such studies may be able to give the level of change in fat mobilisation from adipose tissue depots in relation to work output.

Nutrient transport and work output

The concentration of metabolites is measured in the inflowing arterial blood and in the outflowing venous blood, and the flow in the tissue of interest is measured simultaneously. Using this technique experiments have been conducted on animals to define the type and amount of nutrients utilised by the working muscle and associated hormonal changes (Kartiarso et al. 1987). Generally the isotope dilution and arterio-venous difference techniques have been applied in laboratory experiments. These experiments have demonstrated clearly that glucose and FFAs are the principal metabolic fuels for working muscles (Teleni and Hogan 1989).

Muscle biopsy techniques have been developed for human subjects and small pieces of muscle tissue can be sampled and energy substrate analysed (Bergstrom et al. 1967, Hermansen et al. 1967). By obtaining muscle biopsy from animals during work at different periods, the variation in muscle energy substrates can be followed (Upadhyay and Madan 1985).

Besides other factors, dealt with in earlier reviews (Upadhyay 1989; Teleni and Hogan 1989), the ability to perform work over prolonged hours in the field is dependent on stored glycogen in muscle and nutrient availability from blood and other body depots. It has been demonstrated from limited studies on cattle and buffalo that the diet, duration of work and intensity are some of the factors which affect nutrient utilisation and preference for a particular fuel (Kartiarso et al. 1989). The role of FFAs as an important fuel for work in DAs is directly revealed by the use of isotopes in animal research. Information on DAs, particularly on muscle glycogen content as influenced by various work levels, is not available, therefore some results from human subjects have been considered important for discussion, assuming that metabolic events in mammalian muscles are more or less similar. Results of Harmansen et al. (1967) have shown that carbohydrate utilisation can be calculated from oxygen uptake and respiratory quotient (RQ), and the decrease in the muscle glycogen. The studies have further conclusively indicated that glycogen in the exercising muscle is an important determinant of maximal work time (Astrand and Rodhal 1970). Therefore, as in humans, the initial glycogen level in the skeletal muscle of the DA may be decisive for the ability to sustain prolonged heavy work.

Measurement of Energy Expenditure in DAs

Measurement of energy expenditure of working draught animals in the field has been a difficult task (Teleni and Hogan 1989; Lawrence and Pearson 1989). Several attempts have been made either to directly measure energy expenditure (Brody 1945; Kibler and Brody 1943) or indirectly predict it from related functions (Rometsch and Becker 1991, Richards and Lawrence 1984, Webster 1967). Both direct and indirect systems have been used on draught animals. Some of these methods have been used in laboratory conditions on the treadmill, using the ergometer, etc. but such devices have been used for only limited field trials. Two excellent reviews on the subject are available (McLean and Tobin 1987; Lawrence and Pearson 1989).

Rates of adjustment to work and rest and stress

By measurement of selective physiological functions, it is possible to determine to what degree the work level differs from the rest-level, and such an estimate may be able to indicate the stress experienced by animals in performing work. The rate of recovery to the pre-work state may also indicate stress of work. Animals unable to return to pre-work resting levels during a rest pause often accumulate fatigue as the work progresses over days and weeks in a cropping season. Physiological reactions of lower magnitude completely disappear during rest pauses between work days and most animals recover to resting level. It is, therefore, essential to evaluate work in terms of recovery of change in physiological processes.

The rise in HR and levels attained have been related to work levels on the treadmill in the author's laboratory. Increments in HR along with other physiological reactions and behavioural manifestations in cattle and buffalo have also been interpreted earlier in terms of fatigue (Upadhyay and Madan 1985; Upadhyay 1987; Martin and Teleni 1989; Komarudin-Ma'sum et al. 1991).

The rate of recovery to pre-work level varies according to physiological stress or work levels attained and is proportional to the stress experienced during work. The recovery process in cattle and buffalo has been used to evaluate the level of fatigue and to decide on suitable rest pauses. Heart rate recovery after heavy work is slower than after moderate work, recovery after light work being the fastest. The fall in HR in the first few minutes is steep (Fig. 1) but resting level is achieved after a long period which varies in different environmental conditions and loads. Animals working after several rest pauses do not raise the HR to the same levels as that attained by animals without rest pauses. Experiments on the treadmill and carting trials have revealed that a 20–30 minute rest period significantly lowers heart rates of buffalo but recovery after strenuous work is slow (Fig. 2). Recovery in body temperature requires more prolonged rest, 4–5 hours or more.

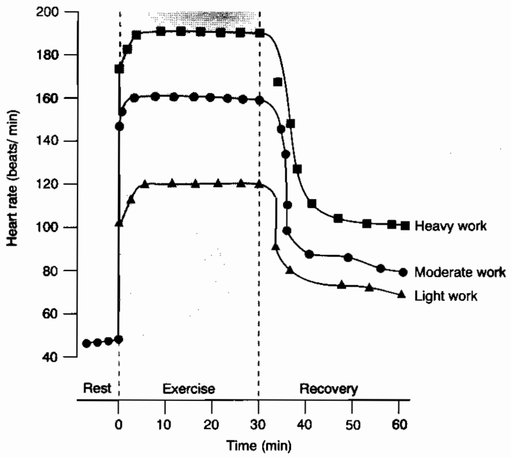

Figure 1. Decreasing heart rate recovery curves with work load in buffalo.

Recovery from low to moderate work requires about 4–5 hours of complete rest in a comfortable ambient temperature, but at high temperatures the time is prolonged to 8–12 hours. Most DAs in the hot-humid season do not recover from a day's work and working over several days affects the body condition and animals run down. Most animals recover after a season's work and regain the weight lost in about a month if adequate feed and feed supplements are available.

Transduction and measurement of biological processes

In DA research, instrumentation for the purpose of quantification has not pervaded all areas, and a major task yet to be accomplished is to develop suitable tools and technology for solving problems of detection and quantitative measurement of biological events and change occurring at rest and during work. Attempts have been made in the past to develop suitable instrumentation systems for monitoring physiological reactions using sensors/transducers or electrodes, making use of transduction properties.

For successful monitoring, physiological phenomena have to be converted into electrical signals and various methods are employed to do this (Fig. 3).

The principle of transduction makes use of a device that recognises the specific property and converts it to an electrical signal. Thus a transducer acts as a sense organ for electronic monitoring equipment. Various forms and types of transducers are in common use for measuring temperature, blood pressure and other physiological changes in humans. Piezoelectric crystals have found numerous applications in biomedical studies and because of their miniature size, isometric nature and large electrical output, these crystals are most useful for the transduction of a variety of time-varying physiological events. They have been employed successfully in medicine for obtaining information for ballistocardiography, heart sounds, pulse wave, muscle pull, respiration measurement, etc. These crystals are well suited to the detection of the pressure pulse and of low-energy acoustic phenomena such as heart and Korotkoff sounds.

Not all physiological functions can be monitored by using transducers and in many circumstances such phenomena are transducted by the impedance method. The phenomena which exhibit a change in dimension, dielectric or conductivity can easily be transducted. Physiological functions like respiration, blood flow, activity of nerve, etc. have been detected by using the impedance technique. The impedance method offers all the advantages of an indirect non-invasive technique required for measuring physiological changes in draught animals and may be applied easily in the form of electrodes on the surface of the body.

Application of New Electronic Instruments

Imaging methods

In human medicine, techniques of imaging body form and functions are being developed which enable a description of physiological and biochemical phenomena in vivo (Wells 1991). These expensive and advanced methodologies necessary for a 'state-of-the-art' description of humans have not been used on animals, and potential applications of these techniques in draught animals remain to be explored. Of the imaging methods available, ultrasound is the most promising for livestock application because of its speed and application for visualising soft tissues which are readily accessible. Work modifies blood flow to tissues and pulsality of arterial pressure increases. The redistribution of cardiac output during work and heat occurs to maintain adequate perfusion to muscle. Ultrasound is an excellent tool for measuring blood flow which may be used for monitoring

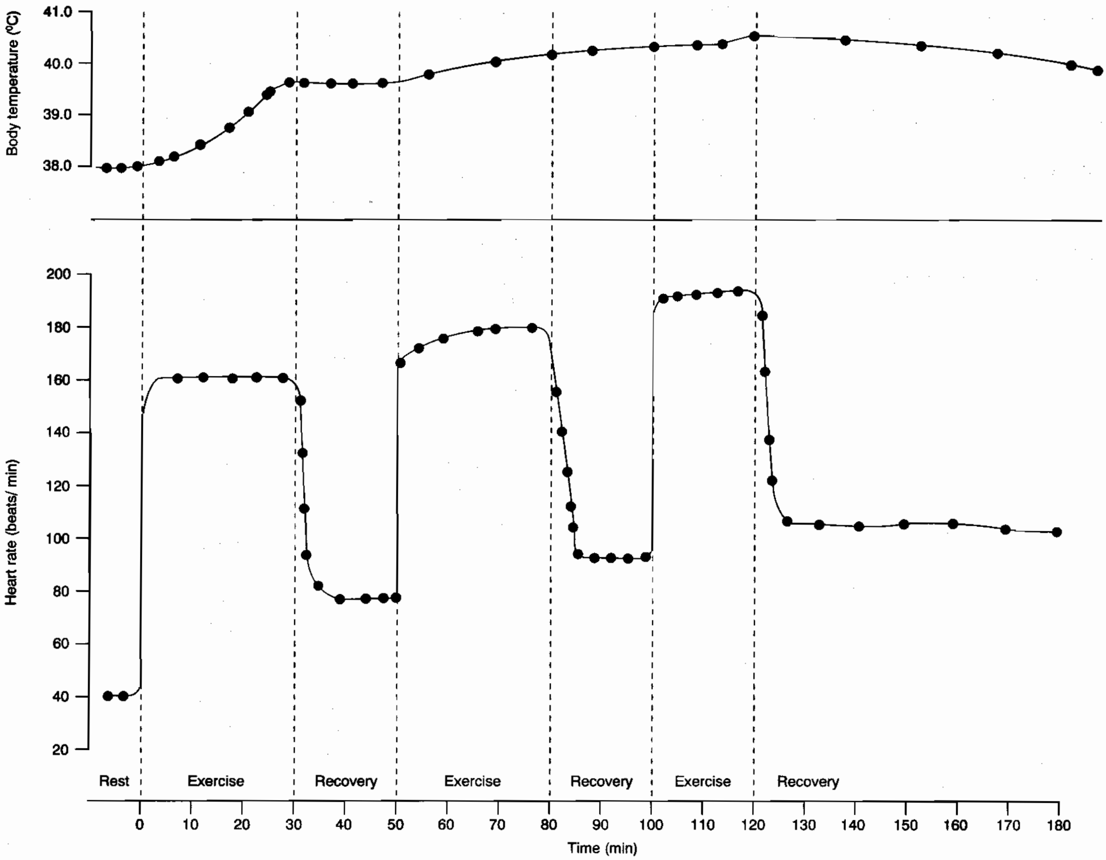

Figure 2. Effect of repeated work-rest cycle on recovery time in rectal temperature and heart rate in buffalo.

changes in animals. When an ultrasound wave is reflected or scattered by a moving target, such as blood, the received wave is shifted in frequency by the Doppler effect by an amount depending on, among other factors, the vector velocity of the target (Wells 1991). The ultrasonic Doppler method can provide a great deal of information non-invasively regarding mean blood flow velocity, flow velocity profile and pulsality of arterial pressure wave. This information can often be related to physiological and metabolic properties of various tissues, e.g. heart and muscle, particularly in working conditions.

Another imaging system offering utility in animal research is magnetic resonance spectroscopy (MRS). Signals from a region of interest identified by imaging are subjected to narrow band frequency analysis. Studies on animals involving changes in metabolic rate in tissues may be able to make use of this technique, since the MRS of phosphorus gives insight into energy metabolism, ATP and inorganic phosphorus concentration (Weiner et al. 1986; Wells 1991). The role of phosphocreatine (PC) in muscle metabolism of oxen has been investigated during work (Upadhyay and Madan 1985). PC reduction has been observed in both Zebu and crossbred. The change in PC has also been related to muscle lactic acid, work and animal fatigue. The potential of MRS in vivo study of biochemical changes during rest and during work of different intensity opens areas hitherto unexplored in draught animals.

Radiotelemetry

Recording of physiological phenomena from distant places, where conventional methods of recording and monitoring are not possible, has been in use in human medicine and space research for several decades. Radiotelemetry has been used limitedly for understanding animal responses. Temperature-sensitive

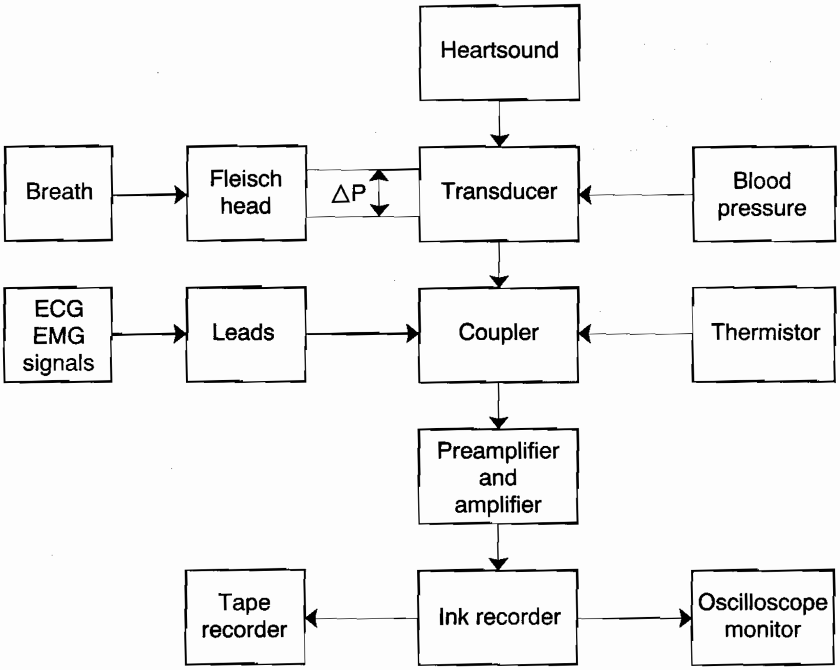

Figure 3. Signal flow for physiological measurements.

radio-capsules consisting of thermistors have been used to monitor temperature variations (Folk 1968) and electrocardiographic changes (Holmes et al. 1966). The techniques and instrument system described by Holmes and colleagues consist of a transmitter which is attached to the animal. The radio signals transmitted are received by a receiver at a distant place and sent for monitoring on an oscilloscope, recorded on tape recorder and/or on a direct pen-recording system (Fig. 4). Equipment and methods for telemetry of blood pressure and flow have also been developed and successfully employed in free-ranging animals (Van Citters and Franklin 1969a,b). It is hoped that such instrumentation systems, after suitable modification, will find their way into draught animal research, particularly for evaluation of stress or work levels.

Modular electronic systems

Advancement of electronic systems has also been put to DAs research (O'Neill et al. 1989; Betker 1989; Lawrence and Pearson 1989). The instrument system developed at the Centre for Tropical Veterinary Medicine (CTVM) in Edinburgh is able to give a complete account of work done by animals pulling in field situations (Pearson 1989). AFRC-Engineering Overseas Division has developed a draught animal performance data logger, which monitors and records mechanical and physiological performance data in field conditions. Three mechanical and four physiological variables can be recorded simultaneously and information can be stored for further use (O'Neill et al. 1989). Another electronic system for measuring performance of animals has been developed at the Institute for Agriculture at Hohenheim University, Germany (Betker 1989). The parameters that may be measured are force, inclination, speed, depth of working and acceleration. Different sensors are used to measure these parameters and each individual sensor gives an output analogue signal and can work even at 60°C ambient temperature. This equipment, if available commercially and cheaply, may find its way into research, but most research laboratories cannot afford these costly modular systems for field experiments.

Conclusions

Biological measurements in draught animals are limited to measurement of oxygen consumption, pulmonary ventilation, blood gases and metabolites, energy substrates, body temperature and some cardiac functions. Research on animals is limited by the methods that can be used without impairing their performance, and this consideration often restricts the number of direct measurements possible in large animals during work, particularly under field conditions.

In general, good temperament, conformation, symmetry, body, leg structure, placement and joints are sought for draught power. Gait conformation and leg defects are also considered in animals where speedy work is required. Information for power output has to be gathered in general from visual assessment of animal structure and general condition and any state of dehydration, distress or hyperthermia. Pulmonary and cardiac functions have also been used for objective assessment of animals. An understanding, though of limited importance, may be obtained from blood biochemicals. Attempts have been made to find out the relationships between various physiological functions including respiration rate, heart rate and blood biochemicals and work capacity and distress. A study of heart rate changes appears to be the most direct, simple and often the only method for evaluating and relating to work. Use of oxygen consumption has been applied limitedly as measuring systems are uncomfortable for animals under field conditions. Oxygen pulse has been used as a test of work capacity in animals. Rates of adjustment to work and rest provide meaningful correlates to the work capacity of an animal and reflect the capacity to adjust during work.

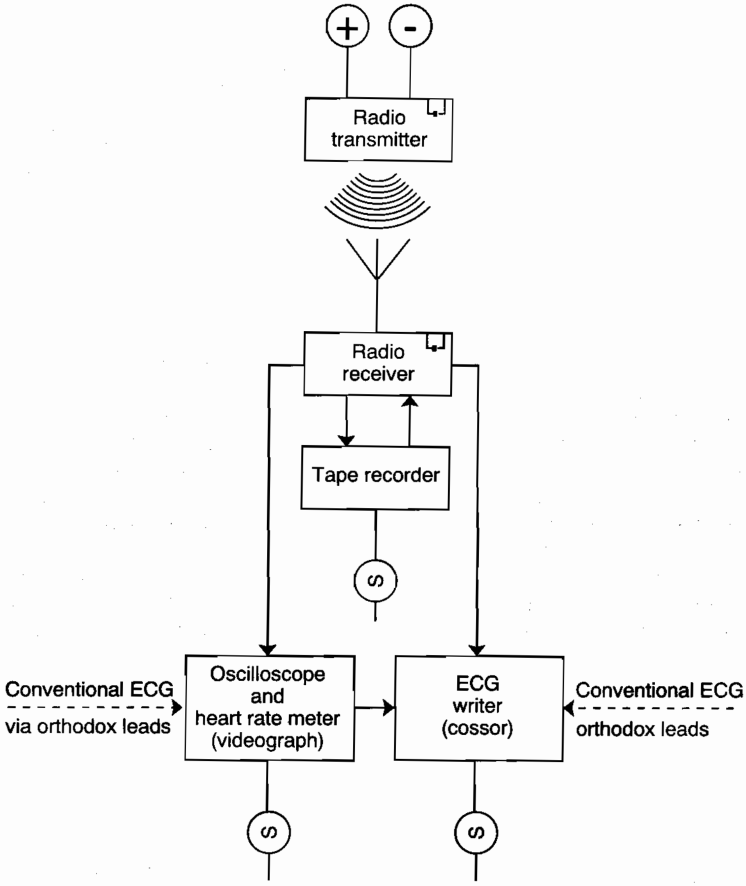

Figure 4. General arrangement of the radiotelemetric transmitter, receiver and recording apparatus (Holmes et al. 1966).

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Nutrition Comparisons between Cattle and Buffalo and Implications for Draught Animal Power

P.M. Kennedy*, G.L.R. Gordon† and J.P. Hogan*

Abstract

In comparisons of digestive function between swamp buffalo and cross-bred cattle fed five forage diets there were no consistent differences in voluntary intake between animal species, but fluid turnover rate and ratio of propionic acid to acetic acid, and protozoal numbers in the rumen digesta, were higher in buffalo. Enhanced fibrolytic activity, detected by digestion of purified cellulose substrate, was generally observed in buffalo; anaerobic fungal populations appeared to be low and were possibly not involved in this difference. There was a more rapid weakening of plant material held in fibre bags in the buffalo rumen, the difference being seen with as little as 12 h fermentation. Large feed particles removed from rumen digesta were also weaker in buffalo. As rumen particle size was reduced, there were generally reductions in organic matter content and buoyancy associated with microbial activity of particles. The amount of protein from supplemental meat meal available in the intestines was inversely related to particle size of the meat meal. It was proposed that the faster reduction of particle size and passage from the rumen of buffalo compared to cattle would increase the supply of protein from protein supplements in the small intestine.

The effects of differences in digestion are discussed in relation to the supply of nutrients for draught cattle and buffalo.

DRAUGHT animals dependent on forages as their main sources of nutrients are in an anomalous position. As with other aspects of animal production, energy requirements are substantially above those needed for maintenance of body weight; Teleni and Hogan (1989) suggested that a 600-kg cow needed an extra 70% more energy for work than required for maintenance. With work, heat derived from muscular work plus solar radiation is added to heat asssociated with inefficiency of metabolism of nutrients. This presents animals, especially buffalo which possess few or no sweat glands, with consequent major problems in heat dissipation. Therefore the question arises: can buffalo overcome this disadvantage by greater digestive efficiency? Appropriate mechanisms that could benefit working animals by reducing metabolic heat production could include more efficient microbial digestion of forages, or increased production of energy substrates that were used more efficiently for work. One such major substrate is glucose, which is derived mainly from ruminal propionate, and from amino acids of microbial or dietary protein origin, absorbed in the small intestine. Increased delivery of protein to the small intestines can be achieved by faster passage through the rumen of dietary protein which is not readily degraded in the rumen, or by more efficient synthesis of microbial protein.

More efficient digestive function might involve control of rumen retention time of digesta to optimise release by rumen microbes of energy from cell-wall polysaccharides, or promotion of ruminal conditions that encourage growth of microbes with low maintenance requirements or high fibrolytic capability. Therefore consideration is required of rumen dynamics and physical constraints to passage of feed residues from the rumen which impede higher intake (e.g., particle size and ease of reduction of size), the supply of readily available organic substrate from cell contents relative to that from slowly digestible cell-wall material, and composition and activity of the microbial population of the rumen.

This paper presents some results from comparisons of digestive physiology of swamp buffalo and crossbred cattle, conducted in Townsville, Australia.

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Methods

Most methods used in diet comparisons were reported previously (Kennedy 1990; Kennedy, Boniface et al. 1992; Kennedy, McSweeney et al. 1992), and some results are summarised by Kennedy (1990) as experiment 4 and one treatment of experiment 5. Comparisons were made between four swamp buffalo and four crossbred (*Bos indicus* x *B. taurus*) cattle, aged approximately three years, each fitted with a rumen cannula and allowed to feed ad libitum (ca. 15–20% excess) every 3 hours using automatic feeders.

Digestion of purified cellulose substrate (cotton wool) was measured by incubation in polyester fibre bags (50-mu mesh) in the rumen for 24 hours.

Fungal sporangia numbers in the rumen were assessed by colonisation after 24 hours of leaf blades of kikuyu grass in polyester fibre bags.

Strength of feed particles was measured as the amount of electrical energy required to grind dried (100°C) particles through a 1—mm screen.

Buoyancy of rumen digesta particles due to microbial activity was estimated from differences in sedimentation rates between a subsample measured immediately on removal from the rumen and that of a subsample in which microbes had been killed. A modification of the method described by Sutherland (1988) was used to measure sedimentation rates.

In an experiment measuring escape of supplemental meat meal protein to the small intestines of buffalo and cattle, meat meal was dry sieved into three size categories; large (retained on sieve of aperture, 0.6 mm, com-

Table 1. Voluntary intake, ruminal digestion, and properties of rumen digesta in buffalo and cattle.

	Dolichos	Verano	Pangola	Sorghum hay	Rice straw
Voluntary feed intake (g DM/kg body weight/day)					
buffalo	12.9	13.8	12.6	17.1	19.8
cattle	13.5	14.6	11.7	17.3	16.2
Proportion of organic matter (OM) truly digested derived from soluble OM					
buffalo	0.47	0.32	0.45	0.23	0.37
cattle	0.49	0.30	0.43	0.23	0.33
Fractional outflow rate of rumen fluid (%/hour)					
buffalo	6.7	8.7	8.5	10.9	8.2
cattle	5.6	6.5	7.1	8.2	5.5
Ammonia in rumen fluid (mg N/L)					
buffalo	113	114	40	139	238
cattle	118	78	39	151	101
Propionate/acetate ratio in rumen fluid					
buffalo	0.26	0.23	0.31	0.31	0.24
cattle	0.23	0.22	0.27	0.22	0.23
Digestion of cotton wool (% in 24 hour)					
buffalo	46.4	27.5	33.1	38.6	43.9
cattle	48.2	20.1	29.2	26.2	31.2
Protozoa in rumen fluid (10^5/mL):					
large					
buffalo	0.39	0.34	0.25	0.13	
cattle	0.80	0.98	0.69	0.65	
small					
buffalo	10.16	12.60	14.51	57.82	
cattle	3.82	1.92	1.88	2.56	
Fungal sporangia (no./mm^2 of leaf surface)					
buffalo	1.8	2.3	0.5	0.7	
cattle	1.1	1.2	0.2	1.2	
Grinding energy of large particles from rumen (kJ/g DM).					
buffalo	277	166	198	129	
cattle	305	186	238	154	

prising 30% of meat meal), medium (passing 0.6 mm sieve but retained on 0.3 mm sieve, comprising 43%), and small (passing 0.3 mm but retained on 0.15 mm sieve, comprising 25%) and separately incubated (4 g) in polyester bags in the rumen for 0, 3, 6, 12, 18, 24 or 48 hours. Mean retention time of the different sized meat-meal preparations in the rumen of all animals was estimated on separate days after marking each preparation (mordanting procedure using ^{51}Cr), dosing into the rumen, and estimating the rate of escape of meat-meal from the rumen from the faecal appearance of ^{51}Cr. Degree of N digestion in the rumen was calculated by the method of Orskov and McDonald (1979). Following recovery from the rumen, the washed, freeze-dried material was sealed in small polyester bags, subjected to acid-pepsin digestion (pH 2.0, 4.0 h, 377 IU/L pepsin), freeze-dried, and inserted into the duodenal cannula. Intestinal availability of protein was estimated by N analysis of meat meal before and after passage through the intestines.

Digestion of five forages

Diets comprised two legumes (dolichos, *Dolichos lablab* and a verano hay; *Styosanthes hamata* cv Verano which contained 50% tropical grass contaminant) and three grasses (pangola, *Digitaria decumbens*, sorghum, *Sorghum almum*, rice straw *Oryza sativa*). Comparisons between the first four diets were made in one experiment, and the rice straw diet represented one of four treatments in a second experiment which followed immediately. Diets were unsupplemented except for rice straw, which was offered with urea (275 g/day) and minerals (300 g/day) spread on the feed.

