

# Farm power and mechanization for small farms in sub-Saharan Africa



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by  
**Brian G Sims**

and

**Josef Kienzle**

The Agricultural and Food Engineering Technical Reports bring to a broad audience the results of studies and field experience related to agricultural and food engineering within agrifood systems. The reports help us take stock of what we know and clearly identify what we do not know; and in so doing they provide information to both the public and private sectors. The Agricultural and Food Engineering Technical Reports serve to direct further work within agrifood systems. The views expressed in this publication are those of the author(s) and do not necessarily reflect the views of the Food and Agriculture Organization of the United Nations.

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# Foreword

In the past, many of the publications concerned with mechanization, draught animal power, hand-tool technology, etc. tended to be rather mono-topical, dealing with only one aspect of the subject. Farm power and mechanization also tended to be separated from the actual processes of crop production and processing; it was a topic created by engineers and was dealt with by engineers. As a result, there is a widespread lack of understanding of the subject, and there are many widely held misconceptions with regard to the essential contribution of farm power and mechanization to small farmers' productivity and livelihoods.

In recent years, the Farm Power and Mechanization Group in FAO has broken away from this rather narrow approach and has put the different sources of farm power, mechanization, machinery, equipment and tools into a much broader context. We have looked at farm power from the perspective of rural livelihoods and farming systems, as well as the critical area of labour saving in HIV/AIDS and migration-affected populations. We have purposely avoided taking rigid positions with regard to any one particular type of technology; instead, we have adopted a much wider brief and have been concerned to identify appropriate solutions for a range of situations.

As a result, we have produced this manual, which provides an overview of options for farm power and technologies that could be suitable for small and medium-sized farmers who are faced with making decisions about the different types of farm power sources available. The manual also lays out the importance of the farming systems and the economic context within which the mechanization takes place. Special emphasis is also given to the financial implications of farm power, as well as to the environmental impact of mechanization that may be inappropriate to the conditions.

Many practitioners, both from FAO and from countries in sub-Saharan Africa, were involved in preparing and commenting on this document, all of whom have long experience with the different technologies and farming systems to be found there. The contributors are mentioned in the Acknowledgements.

We hope that whoever reads this manual, whether out of general interest or to solve some particular development problem, will put it down with a greater level of knowledge and understanding. If we can provide any other information or answer any queries our contact the Agricultural and Food Engineering Technologies Service of FAO.

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This publication is a result of the teamwork of many people, beginning with those who carried out field studies and provided the information on which it is based, and those who contributed to its writing, reviewing and preparation.

The main authors were Brian Sims (Consultant) and Josef Kienzle (Agricultural Engineer, Agricultural and Food Engineering Technologies Service – AGST), with important inputs from Jennifer Heney, Rural Finance Officer (Agricultural Management, Marketing and Finance Service – AGSF) and from David Barton (Consultant) for the chapter on financial and economic aspects of mechanization. Bill Hancox (Consultant) contributed to the section on tractor maintenance and replacement parts. Josef Kienzle coordinated the production with FAO's 'Enhancing Small Farmer Livelihoods' Programme, in the Agricultural Support Services Division (AGS). John Dixon, the leader of that programme and former Senior Farming Systems Officer (AGSF) provided guidance and support, especially for the sections covering farming systems, while Doyle Baker, Chief of AGSF, assisted with aspects of rural livelihoods and mechanization. Lawrence Clarke, Senior Officer and Agricultural Engineering group leader (AGST) provided overall guidance throughout the production of the publication.

Many people reviewed and revised the publication at various stages, beginning with Timothy Simalenga of the South African Agricultural Research Council (ARC) and Calvin Miller, Senior Rural Finance Officer, FAO. The main reviewer was Clare Bishop-Sambrook, (Consultant) and the author of the Agricultural and Food Engineering Technical Report 2 (*Contribution of farm power to smallholder livelihoods in sub-Saharan Africa*). She made numerous, very valuable, suggestions.

A first major building block in the series of field studies that made this publication possible (Agricultural and Food Engineering Technical Report 3) and its companion Technical Report 2, mentioned above, was the 1998 IFAD/FAO study in five countries of sub-Saharan Africa on agricultural implements used by women. Colin Fraser (Consultant) led that participatory study in the field and also revised and edited this publication.

It is particularly important to note that the field work for all of the studies that provided the material for these publications could not have been conducted without the whole-hearted participation of thousands of poor rural people in sub-Saharan Africa. They willingly gave of their time and were forthright in expressing their ideas and opinions. The work could not have been done without them, and it is therefore to be hoped that there will be intensified efforts by governments and development agencies to improve their livelihoods through solving the farm power and labour shortage problems they face – problems that are contributing to keeping them locked in poverty and malnutrition.

Last but not least we would like to thank Louise Newton and Larissa D'Aquilio for their efficient support with editorial issues and the desktop publishing.

# List of abbreviations

AGS	Agricultural Support Services Division (FAO)
AGSF	Agricultural Management, Marketing, and Finance Service (FAO)
AGST	Agricultural and Food Engineering Technologies Service (FAO)
ARC	Agricultural Research Council, South Africa
AU	African Union
CA	Conservation Agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
DAP	Draught animal power
FFS	Farmer Field Schools
FSD	Farming Systems Development (FAO)
ha	Hectare
HIV/AIDS	Human immunodeficiency virus/acquired immunodeficiency syndrome
IFAD	International Fund for Agricultural Development
Kg	Kilogram
LSP	Livelihood Support Programme (FAO)
NEPAD	New Partnership for Africa's Development
NGO	Non-governmental organization
SEAGA	Socio-economic and Gender Analysis Programme (FAO)
SSA	Sub-Saharan Africa

# Executive summary

## CONTEXT AND BACKGROUND

According to the New Partnership for Africa's Development (NEPAD), 200 million people in Africa, or 28 percent of the continent's population, were chronically hungry in 1997–99. By the end the 1990s, only ten countries had been able to reduce their numbers of hungry people in that decade. Food imports have been rising since the 1960s, and Africa became a net agricultural importer in 1980. The agriculture sector now provides only 20 percent of the continent's exports, whereas it provided 50 percent in the 1960s.

NEPAD makes agriculture one of its main priorities “as the engine of NEPAD-inspired growth”. It stresses three aspects: improving the livelihoods of people in rural areas; achieving food security; and increasing exports of agricultural products.

None of these aims can be achieved without giving serious attention to family farm power in small-scale agriculture in sub-Saharan Africa (SSA). Farm power is a vitally important component of small farm assets. A shortage of farm power seriously constrains increases in agricultural productivity, with a resultant stagnation in farm family income and the danger of a further slide towards poverty and hunger.

Studies in SSA in 2003 and 2004 have revealed in a graphic manner that unless the issue of farm power is addressed in a practical way, with solutions that are accessible to small farmers, the region is at risk of increasing poverty and hunger. The Millennium Development Goal of halving the proportion of people suffering extreme poverty by 2015, and the similar goal of the World Food Summit in 1996 to reduce the *number* of starving people by half, are now unlikely to be attainable in SSA until well into the 21st century.

The review and guidelines presented in this publication are the result of several recent studies of the power situation of farm families in small-scale agriculture in SSA. These reports reconfirm that the farm power situation is deficient almost everywhere, and that urgent measures are needed to correct it if the widely promoted goals of raising the productivity of the sector, reducing poverty, and achieving food security are to be achieved.

Another serious concern in SSA is that of soil degradation. The level of degradation varies considerably across the region and is difficult to quantify. However, some figures for soil erosion in Ethiopia were documented in 1988; they ranged from 16 to 300 tonnes of soil per year being washed away, with an average for the country of over 40 tonnes/year on cultivated land. An FAO/World Bank Ethiopian Highlands Reclamation Study some four years earlier estimated that 1 900 million tonnes of soil a year were being washed away from the cultivated land in the Highlands, equivalent to about 100 tonnes per ha. Even if the erosion rate were halved, there would still be a 2 percent per year reduction in total grain production in the Highlands. It is true that erosion and soil degradation in Ethiopia are particularly severe, but in many other parts of Africa there is abundant anecdotal evidence from smallholders themselves who state that they are obtaining much smaller yields from a particular plot than were being obtained by their fathers and grandfathers.

There can be little doubt that conventional methods of farming, with much soil disturbance for seedbed preparation, exacerbate erosion. This and the depletion of soil organic matter and nutrients contribute to soil degradation. Any interventions concerning farm power and farming systems need to take into account the issue of soil degradation; at the very least, they must contribute to halting the degradation process, or better still, reversing it.



## MECHANIZATION

The term “mechanization” is used to describe tools, implements and machinery applied to improving the productivity of farm labour and of land; it may use either human, animal or motorized power, or a combination of these. In practice, therefore, it involves the provision and use of all forms of power sources and mechanical assistance to agriculture, from simple hand tools, to draught animal power and to mechanical power technologies.

Mechanization is a key input in any farming system. It aims to achieve the following:

- increased productivity per unit area due to improved timeliness of farm operations;
- an expansion of the area under cultivation where land is available, as it often is in SSA;
- accomplishment of tasks that are difficult to perform without mechanical aids;
- improvement of the quality of work and products;
- a reduction of drudgery in farming activities, thereby making farm work more attractive.

Mechanization systems are categorized into human, animal and mechanical technologies. Based on the source of power, the technological levels of mechanization have been broadly classified as hand-tool technology, draught animal technology and mechanical power technology.

## AN OVERVIEW OF FARM POWER IN SUB-SAHARAN AFRICA

A series of studies on farm power conducted by FAO in SSA in the years 2002–2004 have shown that the principal labour-demand peaks in the farming cycle are for land preparation and subsequent weeding. The constraints to increased farm production are due, to a large extent, to three factors:

- an excessive reliance on human power;
- the low productivity of human labour;
- a decrease in the labour available.