Table 1 summarises pertinent results. Voluntary intakes were similar between species, whereas fractional passage rates of rumen fluid were consistently higher in buffalo. Concentrations of propionate relative to acetate were generally higher by 3–40% in buffalo compared to cattle. Combined with indications of greater passage of non-ammonia N to the small intestine of buffalo (Kennedy, McSweeney et al. 1992), this finding suggests greater synthesis of glucogenic precursors per unit of digestible organic matter (OM) than in cattle. By contrast, in other reported experiments, ruminal propionate–acetate ratios did not differ, but the rumen fluid passage rates were lower in buffalo than in cattle (Pradhan et al. 1991).

Assuming that 95% of cell contents OM (estimated as OM content less ash-free neutral detergent fibre content) is digested, buffalo derived about13% more of the total intake of digestible OM from cell content OM than did cattle when the diet was rice straw, but for the other four diets, the differences, less than 6%, were not significant (Table 1). Further, the proportion of digested OM from cell solubles was apparently not related to the digestion rates of dietary material or cotton thread in the rumen (reported by Kennedy 1990). The influence of the ratio of soluble OM to that digested from cell walls is therefore not clear, although Kennedy, Boniface and colleagues (1992) suggested that with increase of dietary content of cell wall (and decrease of soluble OM), there were relatively more microbes adhering to fibre in buffalo than in cattle.

The activity of the fibrolytic microbes, as indicated by digestion of purified cellulose, differed markedly with diet; the digestion was least for the verano diet, and most for dolichos. Depression of ammonia concentration below 200 mg N/L, which may lead to a depression of digestion of purified cellulose (Kennedy, Boniface et al. 1992) was only partially responsible for these differences. More of the purified cellulose was digested by buffalo than by cattle fed four of the diets. Similar results reported by Pradhan et al. (1991) were attributed to the higher populations of cellulolytic bacteria with faster breakdown of cellulose.

Buffalo harboured substantially more small protozoa and less larger protozoa than cattle, whereas in buffalo there were fewer large protozoa, possibly due to faster passage of rumen fluid. Recorded numbers of fungi were low and similar between animal species, and were comparable to those for animals given rice straw with 5% Leucaena leaf (Kennedy, McSweeney et al. 1992). Low numbers of sporangia on leaf blades of kikuyu may not necessarily reflect low suitability of the forages for zoospore attachment, as one of the diets used (pangola) was found by Elliott et al. (1985) to be readily colonised by fungi. Accordingly the numbers reported here may not necessarily indicate either a small rumen fungal biomass or low fungal activity. Extensive colonisation by fungi was observed in animals given guinea grass, with no obvious differences between species (Ho et al. 1988).

The increasing evidence of microbial differences between buffalo and cattle was supported by the enhanced weakening of forage particles in buffalo after as little as 12 hours of incubation in polyester bags in the rumen, of particles of all diets except sorghum (Figure 1). Such enhanced weakening without enhanced digestion (see Kennedy 1990) is consistent with greater fungal, rather than bacterial, activity in buffalo. It was notable that the largest differences were seen with dolichos, in which the stem component was 69% of total dry matter but which contributed 97% of grinding energy of the diet, and in verano, in which stem material contributed 86% of dry matter. Calculations (assuming an exponential model) of rate of reduction of grinding energy with time of incubation in the rumen for between 12 and 48 hours showed that for dolichos, pangola, sorghum and rice straw diets there was a respective reduction of grinding energy by about 1.8, 1.25, 2.0 and 1.45% per hour of exposure to the rumen.

Faster weakening of ruminal particles in buffalo was supported by lower values for grinding energies of large particles (retained during wet sieving on a sieve of 1.2 mm or larger aperture) recovered from the rumen (Table 1). Grinding energy of large particles from dorsal and ventral sac of the rumen were consistently smaller (by about 21–36 kJ/g) in buffalo than in cattle; this represented a reduction of 10–13% for the legume diets and 18–19% for the grasses. Grinding energy of ventral large particles was 4–8% lower than dorsal large particles. Using data from the polyester bag study (Fig. 1), grinding energies of ruminal large particles were consistent with dorsal large particles being digested for 12 hours or less, with somewhat longer digestion for ventral large particles.

Table 2. Calculated retention time in the rumen and release in the gut of nitrogen from meat meal separated into three fractions (means for cattle and buffalo).

Fraction	Coarse	Medium	Fine
Mean retention time in the rumen (hour)			
	16.0	10.5	8.0
Release of N (g/kg organic matter)			
rumen	58.0	58.0	56.7
intestines	35.1	40.0	48.1
Unavailable-N	49.2	29.5	18.8

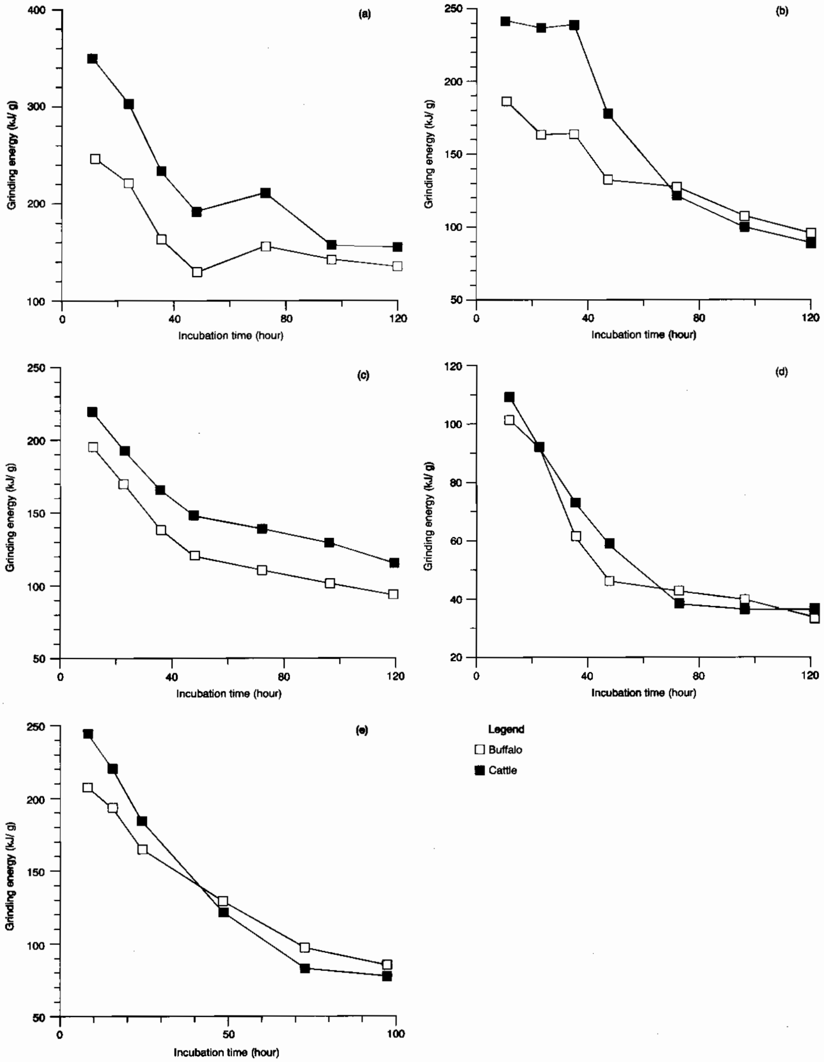

Figure 1. Grinding energy of dolichos (a), verano (b), pangola (c), sorghum (d) and rice straw (e) incubated in the rumen of buffalo and cattle.

As most smaller particles in the rumen are derived from larger particles during ruminative chewing, it would be expected that progressively smaller particles would have experienced increased time for digestion and been depleted in OM content. Such depletion was indeed evident for all diets examined (Fig. 2) with the exception of dolichos. Dolichos leaf and stem differ widely in physical properties; therefore OM content of particles differing in size may be determined by the proportion of leaf and stem material. In addition, decreased particle size was associated with increased buoyancy (decreases in sedimentation rate) due to microbial fermentation (Fig. 2). Small decreases in OM content of verano were associated with substantially larger reductions (factor of >4) in sedimentation rate than for the other diets. Buoyancy of particles in the rumen, suggested by Sutherland (1988) to be of importance in the kinetics of particles, appears to be positively associated with levels of voluntary intake achieved for all diets except rice straw (Kennedy, unpublished).

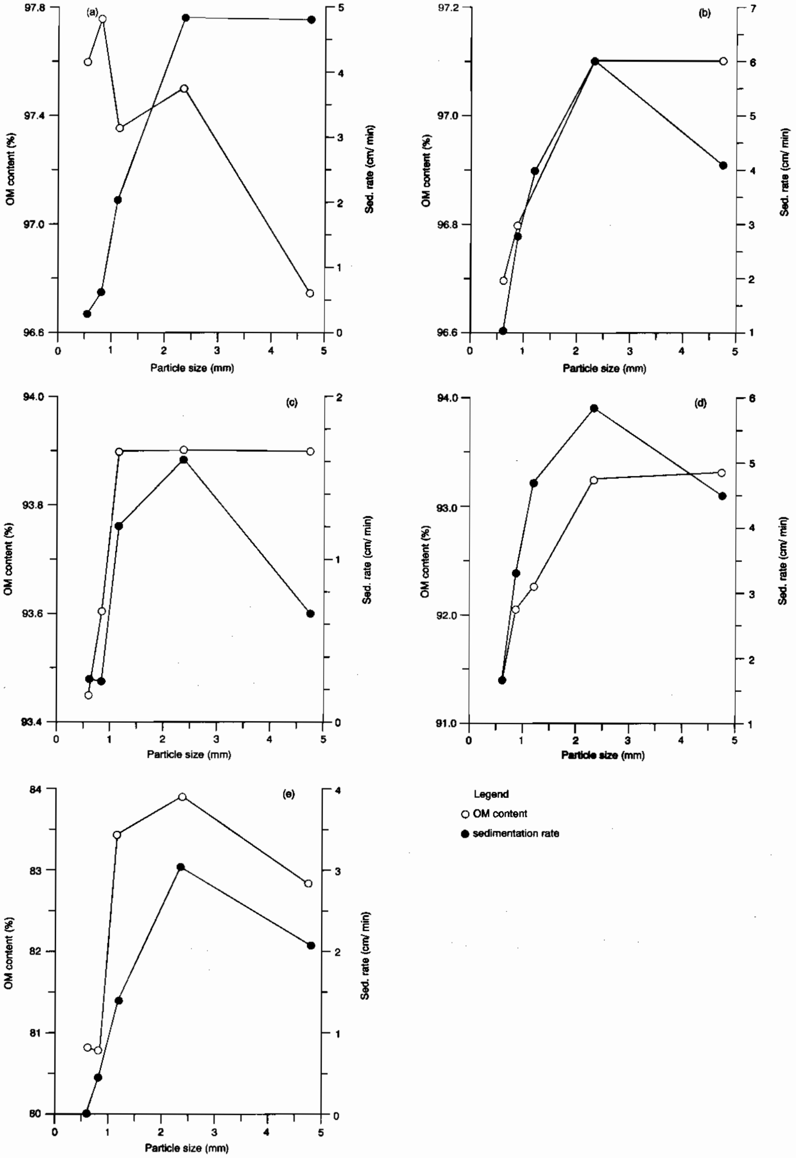

Figure 2. Mean values for organic matter content for cattle and buffalo and decrease in sedimentation rate associated with microbial fermentation of particles of dolichos (a), verano (b), pangola (c), sorghum (d) and rice straw (e) from rumen digesta.

Yield of nitrogen from meat meal

Because rates of ruminative chewing and passage of fine particles are generally higher for buffalo than for cattle in our experiments (Kennedy 1990), buffalo preferentially benefit from greater yield of intestinally-digested protein derived from a protein supplement. To test this, four animals of each species were given sorghum hay ad libitum with 900 g/day of meat meal and 900 g/day of cracked maize. Results obtained using a combination of in situ rumen incubation with the 'mobile bag' technique (de Boer et al. 1987) (Table 2) showed that with decreasing particle size, the amount of N available in the gut of animals increased from about 93 to about 104 g/kg OM. More importantly, the proportion of digestible N absorbed in the intestines was calculated to increase from 38 to 46% in fine compared to coarse particles.

This effect resulted mainly from differences in rates of passage associated with particle size. Although there were only small differences between species in retention time of meat meal in the rumen, the main advantage to the buffalo in enhancing escape of protein supplements from the rumen would appear to accrue from its known superior ability to reduce size of particle (Kennedy, McSweeney et al. 1992). Our experimental data did not allow us to quantify the magnitude of this effect. Limited information for animals fed rice straw supplemented with Leucaena leaf suggested that greater net efficiency of microbial growth in buffalo would also increase protein flow to the intestines (Kennedy, McSweeney et al. 1992).

Implications for Working Animals

It is clear that our buffalo examined under our conditions have advantages over cattle. These are probably insufficient to counter the greater difficulties of heat dissipation encountered by buffalo. However, this conclusion may not apply to animals in parts of Southeast Asia, as there are conflicting reports concerning digestive kinetics of the two species. The type of work reported here should be repeated in other situations before extrapolations can be made.

Acknowledgments

Financial support for this work was received from the Australian Centre for International Agricultural Research and the Meat Research Corporation.

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DAP vs Mechanisation in Rural Development

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Abstract

In the next three decades it is expected that the world population could reach 8 to 12 billion. While the rate of urbanisation in most countries will increase, however, the rural populations in the world and in the less developed countries (LDCs) will continue to climb. Rural development remains one of the major tasks of every LDC government. With the availability of more rural infrastructure such as roads, electricity, irrigation and communication facilities, the question arises whether DAP will continue to play an important role as a source of farm power in comparison with mechanisation. This paper attempts to analyse future prospects of DAP vs mechanisation within the context of rural development and sustainable agriculture perspectives.

In each country, various factors including rural and agricultural infrastructure, changing socioeconomic conditions such as higher farmer educational level, off-farm jobs, increases in prices of agricultural commodities and related government policies such as taxes, credits, agricultural modernisation and others will have a positive effect toward increasing use of mechanical power in some areas, especially in irrigated areas. However, in most LDCs irrigated agriculture comprises only a small proportion of agricultural land, while rainfed agriculture is the larger, in some countries being up to 80% of the total cultivated land. Under rainfed conditions and existing socioeconomic factors, the use of DAP will continue to persist as an appropriate source of farm power, considering also other uses of draught animals by farmers in integrated small farm systems.

In the long run, under rainfed rural farming DAP will have many obvious advantages over mechanisation if considered within the context of sustainable agriculture. It is clear that DAP use in small farms under rainfed conditions will promote better control of air, soil and water pollution while reducing the use of many production inputs, especially fuel and chemical fertilizers. However, it is envisaged that, with more intense pressure from higher demand for food and increasing human population, DAP and mechanisation in certain combinations will become most beneficial to rural farming systems in the future. It is imperative that this aspect, as well as others, on the integrated use of DAP and mechanisation should be given close attention by research and development agencies in the LDCs.

In the less developed countries (LDCs) population in the rural sector is expected to be in the majority even beyond the year 2000, in spite of the increasing rate of urbanisation. Rural populations will increase from 2.53 billion in 1985 to 2.93 billion in 2000, and 3.28 billion in 2025 (Table 1). Rural populations of China (Mainland) and India which in 1985 comprised approximately 80% and 75% of the total populations, respectively, will remain at 75% and 66% in the year 2000. Hence it is quite obvious that in many decades to come rural development will remain one of the major tasks of every government in the LDCs, including those heading into an era of early industrialisation.

Most rural people depend directly and indirectly on agriculture including crops, livestock, forest and fisheries for their food, income and family subsistence. Livestock on small farms in rural areas are generally integrated into crop production systems; they provide not only food, i.e. meat, milk and eggs, but also a source of farm power and manure or faeces for fertilizer, as well as other benefits. Animals used for draught power vary from one location to another, cattle, buffalo, horses, asses, donkeys and camels being common sources for rural farms in various continents. In Asia, buffalo and cattle are generally used as draught animals, as well as for beef and dairy purposes. Buffalo and cattle have been

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Table 1. World population.

Population	Year 1950	1985	2000	2025
World population (billions)	2.5	4.8	6.1	8.2
Rural population (%)	71	59	53	
Less developed countries	83	69	61	
Rural population (billions)				
Less developed countries	1.39	2.52	2.93	3.28
As % of world population	55.6	52.7	48.0	40.7

Source: Adapted from World Commission on Environment and Development, 1987, Oxford University Press, pp. 100–101.

Table 2. Estimated inputs of human, animal and mechanical power in rice production in selected countries of Asia, 1980.

Country		Hours/ha 1965	1970	1975	1978
Japan	Human	1 410	1 178	815	694[a]
	Animal	15	2	–	–
	Mechanical	144	185	179	148[a]
Taiwan[b]	Human	1 088	985	778	601
	Animal	122	103	51	36
	Mechanical	40	56	84	98
South Korea	Human	1 356	1 284	1 176	937
	Animal	92	101	80	56
	Mechanical	4	8	18	48
Philippines[c]	Human	504	552	640	640[d]
	Animal	200	136	136	136[d]
	Mechanical	42	45	45	45[d]
Thailand[c]	Human	409	480	470	462
	Animal	170	165	160	146
	Mechanical	10	15	20	30
India[e]	Human	1 218[f]	958	992	1 285[a]
	Animal	230[f]	247	221	125[a]
	Mechanical	120[f]	n.a.	n.a.	113[a]
Pakistan	Human	619	637	637	637[a]
	Animal	312	308	284	128[a]
	Mechanical	n.a.	neg	2	6[a]
Nepal	Human	1 200[f]	n.a.	n.a.	1 448
	Animal	312[f]	n.a.	n.a.	304
	Mechanical	neg[f]	n.a.	n.a.	2

Notes: n.a. not available; a – 1979; b – refers to first season crop only; c – refers to wet season crop; d – 1977; e – average of Tamil Nadu and Orissa; f – 1968.

integrated into Asian farming systems since time immemorial, especially in lowland-rainfed rice production systems which are quite prevalent in Southeast Asia.

However, during recent decades, studies or data from certain countries concerning the relative use of mechanisation, animal power and human labour on small farms have indicated an increasing role for mechanical power, while the use of animal power is reducing. For example, Table 2 shows the comparative estimated inputs of human, animal and mechanical power in rice production in selected countries of Asia from 1965 to 1978 (Duff and Kaiser 1984). They indicate that, in general, human labour forms the largest portion of farm power in rice production, while in 1978 animal power ranked second, except in Japan and Taiwan, and mechanical power third. In the Philippines and Thailand, mechanical power was about one-third and one-quarter, respectively, of the amount of animal power used in rice production; the use of mechanical power, however, was tending to increase slowly. Such data raise a question on the future role of animal power in relation to mechanisation. This paper is intended to present a view on future prospects for the role of DAP on small farms in the LDCs in the face of increasing mechanisation in the next two or three decades.

Development Policies and Possible Effects on DAP Use

Physical factors

Rural development usually involves construction of infrastructure such as irrigation, electricity, roads and running water systems. It has been clearly observed that wherever irrigation water for agriculture becomes available the use of mechanical power will steadily replace DAP due to crop intensification, especially when and where crop prices are favourable. Availability of rural roads and electricity also tends to influence farmers toward increasing use of machinery due to various social and economic factors. Some farmers who have farms at long distances from their household and can afford to buy a two-wheel tractor usually become primary customers of farm-machinery salesmen. The availability of electricity and television also make the advertising of farm machinery most effective. From our field experiences in the villages, it has been noted that some farmers switch from the use of draught buffalo to machinery just because of advertising or having seen neighbours using small tractors, often without careful consideration of cost and benefits of machine purchase and their use in the long term. In general, the development of rural infrastructure tends to increase the use of farm machinery by farmers.

Socioeconomic factors

One of the major aims of rural development is to improve the educational level of farmers. In most LDCs compulsory education is up to fourth grade, but in some countries has been increased to sixth grade. A direct impact of higher educational requirements means less availability of family labour to take care of draught animals. And, in the longer term, people with better education see better opportunities to get a good job or higher education in the cities. Many rural young people migrate to large cities to work. Hence one of the many constraints to maintaining draught animals is a lack of family labour. Sukharomana (1991), in his study of farmers' attitudes toward buffalo-raising, pointed out that some problems of raising buffalo in Northeast Thailand were shortage of family labour, scarcity of grazing areas and lack of animal feed during the dry season, as well as the occurrence of animal diseases. However, in spite of these problems, more than 95% of the farmers interviewed wished to continue raising buffalo. Eighty-two per cent of the farmers purchased a small tractor because they could afford to, while 7% said they were under pressure caused by a short planting season due to erratic rainfall, the rest due to shortage of draught animals.

In some countries government policies tend to be biased toward mechanisation. As a result, banks are encouraged to give credit to farmers for purchasing small tractors. This alone has a very significant effect on the farmers' decisions to own small tractors, in spite of availability of their draught animals. Many farmers were found to use their tractor unprofitably, while draught animals available became unemployed.

Due to rural development many other socioeconomic factors arise which may influence the use of DAP, for instance, off-farm job opportunities, village security for keeping large animals, market prices of cattle and buffalo, increases in price of agricultural land and intense advertising by machinery companies. Migration of farm labour to big cities to earn off-farm cash income tends to have a negative effect on the use of DAP. However, some farmers would spend their cash earnings on buying cattle or buffalo. The increase in market prices in many countries of cattle and buffalo either for beef or for draught purposes makes it difficult for farmers to obtain draught animals, especially during the time of need, i.e. in planting season. In Thailand, the buffalo bank system that has been launched by both government and non-government agencies to assist rural poor to have access to draught buffalo has been on trial as a rural development tool. It has been welcomed by rural farmers but the number of buffalo banks has as yet for various reasons remained small.

Government policies

Various government policies, laws and regulations have direct and indirect long-term implications on the use of

DAP and mechanisation. They include, for instance, import tax on farm machinery, farm credits and promotion of small tractor use, industrialisation, irrigation, fuel prices and agricultural export promotion. Some of these issues have been partly discussed earlier. It can be seen clearly that if government policies are in favour of mechanisation and industrialisation, the use of DAP in rural areas will be affected, no matter whether or not mechanisation is profitable or suitable for rural farms. The level of fuel prices also has a definite effect on the use of mechanical power. In the long run it can be expected that fuel prices will increase due to increasing world fuel consumption and limited available supplies of petroleum. Prices of agricultural commodities also influence farmer decision on the use of farm machinery. Therefore, government policies in relation to foreign trade or free-trade zones such as AFTA (Asean Free Trade Area) will have some impact on the use of mechanical power in relation to DAP in the long term.

Relative Roles of DAP and Mechanisation in Rural Farming

In the last section some socioeconomic policy factors affecting the use of DAP and mechanical power on rural farms are outlined. At this stage the real policy question is related to the future role of DAP in relation to mechanisation, whether DAP will remain to play an important role in rural farming or disappear from rural areas in two or three decades, as, for example, took place in Japan during the 1970s.

It should be re-emphasised that even with increasing urbanisation in the LDCs, rural populations will continue to expand (Table 1). This means that farming in rural areas will continue to exist though not all rural people will depend on farming. What will happen to agriculture in rural areas in the year 2025? Do we expect an overall revolution in agricultural production in the LDCs? Probably not. Perhaps there could be a green revolution in the production of some agricultural commodities. However, various changes including socioeconomic aspects definitely will occur in LDC agriculture and this might affect DAP use on small farms. Some of these probable changes are discussed briefly here.

It was pointed out earlier that, with increasing government inputs into rural development, rural farmers will have better access to city and off-farm job opportunities. At the same time more farmers will be able to attain a higher level of education and skill training. Farm labour in many areas will become scarce and rural wages higher due to rural migration and effective family planning. Coupled with available irrigation water for agriculture in certain areas, crop intensification, and favourable market prices for agricultural products, etc., some farmers in such areas will shift from DAP to mechanical power. However, without irrigation farmers have to depend on rainfall, risking many uncertainties such as crop pests, drought and flood. In such cases, which include the majority of the LDC farmers, profitable use of mechanical power is quite questionable even though some farmers are willing to invest in small tractors. Those farmers who own small two-wheel tractors in rainfed farming have to use their tractor for custom ploughing, as well as for work such as water pumping and transportation, in order to keep the machine sufficiently and economically busy. Some farmers purchase a small tractor without serious economic consideration, to be fashionable with their neighbours, or because it is affordable through available government credit for machine purchase. It has been evident in many cases that in rainfed areas, small farmers who sold cattle and buffalo and turned to the use of small tractors later discovered many comparative advantages in raising draught animals. Most farmers in rural areas who own cattle or buffalo do not give up animal-raising in spite of using mechanical power. Many of them use DAP and mechanical power in combination since the machine is good for heavier work, for instance, transportation or first ploughing in heavy and relatively dry soil conditions, while DAP is suitable for ploughing in flooded fields, or for raking and weeding, etc.

Farming or cropping systems as well as other factors related to agroecosystems such as soil, water, rainfall and climatic conditions form a set of decisive factors as to whether DAP will continue to be an important source of farm power in rural farms. In lowland rainfed rice-farming systems in most LDCs, for example, it has been evident that cattle and buffalo have been well integrated into cropping systems. Animal manure is used as a fertilizer for crops, while crop residues and by-products are useful as animal feeds. And, more importantly, farmers can use animals for draught as well as for meat and milk without having to provide much cash input. It is evident that in such farming systems in the LDCs, the majority of rural farmers will continue to use DAP as a major source of farm power. It has been observed that farmers who grow crops on the upland will be more inclined toward the use of mechanical power, especially under heavy soil conditions and erratic rainfall. During recent years, in some LDCs the beef or dairy industries have become specialised and profitable. There is evidence that draught cattle or buffalo have been steadily replaced by beef or dairy animals, while the source of farm power is then supplemented by machines.

Other factors such as availability of grazing areas, size of landholding, increase in land price, prices of draught animals and other farm products, and changes in cropping patterns will all contribute to the farmer's decision on the use of DAP or mechanical power. The use of DAP in the LDCs, such as in the lowland rainfed rice production systems, will continue to be important in future decades, though mechanical power will increase.

DAP and Sustainable Agriculture

The world today is facing the problem of how to feed more than 5.5 billion people without damaging the environment and destroying agricultural resources. Every year almost 100 million more people are being added to the already heavily populated earth surface, and by the year 2025 (or 33 years from now) world population will reach 8.2 billion or even higher (Table 1). This means that agriculture has to produce more food to satisfy the basic needs of an increasing population. In the past it has been clearly witnessed that in many LDCs increased agricultural production means more destruction of forest, soil and water, as well as other resources. And even in the developed countries (DCs), increased agricultural output through modern technology means more use of pesticides, chemical fertilizer, intensive mechanisation, irrigation, etc., which will cause increased air pollution, as well as soil and water degradation. This is why the world today is turning its attention to the concept of sustainable agriculture, which means increasing agricultural production without destroying the environment and natural resources, and as a consequence enhancing the survival of mankind. TAC/CGIAR (FAO 1989) defined sustainable agriculture as '... successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources'. The uses of DAP vs mechanisation in rural farming ought to be evaluated from the perspective of achieving agricultural sustainability. Agricultural policies of governments of the LDCs should emphasise not only increasing agricultural yield or maximum productivity but also achieving higher (optimum) farm production level with efficient use of resources and without damaging the environment. To allow further destruction of forest and the environment in the future is to accelerate the extinction of generations of our descendants. Hence the importance of DAP in rural farming should be considered with these criteria in mind, in comparison with mechanisation.

Small-farm animal production for DAP, or other purposes such as meat and milk, has been known generally to be well integrated into crop production systems in rural areas in the LDCs, as is clearly evident in Southeast Asia (Chantalakhana 1990). However, when animals are found in some grazing areas unsuited for crop production or degraded lands such as semi-desert areas or eroded soils, livestock critics usually simply assume that animals cause environmental damage. It is generally ignored that man and management are primarily responsible for such adverse consequences. Appropriate species of draught animals, if well managed under a suitable agroecosystem, will not have a deleterious effect on the environment, but, on the contrary, will enhance it through manure droppings, etc. For example, in the case of draught buffalo in the lowland rainfed rice-farming systems, it is well accepted that buffalo contribute through manure, urine, and labour to rice production, while utilising rice straw, weeds or forages on marginal land and other non-marketable agricultural wastes and by-products which are otherwise not very useful to farmers. The animals, from a socioeconomic standpoint, are regarded as an investment: insurance in case of crop failure due to unexpected calamities such as flood, drought, insect or pest infestation, companion and employment for children, women and old age, inheritance and social status for rural people, and others.

Mechanisation such as the small two-wheel tractor, though proven to be efficient and speedy and to reduce human drudgery under certain conditions such as in irrigated areas, is often found to be expensive and inappropriate under rainfed conditions where rainfall is erratic and unpredictable. The use of mechanical tools and petroleum power in the long run could create unfavourable conditions such as soil compaction, pollution of soil, air and water, and higher price of petroleum.

In the long run these two sources of farm power, DAP and mechanisation, have to be carefully and efficiently managed in support of sustainable agricultural production. DAP and mechanisation do not have to be mutually exclusive, the use of both in appropriate combinations in most countries has proved a sustainable way to farm power utilisation. In certain farming systems, such as irrigated rice, mechanisation may be quite suitable, but in rainfed farming DAP could form a larger share of farm power, depending upon a specific set of socioeconomic factors. It needs to be emphasised here that LDC governments should not favour a mechanisation policy for the sake of following the modernisation trail. The economics of integrated use of farm power sources should be examined and continually monitored in order to be able to adjust simultaneously related government policies to achieve the best benefit from agricultural production with sustainability perspectives.

Ruminant animals are believed to account for 15% of total methane emission into the atmosphere, but this can be controlled by improved husbandry practices and biogas utilisation techniques which, in addition, promote efficient use of manure as fertilizer for crops, and improvements in household sanitation and human health. Chantalakhana (1990) presented an analysis of small-farm animal production with respect to agricultural sustainability perspectives (Table 3), which clearly reflects various positive aspects of keeping draught animals in integrated rural farming systems. Techniques such as use of a biogas digester may not appear socioeconomically appealing in many countries at present, but with future increases in human populations and scarcity of available resources these technologies will become very useful.

Table 3. Analysis of sustainable small farm animal production.

Level of analysis	Typical characteristics of sustainability	Typical determinants
Field/production	Higher yield of livestock; improved soil fertility; control of animal diseases and parasites; control of pollution from animal wastes	Use of locally available feed resources; vaccination against diseases; disease-resistant and heat-tolerant breeds; use of marginal lands
Farm	Integrated crop-forestry-livestock farming systems; insurance in case of crop failure; high regards of social and cultural values of livestock; utilisation of surplus labour	Farmer training; increased interest in new technologies; use of manure and draught animal power; production of biogas; use of crop by-products; household
Country	Preservation of indigenous breeds; maintain social stability; use of exotic breeds	Disease-free zone; role of women, children and old folk; use of lands not suited for crops; reduced rural migration to cities; expansion of domestic/export livestock markets; increased research and extension activities; breed improvement programs
Region/continent/ world	Better nutrition; higher income for farmers; improve soil erosion and salinity due to cropping	More foods, fibre, skins, traction, fertilizer, fuel; favourable effect on the environment; use of animal traction reduces CO_2 emissions

Source: Chantalakhana (1990)

Conclusion

It is obvious that small-farm systems in rural areas will continue to evolve. Clearly, subsistence farming will continue to develop along with national development plans. In most of the LDCs it has been clearly witnessed that agricultural development generally takes a slower pace compared to such other sectors as industry or service. The agricultural sector will begin to shrink steadily as a proportion of the labour force, as will land proportion and contribution to the GNP at a certain stage of national development, in relation, to say, the industrial sector. The area of cultivated land will tend to decline due to urbanisation, hence, more intensive farming systems will replace some areas of subsistence farming when prices of agricultural commodities become favourable and other factors such as technology or capital investment are available. Intensive farming systems commonly employ mechanisation in order to speed up farm work and as a consequence this evolution in agricultural systems will reduce the role of DAP. However, it can be seen in many countries that while this phenomenon takes place, some draught animals such as cattle will also be transformed into specialised livestock production systems such as dairy production and beef. Draught animals such as cattle and buffalo are well-developed multipurpose livestock, therefore it is not difficult to convert them into specialised meat or milk producers.

In spite of all these developments, including those in the industrial sector, small farms in the LDCs will continue to exist for many decades due to factors including socioeconomic and political conditions. In the meantime DAP will continue to be an important source of farm power for rural small farmers. DAP should receive favourable consideration as compared to mechanisation within the framework of agricultural sustainability perspectives, as far as small-farm systems are concerned. The major constraint which hinders wider use and development of DAP is a lack of interest and support for DAP research and development by LDC governments. As mentioned before, most LDC governments tend to be biased toward mechanisation, which is useful only when and where the use of mechanical power is suitable. However, DAP should receive due attention and support from government since in many regions DAP still has many advantages over mechanisation, and should be seen as a component of sustainable agricultural systems. But in many cases the integrated use of DAP and mechanisation offers the best choice for rural small farmers.

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Economic Comparisons between Draught Buffalo Use and Mechanised In-field Transportation of Fruit Bunches in the Palm Oil Industry in Malaysia

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Abstract

Economic comparisons between the use of draught buffalo and mechanised in-field transportation of fruit bunches in the palm oil industry in Malaysia were made, based on information from the literature. It was found that productivity per machine/cart was the highest for the mini-tractor, followed by mechanical buffalo (a smaller version of the mini-tractor), and draught buffalo systems. However, when the same comparisons were made on a per harvester basis, the draught buffalo system was the most efficient. Individual harvester income was highest for the draught buffalo system because of the higher individual output, as compared to the mechanised systems. A larger initial capital investment is required for the mini-tractor system than for the mechanical buffalo and draught buffalo systems. Due to the higher individual output, the labour requirement for a given area was estimated to be lower for the draught buffalo system than for the mechanised systems. In addition, the draught buffalo system reduced weeding costs, resulting in significant savings for the plantation.

HARVESTING and in-field transportation of fruit bunches constitute one of the major cost elements in the production of palm oil. Traditionally, this tedious job was done by human harvesters who had to carry the harvested fruit bunches from the palms to roadside collection points using baskets (kanda sticks), bicycles and wheelbarrows. The rapid development of the palm oil industry in Malaysia has created a shortage of labour in this industry. To overcome the problem of labour shortage and to reduce labour dependence, many plantation managers have introduced draught buffalo and various forms of mini-tractor to assist in-field transportation of the fruit bunches. The economic advantages of using these two systems of transportation over the traditional method have been reported by different workers (e.g. Muirhead 1980, Liang et al. 1984, Anon. 1988, Malek and Yaakob 1989, Teo et al. 1990).

This paper aims to consolidate available information from the literature and to make economic comparisons between the use of draught buffalo-carts and mini-tractor systems for in-field transportation in the palm oil industry in Malaysia.

Sources of Data

Material used for this study was from three sources, (Liang et al. 1984; Malek and Yaakob 1989; Teo et al. 1990. These authors reported on the use of draught buffalo, mini-tractors and 'mechanical buffalo' (a smaller version of mini-tractors) respectively for in-field transportation. It is not possible to make direct comparisons on the costs and returns of the different systems directly from the three sources because the studies were carried out at different times and under varying conditions of total fruit yield, terrain of field and the total operating hours per day. In addition, different parameters were used in the calculation of costs and returns in the different studies. Therefore, several assumptions were made about the original data and adjustments made to allow for more meaningful comparisons. Some background information on the different systems based on the three references used for this study is presented in Table 1.

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Table 1. Some background information from three references on the different systems of in-field transportation of fruit bunches in oil palm plantations in Malaysia.

Systems	Draught buffalo[a]	Mechanical buffalo [b]		Mini-tractor[b]		Mini-tractor[c]		
(Group)	(a)	(a)	(b)	(a)	(b)	(a)	(b)	(c)
1. Period of study								
Date (year)	1982	1988	1988	1988	1988	1988	1988	1988
Length (months)	6	8	12	12	8	40	40	40
2. Average working days/month	21	24	22	25	22	22	21	23
3. Age of palm (years)	9	21	11	12	22	n.a.	n.a.	n.a.
4. Machine or cart								
Units used	18	1	2	6	2	2	3	3
Expected life (years)	10	3	3	5	5	5	5	5
Horse power	–	n.a.	n.a.	19	19	18	18	18
Trailer capacity (t)	0.5	0.4	0.4	1.0	1.0	1.0	1.0	1.0
Cost/unit (MR$)	1 450[#]	4 500[*]	4 500[*]	14 000	14 000	14 000	14 000	14 000
5. No. of harvesters per unit	1	4	4	6	6	17	15	14
6. Fruit yield (t/ha/year)	17.8	12.8	14.8	19.2	12.6	27.5	27.5	27.5

Note: [a] Liang et al. 1984

[b] Teo et al. 1990

[c] Malek and Yaakob 1989

[*] Estimated at 1/3 of the price of mini-tractor (Teo et al. 1990)

[#] Price of buffalo plus cart

Comparisons on Productivity

Output of fruit bunches

Productivity of the various systems (draught buffalo, mechanical buffalo and mini-tractor) was compared for daily fruit output and area covered based on per machine/cart and per harvester basis. It is found that productivity in terms of tonnes of fruits and area covered per day per machine was highest for the mini-tractor followed by the mechanical buffalo and draught buffalo systems. The high productivity of the two mechanised systems over that of draught buffalo was due to the larger number of harvesters allocated to each machine in the former systems. In the draught buffalo system, each buffalo cart was handled by one harvester while 4 to 17 harvesters, working as a team, were allocated to the other two systems (Table 1). However, when productivity was compared based on per harvester basis, the draught buffalo system was the most efficient (Table 2).

Costs and returns

The primary objective of the introduction of draught buffalo and other forms of mechanised in-field transportation in the palm oil industry is to reduce the costs of harvesting. It is found that this cost ranged MR$10.58–MR$16.06/t for the three systems compared. Cost of harvesting and in-field transportation for the draught buffalo system was similar to that reported for the mini-tractor system by Malek and Yaakob (1989), and was 20–30% lower than that for the different groups

Table 2. Productivity of the different in-field transportation systems in oil palm plantations in Malaysia.

Systems	Draught buffalo[a]	Mechanical buffalo[b]		Mini-tractor[b]		Mini-tractor[c]		
(Group)	(a)	(a)	(b)	(a)	(b)	(a)	(b)	(c)
1. Per machine or cart								
Fruit/day (tons)	2.70	6.28	8.53	11.39	6.24	22.77	19.46	18.89
	(1.00)	(2.33)	(3.16)	(4.22)	(2.31)	(8.43)	(7.21)	(7.00)
Area/day (ha)	3.65	11.75	13.82	14.24	11.87	19.87	16.98	16.49
	(1.00)	(3.22)	(3.79)	(3.90)	(3.25)	(5.44)	(4.65)	(4.52)
2. Per harvester								
Fruit/day (tons)	2.70	1.55	1.54	1.82	1.37	1.46	1.48	1.49
	(1.00)	(0.57)	(0.57)	(0.67)	(0.51)	(0.54)	(0.55)	(0.55)
Area/day (ha)	3.65	2.79	3.77	2.19	2.62	1.27	1.29	1.30
	(1.00)	(0.76)	(1.03)	(0.60)	(0.72)	(0.35)	(0.35)	(0.36)

Note: [a] Liang et al. 1984
[b] Teo et al. 1990
[c] Malek and Yaakob 1989
Figures in parenthesis show the comparative values to the base figures of buffalo cart.

Table 3. Cost of harvesting and transportation of fruit bunches and income of harvesters of the different in-field transportation systems in oil palm plantations in Malaysia.

Systems	Draught buffalo[a]	Mechanical buffalo[b]		Mini-tractor[b]		Mini-tractor[c]		
(Group)	(a)	(a)	(b)	(a)	(b)	(a)	(b)	(c)
1. Cost per t								
Pay to harvester	9.57	11.91	10.35	10.52	11.66	8.37	8.23	8.62
Costs of machine								
interest	-	-	-	-	-	0.27	0.33	0.31
insurance	0.06	-	-	-	-	-	-	-
running/repairs	0.03	0.45	0.22	0.66	0.94	0.50	0.73	0.65
depreciation	0.07*	1.19	1.51	1.03	2.46	0.44	0.54	0.51
Sub-total	0.02	1.64	1.73	1.69	1.40	1.21	1.60	1.47
Supervision	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total (MR$)	10.60	14.55	13.80	13.21	16.06	10.58	10.83	11.09
	(1.00)	(1.37)	(1.32)	(1.25)	(1.52)	(1.00)	(1.02)	(1.05)
2. Harvester income								
per tonnes (MR$)	9.57	11.91	10.35	10.52	11.66	8.37	8.23	8.62
output (tonnes)	2.70	1.55	1.54	1.82	1.37	1.46	1.48	1.49
per day (MR$)	25.85	18.46	15.94	19.15	15.97	12.22	12.18	12.84
	(1.00)	(0.71)	(0.62)	(0.74)	(0.62)	(0.47)	(0.47)	(0.50)
3. Deflated harvester income								
per t (MR$)	9.57	9.07	7.88	8.01	8.88	6.37	6.27	6.57
output (t)	2.70	1.55	1.54	1.82	1.37	1.46	1.48	1.49
per day (MR$)	25.85	14.06	12.14	14.58	12.17	9.31	9.28	9.78
	(1.00)	(0.54)	(0.47)	(0.56)	(0.47)	(0.36)	(0.36)	(0.39)

Note: [a] Liang et al. 1984
[b] Teo et al. 1990
[c] Malek and Yaakob 1989
* Shows an appreciation in value
Values in parenthesis show the comparative values to the base figures of buffalo cart.
Consumer Price Index for 1988 = 131.3 (base year 1980).

in the mechanical buffalo and mini-tractor systems reported by Teo and co-workers (1990). The higher costs for the mechanical buffalo and mini-tractor systems were due partly to the high operating costs of running, repairs and depreciation of the machines which ranged10–15% of the total cost in the mechanised systems. This operating cost for the draught buffalo system was almost zero (Table 3). The operating cost of repairs would be expected to be higher as the machines get older, thus further increasing the total operating cost of the mechanical buffalo and mini-tractor systems if the periods of studies were extended (Teo et al. 1990).

Harvester income

Human harvesters are paid according to their output and the prevailing price of the fruit. The latter is determined by the prevailing market price of palm oil in the international market. The estimated harvester income (based on the prevailing price of fruit bunches at the time of each study and that deflated by consumer price index (Table 4)) was always the highest for those working with draught buffalo followed by those in the mechanical buffalo and mini-tractor systems (Table 3). The higher harvester income in the draught buffalo system was due mainly to the higher harvester output.

Table 4. Average price of palm oil and Consumer Price Index (CPI) for Peninsular Malaysia.

Year	F.O.B. value of palm oil ('000 t)	CPI (Peninsular Malaysia)
1980	1 199.1	100.0
1981	1 173.0	109.7
1982	971.5	116.1
1983	984.1	120.4
1984	1 582.6	125.1
1985	1 246.9	125.5
1986	682.9	126.4
1987	821.0	127.8
1988	1 102.0	131.3
1989	927.4	136.1

Source: Department of Statistics, Malaysia, 1990.

Conclusions

The primary objective of introducing draught buffalo and the various forms of mechanised in-field transportation systems of fruit bunches in the palm oil industry is to increase harvesters' productivity. Increased productivity has dual effects, resulting in lower cost of production for the plantation and increased income for the harvesters. The economical advantages of using draught buffalo and mechanised in-field transportation over the traditional method of carrying fruit bunches in baskets has been well documented. The extent of benefits differed between the studies but was generally 30–35% (Liang et al. 1984; Teo et al. 1990).

Although direct comparisons were not made, it is believed that the following general conclusions can be drawn from this study.

(i) Productivity per machine basis was highest for the mini-tractor followed by the mechanical buffalo and draught buffalo systems. However, when the same comparisons were made on a per harvester basis, the draught buffalo system was always the most efficient.

(ii) Individual harvester income was highest for the draught buffalo system, mainly because of the higher individual output compared to the mechanised systems. Repayment to management for use of the machine has decreased net harvester income in the two mechanised systems.

(iii) A larger initial capital investment is required for the mini-tractor system than for mechanical buffalo (Teo et al. 1990). Initial capital investments for the mechanical buffalo and draught buffalo systems were similar.

(iv) Due to the higher individual output, the labour requirement for a given area would be lower for the draught buffalo system than for the mechanised systems. Reduction in harvester requirements help in reducing the overall cost of production because of savings in overheads and fringe benefits paid to the harvesters. In addition, a draught buffalo system reduces weeding costs by MR$16.30/ha/year (Liang et al. 1984), a significant saving for a plantation with an average size of 5 000–10 000 ha.

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Effective Transfer of DAP Technology

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Abstract

As most DAP farmers are resource-poor and operate integrated, mixed-output farms, the generation and transfer of DAP technology require special sensitivity and procedures. Simple technology using local materials and crafts will be the most easily transferable. DAP technology acceptable to resource-poor farmers has seldom been generated on research stations, or transferred by scientists working alone. Farmers themselves should be involved in the training of other farmers. The need for involving local craftsmen and manufacturers, as part of the 'embedding' process in DAP technology transfer should not be underestimated.

The aims and the politics of programs of DAP promotion need careful clarification, as in practice no technology is politically neutral. The organisation of active farmer participation will require changes to most research and extension institutions. Some innovative approaches to working with farmers to raise the status and the performance of DAP systems are described — as the transfer of DAP technology will depend on the ability of scientists to find effective ways of improving their involvement with the human aspects of the systems in which they work.

THE main contentions of this paper are summarised as:

- DAP technology can include anything that enhances the value of the DAP enterprise to the operator (see Appendix);
- DAP technology developed on research stations has seldom been adopted by farmers (in Southeast Asia);
- DAP technology seldom lends itself to conventional models of transfer, by extension agents alone;
- farmers and local artisans are essential agents in the adaptation and transfer of DAP technology;
- simple technology from other farming systems, designed to fit both the local crafts and farming systems, is more readily 'transferable' than more complex ideas for enhancing and promoting DAP use; and
- most DAP technologies require 'embedding' in the farming system.

These characteristics apparently arise from the inherent complexity of the human/animal/soil/crop/market factors applying in all small-scale farm systems (e.g. Rhoades and Booth 1982). The extra dimensions introduced in DAP enterprises by interactions with the handler/animal/work/labour/social components further reduce the likelihood of appropriate technology being transferred by urban-based scientists and planners alone.

Another reason for our difficulties, in Southeast Asia, at least, in developing and effectively transferring DAP technology, is that farmers do not keep animals solely for draught work: yet our efforts to promote DAP seldom take this into consideration. 'We tend to bias our perception by calling them draught animals: they are not, they are draught-capable animals', and to most (Javanese) rearers, calf sales and other benefits of rearing livestock are more valuable than animal work itself (Perkins and Semali 1989).

These notions have parallels in those expressed in the classification by Rogers and Shoemaker (1971) for evaluating innovations. It uses the five criteria of 'observability', 'trialability', complexity, relative advantage and compatibility with the existing system.

In this paper, the emphasis is on Southeast Asia, and the term 'scientist' is used to include both social and natural scientists, who have, after all, the same goals in rural development. Some commonly used terms in technology transfer are defined in the Appendix.

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DAP technology developed on research stations has seldom been adopted by farmers

There is growing evidence (although often poorly documented) of our numerous failures effectively to transfer scientist-designed 'improvements' to DAP systems all over the world (e.g. Eicher and Baker 1982). Starkey (1988a), in the book *Perfected Yet Rejected* estimated that well over $60 million was spent on developing animal-drawn wheeled tool-carriers in various countries, without producing any model that has been adopted by farmers. Yet wheeled tool-carriers have been shown on research stations vastly to reduce labour inputs over the cropping season.

Millions of dollars worth of DAP machinery, harnesses, carts, dynamometers, animal loading devices, and other equipment and research programs abandoned at research centres in Asia and Africa are further evidence that traditional approaches to the development and transfer of DAP technology have been largely unsuccessful.

DAP technology seldom lends itself to conventional models of transfer, by extension agents alone

Traditional models of the process of technology development and transfer show technology being developed on research stations and then transferred by extension workers to the farmer, as depicted in Figure 1.

Most families that utilise DAP are resource-poor farmers, running small, mixed enterprises, a category of agriculture that will need to produce most of the increase in food production to keep up with future population growth (Wolf 1986; Byerlee 1988).

It is widely accepted nowadays that in working with resource-poor farmers there is a need for modification of the traditional technology development and transfer models, to place greater emphasis on the testing of ideas for improvement on-farm (e.g. Farrington and Martin 1987, Merrill-Sands et al. 1991). Hence a logical improvement on the traditional technology development model shown in Figure 1 would be the inclusion of on-farm testing, as depicted in Figure 2.

Further refinements to the model in Figure 2 are suggested for the case of DAP technology later in this paper.

Farmers and local artisans are essential agents in the adaptation and transfer of DAP technology

Farmers are more likely to accept new ideas if they can observe other farmers carrying out these as normal practices. People who live and work daily with draught animals are much more effective as trainers than scientists who work only occasionally with animals. The involvement of farmers (and also artisans or manufacturers, in the case of DAP equipment) is therefore a logical requirement in the development and transfer of DAP technology.

Much has been written on the advantages of farmer participation in technology development (e.g. Rhoades and Booth 1982; Ashby et al. 1987; Box 1987). Participation in this context includes farmer involvement in a

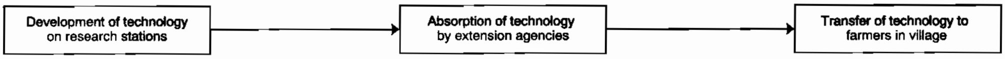

Figure 1. A traditional model of technology development and transfer.

Figure 2. A technology development and transfer model including on-farm testing.

range of activities, from description of the farming systems and careful definition of the constraints and needs of farmers, to farm trials of technology, and then assistance with the transfer process. In a study of on-farm research programs in nine countries, Merrill-Sands et al. (1991) concluded that really close involvement of both farmers and extension agents in the planning and conduct of on-farm trials is paramount for success.

In the transfer of DAP technology, the potential role of farmers from one farming system as trainers of farmers in other areas has perhaps been greatly neglected (e.g. see Marwali et al. 1990).

Simple technology from other farming systems, designed to fit both the local crafts and farming systems, is more readily 'transferable' than more complex ideas for enhancing and promoting DAP use.

In a program of DAP research and development conducted in Java and Timor from 1986 to 1990, numerous ideas for 'improving' local DAP systems were assessed in farm trials (Petheram, Teleni et al. 1989, Liem and Saleh 1990). Of these, the only technologies 'accepted' by farmers were:

- simple DAP tillage practices that allowed poorer farmers to prepare their land independently of richer cattle-owners who had previously prepared their fields at a price of one-third of the harvest (Petheram and Liem 1990);
- simple tillage implements (made with local timber and skills) and taken 'off the shelf' from another DAP system;
- forage species taken from similar agroclimatic areas; and
- bull support schemes, designed to improve the availability of male animals for breeding purposes.

Farm trials in this program showed that farmers' perceptions of 'improvements' to DAP systems differed widely from those of scientists. It appears that this difference in perception is greatest in the case of resource-poor farmers, where even the simplest change can affect drastically their whole social and biological systems. Where farmers are more affluent and infrastructure more developed, the transfer of more complex ideas may be feasible (e.g. Ramaswamy and Narasimhan 1984).

Most DAP technologies require 'embedding' in the farming system

Even where farmers can see merit in a new DAP technology, as offering potential to improve their existing DAP system, there are often reasons why they cannot adopt the idea. The most common reasons for non-adoption of technologies that have been tested on local farms are lack of reliable information on the technology (training and/or advice), lack of capital (or credit), risk of financial loss (and loss of face) on failure, and lack of time and labour to set up (or to test) the technology.

The 'embedding' of technology includes any process or 'intervention' that is needed to ensure that the new idea is accessible and can be reliably adopted and maintained by the target group (Waters-Bayer 1989). In parts of Africa and Indonesia, where DAP was introduced for the first time to large populations, it has generally been found necessary to establish large projects to ensure the promotion of DAP involving animal breeding programs, credit schemes for purchase of livestock and equipment, forage programs, farmer training programs, support for equipment manufacture, and even marketing schemes to handle the extra products resulting from DAP use (e.g. Munzinger 1982, Soejoto and McEvoy 1989).

In attempting to transfer DAP technology aimed at the enhancement of existing DAP systems, scientists must be prepared to convince policy-makers of the need for establishing all the support needed to ensure accessibility and the maintenance of long-term benefits to the community (e.g. manufacture and repair services for carts, Ramaswamy and Narasimhan 1984).

Our efforts to promote DAP must take into consideration that farmers do not keep animals solely for draught

Because farmers do not usually keep animals for draught alone, the promotion of greater DAP use may often be best achieved through enhancing the other outputs of DAP systems (such as calves and growth rate), or through reducing the labour requirements for feeding, or the risk or the effects of animal disease.

Towards an improved model for generation and transfer of DAP technology

The design of the technology transfer process for all types of technology for resource-poor farmers and their complex farm systems can be fraught with unpredictable difficulties, so the development of innovative approaches to technology transfer has in itself become a major area for research (e.g. Thiele et al. 1988; Biggs 1989; Osborne 1990). There is evidence of some particular requirements for the transfer of DAP technology, notably the need to integrate animal handlers and local craftsmen and manufacturers into the diffusion process (Lowe 1986; Basant 1988).

Experience of a range of projects attempting to promote DAP technology in Africa and Asia, and study of the literature, suggest that we should be able to design a process for the development and transfer of DAP technology that is more likely to succeed than most of our past efforts. The model will vary with local circumstances, but a generalised flowchart of activities is suggested in Figure 3.