**Human power:** With human power, productivity is generally low because of the lack of physical energy available and the limited range of hand tools. The situation has been exacerbated by the HIV/AIDS pandemic and other factors, such as migration, which reduce the numbers of young, healthy people available for farm work..

**Draught animal power (DAP):** Draught animal power is generally considered to be an affordable and sustainable source of power for small scale-farmers. Oxen and sometimes cows are the animals of choice, but in some African cultures it is unacceptable for women to use bovines. Donkeys and horses are increasingly being used, as are camels and mules in some areas. Apart from tillage, transport and other field operations, work animals can also be used for logging, pond excavation, and rural road maintenance.

**Tractor power:** Government-run tractor hire schemes in SSA, never widely effective, are now in a state of collapse following a reduction in government expenditure on services that could, theoretically, be provided by the private sector. Private sector tractors have been profitable on large landholdings, but they have seldom proved viable for the smallholder sector in SSA, whether in individual or group ownership, or in private hire services.

## CONSTRAINTS AND OPPORTUNITIES OF DIFFERENT POWER SOURCES

Human muscles still contribute about 65 percent of the power for land preparation in SSA. A typical farm family that is reliant solely on human power can only cultivate in the region of 1.5 ha per year. This will rise to 4 ha if DAP is available, and to over 8 ha if tractor power can be accessed. It is quite common to combine available power sources in order to increase the area farmed, or to reduce the burden on humans.

Tractors or draught animals can be hired for primary tillage and subsequent planting, and weeding can also be done with a combination of power sources and technologies. Application of these alternative power sources can relieve pressure on human labour at critical times of heavy demand.

Making more efficient use of human power, together with the efficient application of draught animal power, provides the best immediate strategy for reducing the problem of farm power shortage in SSA, thereby increasing agricultural productivity and improving the livelihoods of millions of families in the shortest time.

### **DIVERSIFICATION AND EXPANSION IN THE USE OF DRAUGHT ANIMAL POWER**

The power available for farm use can be increased by diversifying the type of work to which power sources are applied, for this makes them more affordable and can further enhance their potential for improving productivity and livelihoods. There is a great potential for diversifying and expanding the use of draught animals. Such diversification and expansion can be brought about in some of the following ways:

- Widening the scope of the number of jobs that animals can do. This can include more crop production jobs, but can also mean water lifting, milling and other stationary power activities.
- Using single rather than multiple animals, and providing them with appropriate (usually lighter) equipment.
- Using animals that have hitherto not been used for farm work. This could include horses, donkeys and mules, even if they have to be restricted to transport.
- Using animals for non-farm work (e.g. road maintenance or dam construction).

Perhaps the greatest potential for diversification is in transport. Farm work tends to take place intensively for short periods. For example, ploughing may be done in a week, and then the animals are not needed for a few weeks until the first weeding, and so on through the farming year. This makes the cost of these operations very high because the investment in draught animals and equipment is not spread over a range of activities and time. Adding transport to the portfolio of activities performed opens the opportunity for year-round work.

Transport is a daily grind for millions of women in SSA; they are responsible for bringing water and fuel wood to the homestead and, frequently, they also have to carry produce to market, all as head loads. The diversification of animals into transport has the potential to ease, or even eliminate, this burden.

### **OPTIONS IN FARM POWER AND TECHNOLOGY**

A study in seven SSA countries in late 2001 and early 2002 examined the crucial role of farm power in increasing production and improving livelihoods<sup>1</sup>. In these countries, despite attempts to increase the use of DAP and tractors, human muscle still constituted the most important power source – with some 65 percent of agricultural land prepared and weeded by hand in the seven countries. The study found that with the omnipresent threat to the ability of families to provide sufficient labour, the cultivated area declines, nutrition suffers, and the spectre of increased hunger and poverty looms over the homestead. (Box 1).

Work in the United Republic of Tanzania in 2003 and 2004 led to the view that, although increasing the supply of farm power to labour-deficient families would be one way to alleviate the stress; another way would be to reduce the requirement for labour in agricultural production. Of course, this would need to be done without compromising family food security. The work was preliminary in nature, but it

<sup>1</sup> The term 'livelihood' has caused some difficulties of interpretation recently, principally as a result of its misuse by some development agencies. In this publication it is taken to mean simply the means of making a living. This involves the application of a range of assets in productive processes.

## BOX 1

**Impact of labour shortages on agricultural production**

Many households respond to power shortages by scaling down their activities, reducing the area under cultivation and growing a limited range of less labour-intensive crops. They struggle to keep pace with the seasonal calendar, which results in delayed or incomplete operations in one season, with adverse effects on the next. Food security falls, nutritional status declines and household members are increasingly susceptible to infection thus becoming less productive. Households become increasingly vulnerable to external shocks, such as poor weather. Their ability to recover and secure a living is compromised by the often irreversible strategies they have adopted in previous seasons to meet short-term needs.

The challenge, in part, is to identify and support opportunities that relieve the burden of labour shortages and enable households to withstand shocks better e.g. from AIDS-related illness and death.

examined the potential for reduced tillage through the use of DAP rippers, followed by direct (zero tillage) planters, using either DAP or human power.

**Hand tools:** Hand tools are the most important implements for smallholder farmers throughout SSA. They are used everywhere for land clearing and primary soil tillage, and thereafter for a variety of agricultural jobs, from weeding to harvest to tree felling.

There is a severe constraint on the area that can be prepared by hoe; more than 60 person-days per hectare are generally required for the job.

Weeding is an absolutely critical operation in the cropping cycle. The penalty in crop yield for late weed control is heavy: more than 30 percent of yield is commonly lost because of weed infestation. Weeding is generally performed by women, who consider it to be their most onerous task, for it is both extremely time consuming and physically taxing. Some crops require more than 50 person-days per hectare for weeding.

**Draught animal power:** The ard (*maresha* in Ethiopia) and mouldboard plough are the two main primary tillage implements used with DAP. The mouldboard plough is good for weed control, but it does not have a great deal more to recommend it. It leaves the soil surface loose and unprotected, which makes it vulnerable to erosion while also accelerating the oxidation of organic matter. It is probably the greatest cause of soil degradation and crop yield decline in SSA. Nevertheless it remains a very popular and widespread implement, and its demise is not imminent.

Narrow-tined chisel ploughs, or rippers, have a mode of action very similar to that of the ard. They are able to burst the soil in a narrow furrow and leave the remainder of the soil protected with surface organic matter. Their use, although still not widespread, is generating interest for its dual attributes of saving energy and time, and of reducing soil erosion.

Ridgers are used for shaping soil into ridges or for earthing up a crop grown on the ridge as a weed control measure. Cultivators are commonly used in many SSA countries, mainly for inter-row weeding of a crop that has been planted in lines.

**Tractor power:** It will generally not be economically feasible for a smallholder farmer, with a typical land holding of up to 5 ha, to own a tractor. As a rule, government run tractor hire schemes have not been viable and have not helped to alleviate poverty or to increase farm production. On the other hand, the concept of a rental market for privately owned and operated tractors has possibilities that may increase in the future.

In the past – and sadly sometimes today – the application of tractors and heavy mechanization in unsuitable situations has led to heavy financial losses, lower agricultural production, and environmental degradation. In these circumstances, tractor mechanization can easily become a burden to national economies, and to individuals, rather than being an essential input with the potential to increase productivity.

### TECHNOLOGY OPTIONS FOR REDUCING THE NEED FOR FARM POWER

Bearing in mind that farm power must be an essential ingredient of agricultural productivity and livelihoods strategies, two approaches to satisfying the need can be considered: on the one hand, increasing the supply of farm power, and on the other, reducing the need for it.

Examinations of the demand for farm power clearly show that the greatest demand comes from land preparation, and as has been indicated, this is also the source of greatest environmental degradation. However, there is now crucially important evidence that traditional land preparation methods may not be necessary and that conservation tillage, including zero tillage, can provide an alternative that is economically and ecologically sustainable. The system is known as conservation agriculture.

### CONSERVATION AGRICULTURE

A principal component of conservation agriculture (CA) is the reduction of soil manipulation to maximise the vegetative soil cover that will protect the soil surface. Tillage can be reduced with the use of rippers. Even greater reductions in energy needs can be made with direct sowing into the stubble of the previous crop, and options exist for this to be done by hand, DAP, or tractor.

The practice of CA aims to conserve, improve, and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. In addition to reducing farm power requirements, it contributes to environmental protection as well as to enhanced and sustained agricultural production. It can be thought of as resource-efficient/resource-effective agriculture.

CA is an alternative to traditional land use and management. It is a practical method to reduce soil erosion, restore organic matter, and conserve soil moisture and soil fertility. The method is based on the following:

- maintaining a permanent or semi-permanent organic soil cover to protect the soil physically from sun, rain and wind and to feed soil biota;
- zero tillage (or minimum tillage). The principle is to eliminate mechanical tillage in order not to disturb the activities of soil micro-organisms and soil fauna;

TABLE 1

**Issues and challenges to the adoption of different forms of mechanization**

Hand tools	DAP	Tractors
<ul style="list-style-type: none"> <li>• labour availability</li> <li>• availability of manufacturers and suitable tools</li> <li>• socio-cultural traditions</li> </ul>	<ul style="list-style-type: none"> <li>• animal diseases</li> <li>• limited tradition of using DAP</li> <li>• security (likelihood of theft)</li> </ul> <p>Availability of:</p> <ul style="list-style-type: none"> <li>• suitable animals</li> <li>• animal husbandry skills</li> <li>• feed/pasture</li> <li>• veterinary services</li> <li>• implements and spare parts</li> <li>• artisans/blacksmiths</li> <li>• extension services for training</li> <li>• timber for yokes</li> <li>• harness makers</li> <li>• financial services</li> <li>• socio-cultural traditions</li> </ul>	<p>Availability of:</p> <ul style="list-style-type: none"> <li>• appropriate tractors, machines and implements</li> <li>• repair and maintenance services, spare parts</li> <li>• trained operators</li> <li>• supplies of fuel, lubricants etc.</li> <li>• implements for weeding and harvesting</li> <li>• financial services</li> </ul> <p>Other factors include:</p> <ul style="list-style-type: none"> <li>• suitable plot sizes</li> <li>• reasonable access to fields</li> <li>• shape of fields</li> <li>• reasonable distances between fields</li> </ul>

- crop rotations to reduce disease and pest problems, to explore different soil strata for water and nutrients, and for biological tillage (e.g. to break hardpans).