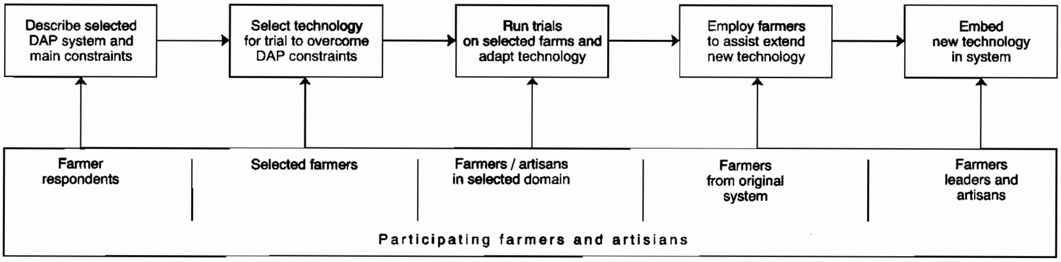

Figure 3. Farmer participation in generation, transfer and embedding of technology.

The first stage of Figure 3 entails a description of the social and economic, as well as the biological and mechanical, features of the system, as the people-related aspects are generally the most important in determining the needs for, and the suitability of, particular technologies. The process outlined in the model is discussed further, later in the paper.

Situations for DAP Technology Transfer

The range of situations in which there is a need for transfer of DAP technology, and of ideas for DAP technology, is very wide. For the purpose of this paper, these can be classed into four major areas, with various subclasses:

1. Introduction of DAP, where no DAP is currently used;
2. Enhancement of performance of existing DAP systems through:
    - (i) the equipment components, such as more efficient tillage implements, carts or harnesses;
    - (ii) the animal components, such as more effective animal breeding, animal (or species) selection, animal training, feeding, health control methods for both animal work and growth;
    - (iii) crop or agronomic components, such as more timely or appropriate tillage; and
    - (iv) the human component, such as training programs for artisans in making implements, and for women and men in animal handling;
3. through intensification of the use of DAP (i.e. using animals for longer periods of the year on the current range of uses); and
4. through diversification of the current uses of DAP, (i.e. extending the use of power beyond the current range of crop and/or transport operations, e.g. cartage, water lifting, sledges, or tillage where no tillage is currently practised).

The introduction of DAP

The introduction of DAP as a new technology to areas in which no draught animals are currently used has been accomplished over vast areas of Africa (e.g. Munzinger 1982, Starkey 1988b) and in the transmigration areas of Indonesia (Soejoto and McEvoy 1989), usually through large integrated development projects. In these situations DAP has been accepted as a source of power to reduce human drudgery, to increase cultivated areas and hence crop production, or as a means of carting produce or water, but more effectively where all the necessary support has been provided.

However, DAP is unavailable to many millions of people, through their poverty or ignorance, through the lack of animal feed or the prevalence of diseases—and DAP is still shunned by millions more, for cultural reasons. The selection of appropriate species, materials and equipment and other components compatible with the system poses challenging problems for future introductions of DAP.

The enhancement of existing DAP systems

The introduction of DAP to non-users in areas where draught animals are already utilised involves seeking ways of making DAP more accessible and/or attractive to the farmer domains concerned, for example, through the use of cheaper, locally made implements (Marawali and Liem 1990), improving village forage supplies (Yudi and Yusran 1989), improving fertility rate in cows (Chaniago and Santoso 1989), increasing calf production (Perkins and Semali 1989), reducing risk of disease (Petheram, Goe and Astatke 1989, p.15), and through credit schemes for animals and implements (Soejoto and McEvoy 1989).

The options for enhancement of the performance of an existing DAP system may be considered by examining the interactions in a simple diagram of a farm system that includes a DAP tillage enterprise, such as shown in Figure 4.

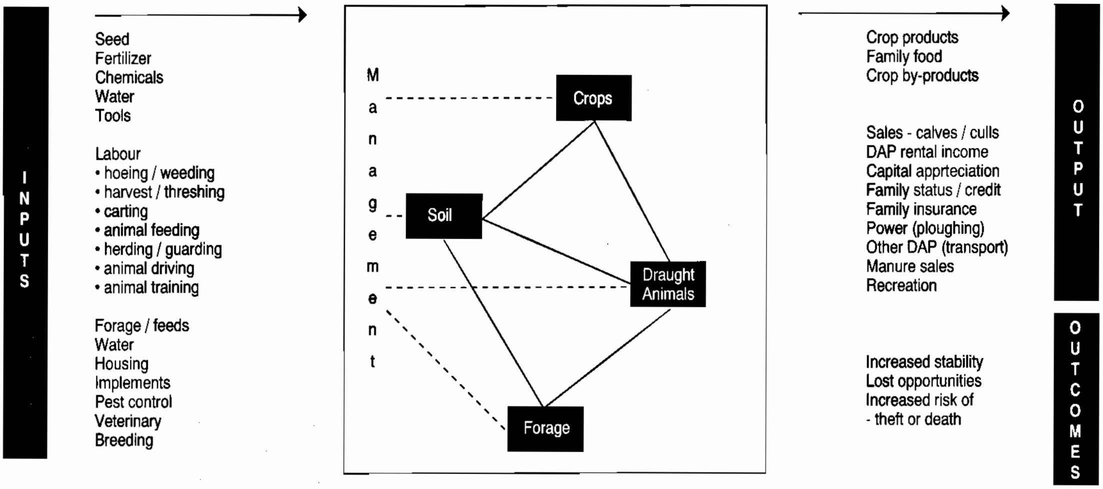

Figure 4. Diagram of a mixed cropping/livestock system, showing main subsystems, inputs and outputs (and outcomes).

The enhancement of the farm system could encompass any idea for change which would make the system more attractive to either rearers or non-rearers of DAP. For instance, technology that would result in reduced inputs per unit of farm output, such as less labour per unit of crop produced, or less labour per animal unit reared; increased output per unit of capital investment, e.g. more calves from the same number of animals, or higher income from rental of stock, or the same work achieved by one animal instead of two; reduced commitment of family labour, allowing greater flexibility and opportunities on the labour market, e.g. improved forage supply can reduce labour for feeding; and reduced risk in crop production, or in animal rearing, e.g. more timely crop establishment or more reliable control of animal disease or theft.

The intensification of the use of DAP

Most draught animals (e.g. in Indonesia) work for less than 50 days per year, although some pull tillage implements for over 200 days and some pull carts for over 300 days per year. It is often assumed that an increase in the number of days worked would constitute an improvement to the rearers, but this is often not so, as the optimum amount of work is dictated by the other activities of the farmer and can affect other production outputs of the DAP system (e.g. calving rate).

There are situations where available family labour could be used to extend the DAP season, if the work is available. Perkins and Semali (1989) point out, however, that where work is limited, an increase by one DAP operator will mean a reduction for others, unless alternative types of work are found. The intensification of DAP has often followed other developments in agriculture, such as irrigation.

Diversification of current uses of DAP

While the range in the literature of potential applications of DAP is very wide (e.g. Starkey 1988b), there is very low diversity in the type of DAP used within individual enterprises in Southeast Asia and in Africa. The most likely new roles of DAP will be simple practices such as the pulling of sledges, or the use of cheap carts. The declining terms of trade of farmers in most countries seem likely to prevent their investment in more efficient but expensive DAP machinery such as tool-carriers (Starkey 1988a). More affluent farmers tend to move towards tractors and implements and motor-driven pumps, rather than adopt more sophisticated DAP equipment.

Nevertheless, in the future, with increasing fuel prices and greater organisational support for farmer groups, there may be a place for wheeled tool-carriers and other more sophisticated DAP equipment, if their use can be organised on a communal, contract or hire basis. The use of animal-drawn dam-scoops for pond excavation by communities in Ethiopia is an example of such community organisation of DAP (Anderson and Astatke 1985).

Aims and Politics in Technology Transfer

No new technology is politically neutral (Biggs 1989). Just as the introduction of tractors benefits richer farmers more than others, so the introduction of DAP, or the promotion of a more efficient implement or cart, can be expected to benefit some groups in society more than others.

It follows, therefore, that decisions on DAP development and transfer should be made within the framework of government policy, if the program is to expect continued financial support. Where agricultural policies place strong priority on equity, the generation and transfer of technology for the poorer sectors of the community would be given greatest support.

The development of DAP was set back in many countries by a period of promotion of tractors as a more modern and efficient source of agricultural power. In many regions now, where the relative advantages of DAP have been well established, a stigma remains against DAP use among many scientists and policy-makers. Removal of this stigma, and raising the status of DAP use and users, are vital prerequisites for rapid transfer of DAP technology.

In most countries, where there is recent interest in promoting DAP, this has been stimulated by a realisation of the relevance of DAP to the vast majority of resource-poor families. Even so, vast resources have been expended in research on DAP that has little or no application to the needs of the mass of families.

Lowe (1986) pointed out that industrial nations have no direct interest in the spread of DAP technology, and that there is often suspicion of, or opposition to, DAP by donor countries because of visions of cruelty to animals, and also to the very simplicity of DAP (apparently to the point of archaism). If DAP promotion is part of national policy, there is an obvious need to ensure that this task is addressed by local agencies and not left to outside agencies alone.

As draught animals are often in the control of the male side of the family, DAP technology has sometimes contributed to the marginalisation of women and young farmers. The development of animal-powered systems tailored to the needs of those groups (e.g. using donkeys) may help to counter such situations (Munzinger 1982, Lowe 1986).

Innovative Approaches to DAP Technology Transfer

In the approach outlined above to developing the DAP component of farming systems, the generation and transfer of technology are almost inseparable. Those involved in the generation and testing are also active in seeking ways of ensuring the adoption of the ideas by the farmers. The most effective transfer agents are farmers and artisans from whose farming systems the technology has been taken, or farmers in the recipient domain on whose farms (and animals and crops) the technology has been tested.

The over-riding requirement in the model depicted in Figure 3 is for the scientists involved to realise that they can never achieve the level of understanding of the farmers' situation that the local inhabitants already have. The role of the scientist becomes that of the catalyst, i.e. stimulating thought and discussion by farmers about their problems and needs, and encouraging farmers' initiatives to improve the contribution of DAP to their livelihood.

Solutions are first sought by considering ideas that are already within the farming community (or which have been used in the past). Ideas from outside the system can be used to stimulate discussion on local solutions to similar problems, and researchers can assist by suggesting ways in which ideas might be tested. Following testing on farms, and adaptation of technology to suit local conditions, further farmer participation is required to develop effective ways of embedding and then spreading the technology. As farmers and scientists become more experienced in participatory research, the farmers will become more willing to take the initiative and to assume the leading role in the process.

Where farm-led technology generation is constrained by the limited experience of farmers of ideas and technology from other systems, a range of techniques is needed to stimulate ideas for possible change in their systems. Ways are also needed to allow farmers to see or test new innovations in action, in a manner that does not place them under risk.

Some form of farmer gatherings or groups are a prerequisite for the transfer process. Groups in which friendships and trust have been built up between scientists and farmers, through time spent working on farm trials or other projects, are ideal for this purpose. Activities that have proved valuable in stimulating ideas among farmer groups include the followng examples.

- Visits by groups of farmers and scientists, all sharing the same transport and accommodation, to farming areas selected for their similarity or for particular innovations in the area. Informal meetings are held with local farmers to see technology in action and to discuss merits and problems (Thahar et al. 1989).
- Farmer-to-farmer workshops are gatherings of people from a number of areas, hosted by a particular village and focusing on a particular DAP activity. Local farmers show others their farms and their trials of new ideas. Scientists take a backstage role, but arrange transport and organisational help, and the careful documentations of opinions expressed (Waters-Bayer 1989).
- Video films of technology from other areas can be a useful source of ideas for farmer groups. The films

should show farmers actually using and discussing the technology concerned.

- Community video (Waters-Bayer 1990) involves producing video films about farmers who have developed or adopted a technology that may have value to others. Production of these films gives the farmers pride and enthusiasm for further technology development, and provides a valuable tool for use with other groups.
- Demonstrations of technology that has been well tested on particular farms can be valuable in spreading new ideas. However, many demonstrations run by scientists demonstrate mainly how little scientists know about farmers' conditions (Biggs 1989). To be successful as a transfer tool, demonstrations must be on farms carefully selected to represent the recommendation domain, and must not be supported by unrealistic inputs.
- Innovators' workshops are gatherings at research or training centres of farmers whose practices differ from the majority. Participants are invited to explain their innovation, with practical demonstrations. The group is asked to rank each innovation in terms of its applicability and problems, thus providing valuable feedback on requirements for further research, and support needed to embed and promote the technology (Waters-Bayer 1989).
- Ploughing contests in villages, involving comparisons of various animals, equipment and combinations, and in which technology new to the area can be demonstrated by farmers from another area and tried out by locals. These venues are valuable in raising the status of DAP in the community, and as a medium to reach numerous farmers not in the regular groups (Petheram et al. 1988).
- The employment of experienced farmers and artisans as trainers from one farming system to train farmers in another region, on animal training and the home manufacture of wooden implements (Marawali et al. 1990).
- Artisan workshops and training programs are an essential component of DAP technology transfer where DAP equipment is concerned. In some regions, the artisans are farmers themselves, and their knowledge of farmer needs, the limitations of local materials and tools and market rates is invaluable in developing and transferring ideas (Lowe 1986).
- Farmer training at mechanisation centres. In Zimbabwe, farmers are trained in both animal-handling and tractor-handling and maintenance, by the same instructors. The aim is to ensure that training in tractors is not given any higher status than training in DAP use.
- Visits to other regions or countries by selected farmers, artisans and scientists, to see and discuss with farmers there particular aspects of technology that may have application to overcome constraints defined in a particular farmer domain.
- Tools and equipment bought from other regions appear to offer scope for use in DAP technology development and transfer. In practice, however, DAP equipment bought without the benefit of user knowledge and techniques can prove useless. Javanese rice farmers and scientists tried to operate for days, without success, a plough brought (by the author) from a similar farming system in Thailand (Santoso, pers. comm.).
- Local DAP manuals for extension agents, containing practical and well-tested advice on DAP in local languages, are rare and badly needed.
- Promotional materials on DAP. Glossy booklets on DAP, with the main aim of raising the status of DAP development among policy-makers and donor organisations, have been produced (e.g. Petheram, Goe and Astatke 1989).

The Organisation of DAP Technology Transfer

As draught power is only one of many elements of livestock enterprises, and as these are usually part of larger farm systems, the generation and extension of information on DAP should be conducted in the context of the whole agricultural and social system, not in isolation. Sometimes the greatest advances in technology can be made through influencing policy-makers and manufacturers, as in the case of tyre subsidies for carts in India, and of large-scale DAP equipment manufacture in Zimbabwe.

As farmers have themselves been responsible for the vast preponderance of innovation in technology development in the past (Johnson 1972; Rhoades 1987), to ignore their potential in the process is patronising and greatly reduces the prospect for progress. For effective transfer of DAP technology, scientists (research or extension) and planners must give priority to the human aspects of developing systems.

The need for research and extension personnel to work with farmers as part of the same team is paramount. Institutional changes to facilitate real farmer involvement in DAP technology generation and transfer are urgently needed. This means changes in organisation, management, incentives to scientists, less elitism and greater linking across disciplines and with other institutions (Merrill-Sands et al. 1991).

Conclusions

Most DAP enterprises are operated by resource-poor farmers with no prospect of making expensive changes. There is ample DAP technology 'off the international shelf' for the needs of most DAP operators: for its transfer the main needs are effective screening, testing and adoption, and then the training of farmers and artisans. The more actively DAP scientists can become involved with both farmers and policy-makers in seeking innovative means of transfer, the greater will be the prospects for advances in DAP systems on farms.

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APPENDIX

Definitions of Some Common Terms in 'Technology Transfer'

Technology

Technology may be defined in the farming context as any way of doing things on the farm. 'New technology' is any way of doing things that is different to that used in the past. The new 'way', practice, idea, technique or piece of equipment need not be completely 'new', but could have been taken from another farming system or region (Anderson and Hardaker 1979).

A technology may involve modern components (e.g. electronic ones) or it may simply be a different procedure, or a different use of existing components or practices, e.g. a different crop spacing, or a modified feeding regime.

DAP (draught animal power) technology

DAP technology is taken here to include any method, equipment or practice used in (or proposed for) a farm system that has a DAP component.

Effective transfer

Effective transfer (of technology) is defined here as the successful communication of practices or ideas, as demonstrated by the adoption of that technology by the target group (or farmer domain). Transfer may be from one area or farming system to another, and does not necessarily involve research at all (Biggs 1989). The transfer of technology is very closely linked to generation in the thesis presented in this paper, and both aspects are regarded as part of 'action research'.

Farm and farmer

A farm is an organised unit in which crop, livestock and other activities are carried out to satisfy the operator's (i.e. farmer's) goals. A farm (or farmer) does not necessarily imply a distinct tract of land (e.g. a landless cattle-rearer). The term farmer may mean more than a single decision-maker, e.g. the family, household, or other group (Ruthenberg 1980).

Recommendation domain

A farmer recommendation domain is a group of farmers who have similar environment, circumstances and problems, and for whom a set of recommendations is being sought (Perrin et al. 1976).

Embedding of technology

The embedding of technology is the creation of the social and economic infrastructure needed to sustain the adoption and application of the technology (Waters-Bayer 1989).

Energy Expenditure and Nutrient Requirement of Working Animals

E. Teleni[*]

Abstract

There is general consensus that the free fatty acids and glucose are the nutrients preferentially used by muscles of working animals. Although amino acids are also oxidised in the working animal, the reasons for their oxidation are yet to be clarified. There is a lack of data on energy expenditures of animals working under field conditions. Published values suggest a range of 1.25–2.7 times maintenance energy in animals used in the cultivation of land for crop production. These animals are generally required to pull draught loads ranging from 40–80 kg while walking at a speed of 0.69–1.1 m/sec for 3–6 hr/day. At this rate and duration of work, in ambient temperatures of 27 to 33°C or greater, an animal is able to sustain a draught load equivalent to about 11% of liveweight. Since draught capacity is largely determined by liveweight, the animals required to pull draught loads normally encountered in the field would be expected to have liveweights ranging at least 182–364 kg. Meeting the nutrient requirements for maintenance of such animals using locally available fodder (6–8 MJ/kg DM) is not difficult but meeting requirements for heavy work and/or pregnancy or lactation is difficult. It is suggested that late pregnancy and early lactation should not coincide with the work season and the planting of shrub/tree legumes for use as supplements should be encouraged.

A relevant discussion of this topic should consider the classes of animals which are or should be used for work, the types of work they are required to do, and the feeds they are normally fed. In some countries, e.g. Indonesia, cows are the main class of animals used for draught work. In others, e.g. the African countries, this is not so, but there is evidence that as the demand for land is increased so also is the tendency to use female animals for draught. The Gambia in the west coast of Africa, with its capacity 300 000 or so head of cattle is a case in point. It appears that future developments would probably involve an increasing use of the cow for draught work.

The nutrition and any feeding strategy developed for such an animal should be based on feed resources which are locally available and those which potentially can be produced in the locality. Smallholder farmers who make up the overwhelming majority of draught animal-rearers are generally reluctant to spend money on proprietary feeds or feed supplements, hence considering such feeds as part of feeding strategies for draught cows is usually of less relevance.

Workload and Energy Expenditure

Types of work

The types of draught work discussed are those related to the cultivation of land for crop production. There are two main operations involved, ploughing and levelling. Ploughing is the operation undertaken first and is followed by levelling if it is required. The number of ploughing and levelling operations undertaken on a plot of land per season varies with villages and districts and with types of crop grown. For example, the ploughing operation may be carried out once or even twice, followed by one or more or no levelling operations. In Indonesia, ploughing and levelling are generally undertaken in land preparation for wetland cropping, while ploughing only is undertaken for dryland cropping (Komarudin-Ma'sum et al. 1992).

Ploughing constitutes a heavier draught load on a pair of animals than does levelling, although the power developed by the pair might be similar for the two tillage operations (Table 1).

It appears that a pair of working animals would adjust its walking speed in accordance with the draught load it is required to pull. On a heavier draught load a pair would

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Table 1. Mean draught load pulled, speed of walking and power developed by pairs of buffalo and cattle during ploughing and levelling operations for wetland cropping in West Java, Indonesia.

Operations	Draught load (kg)	Speed of walking (m/sec)	Power developed (watts)
Ploughing	59	0.53	309
Levelling	39	0.81	328

Source: (B. Bakrie and Komarudin-Ma'sum 1992).

walk more slowly than when it is pulling a light draught load. However, while draught load is an important determinant of the speed at which the animals walk, it should be noted that the driver of the working animals also has a significant, if not controlling influence on their walking speed. Field measurements have indicated that a pair of cattle or buffalo ploughing may be required to pull a draught load varying from 40–80 kg (Pearson 1988; Bakrie and Komarudin-Ma'sum 1992) while walking at speeds of 0.69–1.10 m/sec for three to six hours per day (Petheram et al. 1985). Draught force values recorded during levelling may range 30–50 kg (Bakrie and Komarudin-Ma'sum 1992).

Work capacity

For a pair of buffalo, for example, with a combined liveweight of 600 kg, the range of draught loads which it might be required to pull would represent an equivalent of 7–13% of its live weight. Martin and Teleni (1989) have suggested that at an average walking speed of 0.69 m/sec, a pair of working animals, which are physically untrained, would not be able to sustain for three to six hours a draught load equivalent to 11% of its liveweight, particularly in ambient temperatures of 27–33°C or higher. The same pair of animals would be able to sustain, for the same period, a draught load equivalent to 8% of its liveweight. If the pair was physically trained for a minimum period of two to three weeks, it would just be able to sustain a draught load equivalent to 11% of its liveweight for a three-hour work period. Body weight rather than body condition appears to be the more important factor in the ability of the working animals to sustain draught loads (Little and Bartholomew, unpublished data). Using this data, the minimum liveweights of cattle and buffalo which can sustain the various draught loads under field conditions might be calculated (Table 2).

Table 2. Calculated minimal liveweights of physically untrained and trained cattle or buffalo which are required to sustain draught loads for a minimum period of three hours while walking at an average speed of 0.69 m/sec in ambient temperatures of 27–33°C.

	Minimum mean liveweight of a member of a pair of cattle or buffalo	
Draught loads (kg)	Untrained	Trained
40	250	182
50	313	228
60	375	273
70	438	318
80	500	364

The minimum mean liveweights of animals required to pull the lightest and heaviest draught load are approximately 180 and 360 kg, respectively (Table 2). This range of liveweights could reflect, in the larger body-framed animals such as Brahman or Ongole cattle (both *Bos indicus*) or buffalo (*Bubalus bubalis*), different ages or body conditions. In the smaller breeds such as the Madura and Bali (*Bos sondaicus*) cattle of Indonesia, such a range of liveweights may simply reflect a range of body conditions in the mature animals. In considering the energy expenditures and nutrient requirements of working animals, one is likely to be focusing on animals in the liveweight range 180–360 kg or higher. In areas where draught loads 40–60 kg are commonly encountered, both mature smaller cattle breeds such as the Bali and the Madura of Indonesia and animals with larger body-frame such as the Brahman or Ongole or buffalo could be used. Only larger cattle breeds or buffalo or the males of the smaller breeds are likely to be used in areas where draught loads higher than 60 kg are encountered.

Energy expenditure

It is not surprising that published values on the energy expenditure of draught animals are few since the energy expended by animals working in the field is extremely difficult to measure. Even under controlled conditions in laboratories the procedures are difficult to follow. Lawrence and Pearson (1989) have recently reviewed the various methods for the measurement of energy expenditure, all of which have some limitations as to their application to working cattle or buffalo. Reported estimates of energy expenditure of working animals vary from a low 1.25 times maintenance (Pearson et al. 1989) to 2.7 times maintenance (Goe and McDowell 1980). Using the equation for maintenance metabolisable energy (ME) requirement (Mm) published by MAFF (1984):

$$\text{Mm (MJ/day)} = 8.3 + 0.09 \text{ liveweight (kg)}$$

we can tabulate estimates of energy expended by cattle pulling different draught loads (Table 3).

Nutrient Requirements

Fat and carbohydrate

When an animal works, it expends energy. It is obvious therefore that the major class of nutrients required by the animal to fuel its activity is the energy-yielding nutrients. However, it would be misleading to suggest that each of these nutrients is accorded the same degree of priority by the working muscle, as there are differences in the preferential requirement for each. Studies with exercising sheep (Jarrett et al. 1976; Bird et al. 1981; Pethick 1984) suggest that glucose and free fatty acids are the energy-yielding nutrients preferred by the muscle for sustained exercise. This conclusion is drawn from their observation which showed substantial increases in the uptake of these nutrients by muscle during exercise. However, while the uptake of the nutrients by muscle has been illustrated, the subsequent fate of each, in muscle, can only be speculated on in the absence of data on their relative oxidation in the tissue. It is known that controls of oxidation, in muscle, of glucose and free fatty acids are mutually inhibitory (Paul 1971). During work, the release of the catecholamines and the reduction of insulin in circulating blood provide the hormonal milieu which is conducive to the hydrolysis of free fatty acids from fat depots and their utilisation in muscle. It might be suggested, therefore, that free fatty acids are the dominant oxidative substrate in working muscles.

Protein

Amino acids are likely to be used as energy-yielding nutrients if the ratio of the available energy-yielding nutrients to amino acids were reduced or if amino acids were not in proportions which are compatible with protein synthesis. Additionally, the diversion of amino acids from their primary role in protein synthesis might also be due to requirements by the animals for so-called glycogenic substrates which may substitute for some of the role that glucose normally plays under situations of glucose sufficiency. The release of glucocorticoids in working animals (Fraioli et al. 1987) would result in net protein catabolism (Dohm et al. 1980). This catabolic process would be further enhanced if the animals were working under hot conditions (Graham 1985; Vercoe 1969). The net release of amino acids from protein and the diversion of the energy-yielding nutrients to contracting muscle in the working animal is likely to result in a nutrient imbalance of energy-yielding nutrients to amino acid ratio. This situation would lead to the catabolism of amino acids as direct energy sources or as glucose precursors. In situations where the imbalance is not large (i.e. where the animal has a surplus intake of ME) the rate of catabolism of amino acids might be low or even

Table 3. Estimated metabolisable energy ME requirement and intake by working cattle of different liveweights fed diets of different ME values.

Cattle liveweight (kg)	ME requirement (MJ/day)				ME intake (MJ/day)*			
					Feed ME value (MJ/kg dry matter)			
	Maintenance (Mm)	1.25 x Mm	1.7 x Mm	2.7 x Mm	6	7	8	9
182	25	31	43	67	23	25	29	33
228	29	36	49	78	27	32	36	41
273	33	41	56	89	33	38	44	49
318	37	46	63	100	38	45	51	57
364	41	51	70	110	44	51	58	66

* Calculated by assuming that feed dry matter intake by an animal is equivalent to 2% of its body weight

negligible (e.g. Lawrence 1985). Where the imbalance is high, a higher rate of amino acid catabolism might result in a significantly reduced nitrogen balance (Teleni et al. 1991). Under such circumstances where reduced nitrogen balance might mean negative nitrogen balance, the feeding of an energy supplement (gluconeogenic or high fat) might be considered.

Minerals

Losses of sodium through excessive sweating in cattle working under hot conditions can be a problem, particularly in areas where the dietary sodium levels are marginal or deficient. For example, in Indonesia sodium is quite low in most of the grasses (Little et al. 1988; Winugroho 1989). This is also the case in Sri Lanka (Ibrahim 1985). Supplementation of the diet of the working animal with common salt might be considered. Failing this, tree leaves such as *Sesbania grandiflora* which are high in sodium can be used (Thahar and Mahyuddin 1992).

Meeting Nutrient Requirements

Local fodder

The feeds which are normally fed to working cattle and buffalo are fibrous roughages consisting of green fodder collected from roadsides, borders of cultivated areas and public lands, crop residues such as green or dried rice straws, maize stovers and others and to a lesser extent, leaves of trees and shrub or tree legumes. The ME content of these feeds varies 6–8 MJ/kg DM (Ibrahim 1985) and seldom reaches 9 MJ/kg DM. It is clear from estimations presented in Table 3 that these feeds would barely satisfy the ME requirement of working cattle or buffalo expending energy at 1.7–2.7 times Mm. It would not be surprising therefore to expect liveweight losses in animals eating these diets during the work season. The mismatch between the ME supply from these feeds and the ME requirement of the working animals would be further increased if the working animals were in late pregnancy or in early lactation (see Figure 1). To be able to meet the ME requirement of animals undertaking heavy work (1.7 x Mm to 2.7 x Mm) or working animals which are heavily pregnant or lactating, there has to be a substantial increase in intake of the type of feeds outlined. For example, a 300-kg animal in early lactation and expending energy at the rate of 1.7 x Mm would need to consume an equivalent of 4.6% of its liveweight in DM of a feed with an ME content of 8 MJ/kg DM. This would be difficult to achieve. An option is to improve feed quality beyond 9 MJ/kg DM. This might be practically achieved through the feeding of a supplement of high quality legume shrub or tree leaves. Urea-minerals mix (Leng 1985) or concentrate supplements can also be considered but the costs involved might be prohibitive to the farmer.

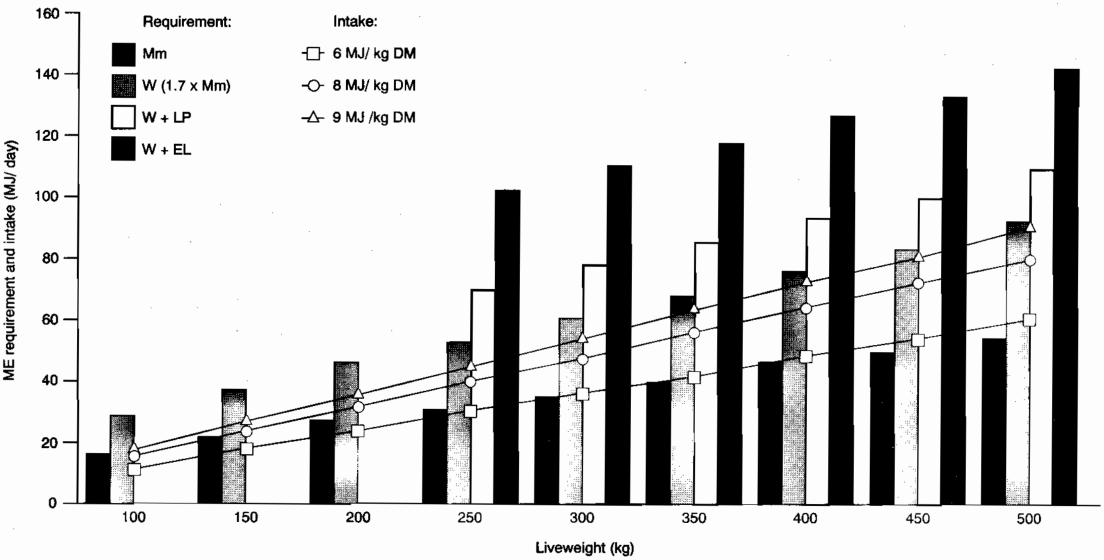

Figure 1. The metabolisable energy (ME) requirement of cattle of different liveweights for maintenance (Mm), work (W) at 1.7 x Mm, W + late pregnancy (LP) and W + early lactation (EL). (Adapted from Teleni and Hogan 1989)

Intake and digestibility

Weston (1985) suggested that increased energy demand by an animal would result in increased feed intake. This is certainly the case in lactating cows where the increased demand by the animals for energy is associated with increased rumen capacity and increased rate of passage of digesta through the gut, resulting in increased intake of feed (Hutton 1963). In working animals, however, Weston's suggestion is yet to be demonstrated. Thus far, reports on the effect of work on feed intake are inconsistent (e.g. Graham 1985; Bakrie et al. 1988; Bamualim and Ffoulkes 1988; Wachiropakorn and Wanapat 1989). It appears that the major factor which could decrease feed intake in working animals is increased heat load which is sustained by the working animals during work and a few hours after work. For example, the body temperature of buffalo could rise from 37.8°C to 41.0°C with three hours of work and not return to normal with three hours of rest in the shade (Teleni et al. 1991). Longer working hours would obviously sustain high body temperatures for longer periods. Such increases in core body temperature are most likely to cause reduced gut motility and rate of passage of digesta (Young 1982) thus resulting in reduced appetite (Tarigan and Teleni, unpublished data). Hence despite the similarity in nutrient demands between lactating and working cows (Teleni and Hogan 1989), it is difficult to see a mechanism permitting a major increase in feed intake in working animals exposed to heat stress from work and from the environment. Buffalo, which have a much poorer heat dissipating capacity than cattle, may exhibit a reduction in feed intake under conditions in which cattle may not.

A possible good effect of increased body temperature and reduced gut motility is the likelihood of an increase in feed digestibility due to the longer residence time of feed in the rumen. In addition to this, on diets which are marginally or severely deficient in ruminally available nitrogen, digestibility could be increased from the increased transfer of plasma urea to the rumen of the working animal (Teleni et al. 1991).

Conclusions

From the discussion it is clear that the ME requirement of working animals can only be just met by feeds which are normally accessible to farmers. In cases where the workload on the animal is heavy, it is likely that the animal would lose body weight during the work season which could extend from 20 days to 60 days per year. This should not be a problem if the major purpose of keeping the animal, if not the only one, is for work. Since the major factor influencing work capacity is body weight rather than body condition, losing body condition in such an animal during the work season is not a problem provided the critical body weight for certain draught load is not compromised.

The problem arises, however, if the working animal is expected, apart from undertaking work, also to produce a calf each 12 to 15 months. The significant and specific requirement by the working muscle, lactating mammary gland and the pregnant uterus particularly in late pregnancy, suggest the undesirability of animals working particularly during late pregnancy or early lactation. No doubt the impact of work on the cow's productivity will depend on the intensity and duration of the daily draught work and the length of the working season. Given the quality of the feeds which are normally available (see Ibrahim 1985) for draught animals, it is likely that the working pregnant or lactating animals will lose body weight. In smaller breeds such as Madura or Bali cattle, such a loss can be critical to their ability to pull draught loads. In addition, an increased rate of liveweight loss can adversely affect their reproductive performance (Teleni et al. 1988; Winugroho et al. 1989). In the larger breeds, the risk involved in liveweight loss is not so much the reduction in work capacity, which is unlikely to be critical, but in the reduction in reproductive performance. Given the range in values of energy expenditures and feeds normally fed to draught animals, it would be difficult to realise the production potential of a working cow (in terms of calf and milk) without consideration of either or all the following practical options:

- cow management strategy which avoids the occurrence of late pregnancy or early lactation in the work season (see Teleni and Murray 1991);
- supplementary feeding of legume leaves or a urea-mineral mix; and
- integration of acceptable cow liveweight and body condition loss in feeding strategies.

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Buffalo Physiology Responses to High Environmental Temperature and Consequences for DAP

Narongsak Chaiyabutr*

Abstract

A review of work on buffalo concerning responses of bodily functions to thermoregulation during heat exposure and their effect on the development of draught animal power (DAP) is given. The cutaneous heat loss under thermal stress and during work is discussed in relation to the peculiar vascular architecture and low sweat gland density in buffalo skin which is shown to be suited for conserving but not for dissipating heat. Thermal hyperventilation, the marked evident reaction of buffalo to heat stress, is discussed in relation to the initiation of panting by thermal stimulation of peripheral receptors, and to the control of respiratory activity by deep body temperature during exposure to either solar radiation or a hot room. Cardiorespiratory responses to thermal stress show different patterns during exposure to solar radiation. The effect of high temperature on changes of turnover of body water, the volume of the blood, the rate of liquid flow from rumen and renal functions of buffalo are discussed. During acute (5 hours at 41°C in a hot room) heat exposure of buffalo, changes of total body water and blood volume are different from short-term (10 days outdoors, unshaded, maximum 39°C) heat exposure. Two phases of changes of body fluid to facilitate the evaporative cooling process in short-term heat exposure are apparent. Changes in renal electrolyte excretion during heat stress are discussed in relation to alteration of hormonal levels and to the acid–base status of the blood. The effect of high environmental temperature on the metabolism of plasma constituents is also discussed. Changes of hormones from pituitary gland, thyroid gland and adrenal gland during heat exposure are also noted.

ALMOST the entire buffalo population (approximately 90%) of the world is found in Asia (Cockrill 1981). The buffalo is used as a source of draught animal power for agricultural activities such as ploughing, harrowing, weeding and for transport. This draught capacity contributes to the success and efficiency of farming systems of smallholder farmers. A number of factors may affect draught capacity of the animal, e.g. age, sex, work load, nutrition and high environmental temperature.

During summer in tropical climates buffalo encounter severe heat exposure unless shaded or housed. Buffalo have a low heat tolerance compared to other ruminants and are incapable of working for long on hot days when they are exposed to direct sunlight. Under such high environmental temperatures the animal body has to dissipate the added heat absorbed from the surroundings as well as the heat produced metabolically in the body during work. Since the buffalo is a significant power source for agricultural operations in tropical countries, it is important to know the degree of thermoregulation of buffalo working in a high environmental temperature which may affect bodily function with a subsequent change in work capacity. Although the physiological responses to acute or short-term heat exposure of resting or non-active buffalo have been recorded by Chaiyabutr and Johnson (1991), precise information regarding physiological responses in buffalo to the combined stress factors, high ambient temperature and metabolic heat from work, has not been available until recently. This paper describes some thermoregulatory responses in the body during heat exposure and considers the effect on the draught animal power (DAP) of buffalo.

Cutaneous Heat Loss

In thermoregulation, heat loss from the skin usually occurs by radiation, convection and evaporation. The use of sweating for evaporative heat loss is a mechanism of adjustment of the body to dissipate the body heatload.

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However, studies on the structure of the skin of buffalo have shown that sweat glands have a poor blood supply (Hafez et al. 1955; Nair and Benjamin 1963) which are similar to those of temperate cattle breeds (Findlay and Yang 1950). The number of sweat glands per unit area of skin is relatively low, about one-third, and the thickness of the corneum layer and epidermis about double, that of cattle (Hafez et al. 1955). The thickness and the black pigment of the buffalo skin probably absorb more heat and lead to disproportionate convective and radiative heat losses from the extremities during exposure to solar radiation. This evidence indicates a lower efficiency of sweating in buffalo which plays little or no part in heat regulation. The mechanism governing cutaneous evaporation in heat-exposed buffalo is still a matter of speculation. Ranawana and co-workers (1984) have suggested that the cutaneous water loss of buffalo exposed to high temperature is not due to true sweating but partly due to insensible loss of moisture by passive diffusion through the epidermis. This suggestion indicates that diffusion moisture alone cannot serve to regulate body temperature during heat exposure.

During such heat exposure, it is well known that increased vasodilation of blood vessels in the skin occurs. Heat is brought to the skin via the blood supply and then lost by radiation and convection into the animal's surroundings. The structure of the blood supply to the skin of buffalo has been elucidated by Shafie (1985), who demonstrated that their vascular architecture is similar to that of cattle (Goodall and Yang 1952). There are three networks or plexuses of arteries and veins in buffalo skin. The arteries and veins always run together. This arrangement allows heat to be interchanged between an artery carrying warm blood to the surface and a vein carrying cooled blood back to the heart. Consequently, pre-cooling of arterial blood can occur followed by the reduction of the temperature gradient at the surface of the skin. This is a useful feature for the conservation of heat in a cold climate but militates against a high rate of heat loss in a hot climate. Therefore the counter-current heat exchange for thermoregulatory mechanisms between superficial blood vessels is inadequate for buffalo exposed to high ambient temperature (Benjamin 1982).

During work or exercise in a thermoneutral environment, an increment of metabolic heat associated with an increase in skin blood flow has been reported in sheep (Bell et al. 1983). However, the morphological features of buffalo skin might not be expected to facilitate dissipation of excess body heat load under this condition. During work without bathing or wallowing, convective cooling is almost impossible in the buffalo, but there is an increase in frequency of respiration which causes moisture to be lost from the body and the tidal volume to be reduced. This in turn leads to limitation of work capacity.

Compared with this thermoneutral environment, when working in a high environmental temperature, a much more severe heat load from the combination of metabolic heat and environmental heat must reduce heat tolerance of buffalo. Physiological responses to the combination of these stress factors have been studied in sheep by Bell and colleagues (1983), and this study has revealed that skin blood flow did not increase as much during exercise in a hot environment as it did during exercise in a thermoneutral environment. There are competing drives for increased blood flow to muscle and skin. Limited data are available for the physiological responses of buffalo to the combination of these stress factors. More extensive studies are warranted to further understanding of this point.

Cardiorespiratory Activities

The separate effects of heat stress on cardiorespiratory activities of buffalo have been reported in acute and short-term heat exposure. Air temperature up to around 30°C (dry bulb) has little effect on heart rate, respiratory rate and rectal temperature (Chaiyabutr et al. 1987; Chikamune 1986), indicating that the buffalo easily manages to balance its heat production against its heat loss. The change in respiratory frequency is marked when air temperatures of 30°C are exceeded, when the animal immediately begins to pant. This panting is thought to be initiated by thermal stimulation of peripheral receptors and is unaccompanied by a rise in rectal temperature (Chikamune 1986). At higher temperatures, e.g. 41°C/31°C (DB/WB), rectal temperature of the buffalo rises slowly at a mean rate of 0.0033°C/min/340 kg body weight during the course of 5 hours exposure. The heart rate is little affected, but the animal's respiration rate rises rapidly at about three to four times normal values under this condition (Chaiyabutr et al. 1987).

A comparison of the effect of heat stress under direct exposure to solar radiation shows different patterns of physiological responses (Table 1). During acute exposure to the sun for 4 hours, the proportional rise in heart rate and respiratory rate are much more marked than for animals after 4 hours exposure in a hot room at an ambient temperature of 41°C (Chaiyabutr et al. 1983b, 1987). The result is, in part, due to the nature of the skin of the buffalo, i.e. the black pigment and the thickness of the skin. These factors will enhance reabsorption of more solar radiation and interfere with heat loss, resulting in a higher heat storage. When the buffalo is exposed to the sun for 8 hours daily over a period of 10 days without wallowing, the maximum respiratory rate, heart rate and rectal temperature (recorded at 1400 hours) are still as high on the tenth as on the fifth day of exposure (Chaiyabutr et al. 1990b), indicating that buffalo have low efficiency for acclimatisation during intermittent heat exposure. This phenomenon differs from the observation in cattle that three weeks of daily exposure to high temperature would induce some degree of acclimatisation

Table 1. Effects of heat stress in either direct solar radiation (1000–1400 hours) or in the hot room on maximum changes in respiratory rate, heart rate and rectal temperature of swamp buffalo after heat exposure for 4 hours.

	No shade	Hot room
Ambient temperature (°C)	40	41
Humidity (%)	59	45
Rectal temperature (°C)	1.5 (4%)	0.8 (2%)
Respiratory rate (breaths/min.)	82 (265%)	50 (215%)
Heart rate (beats/min.)	12 (26%)	9 (21%)

Figures are increases in absolute values of control and figures in parenthesis are percentages of control values (shade). (Adapted from Chaiyabutr et al. 1983b, 1987).

(Bianca 1957). It is reasonable to speculate on the minimum time for acclimatisation in buffalo as heat becomes more intense. Changes in respiratory rate by shift from thermal polypnoea (panting) to thermal hyperpnoea (slow, deeper breath) during exposure to high temperature may be less likely to cause respiratory alkalosis.

In addition to heat gained from the environment during heat exposure, body heat is also derived from metabolic heat including heat for maintenance plus increments for work or exercise. In general the use of the heart rate as an index of heat production during work has been practised in human studies since a linear correlation between oxygen consumption and heart rate has been reported (Rowell 1974). The relationship between heat production and heart rate have also been shown in responses to stimuli provided both by ambient temperature and level of metabolic heat in cattle (Yamamoto et al. 1979). Working or exercise and heat stress can strain the cardiovascular system to the limits of its regulatory ability. Data on cardiovascular response, particularly concerning the distribution of blood flow during exercise and thermal stress, show variation between species. In many panting species, the effects of environmental heat stress are characterised by a decrease in blood flow to working muscle which will limit the requirement for heat-induced increases in blood flow to the skin, respiratory muscles and other tissues involved in thermoregulatory heat loss (Bell et al. 1983). This is in contrast to exercising heat-stressed humans whose temperature regulation depends on sweating and very large increases in skin blood flow. However, little is known of the effect of work in a hot environment on the distribution of blood flow in relation to the cardiovascular functional capacity of buffalo.

Water Turnover and Body Fluid Compartments

Water turnover

It is well known that body water plays a central role, by way of evaporative cooling, in the mechanisms used for heat dissipation. It has been reported that the buffalo is somewhat higher in body water turnover than other domestic ruminants (MacFarlane 1971). During acute heat exposure to a fixed ambient temperature (41°C, 42% RH) for 5 hours, the water turnover rate of buffalo has been shown to increase 88% compared to that kept at normal ambient temperature (30°C, 51% RH) (Chaiyabutr et al. 1987) (Table 2). No significant alterations have been observed in total body water and body weight when buffalo are exposed to heat in a short period of exposure. During acute heat stress, an increase in water turnover simply reflects a part of the process of adaptation by maintaining fluids for evaporative cooling and helping regulate body temperature during the rise of environmental heat. In short-term heat exposure, the non-shaded buffalo prevented from wallowing have a drastically reduced ability to conserve total body water during the first five days after spending up to 8 hours of the day in an unshaded pen. The total body water markedly decreases on the fifth day of the nonshaded period while body water turnover rate increases with time of exposure (Chaiyabutr et al. 1990b). It is contrary to what has been reported for swamp buffalo which are not allowed to wallow and kept largely in shaded conditions (Ranawana et al. 1984). The results of this investigation have demonstrated that lactating, pregnant and heifer buffalo showed a marked increase in water turnover rate with no alteration of total body water when prevented from wallowing over two weeks in an ambient temperature range of 27.7–32.8°C and relative humidity of 62.86%. It has been suggested that an increase in water intake during this period is an attempt to compensate for the lack of wallowing. This is the best indication of the importance of wallowing to the swamp buffalo as a means of cooling themselves. A decrease in body water during prolonged heat exposure without wallowing is harmful to buffalo in a hot climate because it decreases their ability to dissipate the heat through water vaporisation and to slow down the elevation in body temperature by virtue of the high specific heat of water. The significance of these results, however, emphasises the importance of having water available to buffalo at all times.

Table 2. Changes in water turnover rate and total body water of swamp buffalo during acute heat exposure for 5 hours in the hot room (41°C) and short-term heat exposure to the sun.

	Hot room	No shade	
	5 hours	Day 5	Day 10
Water turnover (mL/kg$^{0.82}$/day)	310 (88%)	82 (40%)	172 (84%)
Total body water (L/100 kg)	0.03(0.05%)	-6(-10%)	-7(-12%)

Figures are increases in absolute values of control and figures in parenthesis are percentages of control values (shade). (Adapted from Chaiyabutr et al. 1987, 1990b.)

Body fluid compartments

It has been known that changes in total body water content in animals under hot climate conditions are considered an adaptive reaction to ameliorate heat stress. This adaptive reaction has an important physiological consequence in terms of greatly increased water turnover, also related to water exchange and cardiovascular function. When buffalo are exposed to high temperatures, changes in blood volume and plasma volume are apparent as well as in their composition (Chaiyabutr and Johnson 1991).

Blood volume and plasma volume have been shown to increase by approximately 7% while packed cell volume slightly decreases when buffalo are acutely exposed to high temperature (41°C, 42% RH) for 5 hours (Chaiyabutr et al. 1987) (Table 3). It has been shown that an increase in blood volume could not be attributed solely to an increase in plasma volume. As the increase is greater in the plasma volume than the cell volume, the decrease in packed cell volume is not sufficient to be accounted for simply by an increase in plasma volume and it has been shown that the volume of circulating blood cells increases by approximately 4.5%, in heat-stressed animals. However, the increase in plasma volume is not only a dilution accompanied by a reduction in plasma solids, since the concentration of plasma solids which consist mainly of protein increases significantly when exposed to severe heat (Chaiyabutr et al. 1983b). It has been postulated that during intravascular volume expansion in heat-stressed buffalo, an increase in plasma water could come from extravascular tissue space. An increase in colloidal osmotic pressure caused by increased plasma protein concentration augments water passage from the extravascular space to the intravascular compartment. Another possibility is that an increase in plasma water could come from the digestive tract. An increase in the rate of liquid flow from the rumen during heat stress has been noted (Chaiyabutr et al. 1987). This adaptive mechanism by an increase in plasma water content is useful in assisting the animal in heat tolerance due to the high specific heat of water that slows down the elevation in body temperature. Under prolonged heat exposure to the sun for 10 days accompanied by denial of wallowing, changes of body fluid compartments of buffalo are considered in two different phases (Chaiyabutr et al. 1990b). The first phase occurs within the first five days with initial increases in plasma volume and total plasma water which slightly expand 'isotonically' as a result of addition of fluid which is used for heat dissipation. Total circulating protein increases, but total body water decreases on the fifth day of heat exposure. This is not reflected in the behaviour of blood volume because water is supplied to the blood at a similar rate as it is lost. However, by the tenth day both plasma and blood volume do not follow the same pattern of the first phase but drop by 9% in a second phase of the responses to short-term heat exposure. These changes may be attributed to adaptive mechanisms. Packed cell volume and circulating cell volume on the tenth day of the unshaded period change little from those of the fifth day. Total body water decreases to a point which does not differ from that of the fifth day, while water turnover rate of non-shaded buffalo increases stepwise, indicating higher water requirements for evaporative cooling and lower efficiency in the water retention mechanism during 5–10 days of heat exposure.

Table 3. Changes in blood volume and plasma volume of swamp buffalo during acute heat exposure for 5 hours in the hot room (41°C) and short-term heat exposure to the sun.

	Hot room	No shade	
	5 hours	Day 5	Day 10
Blood volume (mL/kg)	4.1 (6%)	-1.5 (-2%)	-6.9 (-11%)
Plasma volume (mL/kg)	3.4 (7%)	0.5 (1%)	-3.4 (-8%)
Cell volume (mL/kg)	0.8 (5%)	-1.9 (-11%)	-3.3 (-19%)
Total plasma water (mL/kg)	2.8 (6%)	0.5 (2%)	-3.5 (-8%)
Plasma solid (g/kg)	0.6 (13%)	0.3 (4%)	0.4 (5%)
Plasma osmolarity) (mOsm/L	1.5 (0.3%)	2.0 (0.7%)	2.8 (1%)

Figures are increases in absolute values of control and figures in parenthesis are percentages of control values (shade). (Adapted from Chaiyabutr et al. 1987, 1990b).

Renal Functions

Renal haemodynamics

It has been known that control of the turnover of water and electrolytes is important in the survival of mammals in tropical areas. The alimentary canal can provide the fluid for the body while the kidneys are responsible for retaining as much water as possible. There is little information on renal functions in buffalo particularly from the point of view of a compensation with the loss of water and electrolytes through evaporative cooling during heat stress and during work. It has been shown that kidneys of buffalo act to conserve renal loss of water by reduction of urine excretion per unit time during acute heat exposure for 4–5 hours either in a hot room (41°C, D.B.) or when exposed to the sun (39°C, D.B.). No alteration of glomerular filtration rate has been noted, while renal plasma flow and renal blood flow have a tendency to increase (Chaiyabutr et al. 1983a). No significant changes in glomerular filtration rate and renal blood flow have been reported in buffalo following exposure to the sun without wallowing over a period of 10 days (Chaiyabutr et al. 1990a). An autoregulatory mechanism could be exerted mainly by local effects on renal blood vessels during exposure to heat. Extrarenal factors which usually occur during heat exposure, e.g. an increase in cardiac output (Whittow 1968), an elevation of plasma norepinephrine (Alverez and Johnson 1973), might not be expected to affect renal blood flow of buffalo. By comparison, in man, both glomerular filtration rate and renal plasma flow fall during the first few hours of heating (Kanter 1955). The kidneys also appear to be a target for vasoconstrictor activity during exercise in humans (Grimby 1965) and severe exercise in the pig (Sanders et al. 1976). This is a result of blood being diverted from the kidneys to the muscle and skin as cooling takes place. This is not so in either separate effects of acute and prolonged heat stress in buffalo (Chaiyabutr et al. 1983a, 1990a), or the combined effects of exercise and heat stress in sheep (Bell et al. 1983), for these animals rely mainly on respiratory evaporation for heat dissipation. During short-term heat exposure, non-shaded buffalo have been shown to increase their rate of urine flow by 50% on day 10 of exposure (Chaiyabutr et al. 1990a). Whether this represents a mechanism to maintain a core temperature, a shift in blood flow distribution away from other parts of the body to the active tissue like kidneys and thereby non-evaporative cooling through urine excretion is open to speculation.

Urinary electrolyte excretion

During acute heat exposure for 4-5 hours in buffalo, variable changes in urinary electrolyte excretion have been reported. An increase in urinary potassium along with a decrease in urinary sodium have been observed in buffalo exposed to heat in the hot room. Unlike in the hot room, an increase in urinary sodium excretion but a decrease in potassium excretion have occurred in buffalo exposed to solar radiation (Chaiyabutr et al. 1983a). These results depend on the activity of the renal tubular cell. It may involve the change in aldosterone secretion which has been reported to either decrease in cattle (El-Nouty et al. 1980), or increase in man (Collins et al. 1955) during heat exposure. However, in both environments, urinary and fractional excretions of the chloride ion have been shown to decrease during heat exposure. The low urinary chloride excretion is not due to dehydration during a short period of heat exposure, for heat per se has a depressing effect on chloride excretion. During acute heat exposure in buffalo, the mean values of plasma osmolarity, osmolar clearance and free water clearance remain constant (Chaiyabutr et al. 1983a,b). These results reflect the relative constant of both solutes and water excretion.