Unfortunately, short-term solutions and immediate benefits always attract farmers whereas the full technical and economic advantages of CA can only be seen over a medium to long-term period, when its principles of no-tillage, permanent cover crop and crop rotation have become well established within the farming system.

In fact, if the two systems of conventional and CA are applied in two plots with the same agro-ecological and fertility conditions, no great differences in productivity are generally seen during the first years. Indeed, there may even be a yield reduction with the CA treatment in the first year. However, after cultivating the same crops in the same areas for several years, the positive effects of CA usually become evident.

Especially in areas where family labour is becoming a constraint, because of factors such as migration, HIV/AIDS and other diseases, CA could be a good option for farmers. The reduction in on-farm labour requirement allows farmers to:

- extend the cultivated area;
- hire themselves out in off-farm employment;
- diversify their activities, including processing of agricultural products;
- reduce the cultivated area – made possible because of increased yields – and allow marginal areas of poor fertility to regenerate.

## **ROW PLANTING**

Although CA can certainly offer the greatest reduction in farm power needs, even the relatively simple introduction of row planting in conventional farming systems can bring important reductions. For as long as seed is broadcast, all weeding must be done manually (usually with hand hoes). The high labour demand for weeding can, and does, limit the area sown to crops. If, however, crops can be sown in rows, draught animals can be used to pull a cultivator along the inter-row space. There will still be the need for some manual weeding within the row, but the total time taken for weeding will be very much shorter.

## **THE ECONOMIC VIABILITY OF TECHNOLOGIES UNDER DIFFERENT LEVELS OF MECHANIZATION**

Implements, machines and hand tools are different from most other inputs used in agricultural production because they require an initial investment in fixed capital. Variable inputs such as seed and fertilizer are used in a single cropping season, while machines and implements require servicing and maintenance to prolong their useful life. Tractors require fuel and draught animals require fodder and veterinary services; and tractors, implements and hand tools require maintenance and spare parts in the event of wear or breakdown.

Agricultural mechanization will not be successful if the local economy is unable to deliver servicing, fuel and spare parts for both imported or domestically produced machines and implements. This failure often occurs when markets for these items are fragmented or unevenly developed, when transport infrastructure breaks down, or when new models or different makes of machine are imported without considering the need for spare parts.

Mechanization inputs and other farm technologies will only be viable in SSA if they contribute to the following:

- An increase in the productivity of labour. A family relying totally on hoe technology is severely restricted in the area that can be cropped and cared for. Similarly, post-harvest processing tasks are often time-consuming, labour intensive and repetitive. The addition of animal or engine power to agriculture significantly increases the output derived from the human energy expended in crop production and processing.

## BOX 2

**Advantages and benefits of conservation agriculture**

Conservation agriculture offers several important advantages in the context of farm power and environmental protection, these include:

- direct planting with no tillage saves energy;
  - weed control with cover crops and herbicides saves energy;
  - soil erosion is practically eliminated;
  - leguminous cover crops fix atmospheric N and so fertilize the following crop, reducing the need for adding additional fertilizer and so saving labour;
  - permanent soil cover conserves surface soil moisture, which can make the crop more resistant to spells of drought;
  - yields, and livelihoods, are improved, with less risk.
- An increase in the area under cultivation. Where land is available, the addition of animal power to the farming system should normally allow a larger area to be cultivated with the same amount of labour. Larger areas under cultivation imply higher total yields, but they also increase the labour demands for weeding, harvest, and post harvest processing. Thus, in the longer term, enhanced power sources for these operations will also be required.
  - An increase in land productivity by facilitating the timeliness and quality of cultivation. For example, improved land productivity or higher yields will result when timely land preparation and weeding are carried out.
  - An increase in profitability from increased crop production and reduced costs of cultivation, transport and processing by reducing expenditure on labour. If the costs of all farm operations can be reduced with the introduction of animal or tractor power, this will lead to improved returns and profitability.
  - A reduction of the drudgery associated with human powered farming, transport and processing. For example, ploughing with draught animals requires about 60 hours/hectare of human labour compared with 500 hours if the operation is undertaken entirely by hand.

**PARTICIPATORY MECHANIZATION PLANNING AND EVALUATION**

The participatory research concept has its roots in the recognition that if smallholder farmers do not perceive the relevance of the results of research to their own situation, they will not adopt them. Participatory research transfers the initiative and the power of decision to farmers who, in the final analysis, have significant advantages over scientists because they have detailed and practical knowledge of their own production systems.

Participatory planning involves the active participation of all stakeholders in planning and implementing mechanization strategies, with the role of farmers taking on paramount importance. Participatory planning builds upon the indigenous knowledge that already exists in the community and blends it with the ideas and knowledge of other stakeholders e.g. researchers, policy makers, private sector, etc.

Agricultural extension and advisory efforts are essential for the success of any mechanization and sustainable farming system. However, the conventional “top-down” approach to extension has not generally yielded positive results, whereas participatory extension approaches are a way of improving the effectiveness of extension efforts. They aim to empower farmers to plan, manage and implement agreed activities. In essence, the modern participatory approach tries to ensure that projects – from planning, through implementation, and evaluation stages – should be participatory, consultative with all stakeholders, flexible, empowering, gender-sensitive, and sustainable.



## **THE PROCESS OF MECHANIZATION PLANNING AND STRATEGY FORMULATION**

The main purpose of mechanization strategy formulation is to create an environment in which agricultural mechanization will develop from the existing situation to a desired future state. The strategy is formulated paying specific attention to the roles of government and the private sector. The output (Figure 1) is a suite of policy and institutional recommendations, supported by programmes and projects when appropriate.

## **THE PROCESS OF TECHNOLOGY DEVELOPMENT**

Development programmes often include technology that is novel to people in the target region. There may be a strong temptation to make decisions about the “most appropriate” technology without involving the stakeholders who will be affected by the adoption of new practices or equipment. The process of participatory technology development guides the people involved in development programmes to resist the temptation to impose, and it includes the other stakeholders from the earliest possible point in the programme.

In the context of farm power and the development of mechanization technology, the process followed will generally be in line with the following sequence:

- technical specialists and farmers working as partners;
- identifying the problem;
- selection of possible technical solutions;
- construction of prototypes;
- on-farm evaluation of the technological options;
- an iterative process of technology development;
- pre-production prototype;
- final field tests;
- first commercial batch production;
- batch production.

Local circumstances may sometimes call for the process to be modified. For example, technical transfer from one industrially developing country to another (south – south cooperation), facilitated by a development agency, may be a possibility. The formation of strong coalitions that promote rural change by means of research and development of technology are more important than the specific method applied.

## **ERGONOMICS IN DEVELOPMENT OF TECHNOLOGY**

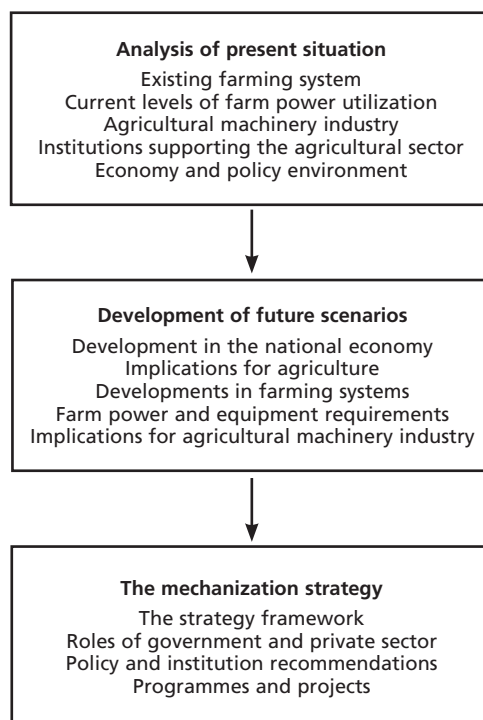
Improvements in the design of hand tools, made possible by fairly simple and ergonomically sensible changes, could make a big difference to the productivity and health of farm families. This is particularly true in the case of women, who are bent double for hours and days on end while they weed the family’s crops.

Manual operations such as hoeing are physically demanding because of their energy and postural requirements and are considered sources of great drudgery. Approaches to identifying ergonomic problems and producing solutions – if genuinely participatory and inclusive of all stakeholders, especially of women – may hold the key to breaking out of cultural ruts and reducing unnecessary drudgery.

Essential ergonomic concepts that need to be considered are:

- work and work intensity
- physical work capacity
- comparative work intensity
- how hard people can work
- measurement of workload
- gender specific effects of agricultural work
- the concept of fatigue
- avoidance or reduction of fatigue and its effects.

FIGURE 1  
Stages in mechanization strategy formulation



## TECHNICAL AND ECONOMIC EVALUATION WITH FARMERS

The latter half of the last century saw a tremendous investment in research and development aimed at producing equipment for smallholder farmers. Regrettably, however, adoption by farmers was often disappointing to the developers, and numerous items of 'improved' equipment have ended up on the scrap heap. This emphasizes the importance of the participation of farmers in the whole process of technology development.

From an engineering point of view, on-farm evaluation by farmers is not the same as technical evaluation or testing. FAO's Agricultural Services Bulletin 110 on testing and evaluation of agricultural machinery and equipment gives detailed procedures for testing a wide range of implements, including hand hoes.

Technical evaluation and testing should be conducted during a technology development programme; it should be undertaken by trained technical staff. Conscientious and thorough testing is important because it can lead to improvements in performance, durability and ease of use.

Economic evaluation of technology involves costing its acquisition and use. The main points that need to be considered are:

- whether the technology is viable;
- an estimation of costs and benefits;
- implications of scale;
- effect on household cash flows;
- how to select the best option.



## **POLICY IMPLICATIONS AND THE ROLES OF THE GOVERNMENT AND PRIVATE SECTORS**

NEPAD has a Comprehensive Africa Agriculture Development Programme (CAADP) that seeks to reverse Africa's agricultural crises through rapidly increasing productivity and efficiency in the sector. The case has been made in this Executive Summary – and it is also made in the main part of the publication – for the need to improve the farm power and mechanization options to smallholder farms in order to reach the goals outlined by NEPAD. NEPAD is an initiative by African leaders, so it can be assumed that there is a high level of political commitment to its goals. This needs to translate into mechanization strategies as an integral part of all agricultural development plans.

The principal role of government is to provide the conditions (i.e. enabling environment) for a largely self-sustaining development of the agricultural engineering sector. With the widespread move towards market economies, policies must be aimed at removing the most damaging forms of market restrictions, leaving market forces to operate where they can be effective in promoting both growth and rural poverty alleviation. For example, in some countries, high government import duty on steel has been a major factor hindering the local and economical production of farm implements. The import duties are levied across-the-board on the assumption that the steel it is destined for building construction, a relatively prosperous sector compared to small-scale agriculture. Governments could consider a system of rebates of import duty for manufacturers of agricultural tools and implements when they can show how they used the steel. It would, however, be important to eliminate any potential for corruption in such a scheme.

Many of the activities to promote and develop mechanization will take place in the private sector. The main role of this sector is to facilitate the delivery of inputs and services. Other roles will include providing necessary information and training and participating in networking activities to achieve an efficient balance between supply and demand. Efforts are required to ensure that this sector can function effectively, supported by appropriate training, extension, favourable fiscal policies, and research.

It cannot be repeated too often that farm power is critical to a better future for the people of sub-Saharan Africa. It is hoped that this Executive Summary will provide basic information to policy makers about the needs and options in farm power in that region, while the rest of the document provides greater detail for the actual planning and implementation of farm power strategies.

## Chapter 1

# Introduction

### 1.1 BACKGROUND

The eradication of extreme poverty and hunger is the first of the United Nations' Millennium Development Goals. By 2015, as a first step, the objective is to have reduced by half the proportion of people living on less than a dollar a day, and also to have reduced by half the proportion of people who suffer hunger, in line with the World Food Summit Resolution of 1996.

In sub-Saharan Africa, the escalating levels of poverty and underdevelopment, and the continued marginalization of the African continent in general, constitute enormous challenges that call for urgent and energetic actions if the 2015 objectives are to be met. Indeed, the prospects for doing so are already looking grim, with the UNDP Human Development Report of 2003 stating that the 2015 objectives would probably only be attained well into the 21st century in sub-Saharan Africa (SSA).

It was precisely because of this gloomy outlook and the need for energetic action that a number of African leaders, and the OAU, took the initiative of creating the New Partnership for Africa's Development (NEPAD). This amounts to a radical intervention, spearheaded by African leaders, to develop a new vision and strategic framework for that will ensure Africa's renewal.

Agriculture is one of NEPAD's six priorities, and agriculture is seen as the engine of NEPAD-inspired growth, beginning with the aims of improving the livelihood of people in rural areas, achieving food security, and increasing exports from the sector. It is explicit in NEPAD's strategy that growth in the agricultural sector will stimulate growth in other economic sectors.

Agricultural productivity needs to be greatly enhanced if the sector is to play the role expected of it by NEPAD. Some figures illustrate the magnitude of the challenge being faced. NEPAD's documentation states that in 1997–99, there were 200 million chronically hungry people in Africa, representing 28 percent of the total population. Furthermore, the situation is deteriorating, for in the seven or so years (from 1990–92) leading

up to 1997–99 there was an increase of 27 million hungry people.

During the 1990s, only ten African countries reduced their number of chronically hungry people. At the end of the 1990s, 20 percent of the population in 30 countries were undernourished, while in 18 of those countries, as much as 35 percent of the population was similarly afflicted. In 2001, 28 million people were facing food emergencies.

Since the 1960s, food imports into Africa have been rising steadily, and the continent became a net importer of agricultural produce in 1980. Agriculture in Africa employs 60 percent of the labour force and produces just 20 percent of exported merchandise, while it was 50 percent in the 1960s.

NEPAD sums up its view of the importance of the agricultural sector in these words:

*Until the incidence of hunger is brought down and the import bill reduced by raising the output of farm products, which the region can produce with comparative advantage, there is no way in which the high rates of economic growth to which NEPAD aspires can be attained.*

(From the summary of NEPAD Action Plans)

### 1.2 THE CRUCIAL ROLE OF FARM POWER

The review and guidelines presented in this publication are the result of several recent studies on the farm family power situation in small-scale agriculture in sub-Saharan Africa (SSA). These reports reconfirm many earlier studies to the effect that the farm power situation is deficient almost everywhere and that urgent measures are needed to correct it. In fact, the increases in agricultural productivity required in SSA to meet the MDG and NEPAD objectives will not be achievable without giving very serious attention to the issue of family farm power in small-scale agriculture.

Farm power is a vitally important component of small farm assets, and a shortage of it lies at the heart of many of the problems of small-scale farming in SSA. If the major constraint of farm power cannot be lifted, there will be little

increase in agricultural productivity, stagnation in farm family income, more hunger, and less food security. Nor will it be possible for agriculture to become “the engine of NEPAD-inspired growth” that will also “stimulate growth in other economic sectors”. In brief, unless the farm power shortage is overcome, there is a danger that rural people in SSA will face a further slide into poverty and hunger, while their national economies remain stunted. Studies in SSA (Bishop-Sambrook, 2005; Kienzle, 2003; Ribeiro, 2004) have revealed in a graphic manner that unless the issue of farm power is addressed in a practical way, with solutions that are accessible to small farmers, the region is at risk of increasing poverty and hunger.

Labour shortages in the agricultural sector of SSA have been a growing problem in recent decades. One factor creating those shortages is migration – mainly of men – to seek work in towns because their farming activities have been unable to provide a decent livelihood for them and their families.

A second factor is HIV/AIDS, which started out as a mainly urban problem in SSA, initially affecting more men than women, and those with relatively high incomes. Now, however, it has moved rapidly into the rural areas. It is estimated that by 2020, the epidemic will have claimed the lives of 20 percent or more of all those working in agriculture in many Southern African countries (FAO, 1995). Clearly, since AIDS mostly devastates the productive age group – people between 15 and 50 – it has a severe effect on a household’s labour availability, and hence on its productive capacity. But it is not only the loss of life to AIDS that affects labour availability and agricultural productivity. Some of the other effects of the AIDS epidemic are: AIDS sufferers often cannot work during bouts of related sickness and need care and support from another household member; once households experience labour shortages caused by AIDS, they are often unable to participate in the labour groups that are commonly mobilized for key farming operations; and finally, in extreme circumstances, households sell their productive assets, such as draught animals, tools, and implements, to raise cash (FAO, 1995).

Another serious problem affecting agricultural productivity in SSA is that of soil degradation. The level of degradation varies considerably across the region and is difficult to quantify. However, some figures for soil erosion in Ethiopia

have been documented, ranging from 16 to 300 tons of soil per year being washed away, with an average for the country of over 40 tons/year on cultivated land (Hurni, 1988). A World Bank/FAO study four years earlier estimated that even if the erosion rate were halved, there would still be a 2 percent per year reduction in total grain production in the Ethiopian Highlands. Erosion also carries away plant nutrients, as does cropping without replacing soil nutrients with fertilizer, sometimes termed “mining” of nutrients.

An influential body of opinion holds that the fertility of soils in SSA is declining, and it is true that crop yields per hectare are falling. However, there can also be political and social reasons for this, as well as the expansion of crop production into less favourable areas. There is considerable debate on the subject (DDPA, 2005; Campbell, 2005). Nevertheless, there is abundant anecdotal evidence in many parts of Africa from smallholder farmers themselves who state that they are obtaining much smaller yields from a particular plot than were being obtained by their fathers and grandfathers.

There can be little doubt that conventional methods of farming, with much soil disturbance for seedbed preparation, leave the soil prone to erosion. Conventional soil tillage also speeds the depletion of soil organic matter and nutrients, contributing to soil degradation. Any interventions concerning farm power and farming systems need to take into account the issue of soil degradation; at very least, they must contribute to halting the degradation process, or better still, to reversing it.

### **1.3 MECHANIZATION FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT**

Agricultural mechanization has been defined in a number of ways by different people. Perhaps the most appropriate definition is that it is the process of improving farm labour productivity through the use of agricultural machinery, implements and tools. It involves the provision and use of all forms of power sources and mechanical assistance to agriculture, from simple hand tools, to animal draught power (DAP), and to mechanical power technologies.

Mechanization is a key input in any farming system. It aims to achieve the following:

- improved productivity of labour;
- a reduction of drudgery in farming activities, thereby making farm work more attractive;

- an expansion of the area under cultivation where land is available, as it often is in SSA;
- increased productivity per unit area as a result of improved timeliness of farm operations;
- accomplishment of tasks that are difficult to perform without mechanical aids;
- improvements in the quality of work and of products.