The kidneys of buffalo in a hot environment are responsible for retaining as much water and electrolytes as possible. During short-term heat exposure to the sun for 10 days without wallowing, buffalo excrete more urine per unit time which coincides with increases of renal osmolar clearance, urinary excretion of potassium ion and urine pH on day 10 of exposure (Table 4). The urinary and fractional excretions of inorganic phosphorus and chloride ions decrease throughout the non-shaded period while the urinary and fractional excretion of sodium markedly increase in the first five days of heat exposure, and fall thereafter. The urinary excretions of calcium and magnesium show no alteration throughout the experimental period (Chaiyabutr et al. 1990a; Chaiyabutr and Johnson 1991). Many factors could come into play in explaining this evidence, e.g. increase in aldosterone and anti-diuretic hormone (ADH) level in plasma during a marked reduction of total body water and plasma volume in the state of dehydration, thus the kidney is much less able to conserve potassium than sodium in this state (MacFarlane et al. 1967). Respiratory alkalosis in heat-stressed animals (Hales and Webster 1967) is another factor that is suspected to affect urinary electrolyte excretions. The kidney plays a significant role in acid–base regulation by increased exchange of potassium ions for hydrogen ions in the renal tubular fluid (Johnson and Selkurt 1966). An increase in electrolyte excretion, particularly potassium ions, can create an osmotic diuretic effect (increased osmolar clearance) which contributes to an increase in urine output in buffalo.

Table 4. Changes in urinary electrolyte excretion (UV), osmolar clearance (Cosm) and free water clearance (C_{H20}) during prolonged heat exposure to the sun of swamp buffalo.

	Shade	No shade	
		Day 5	Day 10
Urine flow (mL/min)	2.3	2.4	3.5
Cosm (mL/min)	4.6	5.0	7.0
C_{H20} (mL/min)	-2.3	-2.5	-3.5
$U_{Na}V$ (muEq/min)	48 (0.4%)	158 (1.3%)	13 (0.1%)
$U_{K}V$ (muEq/min)	441 (126%)	430 (140%)	788 (215%)
$U_{Cl}V$ (muEq/min)	165 (1.8%)	44 (0.5%)	78 (0.5%)
$U_{Pi}V$ (mug/min)	75 (1.2%)	37 (1.1%)	22 (0.5%)

Figures in parenthesis are fractional excretion of electrolytes. (Adapted from Chaiyabutr et al. 1990a.)

Plasma Constituents

It has been shown that acute heat exposure does not influence the plasma concentrations of Na^+, Ca^{++} and Cl^- while the plasma concentrations of K^+ and Pi show a tendency to decrease after 5 hours of heat exposure of buffalo (Chaiyabutr and Johnson 1991). The mechanisms involved in the changes in plasma electrolytes during heat stress are probably complex. During acute heat exposure, the stimulation of the sympatheco-adrenal system would be activated to increase the catecholamine production. These changes may cause increasing cellular potassium uptake (Sterns et al. 1981). The shift of K^+ into cells may also be enhanced by insulin (Rose 1977) which should be consistent with the concomitant increase in glucose production in heat-stressed buffalo (Chaiyabutr and Buranakarl 1989). Other factors affecting the plasma K^+ level may occur during a state of alkalosis which usually takes place in a panting animal. The hydrogen ions are released from the intracellular compartment with potassium ions moving intracellularly. During panting in acutely heat-stressed buffalo the sequence of initial respiratory alkalosis may also be responsible for the reduction of plasma inorganic phosphorus. These results are similar to those in man and steers exposed to heat (Coburn et al. 1966; Terui et al. 1979). The mechanism probably relates to cellular trapping of phosphorus for formation of phosphorylate glycolytic intermediates during increase in metabolic demands on heat stress animals (Knochel and Caskey 1977).

During short-term heat exposure, non-shaded buffalo have shown a decrease in plasma potassium and inorganic phosphorus concentration while plasma chloride concentration increases with time of exposure. Plasma sodium and plasma osmolality have been shown to remain constant during exposure to heat (Chaiyabutr et al. 1990a). It is possible that increases in plasma chloride concentration and urine pH in non-shaded buffalo could be due to respiratory alkalosis. A likely explanation might be that compensation for this disturbance is by increased renal excretion of bases instead of chloride, resulting in an increase in plasma chloride concentration (Johnson and Selkurt 1966). The reduction of the plasma concentration of Pi and K^+ during prolonged heat exposure has been shown to be more obvious than the effect of acute heat exposure. The process of these changes might be suspected to be similar to the effect of acute heat exposure (Table 5).

In acutely heat-exposed buffalo, many of the processes involved in body metabolism are affected. Increases in the plasma concentrations of protein, creatinine, glucose and urea have been reported (Chaiyabutr et al. 1983b, 1987). An elevation of both plasma protein and creatinine are probably the result of the accelerated endogenous nitrogen catabolism particularly in the muscle. Studies on glucose kinetics have shown that buffalo

Table 5. Changes in concentration of plasma constituents during prolonged heat exposure to the sun of swamp buffalo.

	Shade	No shade	
		Day 5	Day 10
Plasma Na^+ (mEq/L)	132	133	132
Plasma K^+ (mEq/L)	4.0	3.9	4.0
Plasma Cl^- (mEq/L)	102	108	110
Plasma Pi (mg%)	6.5	4.6	4.2
Plasma Ca^{++} (mg%)	10	9	9
Plasma protein (g%)	7.0	7.5	7.8
Plasma creatinine (mg%)	1.6	2.0	2.0
Plasma glucose (mg%)	79	102	100
Plasma urea (mg%)	27	34	32

(Adapted from Chaiyabutr et al. 1990a,b.)

acutely exposed to environmental heat (41°C for 4 hours) increased plasma glucose concentration and glucose turnover rate (by approximately 68%) while recording a decrease in glucose carbon recycling (Chaiyabutr and Buranakarl 1989). An increase in glucose turnover rate has been suggested to be due to the increase in the rate of gluconeogenesis particularly from compounds of endogenous origin, e.g. amino acids, lactate. Among other constituents of buffalo blood, urea production has been observed to increase in the buffalo during heat stress (Norton et al. 1979). This may affect the glucose production of heat-stressed animals. The enhancement of the glucose production rate during heat exposure has been shown to be alleviated by the effect of intravenous exogenous urea infusion. The reduction of the glucose turnover rate and glucose clearance rate in heat-stressed buffalo given exogenous urea has been apparent with a progressive increase in plasma glucose concentration and no alteration of glucose carbon recycling. These changes in glucose kinetics indicate the process of underutilisation rather than overproduction. An increase in plasma urea concentration of the heat-stressed buffalo will affect the renal urea reabsorption. Renal urea reabsorption decreases in heat-stressed buffalo when given exogenous urea infusion but it is not affected in normal buffalo (Chaiyabutr et al. 1992). It is suggested that the limitation of renal urea retention for protein synthesis would occur during heat stress.

Hormonal Response

Hormones from endocrine glands, e.g. pituitary gland, thyroid gland and adrenal gland, are known to control many vital physiological and biochemical events to maintain homeostasis under different environmental stresses. It is known that high environmental temperature has an effect on the function of the endocrine system of most animals (see Yousef and Johnson 1985). However, little is known of the effect of a hot environment and work on the endocrine activity of buffalo. Recently, Loypetjra and co-workers (1987) have studied the effect of short-term heat exposure on hormonal response in resting swamp buffalo. Changes of serum concentrations of thyroid hormone have been reported in buffalo exposed to the sun for 10 days. In the first day of acute sun exposure, the concentration of triidothyronine (T3) in the blood serum slightly increased. Serum T3 concentration became reduced below normal if buffalo remained continuously exposed to the sun. These responses are similar to observations in sheep and cattle exposed to hot environments (Guerrini and Bertchinger 1983; Voltorta et al. 1980).

There is no significant change in the serum growth hormone (GH) of non-shaded buffalo while serum concentrations of prolactin (PRL) and cortisol markedly increase, particularly in the afternoon throughout the non-shaded period (Loypetjra et al. 1987) (Table 6). There is no correlation between the temperature humidity index (THI) and T3 or GH levels in either shaded or non-shaded periods. The correlation is apparent between THI and PRL or cortisol in non-shaded buffalo but not in the shaded. However, knowledge of the role of these hormones in regulation of bodily functions in response to environmental stress and work is incomplete and further research is required in buffalo.

Table 6. Changes in serum concentrations of thyroid hormones, cortisol, growth hormone and prolactin of swamp buffalo during exposure to the sun for 10 days.

	Control	No shade
Triiodothyronine (ng/mL)	0.38 ± 0.02	0.34 ± 0.02
Cortisol (ng/mL)	3.99 ± 0.54	6.44 ± 0.59*
Prolactin (ng/mL)	42.3 ± 5.2	117.3 ± 8.8*
Growth hormone (ng/mL)	4.4 ± 0.1	4.1 ± 0.1

Mean ± SD (adapted from Loypetjra et al. 1987).
* $P<0.05$

Conclusions

It is clear that buffalo are better equipped both physiologically and anatomically to withstand low ambient temperature than to withstand high ambient temperature. Under high ambient temperature, buffalo become stressed and the animals fail to adjust; their bodily functions and subsequent work capacity are adversely affected. Under such conditions, good management can be highly beneficial. Adequate shade, wallowing, spraying and/or artificial cooling will be essential to maintain buffalo comfortably and profitably.

Although several studies have been done on thermoregulation in water buffalo, many questions remain unsolved. This is confounded by the fact that there are two major types of water buffalo, the riverine and swamp types. The differences of habitat and cytogenetic status between swamp buffalo and riverine buffalo have been reported elsewhere. The riverine buffalo prefers water for wallowing and is used mainly for milk production, whereas the swamp buffalo wallows in muddy water and is used for draught power and meat production. Such differences are of course to be expected in view of increases in the metabolic demands in high-yielding breeds. Attempts have been made in many countries to cross the swamp buffalo with the riverine in order to produce crossbreeds for both draught and milk purposes. However, there are very limited data on the heritability of heat tolerance in different breeds of buffalo. Methods and criteria for selection of either the pure breeds or crossbreds buffalo for high heat tolerance still remain to be found. Basic knowledge concerning the normal functioning of temperature regulation in the buffalo must be gained before its mode of action in a hot environment can be fully understood and the full potential of DAP exploited.

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Feeding Draught Animals in Indonesia

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Abstract

In Indonesia draught animals (DA) are mainly cattle and buffalo. The DAs are kept by smallholder farmers. In Java which has about 60% of the total large ruminant population, farmers practise a grazing and cut-and-carry system. Outside Java, grazing is the main practice and therefore farmers are reliant on native grass. During the wet season fresh and green materials are available but in the dry season crop residues which are usually low in both quantity and quality are commonly fed.

In most cases, calves are born in the dry season. The lack of feed during this time may reduce milk production resulting in high calf mortality. Mating usually is carried out during the wet season where liveweight and body condition are increasing.

Improved feeding systems during the dry season, which is characterised by lack of feed and water, are suggested. The paper describes feeding practices and their consequences for reproductive performance of the animals.

IT is well accepted that poor feeding makes animals prone to parasite infestation. High fibrous feeds given to animals kept in high environmental temperatures lead to reduced feed intake. About 99% of large ruminants are kept by smallholder farmers who raise them by traditional methods. The main objectives in keeping draught animals are for power and calf production.

Feed and Feeding

The dry season varies from three to eight months each year in the eastern part of Indonesia. Feeding practices can be divided into dry feeding and wet feeding systems. The difficulty in feeding (both in terms of quantity and quality) is obvious during the dry season where the role of agricultural and industrial by-products is more important. Grazing is gradually changed to cut-and-carry feeding systems in the growing period of paddy and secondary crops when less grazing land is available. Low feed availability may force farmers to sell the mature animals and replace them with young ones.

Types of feeds available for DA feeding generally are:

Local or field grasses These could be fed as mixtures of different grass species or mixtures of grass and legumes. Although such feeds play an important role in feeding DAs they have attracted little research interest.

Agricultural by-products These include mainly cereal and legume straws. *Imperata cylindrica* (alang-alang) also can contribute significant amounts to the diets of DAs.

Industrial by-products Cottonseed meal, copra meal, rice bran, pineapple waste and oil palm waste, and cassava waste are all grouped under this classification.

Legumes Tree legumes such as *Leucaena leucocephala, Glyricidae* and *Calliandra* are quite important feeds for DAs in some parts of Indonesia.

Agricultural by-products are important for dry period feeding, particularly when fresh field grass is scarce. Unfortunately many industrial by-products are required for either export purposes or use in intensive commercial animal industries (e.g. cattle-fattening and the dairy industry).

While these requirements still exist there has been a trend toward commercial arrangements between business and local farmers which has given farmers greater access to by-products for feed supplementation.

Storage of dry feeds (e.g. rice straw and peanut vines) is practised but storage of green feeds is not common.

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Because of the small income contribution from DAs, feed technology introduced must be cheap, easy, and require little time.

In the absence of deliberate improvements to field grass, its feeding value varies between poor and good quality (Santoso et al 1993.)

During the dry season, DAs usually lose liveweight and body condition. This is due mainly to lack of both feed quantity and quality. Calves born in this period are subjected to a lack of milk from cows, hence a high calf mortality of 20–50% (Wirdahayati 1990) results. It should be noted that farmers give more attention to feeding DAs if they are multipurpose (e.g. power, calf, manure, savings, rent, social aspects). A cut-and-carry system is often practised and DAs with better body condition result. Examples of this system can be observed in Java, Madura, Bali and most transmigration areas in Indonesia. In contrast, in another system, DAs must look for their own feed in open fields or forests. Here there is little farmer involvement in producing enough feed. Examples of this system are Sumba, Nusa Tengarra, and some parts of Sumatra. During the dry season, DA body condition here is extremely poor, though the main DA functions are for trampling ('merancah') once a year and savings.

West Java

This is an example of growing areas where agricultural land is being converted continuously into industrial complexes. There is a combination of cut-and-carry and grazing systems. Socioeconomic effects and the difficulty of providing feed forces the farmer to sell his animals.

East Java

Rice straw forms the bulk of the diet during the dry season in East Java. Native grasses cut and carried form the bulk of the diet in the wet season (Yudi and Yusran 1989). This province is a good example of how crop residues can be utilised efficiently.

Riau

Cattle and buffalo are not used here for draught. Agriculture is the responsibility of women, while men are out in the rubber 'getah' forest. Feeds are based mainly on grazing. However, the husbandary of DAs is being introduced gradually by transmigration farmers. These farmers who are from areas such as Java and Bali are very familiar with the cut-and-carry system and using cattle and buffalo for power.

South Sumatra

Transmigrants in South Sumatra provide cut grass mostly during nights in working seasons, due mainly to the fact that farmers and animals are so busy that there is limited time to obtain feed during the day. A combination of local grasses and local legumes in Karang Agung II has been found to eliminate mineral deficiencies (Ashari Thahar, unpublished data).

South Kalimantan

The local species is the swamp buffalo which lives around swampy areas. It is kept extensively, and during the dry period grazes in the jungle areas. Recording its diet is difficult. Like the other transmigration areas Bali cattle are already used for tillage purposes. Grazing is often done after children return home from school.

South Sulawesi

Here local government tries to persuade farmers to keep Bali cattle semi-intensively.

Nusa Tenggara

The diet is based mainly on local grass with grazing during both wet and dry seasons. Supplementation with water-source material such as banana stem ('gedebog pisang') is often practised. Lamtoro (*Leucaena leucocephala*) was widespread but since a leaf mite (psyllid) attacks the plants, other tree legumes such as *Gliricidia* and *Calliandra* have been introduced.

Irian Jaya

Feeding in the forest is practised. Transmigrants have been shown to raise animals much better than local owners.

Adaptability

Under field conditions in the Wonosobo area in Central Java, Ongole cattle show better body condition compared to Friesian-Holstein crosses when feed is poor. In South Kalimantan, Bali cattle have better body condition compared to Ongole when feed is low in quality. Residual feeds left uneaten by Ongoles can be eaten by Bali cattle, but residual feeds left by Bali cattle are not eaten by Ongoles (Winugroho, personal observation).

Effect of Work on Feed Intake and Digestibility

The effect of work on feed intake is not consistent. The capacity of animals to do work is dependent largely on the efficiency with which available energy is used. Contracting muscle requires glucose and long-chain fatty acids; the efficiency of energy utilisation for work is dependent on the supply of preferred nutrients in the feeds, on body reserves, and on the intensity of work. An efficient rumen fermentation can supply adequate nutrients to replenish body energy stores, provided there is a sufficient interval of rest between working periods (Ffoulkes and Bamualim 1989). The authors stress the importance of feeding undegraded concentrate supplements to hardworking animals, and to pregnant and lactating animals that are required to work.

With regard to the effect of work on digestion, work increases the availability of feed energy in buffalo (Ffoulkes and Bamualin 1989).

Effect of Feeding on Reproduction

Calves are born usually during the dry season. Calf mortality is high. Liveweight loss during the dry season is about 300 g daily, the animal regaining this amount of weight during the wet season (Bamualim et al. 1991).

Adaptability of Indonesian cattle toward feed quality varies. Madura can stand low-quality feed for a long time without sacrificing normal ovarian activity, but not Bali and Ongole cows. However, Madura cows need more time to recover after they stop the normal ovarian activity, compared with the other species (Wijono et al. 1992).

In general, reproductive performance of DAs is characterised by low calving rate, high calf mortality (born in dry period, lack of milk, parasite burden), and long calving intervals. Liveweight loss occurs during the dry season and working periods which usually take place three times a year.

There is excellent information available on the minimal liveweight and body condition in which a cow should be maintained in order to maintain its normal reproductive function.

Nutrition requirements should take account of workload and environmental temperature. The effect of work on the oestrus cycle is discussed below. Some potential alternative feeding strategies are advanced to ensure that the animals can maintain normal reproductive function all year round, allowing for both work and maintenance during dry periods.

Body condition scores indicate the nutrition status of animals. By observing the body condition of an animal, its cyclicity can be estimated. Cyclic animals tend to have higher body scores than acyclic animals (Momongan 1985). A method to score the buffalo has been suggested by Momongan (1985), while how to score Indonesian cattle is proposed by AMLC (Anon. 1990a), and a method specially for Bali cattle is suggested by IFAD (Anon. 1990b). Nicholson and Butterworth (1986) have published a manual on how to score Zebu cattle.

Reduced body condition which is usually followed by reduced liveweight can be due to work, dry season effects (temperature and lack of feed) and/or parasites.

Winugroho and Situmorang (1989) in their review concluded that at the end of the working period a mature female buffalo should have at least 350 kg liveweight and a body condition score of 6 (range 1–10) in order to maintain normal ovarian activity. A reduced percentage of fat and protein in the body seems to stop normal ovarian function of Ongole cattle (Winugroho et al. 1991). These workers suggest that the borderline liveweight is 258 kg for Ongole cows. Sumbung (1991) found that Ongole heifers started normal ovarian activity when they reached a liveweight of 268 kg. Cessation of normal ovarian activity in buffalo cows varied depending on initial liveweight and body condition of the animals (Winugroho et al. 1989). The higher liveweight and body condition scores there are, the higher percentage of liveweight loss can be allowed before normal ovarian activity is disturbed, this ranging from 22 to 16% initial liveweight.

Jainudeen (1985) highlighted the features of female reproduction of *Bos indicus* and *Bubalus bubalis*. He discussed the stages of the female reproductive cycle which are vulnerable to thermal stress and inadequate nutrition. High environmental temperature alters, for example, the duration of the oestrus cycle and the duration and the intensity of oestrus. It can cause a failure in the fertilisation process, and it can increase embryonic loss. An environmental temperature of 33°C reduces the daily liveweight gain of Ongole cattle and their peak progesterone concentrations (Putu et al. 1991). Thermal stress reduces feed intake and consequently will reduce the liveweight of animals. If thermal stress is of a long duration and liveweight is below borderline then it can be expected that the animal will cease normal ovarian function.

Work per se is not a major factor influencing ovarian activity provided energy reserves are adequate (Winugroho et al. 1989). Provision of supplementary feed for thin working buffalo can encourage a return to normal ovarian activity. If lactating cows and buffalo lose body condition during the first 60 to 90 days postpartum, oestrus is likely to be delayed. This can be due to energy or protein deficiency (Jainudeen 1985).

Limited information is available on the effect of work on female fertility. Work requires additional nutrient intake (reviewed by Teleni and Hogan 1989). If minimal liveweight and body condition are known, and feed requirements for working animals and liveweight loss can be estimated during work, then feeding strategies can be developed.

Parasites have been shown to reduce power in working buffalo (Bakrie 1991) where liver fluke were used to infect the animals, and also when the animals were infected with trypanosomes (R. Payne, pers. comm.).

A possible feeding strategy is to feed animals so that they store body fat. A nitrogen bank can be developed by farmers such as by planting tree legumes, so that during the dry season or working season when feed is limited, the animals can maintain normal ovarian activity, notwithstanding the fact that fibrous feedstuffs are the main feed sources.

Feeding Strategies

If minimal liveweight and body condition of DA breeds are defined then three basic approaches can be considered, assuming liveweight loss due to dry season and work can be estimated. The approaches are (a) to fatten animals during the wet period; (b) to supplement the animals during the dry period; and (c) a combination of (a) and (b). The decision is often made by the farmer based on household time allocation.

If limited amounts of supplement are available, it should be offered in the appropriate animal physiological status. Best responses can be effected when supplements are given a few weeks before and after mating, and a few weeks before parturition. This helps the animal to produce good ova followed by good implantation, and good milk production once the calf is born.

Consequently, in an area with a regular feed shortage, farmers should consider planting or otherwise introducing improved but adapted grasses and legumes.

Acknowledgments

The author thanks Dr E. Teleni and Dr W.J. Pryor for their invaluable comments and suggestions in the paper.

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Feed Resources and Nutrition Needs for Draught Power

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Abstract

Draught power users aim to gain many contributions from their animals. A feed-year strategy for draught power therefore matches available feed resources with a varying nutrient demand throughout the year that may encompass periods of growth, utilisation or repletion of body reserves, reproduction and lactation as well as intermittent or continuing work. Feeds are drawn from the local materials seasonally available, and these have been described for many localities. Among the feeds available, many that are utilised over much of the year are characterised by high content of cell wall, low digestibility and low nitrogen content. Fibrous crop residues are the most likely materials stored for feeding when other forage is scarce and strategies for optimising their use are outlined. Identifying feed resources to support the demands of late pregnancy and lactation in continuously working animals poses the extreme case example. A strategy for optimisation involves modification of expectations, as well as devising the best practical feeding system based on available materials.

The basic demand for substrates is thought not to be different from the generalised requirements of animals of like size as calculated from existing statements of energy and specific nutrient requirements. However, factors associated with work and environment result in substrate distribution and tissue uptake patterns different from those of animals under conditions in which statements of nutrition requirements were developed. With periods of sustained muscular work blood circulation patterns change and rate of heat production increases. Diets and intake patterns which further increase heat production during working periods place a limit on the work rate, and on feed intake. When the substrate demands of growth, pregnancy and lactation are superimposed on the needs for work, there is both an elevation of the total nutrient demand and a major change in balance among required nutrients. Unbalanced substrate provision increases heat production, distorts metabolite accumulation, and affects the distribution of synthetic processes. Furthermore, body reserves status is a critical issue in determining the balance of nutrients required to support work and lactation. There remains a need for more feed combination response curves and good diagnostic methods to determine under field experimental conditions the nature of a nutrient limitation, both in terms of the nutrient involved and the avenue and magnitude of effect.

DRAUGHT power will continue to be important in crop production in many regions, particularly in those countries attempting to retain smallholder family production systems as well as increase overall food production into the 21st century.

Draught power users aim to gain many contributions from their one necessary investment in a major power unit. Patterns of use of the large ruminant draught animals will differ depending on the owner's efforts to optimise income. Objectives include on-farm cost reduction and resource retention, operational flexibility, alternatives in generating cash flow, potential for off-farm work, and security. Perkins and Semali (1989) have termed them 'draught-capable animals' rather than 'draught animals'. In keeping with this whole-system approach, there is increasing dependence on the working female, whether cattle or buffalo. Among all sources of power, only female livestock reproduce and 'own' their offspring and can produce milk.

In identifying feeding systems and management strategies to meet the nutrient demands for draught power, we thus need to be able to accommodate the most demanding combination of growth, build-up or repletion of body

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reserves, long-term physiological cycles and intermittent intensive effort. A feed-year strategy aims to match available feed resources with nutrient demand throughout the year. To do this it must accommodate work at specific seasonal intervals, cyclic oestrus patterns, and phases of pregnancy, calving and lactation in relation to phases in crop production. The feed resources often do not permit an 'easy fit' and it is necessary to determine the achievable objectives.

Conditions for Sustained Draught Work

Draught load of up to 10% of liveweight for animals travelling at 2.5 km per hour is considered reasonable, provided the work period is not more than 3 hours without a rest period and ambient temperature lies between 27 and 34°C (Goe 1983; Ffoulkes et al. 1987). Animals may be required to work up to 6 hours per day, and from 30 to 200 days per year (Petheram et al. 1985). Working female animals may be at various stages of pregnancy or lactation.

In order to identify feeds and their combinations as sources of the nutrients required to support different patterns of work in different physiological states, there are three issues to be explored:

(1) the nutrient requirements expressed in a context of the homeostatic limitations of the animal;

(2) the yields of nutrients from different classes of feeds and combinations of feeds; and

(3) the consequential generation of conditions limiting intake or resulting in metabolic outcomes that challenge homeostatic limits.

This calls into consideration the physiological state of the animal, the condition or level of body reserves of the animal, the environmental conditions, the program of daily work and recovery and the feeding methods, as well as nature of the feed itself.

Increased metabolic activity as a response to work is associated primarily with increased muscle metabolism. To permit this, increases in oxygen and nutrient delivery to muscle are critical. However, the extent to which these are achieved depends on the distribution of blood flow among the tissues, particularly those supplying or modifying substrates for muscle use. Thus during exercise in other species, blood flow to adipose tissue is increased (Upadhyay and Madan 1988). The extent to which other organs, particularly liver, are also called upon to increase their metabolic activity varies throughout a period of work. For this to be effective, homeostatic processes involve modification of the patterns of arterial blood flow and the rates of removal of cell products in venous blood flow. Homeostatic embarrassment such as high core body temperature, build-up of lactic acid and reduction in cellular pH can lead on to metabolic dysfunction and cell damage. Increased respiration rate, pulse rate, body temperature and peripheral circulatory and haematological changes occur during periods of draught work (de los Santos and Momongan 1988, Upadhyay and Madan 1988, Pietersen and Ffoulkes 1988). The overall increase in metabolic activity, its distribution and its consequences therefore depend in part on the balance of substrates available to the various tissues and, in the final analysis, on the pattern absorbed from the digestive tract.