Based on the source of power, the technological types of mechanization have been broadly classified as hand-tool technology, DAP technology, and mechanical power technology. Sophistication, capacity to do work, costs, and in some cases precision and effectiveness, determine the levels of efficiency that can be achieved in each system.

One of the major reasons for the disappointing performance and contribution of mechanization to agricultural development in SSA has been the fragmented approach to it (Rijk 1989; Mrema and Odigboh, 1993, Simalenga 1997). This often arises from poor planning and an over reliance on mechanization inputs that are provided as aid-in-kind from donors and prove unsuitable for local conditions. Poor co-ordination within and between government agencies and the private sector dealing with mechanization have compounded the problems. The formulation of national agricultural mechanization strategies can help to overcome these constraints. A holistic or system analysis approach is required in the planning process, and all the key players in the economic and cultural environment in which development is to take place must be considered.

The type and level of mechanization in a particular area should initially be guided by the producers of mechanization inputs, both to suit their business and to meet their clients' particular needs and circumstances. However, the process of making mechanization choices should bring farmers in as the focus of policy, planning, and development.

#### 1.4 THE SCOPE AND PURPOSE OF THIS PUBLICATION

The purpose of this publication is to provide information and guidelines for policy makers in agricultural and rural development and for regional and district staff with responsibilities in this area. The Executive Summary will perhaps be the most appropriate for policy makers, while the rest of the publication provides more detailed information and guidelines for planning and implementing farm power and mechanization initiatives.

#### BOX 1.1

##### Mechanization: the salient points

Agricultural mechanization is not an end in itself; it is an input in agricultural production and rural development.

Mechanization is NOT only tractors and other mechanically-powered equipment. Tractor power is just one of the options in mechanization, which involves the use of all manner of tools, equipment and machinery.

The most appropriate machinery and power source for any operation depends on the work to be done. However, the affordability, availability and technical efficiency of the selected option need to be established and taken into account in the planning process.

In sub-Saharan Africa, some of the successful mechanization introductions have used draught animal power (DAP).

The sustainable development of mechanization depends on the existence of markets where prices guide the supply and the demand of equipment.

The power sources and operations covered in this document are the following:

- human, animal, and tractor power sources
- land preparation, weeding, ridging, crop harvesting, and threshing
- small-scale irrigation technology based on human-powered water pumping.

The publication does not address the whole spectrum of farm power and mechanization options for smallholder farmers in SSA. Such a document would need to be greatly expanded and would include pest control, crop processing, transport, and irrigation, as well as a consideration of alternative power sources, such as water, wind, and sun.

The document is structured to provide an overview of farm power and farming systems in sub-Saharan Africa (Chapter 2), followed by an examination of how farm power affects agricultural productivity and rural livelihoods (Chapter 3). These considerations set the scene for a discussion on technological options in farm power, covering means of increasing its availability but also of reducing the need for it through agricultural production systems that call for low inputs of energy (Chapter 4). The household-level financial and economic implications of farm power options are then explained (Chapter 5), followed

by a description of participatory approaches to mechanization planning and evaluation (Chapter 6). The publication ends with policy and operational guidelines, and also considerations for creating an enabling environment for fostering solutions to the problems power on small-holder farms in SSA (Chapter 7).

## Chapter 2

# Farming systems and the role of farm power

This Chapter outlines the farming systems in SSA and describes the farm power situation. It also highlights the levels of poverty, vulnerability, and attitude to risk of smallholder farm families, and the impact of the decreasing human power source at the homestead level.

### 2.1 FARMING SYSTEMS IN SUB-SAHARAN AFRICA

A farming system attempts to describe the pattern of agricultural enterprises and their interactions under broadly similar agro-ecological conditions. However, there is now a widely accepted view that a farming systems analysis should include *all* factors impinging on farm family livelihoods, including social and environmental factors (Dixon *et al.*, 2001).

SSA has a total land area of 2 455 million ha of which 173 million ha are under annual cultivation. Dixon *et al.* (2001) have identified 15 farming systems in the region. The five most important in terms of population, poverty and potential for growth are summarized in Table 2.1. The principal farming systems, in terms of areas cultivated and population involved, are: cereal-root crop mixed; maize mixed; and agro-pastoral millet/sorghum. These broad farming systems – together with

their geographical zones – are useful for planning purposes, but in addition, the different household types in each zone need to be recognized.

All of the most common farming systems in SSA are dominated by smallholder peasant farmers (Kayombo and Mrema, 1994). These farmers produce almost wholly for subsistence with little surplus for the market. Given the present and future population pressures, it seems unlikely that this sector will be able to produce enough food for the increasing number of urban-based people.

### 2.2 MAJOR PRODUCTION ASSETS AND CONSTRAINTS

The SSA region is relatively well off in terms of its endowments of natural resources. However, its incidence of hunger and poverty is among the highest in the world. The urgency to provide sustainable answers is not new. Mrema and Odigboh, writing in 1993 and quoting the World Bank, stated that the transformation of agriculture in SSA is crucial and that Africa's future is at stake. Ten years ago, growth rates for food production of the order of 4 percent per year were needed, whereas in fact, both GDP and food production have fallen since then; and with the

TABLE 2.1  
Principal farming systems in sub-Saharan Africa

Farming system	Land area (% of region)	Population in agriculture (% of region)	Principal livelihoods	Location
Tree crop	3	6	Cocoa, coffee, oil palm, rubber, yams, maize, off-farm work	Humid zone of West and Central Africa
Cereal-root crop mixed	13	15	Maize, sorghum, millet, cassava, yams, legumes, cattle	Dry sub-humid zone of West Africa and parts of Central and Southern Africa
Maize mixed	10	15	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work	East and Southern Africa. Plateau and highland areas at 800–1500 masl
Agro-pastoral millet / sorghum	8	8	Sorghum, pearl millet, pulses, sesame, cattle, sheep, goats, poultry, off-farm work	Semi-arid zone of West Africa and large areas of East and Southern Africa
Irrigated	1	2	Rice, cotton, vegetables, rain-fed crops, cattle poultry	Large-scale irrigation schemes, e.g. Gezira, West Africa and Somalia

Source: Dixon *et al.*, 2001



increase in population, the GDP per capita is also on the decline. It is now less than \$US400 per year in 75 percent of the countries of SSA. What is going wrong and what are the major constraints to be overcome? Each farming system has its particular assets and constraints, but the assets and constraints that are common to many farming systems can be identified, as can the relative importance of issues related to farm power for smallholder farmers in that context.

### 2.2.1 Land and water

At the macro level, land availability is not a limiting resource in SSA (Dixon *et al.*, 2001). However, at the local level, population density can make land availability a constraint, with the result that farm families have the potential to cultivate more land than they have access to. In such cases, it is possible that a change in power source from say, draught animal power (DAP) to human, could be appropriate to match the land resources available and to free up land, hitherto used for grazing or fodder production, for growing food or cash crops.

Under certain inheritance systems, land can also become a limiting production factor for individual families following the death of the male head of household. In such circumstances, the family members left behind may be vulnerable to grabbing of land and other assets by relatives of the deceased (Bishop-Sambrook, 2005).

The point to be noted is that mechanization planners and developers need to bear in mind the land and water available for agricultural production. If land is a limiting factor, strategies that result in sustainable intensification of production will be more relevant than those that enable greater areas to be cultivated. If water is a limiting factor, options such as rain water harvesting, water conservation, or irrigation technology, can be introduced to the communities.

### 2.2.2 Farm power sources

**Human power:** In SSA, more than in other parts of the developing world, human muscle is by far the most important power source for smallholder farmers. In SSA it provides 65 percent of the power required for land preparation (see table 2.2), while the figure for crop weeding is even higher.

The most important tool used by human power is the hand-hoe. In one form or another, it is used everywhere for land preparation and weeding. Today, most of the factory-produced hoes are imported into SSA, mainly from China

TABLE 2.2  
Sources of power for land preparation (% of total)

	Human muscle power	Draught animal power	Engine power
Sub-Saharan Africa	65	25	10
East Asia	40	40	20
South Asia	30	30	40
Latin America and Caribbean	25	25	50

Source: Clarke and Bishop (2002); Mrema and Odigbo (1993) drawing on various sources of information

and India. This results from the removal of import tariffs, which opened the door to the cheap, imported hand-hoes. These are sometimes of inferior quality to the locally made tools, and when they break there is no redress. In Uganda, the Chillington factory in Jinja that once made Crocodile brand hoes could not compete with cheaper imported products and had to cease manufacturing. Cock brand hoes imported from China now dominate the market. Reputedly fake Cock brand hoes of inferior quality, which tend to break easily, are also imported, perhaps from India (IFAD/FAO, 1998).

Local metal-working artisans also make hand tools, and they are usually the people who are called on to repair broken or worn equipment. However, the quality of their work is often variable, and they need to search constantly for good raw materials, especially carbon steel for soil-engaging parts. In some countries, they are often compelled to use scrap mild steel from vehicles for hoe blades, which wear out very quickly.

The amount of land that can be successfully cultivated by a family using hand-hoes will depend on the farming system and the make-up of the farm family labour pool. There are three peaks of labour demand during the cropping cycle: land preparation, weeding, and harvest/post-harvest activities (FAO, Bishop 1995). As a guide, it has been found that with three household members working on a farm full-time, there is sufficient labour to cultivate approximately 1.5 ha by hand for one rain-fed crop a year.

TABLE 2.3  
Adult male equivalents of different human power sources

Age (years)	10–14	15–19	20–50	>50
Male	0.25	0.67	1.00	0.67
Female	0.25	0.50	0.67	0.50

Source: FAO (1995)

Not all family members have the same value as sources of farm power. Age, sex, nutrition, and health all have an effect on the power output that can be sustained. Table 2.3 gives one estimate of the differences.