In a thermoneutral environment where heat dissipation is efficiently accomplished, these processes may not be of concern. If the work output is sustained over all working days without signs of stress, bioenergetic efficiency is not an objective if the only feeds available constrain the options.

The Nutrient Requirements of the Draught Animal

Draught power capability is proportional to body size and body condition. Nutritional requirements therefore relate to those for attainment of appropriate size as well as those associated with performance at current size. Body size is a function of both genetic potential and of environmental limits to achievement of that potential. In particular, the lifetime course of liveweight change in many draught power animals involves cyclic patterns of slow or negative growth and of depletion and repletion of body reserves reflecting the pattern of nutrition support. If animals are born and raised within a draught- utilising system, there is a need to optimise nutrient provision to the preparation of an animal with good draught potential as well as to feed for current draught performance.

The mature non-pregnant, non-lactating working animal sets a baseline of demand in terms of the total quantities of substrates and the balance between the specific nutrients absorbed. The energy requirements of ruminant draught animals have been estimated by Lawrence (1987) using empirical values for energy expenditure in different kinds of work and incorporating these into the ME system (ARC 1980). However, there is only rudimentary understanding of the bioenergetic efficiency complex and the competition and interdependencies between tissues in the overall demand for substrates. The preferential requirements of individual tissues for particular energy-yielding substrates operate in a partitioning system. Unbalanced substrate provision in such a system has consequences in terms of heat production, the yield of ATP and its effective application in synthesis and other work. When the substrate demands of growth, pregnancy and lactation are superimposed, this results in both an elevation of the total nutrient demand and a major change in the requirements for specific metabolites, whether absorbed directly or generated by synthesis or mobilisation.

Studies and reviews of the nutrition of draught animals (Goe and McDowell 1980, Goe 1983, Preston and Leng 1987, Lawrence and Smith 1988, Teleni and Hogan 1989) lead to one general conclusion, as follows. Working animals, though exhibiting species-related and individual variation in physiological capabilities, are responding to interactions between environment and intake, digestion, metabolism and the physiological processes involved in heat, fluid and cell ionic balances. In these terms, needs for energy and protein for maintenance or controlled fluctuation of liveweight, and beyond this for foetal physiological competence and growth or lactation during non-working periods are not different from the generalised requirements of animals of like size as calculated from existing statements of energy and specific nutrient requirements. Significant departures from prediction arise because of characteristics of the different feeds available in terms of their physical and metabolic consequences. They also arise from differences in what the animal can achieve in terms of accommodating any extra loads of digesta, metabolites and heat that must be borne in order to achieve the appropriate levels of specific metabolites at the muscle, placenta and mammary gland. Any differences in *feed* requirements arise through effects of environment and feed type on the level and pattern of daily intake achievable, the times and rates of heat production and heat loss, and the effectiveness of metabolic transformations to provide all tissues with appropriate physiological conditions and substrates at levels supporting their individual continued functional operation.

Studies of the draught animal during periods of work suggest that conditions should resemble more those of marathon running than of weight-lifting or sprinting. While the intensity and duration of the effort depend largely on the man behind the animal, the drive to get work done includes recognition of dependence on the animal operating within tolerance limits for sustained performance. The substrates required in sustained draught effort are similar to those utilised in any long-term repetitive aerobic muscular action (Teleni and Hogan 1989). Long-chain fatty acids and glucose are critical. The requirement for glucose should be principally to provide in muscle the pathway environment satisfactory to the continuing oxidation of acetyl CoA. Periods of anaerobic effort may be encountered, but unless this is short-term and followed by a period for recovery, they place physiological loads on the animal that diet alone will do little to overcome. The interactions of training (Martin and Teleni 1989), current diet and body reserves with capacity for draught load, speed, length of daily work periods, recovery rate, and the period over which daily work can be sustained are recognised but there is as yet inadequate basis for development of a complete model.

Lactation imposes a demand for balance between substrates that is similar to that required for work (Preston and Leng 1987). The solution to a nutrient demand in working and lactating animals is therefore a common one in terms of substrate balance. Success of a nutrition strategy will also depend in both cases largely on the level of current feed intake and, over short periods, on level of body reserves. For working animals that are also lactating (Srivastava 1989) the dual demand and the metabolic partitioning effects will reduce performance in both production components under most dietary circumstances.

For pregnant animals, particularly in late pregnancy, the substrate demand and blood flow patterns established during work and recovery critically affect the metabolic competence, growth rate and viability of the foetus. The foetus has a high demand for glucose and amino acids, and is poorly placed to compete when circulation is diverted to the surface. It also constitutes a further and continuous source of deep body heat and so exacerbates the interaction of work with heat dissipation.

Protein Requirements

There is a suggestion that protein catabolism and amino acid oxidation is increased by draught work (Graham 1985), particularly under hot conditions. The extent to which this imposes a specific increase in absolute requirement for protein also depends on the interrelationships underlying glucose supply and demand (MacRae and Egan 1980). In working animals with increased total energy substrate oxidation, glucose and amino acids will be swept into catabolism under the prevailing conditions of partitioning of metabolism, even while the dominant substrates are long-chain fatty acids or acetate (Pethick 1984). However, the balance in rates of catabolism may still be such that at the prevailing level of absorption of all exogenous substrates, the *relative* demands for amino acids is reduced. Working animals with high energy requirement may have a relatively lower protein:energy ratio requirement, provided the intake achieved permits. In contrast, if the diet is such that intake is restricted, causing greater dependence on endogenous substrates, amino acid catabolism may increase, resulting in deeper negative N balance. This should not be interpreted simply as an increase in protein requirement.

Feeding and Heat Stress

The ruminant has an advantage over non-ruminant draught animals in the effectiveness of use of fibrous roughages. However, thermoregulation is more difficult for the ruminant both in terms of the avenues of heat production and the ability to dissipate heat. Bakrie et al. (1987) have reported comparative studies which indicate that working buffalo have poorer capacity for heat dissipation and show signs of heat stress earlier in a working period than do cattle. Steers of small size have a different physiological response pattern from larger steers. Handling this requires control through managing the rate of work, meeting requirements for rest and direct cooling, and through feeding strategies.

The last includes the nature of the feed and times of feeding. Heat production arises through fermentation and digestion as well as in metabolic processes in the animal tissues. The balance of nutrients absorbed also influences the time and site of heat production per unit of useful energy developed through the high energy phosphate cycle and its application to work. With periods of sustained muscular work and its attendant elevation of rate of heat production, diets and intake patterns which result in high rates of intraruminal heat production during working periods present a problem. This is either to place a limit on the work rate, or on the intake and hence the availability of substrate for working muscle and for other tissues. Heat stress combined with such nutrition effects is a primary cause of female infertility (Jainudeen 1985) and probably on the distribution of blood flow, affecting the foetus and lactation.

'Quality' of the Diet

Research reported in 1989 (Petheram et al. 1989) concluded that the feed intake of a working buffalo is reduced when the diet is of poor quality. Quality in this case was measured as digestibility. The period of peak draught requirement in a seasonal dryland cropping system coincides with the period of lowest digestibility. Furthermore, low digestibility of herbage correlates with a low intake, low proportion of the gluconeogenic propionate in the volatile fatty acid yield from fermentation, and low rate of microbial protein synthesis per unit organic matter fermented.

While the relationships between digestibility, fibrousness of the diet and intake are in the general sense well appreciated, the physiological and behavioural complexity that underlies the response to a specific feed denies us the opportunity for accurate prediction. This may not be important if we are interested only in predicting the *direction* of likely response to an alternative forage or to a supplement. However, response to a change aimed at delivering more of a specific nutrient is likely to work only if, in the overall metabolic circumstances, lack of that nutrient or its metabolic products is responsible for a high heat increment or metabolic embarrassment to the homeostatic process. The benefit of ruminally undegraded but intestinally digestible sources of nutrients is achieved when they contribute to meet specific nutrient demands in this sense.

Species Differences

Kennedy and co-workers (1987) have provided evidence that with poor quality feeds, buffalo are likely to perform better than cattle, because of differences in rumination, digesta flow rates and urea recycling to the rumen. It is possible that species differ in relative blood flow distribution and in the delivery and extraction of substrates from circulation to the various organs and tissues. It is also possible that the activity of metabolic paths in the tissues is differentially set among species, due to endocrine output and receptor differences. Certainly physiological state influences the partitioning of substrate use among tissues. However, current techniques for measurement of such physiological processes are inadequate and only very large experimental changes can be detected.

Consequently, the significance of small incremental change or unmeasurably small differences between individuals or species cannot be placed in context, even though the summation of such effects may mean the success or failure of a nutrition or feeding strategy. Empirically evaluated differences between species in performance on particular feeds are explained by correlation to measurable differences such as digestibility and intake per unit liveweight. Thus to say a buffalo needs less protein per unit energy to perform the same work or achieve the same production performance does not take account of the extent to which protein may be spared by other gluconeogenic substrates.

There is a need for more dose response curves for each draught species for feed components and specific nutrients. There is also a need for good diagnostic methods to determine the nature of a nutrient limitation, both in terms of the nutrient responsible and the avenue of its effect.

Crop Residues as a Principal Feed Resource

Within the total plant biomass available as the feed resource in many systems, the residue after harvesting the crop represents a major proportion of on-farm feed. It has been estimated that in systems throughout South and Southeast Asia, crop residues provide 30–80% of feed used by animals kept principally for draught (Mathers 1983). Most effective utilisation of this bulk of potential metabolic substrates requires planned allocation. Stubbles are grazed, but this is usually of limited duration in the cropping sequence. Harvested straw is stored and hand-fed untreated, or can be treated principally to improve digestibility. Depending on the quality of straw and the availability of other materials supplements will be used to provide additional total nutrients or specific substances to improve efficiency of roughage use.

Among the crop residues, rice straw is one of the most variable materials studied, in terms of composition and digestibility of morphological components. Pearce (1986) has emphasised this, providing data from relatively uniform crops that show major differences among stem and leaf fractions. The feeding value of the stubbles and straw materials depends on the cultivar, degree of senescence at harvest time, the soil moisture conditions and extent of regrowth after grain harvest, the height of harvesting, and the conditions of feeding. Any given straw offers a range of material, important if selection is permitted. The extent of selection will depend on the amount offered, but can be sufficient to permit liveweight gain on feeds which otherwise would not support maintenance.

In some systems the combinations of feeds are limited. There may be little opportunity for grazing for extended periods of the year, and straw is a principal or even sole feed. Methods of supplementation or treatment of straw to improve its feeding value have been sought for many years, but the fact is that these require a cash outlay and are not rapidly taken up. While the refractory nature of the fibre constituents of cell walls is the dominant factor resulting in low feeding value, in many instances the primary deficit is likely to be rumen degradable N. Urea blocks have been produced and used where there is a recognised cash return through, for example, sales of extra milk produced. Feasible small-scale systems for treatment of straw with urea have been developed (Jayasuriya 1983; Wanapat 1986), and result in improvement of digestibility and intake. The effect increases as the digestibility of the base straw increases from 30% up to about 50% and then diminishes until little effect of urea treatment is found with straw of digestibilities above 55%. Part of the effect is due to the N added and is paralleled by feeding urea.

There are other feed materials widely distributed or deliberately cultivated which can serve to supplement straw. However, it is by no means universal to provide supplementary feed in the form of browsed or cut-and-carried tree and shrub, leaf, grass or concentrate to draught animals fed straw during periods of work or pregnancy and lactation. The consequences are low productivity. It is necessary to discover, for each set of circumstances, whether this is an informed decision, is an unavoidable consequence of feed resource availability, or is due to acceptance of conditions by those unaware of possible alternatives (Petheram et al. 1985).

Feeds and Feeding Strategies

Feeds are drawn from the materials seasonally available, with the fibrous crop residues the most likely materials stored for use at other times. Seasonal forage components of the diets of the large ruminants used for draught have been described for Indonesia (Petheram et al. 1985), India (Ramaswamy 1985), Philippines (Moog 1986), Thailand (Wanapat 1985), sub-Saharan Africa (Butterworth and Mosi 1985) and tropical America (Parra and Escobar 1985). Among the feeds available the bulk materials utilised over much of the year are characterised by high content of cell wall, low digestibility and low nitrogen content. Strategies for optimising use of fibrous crop residues as animal feeds have been outlined by Dixon and Egan (1987) and Leng (1987).

Ideally, draught animals should be in good condition with adequate fat stores, to work efficiently. Cultivation of land in seasonal cropping systems occurs at the end of the dry season when animals are normally in poorest condition from feeding on the lowest quality straw-based diets. Feeding strategies therefore need to ensure that the feed reserved for the period of four to six weeks prior to the major draught work period is of better quality, either by reserving best quality roughage or treating to improve digestibility and N content, or by feeding supplements. Feeding to build up body reserves will also assist in raising fertility of the female and support non-lactating animals in early to mid pregnancy. With both working animals and reproducing female striving to regain liveweight and body reserves, supplements high in lipids, such as rice bran, prove useful (Konanta et al. 1986).

Animals that are used for draught in year-round cropping systems have little opportunity for recovery between working periods. These animals therefore should be fed throughout to ensure close approximation to maintenance of liveweight or body condition score. There is a major problem in finding the opportunity, without high levels of special supplementation, to support the demands of late pregnancy and lactation in continuously working animals. Thus the strategy for optimisation often involves modification of expectations of the animal, as well as devising the best practical feeding system based on available materials. Aiming for a two-year or longer calving interval permits a long cycle with opportunity for recovery. Such a pattern may emerge naturally due to suppression of oestrus in cattle and buffalo of relatively low liveweight or poor condition (Robinson 1977; Teleni et al. 1988, Teleni and Hogan 1989). To enable work and simultaneously to build up condition or support production, use of rumen undegradable concentrate sources of fat, protein and carbohydrate are of advantage. Upadhyay and Madan (1988) reported that for working animals in India, farmers claimed that mustard oil, butter oil, rice bran and molasses enhanced work performance.

An expert system to support a feed-year strategy model for multipurpose animals that will operate in the wide array of circumstances envisaged is in the process of development.

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Management and Health of Draught Animals

R.S. Dharsana* and R.S.F. Campbell†

Abstract

Because of the continuing effectiveness of draught animal power (DAP) in crop production, management and health services should receive stronger support from the extension organisations.

In some areas, the most urgent need is to improve animal fertility so that calf production helps to replenish livestock, including bulls, and is a better source of income for the farmer.

There is a need for improved understanding of disease problems at the village level. Both clinical and subclinical diseases may reduce animal performance, fertility and calf survival. Since preventive or curative methods are now available for most of the known problems, diagnostic services should be strengthened in agricultural areas dependent on DAP.

DRAUGHT animals contribute significantly to Asian agriculture. Nearly 85% of total draught power used in agriculture is still provided by draught cattle and buffalo which are mainly raised traditionally as a source of power by smallholders with zero or very low levels of input costs. They are used to farm crops, as a source of meat for domestic consumption and for sale, as a source of calves and a consumer of crop by-products, and as a means of recycling nutrients into the land. Although crop production may be good, the system is sometimes characterised by low animal productivity due to poor genetic quality or poor management of nutrition, health and reproduction.

Genetic improvement is a gradual process, but it is still an important part of animal husbandry. No matter how good management is, superior performance will not be attained if animals are of poor genetic stock. More rapid improvements can be made in animal performance through management practice before the benefits of genetic improvement programs can be manifested fully. Where disease is identified in bulls, cows or calves, remedial methods may bring rapid economic returns.

Management of Draught Cattle and Buffalo

Good livestock management is essential for the economic viability of the enterprise, since the availability of inputs and their costs are factors affecting the utilisation of livestock.

The Crop–livestock System

Where draught animals contribute to efficient crop production and at the same time do not compete with crops for land or cause degradation, the mixed crop and livestock system will continue to dominate the ruminant production systems in Asia for the foreseeable future. In this system the three principal ways of feeding animals are:

(i) roadside, communal and stubble grazing,
(ii) tethering, and
(iii) cut-and-carry feeding (Mahadevan and Devendra 1985).

Fodder from those sources are usually of poor quality, being mainly grasses, weeds, crop residues and, less often, agro-industrial by-products.

In general, draught animals are underfed during dry seasons and the work periods. Farmers are reluctant to provide concentrates since their concern is to keep the animal alive with minimal input cost. Very little health or other management is involved. Poor nutrition combined with inadequate health care and the burden of overwork

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may cause a problem in maintaining fully efficient draught animals. Death of the animal is a total loss to the small farmer but national economic losses from reduced work capacity, infertility, poor growth due to work stress and chronic or subclinical infections are not sufficiently recognised as problems that can be solved.

Common Diseases in Draught Cattle and Buffalo

Health programs for working animals differ from other domestic species in that cattle and buffalo are subjected to heavier physical stress and occupational injuries (Wells 1986). The problems that may result directly from their draught use are fatigue, heat stress, physical injuries (harness wounds, foot lesions, strains), poisonings (plants, pesticides, fertilizers), and infertility.

Overwork in an animal may also suppress the immune system, resulting in increased susceptibility of animals to endemic diseases. A large number of bacterial, viral and parasitic diseases can affect draught animals, though some may be prevented simply by changing the management system or by appropriate vaccination programs. Others require intervention by treatment.

Some commoner or important diseases in draught cattle and buffalo in Asia are haemorrhagic septicaemia, anthrax, blackleg, foot-and-mouth disease, rinderpest, malignant catarrhal fever, trypanosomiasis, fascioliasis and neoascariasis (in calves). A detailed account of diseases in draught animals is given elsewhere by Dharsana and Campbell (1992).

Health Maintenance

Smallholders raise cows mainly for draught purposes in the paddy field, for calf, meat and sometimes for milk production. The principles for health maintenance of working animals have been described by FAO (1972), Muzinger (1982), Wells (1986), and Dharsana and Campbell (1992). Good management is necessary both for the animal's welfare and to derive maximum economic benefit. Improvement of the smallholder system will require long-term technical and financial assistance from governments through the extension services in cropping systems and animal production. The major points for good draught animal management are described below.

Nutrition based on good-quality feed and water

Draught animals are usually fed the least nutritious feed resources in developing countries. Providing feed supplements and minerals for the animals can lead to improved performance. However, information on cost of feed is necessary to decide when, how much and to which animals to give supplements. Feeding draught animals with higher energy feed during late pregnancy, lactation and work periods can reduce the stress and weight losses associated with these periods (Leng 1985; Teleni and Murray 1991). Improved quality of the diet in the working animal is recommended since cattle do not appear to eat more when they are working (Lawrence 1985).

Disease prevention

Major economic losses in draught animals are caused by abiotic and biotic factors. Some diseases caused by biotic factors can be prevented by regular vaccination, deworming and deticking, for example, but the point to decide is which pathogenic agents should be eliminated as economically as possible in order to offer the animal a chance of survival and production.

A sound knowledge of the epidemiology of diseases in the region is therefore essential to design programs of disease prevention and control which are effective and of low input cost. Unfortunately, little accurate information relating specifically to diseases of draught ruminants is available (Hoffmann and Dalgliesh 1985; Wells 1986). An effective disease prevention program cannot be applied in the absence of reliable data. Significant results can be obtained when based on sound research. For example, Roberts and Fernando (1989) showed that neoascariasis is an important disease of calves that can be controlled easily and successfully by a single dose of 250 mg Pyrantel between 10 and16 days of age.

Hygiene

All microbial agents and parasites thrive best in unclean surroundings. Sanitation to combat them means ensuring clean environments for animals. The high incidence of ecto- and endo- parasitic diseases and losses in calves in Asia is partly due to poor hygiene practices. For example, clean drinking water unpolluted by other animals or man may eliminate infections and parasitic diseases.

Avoidance of stress

An underlying principle in the management of working animals is to reduce stress to a level which animals can accommodate (Wells 1986). Thermal and work stress are among the major factors adversely affecting female fertility in draught cows and buffalo in a tropical environment (Jainudeen 1985). Buffalo are more susceptible to heat than cattle because of their skin structure and should have access to water for cooling (Pietersen and Ffoulkes 1988; Hirokazu 1989). Death, abortion, infectious diseases, and other ailments due to work stress occur from time to time in village animals.

Preventing injuries

Injuries caused by harness, work and biting insects should be prevented because they reduce the efficiency of draught animal power. Some agricultural implements being used for draught animals are still inefficient and primitive and, as a result, efficiency of land preparation may be low. Wounds or harness sores are experienced by many draught animals in Indonesian villages. Traditional treatments of the wound sometimes worsen the lesion and lengthen the healing process.

Other injuries which may occur during work affect mostly the limbs, caused either by excessive friction or by external injuries (sharp stones, nails, et.c). Repair of the equipment and prompt antiseptic or antibiotic treatment of wounds and sores will minimise the power wasted.

Controlled breeding

In traditional systems controlled mating and breeding are not practised because of the communal grazing areas and the lack of bulls to select from. Controlled mating and breeding using an approved bull or artificial insemination will prevent parturition during stress periods, harsh climate, and when feed and water are limited, and also prevent the spread of infection and unwanted characters to the offspring. Management regimes to optimise nutrition, reproduction and work practices have been described by Teleni and Murray (1991).

Discussion

A list of health maintenance requirements is easily compiled but implementation may be difficult. For example, a vaccination program may not be performed at the optimal time because farmers were not available to assist as they were too busy with their main field activities, or when the simple drugs needed were in short supply (Wells 1986).

Recommendations for changes in the system are sometimes not acceptable. For example, some researchers or policy-makers recommended regular treatments against helminths several times each year throughout the animal's life. The animals gained several kg liveweight but were slaughtered at a fixed price per head, not per bodyweight, so the farmers gained no advantage. Innovations will not achieve long-term success or acceptance with the target group — farmers — unless they are practical and economic (Hoerchner 1989).

Technologies are being developed for intensified farming but each must be carefully designed and assessed. Management stability means the ability and readiness of the farmer to carry through an appropriate management program that will ensure its success (Harwood 1979). Stability can be assessed only under actual farm conditions. Before a new technology is recommended, it should be tested and proved under farmer management. Eventual success will depend on competent extension organisations.

Conclusions

There is good scope for improving draught animal performance through improved management practices in the smallholder system. Good feeding and avoidance of stress and injuries do not involve sophisticated techniques or high cost, and can be adopted by smallholders with assistance from extension staff. Disease prevention and improved breeding programs need government intervention. Any disease control should be of low cost, simple, and acceptable to farmers. Changes of management should be introduced gradually to ensure the farmers' income stability and minimise risk.

There is an urgent need for more studies on animal diseases, on the interaction of disease and work, and on the epidemiology of diseases in each region of Asia where draught animals are of economic importance.

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Draught Animal Power in Bangladesh

A.W.M. Shamsul Islam*

Abstract

Bangladesh has a human population of approximately 12 million people living in an area of 144 000 km^2. Crop production has not kept pace with population growth. Greater production and intensification will be possible only if an adequate DA resource can be maintained.

There are about 23 million cattle and buffalo in Bangladesh of which about 11 million are available for draught purposes. They provide about 98–99% of the total DP in the country. Due to the poor economic condition of the farmers associated with extensive, scattered and fragmented landholdings, and also due to its negative effect on employment, mechanised cultivation would have major adverse consequences. Accordingly DAP will continue to play a crucial role in Bangladesh agriculture.

To meet these needs there is a need for expanded research and the planning of national development strategies for the present and the future.

At present DA numbers are estimated to be 30% below national requirements and their distribution within the country is uneven.

Out of 10 million farm households, 76.2% owned cattle. It was observed that, of these, 25% of farmers used cows as DA, 50% had two or more DAs and 10% had only one DA. It was also observed that the draught power supply situation varied from village to village as well as among farmer groups.

Under present socioeconomic conditions and scattered landholdings, priority should be given to the improvement of DAP, both quantitatively and qualitatively, through a proper feed supply, proper animal care and improvement of draught power technology. Present subsidies on imported tractors and power tillers should be withdrawn and slaughtering of young stock restricted in order to increase DA supplies. Support for breeding programs should be extended. More training and educational programs need to be undertaken to create greater awareness of DAP utilisation, while single-animal ploughing should be popularised.

BANGLADESH has a human population of approximately 12 million people living in an area of 144 000 km^2. Crop production has not kept pace with population growth. Greater production and intensification will be possible only if an adequate DA resource can be maintained.

In Bangladesh there are about 23 million cattle and buffalo of which about 11 million are available for draught purposes. They provide 98–99% of the total DP in the country. Due to the poor economic condition of the farmers associated with extensive, scattered and fragmented landholdings, and also due to its negative effect on employment, mechanised cultivation would have major adverse consequences. Accordingly DAP will continue to play a crucial role in Bangladesh agriculture.

To meet these needs there is a need for expanded research and the planning of national development strategies for the present and the future. At present DA numbers are estimated to be 30% below national requirements and their distribution within the country is uneven.

Draught Animal Numbers and Distribution

Of the approximately 23 million cattle and buffalo, about 11 million are available for draught purposes. Cattle, and to a lesser extent buffalo, provide draught power for land preparation, threshing, rural transportation, and crushing of oilseeds and sugarcane, etc. There is a shortage of bullock draught power placing an over reliance on females which in turn is leading to a reduction in national milk production. Total available draught power is estimated to be 30% below requirements. Draught animal numbers have been declining over the past few years with

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significant reduction in large male animals along with an increase in female and immature animals used for draught purposes. It has been reported that the number of draught animals per ha of agricultural land was considerably higher in Chittagong region (0.61) than Khulna region (0.41) (Jabbar and Green 1983). The draught performance of buffalo is rated about double that of cattle.

Ownership Patterns

Out of 10 million farm households, 76.2% owned cattle (Islam 1985). It is usually observed that draught animals on large farms are in better condition than those on small farms. Generally oxen are used on large farms, oxen or cows on medium-sized farms, and cows on small farms. Farms using only bullocks averaged 2.2 ha in area, those using only cows averaged 1.3, and those using one of each averaged 1.8 ha. Farms without draught animals averaged only 1.0 ha. It is evident that there is a significant correlation between farm size and the quantity and quality of draught animals owned. It has been observed that 40% of farmers do not possess any animals, 25% use cows as draught, 50% have two or more draught animals, and 10% have only one draught animal. The draught power supply situation has been found to vary from village to village as well as among farmer groups.

Existing Draught Power Situation

Socioeconomic aspects

Draught cows predominate on small farm holdings. The small farm holders depend largely on livestock for their survival and are considered as a national target group for livestock and other agricultural production. The farmers keep their cattle and buffalo primarily for draught purposes, and hence milk, meat and other products are considered secondary. For the farmers who have only one animal it is usual to share the animal with other farmers for land cultivation. Smallholders who have excess animal power often hire out their animals for some cash income during peak crop cultivation period.

Draught Power Utilisation

There are 11 million working cattle in the country and they are used 89.7% for land preparation, 1.1% for transport, 5.1% for both cultivation and transportation and 4.2% for other operations. Buffalo are reared mainly for draught purposes and 69% of them are used for land cultivation and transportation. Heavy animals, particularly heavy bullocks, oxen and buffalo, are used in carting and transportation in the rural areas.