There is usually a gender distribution of labour, with men and women assigned to different tasks. Ploughing with oxen is normally a male preserve, while crop weeding is mainly done by women. Today, however, this distinction is somewhat blurred as many men leave the land to work in towns. The result is that women may represent much more than 50 percent of the rural population in a given region, and they have to cover many farming activities.

Sweeping changes in technology in SSA are difficult to foresee in the short term. Despite developments of agricultural machinery and implements powered both by animals and engines over the past couple of centuries, agriculture in SSA is still carried out with an almost entire reliance on hand power (Mrema and Odigboh, 1993).

Smallholder farm households in SSA face the need to acquire more farm power, or to use their present power resources more efficiently. However, productivity increases through labour saving technologies, such as line planting for subsequent inter-row weeding, require time to learn and incorporate into the farming systems. And sadly, vulnerable households that have lost labour to disease, migration, or other causes, can find themselves in a situation in which they are continually depleting their asset base. This can lead to greater poverty and hunger, unless measures can be taken to alleviate their situation, for example through mutual support, or self-help groups.

The reliance on human power in SSA is chaining small-scale farmers to poverty. The population of the region is expected to continue to rise steeply, so there will be many more mouths to feed. Urbanization and disease will continue to reduce the active rural population. With this scenario, it is difficult to see how the need for increased agricultural productivity in the smallholder sector will be met without either an increase in the availability of farm power, or alternatively, through adopting farming systems that reduce the need for power, for example, through conservation agriculture that significantly reduces – or even eliminates – tillage.

Draught animal power (DAP): This accounts for 25 percent of the power used for land

preparation in SSA. It is mainly applied to mouldboard ploughs, although the ard-type *maresha* plough is used with DAP throughout Ethiopia and Eritrea. Bovines, principally oxen, are the most commonly used animals; they are yoked in pairs by withers yokes. Ridgers, and cultivators for inter-row weeding, are common, but less so than ploughs. DAP is restricted to areas that are free from the tsetse fly, and where animals are not overly affected by tick-borne diseases.

When DAP – as opposed to human power – is available, the amount of land prepared can be increased, but doing so may create labour bottlenecks later in the cropping cycle, especially for weeding (see section 3.2 and box 3.1).

Tractor power: This contributes only 10 percent of the power used for land preparation in SSA. It is used almost exclusively for primary cultivation with disc ploughs. Tractor power, and DAP too, are used extensively for transport with the aid of a wide variety of carts and trailers. It is probably true in many circumstances that transport is a more profitable activity than tillage.

### 2.2.3 Access to capital

Even modest changes to mechanization technologies usually require some injection of cash. Smallholder farmers in SSA, especially the majority without access to irrigated land, are usually short of capital. The accumulation of money to buy items such as agricultural tools, equipment, or draught animals, or to access tractor power, poses problems. This is not to say that cash does not flow in the small farming economy ... it clearly does! The problem in many cases is the lack of institutional arrangements to encourage safe saving, and also to channel external funds from institutions ready and willing to supply loans on attractive terms to the farming community.

Capital may be realized from physical or natural assets. Cows, oxen, or goats are familiar examples. One difficulty is that social and cultural pressures may mean that these valuable assets are realized in unproductive ways, at least in the short term. Sacrificing working animals for funeral feasts is one example.

Farmers invest in order to improve their production, and the investment can be financed through savings or by borrowing, frequently through informal arrangements (Heney, undated). While due attention must, of course, be paid to the viability of any mechanization change being contemplated, planners should at the same time be



aware that existing financial arrangements *may* be sufficiently robust not to have to set up special funds or credit lines.

#### 2.2.4 Physical assets and social capital

The number and range of farm tools and implements owned by a household vary according to its size and wealth. Most households own an essential range of hand tools, such as hoes and axes, with the range differing slightly according to the farming system and the region. The majority of DAP owners have mouldboard ploughs and carts. Even tractor-owning households maintain a full complement of hand tools because some operations are still performed manually.

In most of SSA, the majority of farmers are at best semi-literate, having attended very limited primary schooling. However, these farmers have a wide range of livelihood skills that enable them to utilize the natural resource base creatively. Many and varied community organizations and social groups exist in most rural areas. The focus of these social groups ranges from circumcision and burial ceremonies to welfare groups for the provision of capital, and to social groups for overcoming farm power constraints. Any mechanization planning in a particular community should take account of the existence and functions of these groups.

### 2.3 POVERTY, VULNERABILITY AND RISK

Currently 43 percent of the total population of SSA live below the poverty line (Dixon *et al.*, 2001).

Poverty is a major constraint to economic and social development. Poor households are usually unable to break the inter-generational cycle, for example by investing in education for their children or by accumulating sufficient assets to ensure a reasonable standard of living. Poverty, therefore, has an impact upon the capacity of a household or community to invest in production and to introduce new technologies and enterprises. Furthermore, poor households often have limited information about development opportunities and poor contact with formal providers of information.

Poor households tend to be particularly vulnerable to harm from adverse events, such as livestock disease, drought, flood etc., because they have limited accumulated assets with which to mitigate the impact of these events. Vulnerability varies between individuals and households according to their capacity to prevent,

#### BOX 2.1

##### Poverty and its generational trap

Poverty is defined as a lack of income, expenditure, and consumption, as well as a shortage of basic needs such as food, water, shelter and clothing. Access to services such as education, health, credit, and participation in political processes are also considered to be indicators of poverty. People with a daily income of less than USD 1.00 are classified, internationally, as living in poverty.

Poverty tends to pass from one generation to another because parents are unable to invest in education or productive assets for their children.

mitigate, or cope with adverse events. In general, households that are headed by women, children, or the elderly, are more vulnerable than others. Vulnerability is also influenced by location (e.g. in relation to the risk of flooding, drought or erosion), by the ownership of assets, and by the quality of access to resources, such as water, trees, and arable land. Table 2.4 describes some of the constraints faced by vulnerable households when contemplating investment in new technology.

The concept of risk refers to situations of uncertainty in which events may arise that can damage well-being. That uncertainty can relate to the timing and/or the magnitude of the events. The vulnerability of a household and its susceptibility to risk will influence its capacity to invest in agricultural production, and also determine whether it will prioritize subsistence over commercial production. Risk-averse households may, therefore, be unwilling or unable to invest in new technology, even when funds are available.

### 2.4 OTHER FACTORS AFFECTING RURAL DEVELOPMENT EFFORTS

Throughout the SSA region there are many factors at play which have an impact – usually negative – on the possibilities for improving the farm power and mechanization situation for smallholder families. This section deals briefly with the most important ones.

#### 2.4.1 Structural adjustment programmes and globalization

Globalization has, on the one hand, been accused of increasing rural poverty, while on the other

TABLE 2.4  
Constraints faced by vulnerable households

Vulnerable households	Constraints to technology adoption
Female-headed households	<ul style="list-style-type: none"> <li>• <i>Time</i>: care of sick husband</li> <li>• <i>Labour</i>: loss of husband on death</li> <li>• <i>Cash</i>: purchase of medicines</li> <li>• <i>Asset base</i>: sale during sickness, funeral expenses, property grabbing by relatives</li> <li>• <i>Skills and knowledge</i>: may be lost on death of husband</li> </ul>
Grandparent-headed household	<ul style="list-style-type: none"> <li>• <i>Time</i>: care of young orphans</li> <li>• <i>Cash</i>: additional demand from orphans</li> <li>• <i>Asset base</i>: may have been distributed to children</li> <li>• <i>Skills and knowledge</i>: limited opportunities to gain new skills</li> </ul>
Orphan-headed household	<ul style="list-style-type: none"> <li>• <i>Time</i>: time and energy available but may there may be an aversion to farming</li> <li>• <i>Cash</i>: extremely limited</li> <li>• <i>Asset base</i>: eroded during parents' illness and death</li> <li>• <i>Skills and knowledge</i>: not yet developed</li> <li>• <i>Age</i>: eligibility to own land, open a bank account, etc.</li> </ul>

Source: After Bishop-Sambrook, 2003.

it has been lauded as having the potential to reduce it (Hertel *et al.*, 2003). In reality, the impact of trade liberalization is country specific and affects different wealth strata differently. Potentially, the impact is greater on specialized household economies, whereas multiple sources of household income will soften the blow. The majority of the poor in developing countries have specialized earnings patterns and are likely to be disproportionately affected by trade liberalization. In addition, global trade liberalization tends to raise food prices, and this has an adverse effect on the poor since they spend a higher proportion of their income on food.

Trade liberalization can also affect the quality of farm power inputs. The case of Chillington hoes manufactured in Uganda being replaced by cheaper imports from China and India, as described in section 2.2.2, is one example.

#### 2.4.2 Rural/urban migration

The agricultural sector in SSA employs 67 percent of the total labour force and is the main source of livelihood for poor people (Dixon *et al.*, 2001). However, although the rural population is projected to grow in the future, it will do so at a slower rate than the urban population. Urban population is currently 33 percent but is expected to grow to 50 percent of the total by 2030. Dixon

*et al.* (2001) note that SSA is unique in that rapid urbanization has been occurring during a period of economic contraction.

#### 2.4.3 Malnutrition

Malnutrition has a profound effect on people's quality of life and ability to work. The number of malnourished people in SSA is rising dramatically. Dixon *et al.* give data showing that the daily energy intake in SSA during the period 1995–1997 was about 20 percent below the level for developing countries as a whole. Projections to 2030 expect an 18 percent increase in calorie intake, but absolute numbers of malnourished people will rise unless deliberate measures are urgently taken.

From the farm power perspective, malnutrition has serious implications. Some workers have been found to expend more energy than they can derive from the food they can purchase with their wages (Sen, 1984). Other studies have shown that the physiological response to low energy intakes is slow growth in children, followed by reduced stature in adulthood. This makes it important to address the human energy demands of working with tools and equipment in order to make the most efficient possible use of the energy available (McNeill *et al.*, 1998).