Draught Potency

Cattle in Bangladesh are generally small in size with average weights of 175 kg for bullocks and 150 kg for cows (de Lasson and Dolberg 1984). The draught potency of these animals is, however, poor and several other factors like poor feeding, management conditions and indiscriminate slaughtering of heavier animals affect the draught power situation seriously. The maximum draught potencies of bullocks, cows and buffalo are believed to be 0.49, 0.25 and 1.0 hp respectively (Sarker 1981; GOB 1980; Hussain 1981).

Availability of Draught Animal per Land Unit

The draught power requirement per hectare varies greatly between crops and types of soil. It has been observed that a pair of animals can cultivate 1.1 ha of land (Barton 1987). Draught animal power demand varies between regions, farming systems and, most importantly, sessions. Broadly, peaks of DAP demand fall into three periods: 1 March – 20 March, 20 July – 20 August, and late November to early December. The farmers have to hire draught animals during the 'turnaround' period.

Shortage of Draught Animals

Reports of draught power shortages are known from other Asian countries, so Bangladesh is not unique in this respect. Sometimes humans are harnessed to the plough and there is increased field culture by hoeing. The shortage of draught power is estimated to be 19–27% for the whole country on an aggregated basis, and 37% during the peak season. The extent of the shortage varies during the dry and the wet season, between districts, and also depending on soil type and moisture content and size of the animals (Islam 1985).

Cows Used as Draught Animals

The farmers of Bangladesh have been using cows for draught purpose since the 1950s. A relatively large number of cattle was slaughtered in Muslim Bengal and replacements used to come mainly from neighbouring West Bengal. After partition of Bangladesh from Pakistan this natural source of supply virtually stopped. The absence of replacement animals encouraged the use of cows, and subsequent population pressure and reduction in size of land holdings also accelerated the process of bringing cows into draught use. Of the rural cow population, 49.4% are used for draught purposes. This constitutes about 30% of the total draught animals used. The reason for keeping cows and using them as draught animals is that they are more economical than others. They provide milk and calves in addition to power for ploughing and are less costly than males. For the smallholder who does not have sufficient land to justify keeping a pair of bullocks, the use of cows for land cultivation offers an economically attractive alternative. Milk yield and fertility may be affected but these could be restored with proper feeding of balanced rations.

Draught Constraints

Some of the major constraints which contribute to the limited availability of draught animal power follow.

Feed scarcity

Nutritional status influences the draught output. Livestock feed supplies have deteriorated over recent decades as grazing lands and lands for fodder crops have been replaced by crops of rice and wheat due to population pressure. The farmers usually collect fodder or graze their animals in harvested/fallow lands or at roadside or pondside. As a result, the main sources of livestock feed are now rice straw and small amounts of green forage. During the dry season animals are supplied with only dry straw, tree leaves, banana leaves, gruel and almost negligible amounts of concentrates, as green forages are not available. Except for a few dairy farms, no farmers cultivate high-yielding fodder crops in Bangladesh. Consequently animals are physically weak when they start pulling ploughs after the dry spell.

Animal health

Disease is the main cause of poor health of livestock in Bangladesh. Most draught animals are suffering from some of the following diseases or injuries: humpsore, yoke-gall, maggot infestation, wounds, sprains, lameness, nasal granulosa, stringhalt, foot-and-mouth disease and parasitism. These severely limit the draught performance of affected animals.

Farm implements and harvesting devices

Traditional ploughs of various shapes and sizes can be found all over Bangladesh. The design has not changed for centuries. With traditional ploughs most of the soil breaking is done by the narrow metal shave with wide wooden sides. As a result about 6–8 tilling operations are required for seed-bed preparation and the number of days required for the preparation of one hectare varies within 20–30 days. Other farm tools and implements used are also very much indigenous and require more draught animal days per unit area. Poor harnessing and yoking devices also add to the problem.

Why not Mechanisation?

Mechanisation in Bangladesh is not favoured due to segmentation and fragmentation of land ownership, high initial investment, lack of spare parts and trained manpower, the constraints of soil topography, the displacement of both human and bullock labour, and increased fuel prices.

Indiscriminate Slaughtering

During Eid-Azha, a Muslim festival, thousands of young animals are sacrificed, which contributes to a gloomy picture for DAP sources. Moreover, yearly consumption of meat takes the lives of more than two million cattle. A substantial portion of this slaughter consists of draught animals.

Draught Animal Supply

The number of draught animals, particularly bullocks, is declining for a variety of reasons. On the other hand, demand for draught power is increasing as intensification of crop production is essential to feed the growing population. To cater for the needs of draught power for modern crop varieties it is estimated that draught animal numbers have to be increased substantially by about 50%. But with present levels of feed availability and management constraints it would be impossible to increase the animal population to such a level.

Suggestions for Improvement

In spite of many constraints DAP will remain as part of Bangladesh agriculture for some decades due to its millions of fragmented smallholdings and difficult hilly terrain. Even when land preparation and threshing can be mechanised, animal use for other operations will be preferred. Some possible solutions to overcome draught animal power constraints are advanced.

Institutional support services

Veterinary and extension services provided by the government should be further extended to foster the improvement of DAP. Loans or credits on soft terms, and in some cases, actual subsidies, need to be given to the farmers through the banks. Training and frequent demonstrations on the management of livestock health and care as well as uses of improved equipment must be organised by extension services.

Research and development

Universities and research institutes which are involved in research on animal husbandry and implement design and development should give attention to conducting adaptive research and identifying constraints on DAP improvement. Research results should be made available to extension workers through seminars and workshops for on-farm extension.

Supply of animal feeds

Better feeding can be ensured by growing feed such as leucaena, cowpea, azolla and water hyacinth. Intensive efforts need to be made to motivate farmers to enrich available straws through treatments.

Design of farm implements

The use of improved implements, harnessing devices and better tools should help overcome draught power shortage to a substantial extent and reduce the overall need for more draught animals. The different types of ploughs and yokes should be collected, modified and even used to replace mechanisation of some transportation activities. Present subsidies on imported tractors and power tillers should be withdrawn.

Genetic improvement

Cross-breeding programs to develop suitable breeds need to be encouraged, particularly at the private level.

Single-animal ploughing

One feasible way to increase the supply of DAP is to use single-animal ploughing. Single buffalo ploughing is being introduced in some areas of Bangladesh where this species is more common. Larger cattle can also be used in single-animal ploughing. The widespread introduction of single-animal ploughing in Bangladesh would have far-reaching economic, social and technological effects on the agriculturally-based economy of the country.

Preventive care and treatment

Proper animal health preventive and curative mechanisms should be adopted against humpsore, foot-and-mouth disease, and parasitic and other infestations.

Conclusions

Under present socioeconomic conditions and scattered land holdings, priority should be given to the improvement of DAP both quantitatively and qualitatively through proper feed supplies, animal care and improvement of draught power technology. Present subsidies on imported tractors and power tillers should be withdrawn. Slaughtering of young stock should be restricted to increase draught animal supplies and support for breeding programs should be extended. More training and educational programs need to be undertaken to create awareness of DAP utilisation. Single-animal ploughing should be popularised.

There is an urgent need to investigate the relationships between work output and disease in draught animals with the aim of producing a cost-effective health plan to improve the productivity of such animals.

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The Role and Management of Herbivores for Draught Animal Power in Pakistan

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Abstract

Oxen, buffalo, horses, mules, asses and camels contribute to draught animal power (DAP) in Pakistan. Among these, cattle bulls and buffalo bulls have a major role. Total population of draught animals is 10.87 million head, providing almost 60% of our rural energy needs. Prevailing economic and social conditions plus farm size reveal that DAP would be the principal source of energy for farming operations in Pakistan for decades to come. Draught animals are still maintained under primitive conditions; feeding and management is generally inadequate. Harnesses and implements are also unimproved.

DRAUGHT animals make an important contribution to the agricultural and rural economies of developing countries, and will continue to do so for years to come despite mechanical power introduced in most agricultural operations.

The livestock sector is an integral part of the agricultural system and along with several products, animals still generate approximately 60% of the motive power in Pakistan (Anon. 1990–1991). DAP is produced by buffalo, cattle, donkeys, mules, horses and camels. These animals not only provide DAP but also convert crop residues and agricultural and industrial by-products into high biological value food which otherwise goes to waste, creating the problem of its proper disposal. Besides this, animal power does not have to be manufactured or entail any investment in expensive and non-renewable fuel. Use of machinery can be afforded only when farming systems provide sufficient income to pay for its purchase, operation, maintenance, repair and depreciation. The progress of mechanical power in the agriculture of Pakistan has also been delayed due to small farms, irregular fields, abundance of underemployed labour and insufficient mechanical skills accompanied by lack of training, maintenance and repair facilities. Under these conditions DAP has acquired more importance than ever before (Ahmad 1983).

Extent and Use of DAP

There are 10.87 million draught animals in Pakistan. Changes in species are shown in Table 1.

Table 1. DAP in Pakistan

DAP source	1980-81 Number ('000)	1988-89 Number ('000)
Oxen	6 170	6 792
Buffalo	184	222
Camels	660	750
Horses	343	352
Mules	44	47
Asses	2 163	2 709
Total	9 564	10 872
Mechanical Power Source		
Tractors	107	242.9

Agricultural Statistics of Pakistan 1989–90. Government of Pakistan, Islamabad.

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Table 2. Relationship between bodyweight and weight pulled and draught developed.

Species	Bodyweight (t)	Weight pulled (t)		Draught developed (kg)		Relationship of bodyweight to draught developed(%)	
		Winter	Summer	Winter	Summer	Winter	Summer
Camel	0.81	4.65	4.50	63.40	54.23	7.84	6.70
Bullock	0.67	4.02	3.89	54.33	52.10	8.09	7.76
Mule	0.40	1.59	1.45	21.10	19.30	5.28	4.82
Horse	0.46	1.55	1.44	21.08	19.13	4.58	4.15
Donkey	0.24	1.05	0.85	14.08	11.33	5.84	4.72

It is estimated that nearly 60% of our rural energy needs come from animals, 20% are owed to human exertion, and the rest are met by tractors and electric power (FAO 1974). FAO (1969) has estimated that the farm power requirements of developing countries like Pakistan are 0.49 hp/ha. The farm mechanisation committee set up by the federal Government of Pakistan assessed the available farm power to be 0.25 hp/ha. At present Pakistan has a fleet of 271 900 tractors (Anon. 1990–91). They are capable of producing 5.46 million hp if run to maximum capacity (Kemp 1987, tractors on average produce 15 kW (1 kW = 1.34 hp)). There is an 11.9% annual increase in the number of tractors. Thus probably it will take decades to replace DAP completely. Due to the shortage of farm power requirements all cropped areas are not fully utilised. It would take billions of rupees to meet the energy gap by mechanisation. Additional to economic issues, social and technical reasons indicate that animal energy will remain the principal energy source for farming operations in Pakistan. Of all farms, 74% are classified as small (less than 5 acres) with severely fragmented land. Owners do not have the skills to use tractors or other mechanical tools. Under the prevailing social order the land holdings continue to decrease in size and small farmers thus will depend more, if anything, on DAP for agricultural operations. Livestock also serve as a source of earning a livelihood for small farmers. Besides this, small farmers are unable to pay for the heavy cost of tractors, allied machinery and fuel. Thus draught animals are and will continue as an integral part of the existing agricultural system.

Work and Tractive Performance

The main farming operations performed by work animals are ploughing, levelling, planking, interculturing, part threshing, transportation by cart and on back, fodder chopping, cane crushing and lifting of water from wells. Oxen are the main draught animals on the farm. Camels and donkeys are engaged in farming in rainfed semi-desert areas. Cows are generally used for trample-threshing of wheat in the Barani areas of the Punjab. The male buffalo bull is considered to be a superior animal for transporting wheat, rice straw and wood on bull carts from farm to market, whereas female buffalo are considered ideal work animals for the paddy fields. Mules and horses are used mostly for transportation of farm produce. Camels, donkeys and horses are also used as pack animals.

The work efficiency and traction power of the draught animal depend upon breed, size, bodyweight, nutrition level, environmental temperature, quality of harness, kind of farming tool/implement and upon the taming skills of the operator. Draught power is known to be directly dependent on the animal's weight and feeding rate (Hopefen 1969). The draught capacity of bullocks varies 0.3–0.8 kW, the average being 0.5 kW and a pair of bullocks is capable of generating 0.75 kW of power. Small animals have relatively better draught efficiency because their line of pull is lower (Butt 1969). It was further reported that a bullock can exert a draught of 12–15% of its body weight for six hours daily both during winter and summer. In one study female buffalo were used for ploughing. The average speed was 133.3 ft/min and animals developed 0.63 hp. The area ploughed on average was 0.23 ha in 3 hours without affecting milk yield and composition (Muqtadir 1973). Din (1969) reported that with the increase in environmental temperature the body temperature and respiration increase but work efficiency decreases.

A pair of buffalo bulls can mulch up to 0.4 ha/day in 8 hours and females up to 0.24 ha. In pneumatic-wheeled carts a pair can carry 2–2.5 ton over a distance of 15 –20 km at a speed of 3.5 km/hr. These operations are undertaken mostly around sunset and early morning hours to avoid exposure to heat in summer (Fahim-ud-Din 1989).

Hanjra et al. (1980) conducted a study on comparative efficiency of draught animals and reported that the values for weight pulled and draught developed, both for winter and summer, were highest in the camel followed by bullock, mule, horse and donkey. However, all the animals pulled a greater weight in winter than in summer (Table 2).

The camel was found to develop maximum power followed by bullock, horse, mule and donkey. The differences among various species were significant. As the camel can exert greater draught than the bullock, mule, horse and donkey, the power developed by this species would also be higher since the power developed by an animal depends upon the draught exerted and speed of work (Table 3).

In general, tractive efforts range 10–14% of bodyweight at speeds of 2.5–4 km/hr. Exceptions are the mules and asses (10–16%). Large differences exist between species in the percentage of body weight that can be used in a pack. Horses and mules can pack-carry 12–15% of bodyweight while asses and camels are reported as capable of carrying loads equivalent to 27–40% of bodyweight (Goe 1983).

Feeding and Management

Cattle and buffalo

In Pakistan the animals are kept near the farm homestead. Since the number per farm is small these are raised along with other animals. Different types of structures ranging from thatched roof to brick are used. In summer the animals are tied under shady trees but stay out in the open in winter where movable mangers are used for feeding.

Draught cattle and buffalo are mostly stall-fed. Animals weighing 350–450 kg on average receive 30–40 kg green chop (seasonal green fodder), 2–5 kg dry roughage and 0.5–1.5 kg concentrate. Salt licks are also provided. Watering is carried out 3–4 times a day in summer and once or twice in winter. Buffalo bulls also have access to wallows.

The animals are trained for work at the age of 3 years, generally in pairs. Animals are walked or trotted at the beginning and cattle are mostly blindfolded. This is followed by attaching a heavy wooden plank and moving the animals in open fields. Next the animals are yoked to a light cart so that they become used to both the systematic application of pull and a neck load. Slowly the weight is increased with training.

Health cover is provided by government-run veterinary hospitals. Castration is also practised to make the animals more docile during work.

The working schedule is variable depending upon the season of the year, land ownership and cropping intensity. Generally the animals work 550–650 hours per year. The useful life is 12–15 years.

Both cow and buffalo females are used for light work when not in an advanced stage of pregnancy. Experimental work in Pakistan indicated that the female buffalo can be used for draught purposes without any ill effect on milk yield or health provided adequate feeding is carried out.

Horse, donkey and mule

The use of the equine species is limited mostly to haulage of merchandise and as pack animals. Usually these animals operate within the cities and towns and for haulage of material from nearby villages.

Indigenous breeds of horses are used for pulling carts (both for carrying loads and passengers). Animals are housed in different types of structures. They stay outside in summer under tree shade or in thatched-roofed mud houses. During winter the animals are taken indoors.

Equine species are well known for their draught ability. For fast work, the horse is used mainly in the cities for public transport carrying 4–6 people in a cart

Table 3. Speed of work and power developed by various draught animals.

Species	Pace (m)	Pace/sec	Speed (km/hr)	Power developed (kW/hr) Winter	Summer
Camel	0.93	1.98	6.63	0.91	0.79
Bullock	0.69	2.11	5.22	0.79	0.58
Mule	0.72	3.08	8.00	0.52	0.47
Horse	0.74	3.20	8.50	0.52	0.48
Donkey	0.51	2.92	5.36	0.18	0.15

(tonga). Horses work 6–8 hours a day (survey data 1984, Department of Livestock Management, University of Agriculture, Faisalabad) with small rest intervals between. In summer they are frequently watered, 4–6 times a day. During working hours at intervals the animals are offered small quantities of fodder. On average a medium-sized horse (weighing 400 kg) is fed 25–30 kg alfalfa (or other green chop), 2–3 kg oaten hay and 2–3 kg concentrates (consisting of oats, gram (chick pea) and wheat bran). When the horses are idle the concentrate is withdrawn. After working hours it is customary to wipe off sweat and give a body massage for 15–20 minutes.

Horses have a long useful life (15–20 years). When used for riding and slow work this could extend to 20 or 25 years. In hilly tracts horses are rarely used for agricultural operations.

Mules and asses are well known for endurance and sustained work. The animals are well adapted to varying conditions. Mules are used for haulage of loads. They are excellent pack animals in hilly tracts. Due to its surefootedness the animal is rated the best pack animal in the northern areas of Pakistan.

In recent years donkeys have replaced other draught animals for medium draught purposes. They are excellent animals to pull carts with a medium load (400 kg). The daily working hours are long (8–10 hours).

Feeding requirements are simple. In the suburban areas the animal may be taken out for grazing and little stall-feeding is carried out. In the cities where donkey carts are used for transporting merchandise, the feeding is better. It consists of 8–12 kg green fodder, 1–2 kg chopped hay and 0.5–1 kg concentrate. Horses and mules are shod when being used on metalled roads. Rarely are horses castrated. Training of horses starts at the age of 3–4 years. First the animals are moved in circles. Then an empty cart/tonga is attached for several days and slowly the weight is increased. Animals are led on the road for a week till they develop road sense.

Camel

The camel is used both as a pack animal and for pulling heavy loads. In the desert and semi-desert areas of Pakistan where metalled roads do not exist, the camel even today serves as an excellent pack animal. Mature animals carry 300–400 kg loads and cover up to 30 km per day.

The camel can meet most of its feed requirements through browsing. In the cities the animals are stall-fed with green chop (30–40 kg) and concentrate (crushed oats, cotton seed, maize, rice bran and gram, etc.) at a rate of 2–3 kg/day.

The animals are trained for work at the age of 5–6 years. Earlier a nose-peg is applied for controlling the animal. At the start of training a rope is tied to the nose-peg and the animal is made to walk and trot. It is also taught to obey commands for kneeling, sitting and rising. Then a small pack load is placed for several days followed by a heavy weight. The riding camels are trained more carefully.

For many agricultural operations (water-lifting, cane-crushing, transport) the camel is considered as good as a pair of bullocks. Riding camels may cover up to 50 km in a day. Their useful age lasts 15–20 years.

The usefulness of draught animals can be enhanced and maintained over longer periods of time by careful task scheduling, better veterinary care, feeding and improving working conditions through improved implements, harnesses, training and taming. Organised scientific measures needed to improve and maintain the health and strength of work animals will also contribute to increased animal power utilisation. Areas of research work needed in this regard in Pakistan include better formulation of maintenance and work rations, better veterinary care and improvement in the existing draught breeds.

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An Evaluation of Animal-drawn Ploughs in Indonesia

Sumanto*

In Indonesia (in Java and in part outside Java) the animal-drawn plough is still popular mainly for crop cultivation in hilly and narrow or transmigration areas. Research into the plough in this country is limited, therefore its potential and problems are not yet fully known. Surveys were conducted in many areas, such as in West Java, East Java, South Sumatra and Kupang-NTT to identify and evaluate ploughs, and trials were carried out in specific areas to modify them for more efficient use.

Results showed that the forms and dimensions of ploughs vary between locations. The particular characteristics of ploughs vary according to the local farmer's experience. Other observations were that the working animal capacity also varies due to many factors, such as the type or weight of animal, the land condition and the type of plough. Generally, farmers use a pair of animals for ploughing except in a part of West Java. But even there the plough is still the same type.

Buffalo appear to be more content working in wet or muddy land (e.g. West Java) and cattle are more suitable working in dry land (e.g. East Java and South Sumatra–transmigration areas). A single animal for ploughing is more efficient than a pair of animals. It is not suggested that ploughs need to be standardised for efficiency in this country, but that they need to be selected taking account of regional conditions.

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Farming Systems and Use of Draught Animal Power in Support of Sustainable Agriculture in Indonesia

Santosa* and T. Chaniago*

Draught animal power (DAP) use in some relevant farming systems was studied by collection of data from rearer farmers' samples based on survey and monitoring procedures. Samples were taken from four farming system types: Dry Land Extensive (DLE), Dry Land Intensive (DLI), Wet Land Intensive (WLI) and Tidal (T). The number of animals varied from 50–100 (tramping) to 1–2 (ploughing and harrowing). Animal days worked per year ranged from 20–25 in DLE to 10–282 in T. Capacity of animals worked ranged from 5–10 days/ha in DLE to 35 in WLI. Hours/day ranged from 3 to 4.9 over all systems.

High demand for DAP was observed in most parts of Java, particularly in transmigration areas. DAP is increasing in importance and determines the ability of farmers to operate land and to increase crop production and farmer income. Under certain conditions, however, the role of DAP declines, particularly in large plain areas, where highly intensive rice production schemes have been planned according to government policy (North Coast of West Java). Rice cultivation is provided here by strict water irrigation systems requiring the simultaneous completion of planting work. In these areas DAP is difficult to use and mechanisation is an alternative.

Land preparation practice adopted by farmers in most rural areas reflected the traditional custom and skills where farmers take optimal advantage of the environment.

a) Trampling practice (in Nil for example), carried out where there is a very short wet period, shortage of labour and a need for speedy planting time. A high number of cattle makes this practice possible and the soil structure in the region appears as another reason for it.
b) High intensivity of land preparation as commonly observed in most wet areas of Java. This usually requires more days of work compared to extensive practice.
c) Zero tillage is often found to substitute where DAP cannot be practised, particularly in areas with heavy soil condition, (e.g. in tidal areas), where there is deep clay soil or on newly cleared land.

The number of days and capacity of animals worked depend upon factors such as the intensity of land preparation, cropping intensity (number of croppings per year), hours of work per day and demand of the labour market.

The high demand for DAP coupled with the variation of land preparation styles, particular in the outer islands and transmigration areas of Indonesia, highlights the importance of study of all factors which may act as both constraints or advantages in DAP development programs.

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The Relationship Between Liveweight, Body Condition and Ovarian Activity in Indonesian Cattle

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In East Java, female cattle are the main class of animals used for work in land tillage. One of the reasons for using females is the opportunity to extract extra income through calf production. However, the usually long dry seasons in this region of Indonesia result in low availability of feed in both quantity and quality and it is not uncommon that cattle lose weight during this period. The problem is exacerbated when cows are worked at the end of the dry and beginning of the wet season.

Utilising body reserve nutrients (body condition) in a feeding management package would be a sound strategy provided one is aware of the limits within which one can manipulate body condition with compromising the reproductive ability of the animals. This study was undertaken to define such limits.

Forty cows of which 10 were Bali (*Bos sondaicus*), 20 Madura and 10 Ongole crosses (*Bos indicus*) were fed a sub-maintenance diet of rice-straw and elephant grass 1:1. Ovarian activity was monitored by rectal palpations and plasma progesterone concentrations at 10-day intervals. All animals were assessed to be of a body condition score of 7 (on a scale of 1 to 10) before they were restrictively fed.

The Bali, Madura and Ongole cows became acyclic on losing 18, 23 and 20% of liveweight, respectively.

It would appear from the above that the different breeds of cattle react differently to nutrition stress. Bali cattle appear to be more sensitive than the Madura and Ongole crosses which were similar in their response to those of Brahman cross cattle (*Bos indicus*).

It is suggested that such differences in breed response to nutrition stress should be taken into account when developing feeding management strategy for draught cows.

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Mineral Characteristics of Feed Used for Draught Animal Power in Indonesia

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The characteristics of mineral content of fodder can be broadly classified based on three criteria of soil pH levels : low (< 5.0), medium (5.0–6.0) and neutral (> 6.0). This characterisation can be used to recommend better management of fodder development and utilisation.

A number of tree and grass fodder species was sampled in the three criteria of soil pH in Indonesia, from Sumatra for the low pH of histosols, Java for the medium pH of inceptisols and from the South Eastern Islands for the neutral pH of vertisols and alfisols, and analysed by ashing and atomic absorption spectrophotometry.

Sodium deficiency was found to be the most common in almost all native fodder species of the three criteria of soil pH types. Cu, P, and Zn are believed potentially deficient in all fodder species from the medium soil pH areas and very likely to be deficient in the low pH areas. Native pastures of the neutral soil pH areas are likely to be Mg-deficient in Timor; Cu -deficiency occurs during the dry season and Zn is likely to be deficient throughout the year in the mixed pastures of the neutral soil pH area. Grass fodder species are marginally Ca–deficient in the medium soil pH and likely Ca–deficient in the low soil pH areas. In the dry agroclimatic zone, mineral concentrations are most likely higher in the wet than in the dry season. These facts can be used to plan better utilisation of fodder for improved livestock development.

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Feed Resource Needs for DA

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The energy requirements for working large ruminants is 1.7MJ of metabolisable energy (ME). This requirement cannot be met from tropical grasses or rice straw alone.

In general tropical grasses contain approximately 7 MJ/kg DM and a crude protein (CP) content of less than 9%. These just meet maintenance requirements of large ruminants.

Rice straw usually has ME of 6 MJ/kg DM and CP of less than 6% which does not meet maintenance requirements let alone a capacity for work. Therefore feed supplements are necessary to increase intake of the basal diet and/or to provide additional energy.

ME and CP have been determined from available common feeds in a study at BBT, Ciawi, Indonesia.

Table 1. Energy and protein analyses of common feeds in Indonesia.

Feed type	Used as	Me (MJ/kg DM)	CP (%)
Native grasses	basal diet	7	9
tree legumes	protein supply	9	25
crop residues:			
rice straw	basal diet	6	6
corn stover	basal diet	7	6
sugarcane top	basal diet	8	6
cassava forage	protein supply	12	27
sweet potato forage	protein supply	10	13
soybean forage	protein supply	11	23
groundnut forage	protein supply	9	15
crop by-product			
rice bran	energy supply	10	10
broken rice	energy supply	16	10
rice polishing	energy supply	14	13

Other studies have shown that the basal diets used were usually deficient in Na, P and Cu. Therefore supplements to these feeds should also supply these minerals.

Available sources for these minerals are, for example, sweet potato for Cu, Sesbania for Na and rice bran for P.

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