#### 2.4.4 Declining asset bases

The asset bases of poor SSA farm families are vulnerable to shocks, such as the incidence of HIV/AIDS. The reduction of livelihoods assets starts during the period of sickness when financial and physical assets of household goods, farm implements, animals, and land are sold to cover medical expenses and to compensate for the fall in farm production (Bishop-Sambrook, 2003). In addition, after the death of a key household member, the remaining family have to shoulder the burden of the funeral expenses and defend the property from relatives who may claim a share. Table 2.4 gives a summary of findings about vulnerability from survey work in Kenya.

#### 2.4.5 Demographic trends

The current population of SSA is given in Table 2.5, and the trend is towards a continuing rapid increase.

Although the predicted population increase is up to 50 percent by 2020, the incidence of HIV/AIDS will inevitably reduce the increment. Today it is estimated that up to 28 million people are infected with HIV in SSA, and this will lead to a highly significant mortality rate

TABLE 2.5

**Total, rural and agricultural populations in sub-Saharan Africa (millions), 2001**

Total	Rural	Agriculture	Agriculture economically active	Females economically active in agriculture
624	417	396	182	87

Source: FAOSTAT

as the disease takes hold. The percentage of women economically active in agriculture will rise if young adult males continue to succumb at a greater rate than women. And the number of children, many of them orphans who will be obliged to do farm work, will also rise. Migration from the rural to the urban sector will continue, and this too will have an effect on the percentage of the population remaining in agriculture. However, amidst all the uncertainty, it is fully evident that there will be more mouths to feed, and therefore, a pressing need to increase agricultural productivity.

## Chapter 3

# Rural livelihoods and the role of farm power

### 3.1 LIVELIHOODS IN CONTEXT

A livelihood strategy is the means of making a living. It must entail the application of a combination of assets to productive enterprises. The more successfully this is done, the better the outcome in terms of improved livelihoods.

The assets that a smallholder farm family can organize to produce their livelihood can be divided into five categories (Carney, 1998).

- **Human assets:** These relate to the number of family members, their ages, sex, health and nutrition. The levels of education and acquired skills affect the creative potential of each person. Human assets also include members of the extended family who are available for farm work, and in addition, any hired labour used on the farm.
- **Natural assets:** These refer to the area of land worked by the farm family. They include areas of rainfed and irrigated land, fallow, hedges, trees, and livestock.
- **Physical assets:** Farm power sources, whether DAP or mechanized; farm tools, equipment and machinery both for production and processing; production inputs such as seed and fertilizer; the house and its contents; and the means of transport employed.
- **Financial assets:** These include any savings that have been set aside, remittances from outside the household, and access to formal or informal credit arrangements.
- **Social assets:** The productive potential of human assets can be greatly improved through memberships of groups. These may include, for example, reciprocal labour or mutual support groups, or associations of producers or of irrigation users. Being a chosen leader of any group or association is often an added benefit.

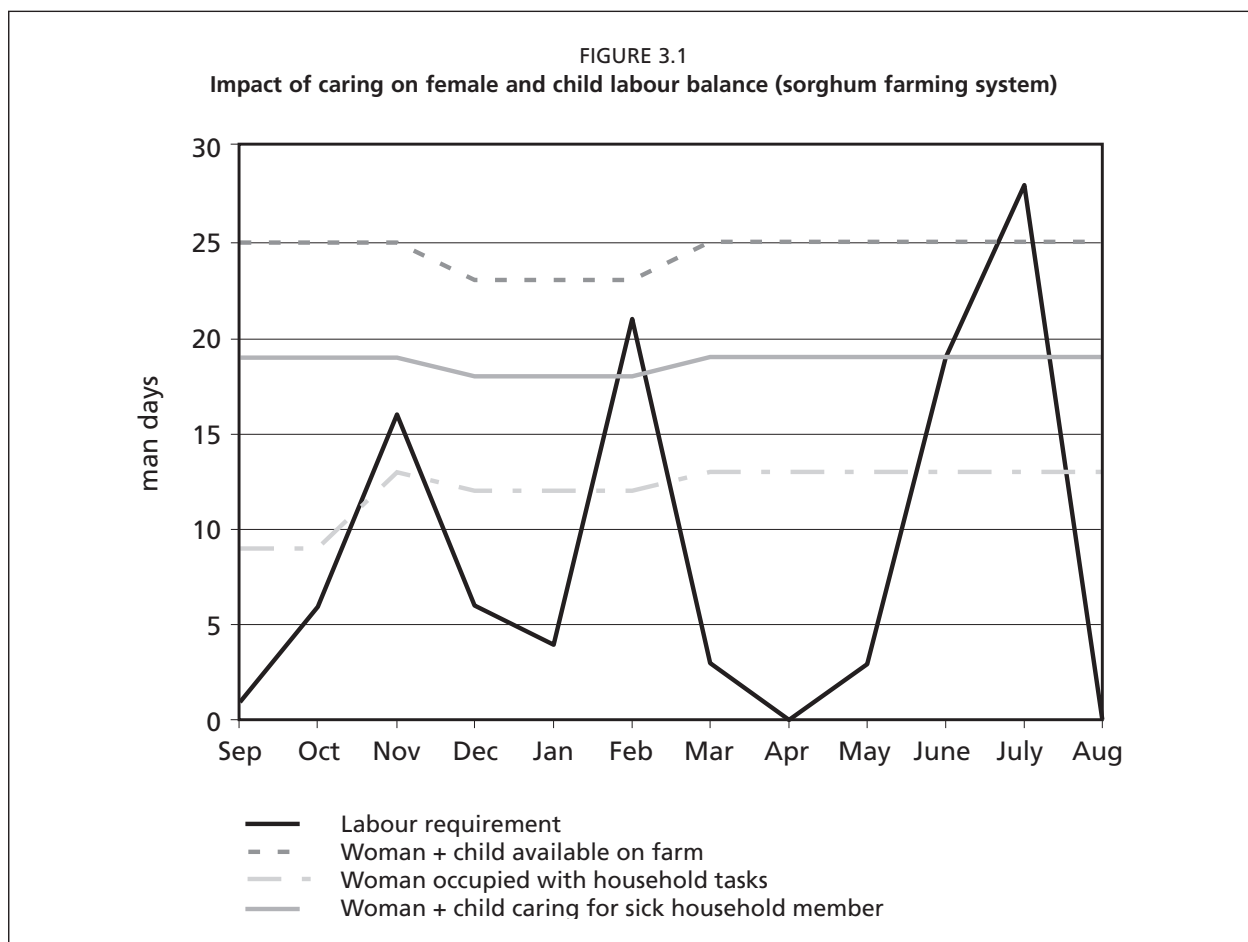
The farm family applies these assets to satisfy its priority requirements. These are likely to be (Twomlow *et al.*, 2002):

- **Food production:** Securing the nutrition of the household members.
- **Household needs:** Securing the procurement of additional food and other necessities, such as clothes, school fees, utensils, and tools that are required to support the existence of the household.
- **Social requirements and arrangements:** These include observing ceremonies and rituals, for example, in the case of the death of a family member. Costs associated with social commitments, for example, to groups and associations. This latter category is an important asset to enhance the family's capability to secure its livelihood in case of adverse events in the future.
- **Cash availability:** To purchase required inputs in agriculture and cover other household commitments.
- **Reduced vulnerability:** This includes food security and the capacity to withstand man-made or natural disasters that can affect agricultural production.

From the above, it can be seen that a family's farm power and mechanization potential is an important production input into the livelihood strategy that the family opts for. But farm power on its own will not produce a livelihood: it needs to be judiciously applied in conjunction with other inputs through a process which is informed, improved, and made possible by the interaction with the other household assets. In this sense, the knowledge and skills base of the human capital is of the utmost importance.

### 3.2 FARM POWER – A CRUCIAL PRODUCTION INPUT

The natural assets and their environment available to a farm family will largely determine the type of farming system that it is possible to pursue as part of a livelihood strategy (see sections 2.1 and 2.2). The farming system will determine, for example, the areas of different crops that it is possible to produce with the existing farm power sources.



Source: Bishop 1995

The availability of power determines the area under cultivation, the timeliness of operations, the effective use of other inputs and, ultimately, the productivity of the system (FAO, 1995). The dominance of the human power source in SSA has been noted, and it follows that the quality of the human capital available to the farm family is crucially important. The productive capacity of a farm family is not static: ill health affects not only the family member afflicted but also those who have to care for the sick person, while malnutrition and migration all conspire to make human assets an inconstant factor.

Household family size is very variable in SSA. The average may be in the region of five or six members, but the range is wide. In addition, not all members are available for farm work all the time, for families may devote much of their effort to off-farm work. Seasonal migration of labour to urban centres and elsewhere to earn off-farm income mostly involves male family heads. In addition, those that can devote time to farming have differing work potentials (see Table 2.3).

A reasonable assumption would be that each

family member active in agricultural production can devote some 20 days per month to farming; the balance is used for household duties, leisure and perhaps casual off-farm work, which could be seasonal. This figure would have to be adjusted to take into account any extraordinary situation such as ill health and caring for the sick<sup>2</sup>.

A study in several countries of SSA (FAO, 1995) analysed family labour availability for farm work throughout the year assuming that two parents and one child were available. Figure 3.1 shows that the maximum availability is 60 man/days<sup>3</sup> per month, but when this is adjusted for the relative productivity of the woman and the child, the figure is reduced to 47 man/days per month. Taking into account poor health and nutrition,

<sup>2</sup> A further impact of HIV/AIDS is that members of extended families who have settled in urban areas may be sick with the disease and return home to their village for care. This has an additional and severe effect on the labour availability for agriculture.

<sup>3</sup> The term 'man/days' is used to highlight the fact that men, women and children have different work and power outputs (see Table 2.2). It does *not* mean that women do less arduous farm work than men in the aggregate.





FAO/KIENZLE

**Plate 3.1**

*Disc ploughing with tractor combined with hand sowing of maize*

this number is reduced further to 43 days per month, dropping to 40 days per month during the hungry months of December to February.

Another study in SSA (Bishop, 1995) highlighted the impact of caring on the female and child labour balance in a sorghum farming system (see Figure 3.1). The Figure also shows clearly the peak in labour requirement in the month of June and how it exceeds the family labour availability, an all too common occurrence in human-powered farming in SSA.

Using these data and with a knowledge of the labour requirements throughout the cropping cycle(s) for the farming systems being practised, it is a straightforward matter to estimate the area that a family can manage to farm. Increasing the area of land prepared beyond 1.5 ha – for example, by using DAP or tractor hire – will probably create a labour shortage at weeding time. Overcoming this potential labour shortage will need to be planned for from the outset, either through the provision of additional labour or with the adoption of new technology (Box 3.1 gives an example of inter-row weeding).

In general terms, the use of DAP for land preparation in SSA will allow an area of up to 4 ha to be farmed, while tractor use (either through hiring or ownership) will increase this much

**BOX 3.1****Alleviating labour bottlenecks**

Ms A is a widow and was wondering whether to sell the family's single ox to produce the cash needed to hire casual labour at weeding time. She was finding that land preparation and weeding her 1 ha maize and bean plot, with only her labour and that of her son and daughter, was too much of a burden. She talked to her neighbour, Ms B, about her difficulties and her neighbour proposed that they pool resources. Ms B also had a single ox and a plough and was prepared to put up 40 percent of the cost of a DAP inter-row cultivator if Ms A would put up the rest. Ms A approached her mutual support group for a loan that she would need in addition to her meagre savings, and they agreed.

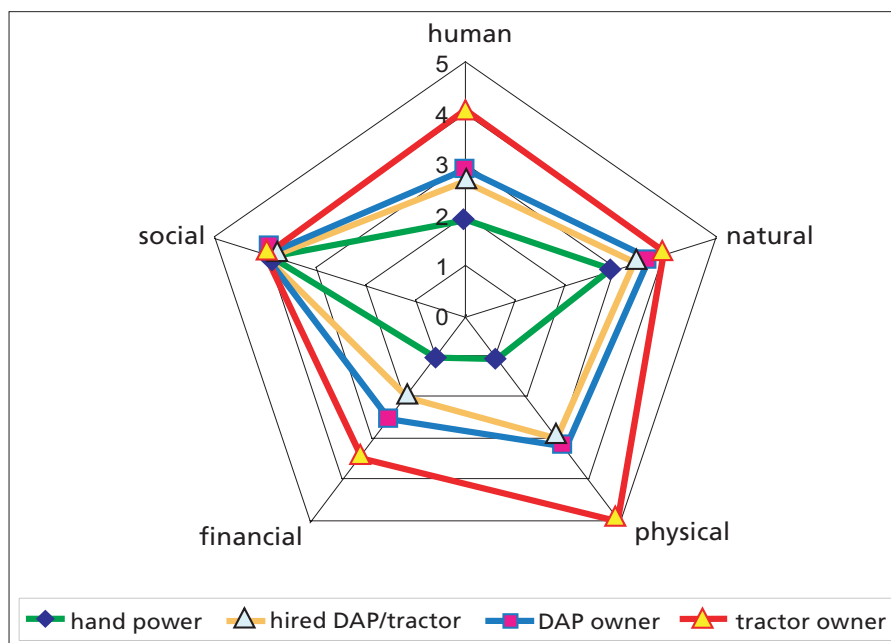
A and B can now prepare their land with DAP, and after having learnt to plant in rows, can weed the crops with the DAP cultivator. The in-row weeds are easily dealt with by her available family labour. So, instead of depleting her physical asset base, she planned ahead and has increased it. She has also strengthened her social assets and has more free time as well.

more, to over 8 ha. (Bishop-Sambrook, 2005).

It is quite common to combine available power sources in order to increase the area farmed or to reduce the burden on humans. Tractors or draught animals can be hired for primary tillage, and the subsequent planting can use human power (Plate 3.1). Weeding, which imposes high labour demands, can also be done with a combination of power sources and technologies, such as the use of herbicides, as discussed in section 4.1.4. Application of these alternative power sources and technologies can relieve pressure on human labour at critical times of the year.

The household assets catalogued in section 3.1 can be represented in the form of a pentagon. If the assets are then quantified for the range of situations existing in a region, or community, the relative resilience (or strength) of each asset can be compared. The quantification exercise is subjective and must be done in a highly participatory way, with researchers and representative members of the farming community taking equal responsibility. One such study in Ghana did precisely that and produced the result shown in Figure 3.2.

FIGURE 3.2  
Livelihoods asset base for farm power groups. Ghana



Source: Bishop-Sambrook, 2005

Figure 3.2 shows the assets of the four categories of farm power users. Each asset base for each farm power group was quantified in an exercise involving representatives of all farm power groups. All groups had approximately the same high value of social assets<sup>4</sup>, but the levels of the remaining four assets varied widely. The tractor owners were the strongest in terms of their skills base (human assets), ownership of a wide range of equipment (physical assets), and to a lesser extent, their financial resources. There was little difference between the assets of DAP owners and the hirers of DAP/tractor, but the human-powered farms were poorest in terms of all assets. They were therefore the most vulnerable to shocks. Improving access to greater farm power, though not in itself ensuring an improved livelihood, would seem to be an important ingredient in the process required to reach that goal.

### 3.3 DIVERSIFICATION OF FARM POWER

Diversification in the employment of physical assets makes them more affordable and further

enhances their potential for improving livelihoods. DAP is an important case: animals may be used singly rather than in pairs, and new classes of animals can be brought in to perform farm work. Draught bovines – oxen, cows or bulls – are all capable of field work. Their use in pairs, although traditional, is not always necessary if appropriate harnesses can be provided and if light-weight implements can be manufactured. The same is true for animals that may have traditionally only been used for transport purposes. These are principally equids that can perform agricultural tasks perfectly well, provided they are equipped with adequate harnessing arrangements and suitable light-weight equipment (Inns *et al.*, 1997) (Plate 3.2).

The diversification of donkey use may have particularly important implications for women (Box 3.2). In some cultures the use of draught bovines for land preparation is a predominantly male preserve and women rarely take on this job. The same is generally not true of donkeys which may be seen as “female” animals as opposed to “male” bovines (Sylwander, 1994).

Transport is a daily grind for millions of women in SSA whose responsibility it is to fetch water and fuel wood to the homestead; and they often have to carry produce to market as well, all as head loads. Estimates of annual head-load

<sup>4</sup> This is an indication of the perceived importance of social networks and safeguards to reduce risk and the impact of shocks.

### BOX 3.2 Draught animals for women

There are no taboos in Zimbabwe against women using draught oxen, as there are in many other SSA countries. However, they do have great difficulty in using the present range of ox-drawn implements. Donkeys are used in many parts of the country, especially the east where the severity of droughts in the 1990s reduced the cattle population more than elsewhere. A team of donkeys is easier to handle than a pair of oxen, and light weight ploughs are now available on the market.

However a commonly held view is that donkeys are associated with poverty and have no prestige. One cannot buy a wife with them, or give them as a wedding present, and they are inedible. However, it is precisely because they are cheap, hardy, survive droughts, have no prestige, require little care and have no taboos that they are more accessible to women.

Source: IFAD/FAO, 1998

burdens for rural women can be as high as 60 ton-km (O'Neill, 2000). The diversification of animals into transport would have the potential to ease, or even eliminate, this burden (Plate 3.3)

Diversification of animal use can also enhance a family's livelihood asset base as was mentioned in the Ghana study in Figure 3.2.

Better access to farm power would also widen the possibilities of the number and types of farm enterprise that can be undertaken. Diversification into cash crops, such as vegetables and root-crops, may become tenable when all available resources do not need to be devoted to providing food for the family.

### 3.4 LIVELIHOODS FOR ALL IN THE SUPPLY CHAIN FOR FARM POWER

Farmers often complain that tools and implements for mechanization are too expensive or of inferior quality. There are many stakeholders in the mechanization supply chain, and if that chain is to be sustainable, it is important to remember that all stakeholders must make a reasonable livelihood. Local manufacturers of hand tools, DAP-powered implements, and perhaps tractor-mounted implements, will only stay in the business if they can be sure of a good market for their produce. They will, in turn, provide the means for their workers, distributors, and sales force to earn livelihoods.



**Plate 3.2**  
*A high-lift harness attached to a light-weight plough to enable a horse to be used for soil preparation*



**Plate 3.3**  
*Cart with a special purpose body: water carrier in the Sudan. A simple design ideal for a local entrepreneur (Source: Sims et al., 2003)*

Blacksmiths and artisans are key links in the supply chain. They are usually sought out for repairs to tools and equipment. However, they may also be producers of hand tools, and sometimes of DAP implements, although they cannot fabricate uniform products. Their local function is important because they can interact directly with farmers and introduce adaptations according to specific needs, something that a central factory may find hard to do. Local retailers are the most common source of tools and replacement parts for the equipment of smallholder farmers. It is important to remember that their presence reflects their livelihood strategy. They must not be viewed as making a living at others expense, but as providers of an essential service: they risk their capital and invest their effort and time to bring goods to the end-user.

Although farm power is clearly not the only vital input for sustaining livelihoods, it is such a crucial one that a decline in its availability



can have a very damaging effect. The impact of disease, especially of HIV/AIDS, on human power availability has been noted. But there are also dangers for DAP users from the effects of drought, death of animals from trypanosomiasis and tick borne diseases, forced sales to cover crises, as well as from theft. Tractor hire schemes are in terminal decline in most of SSA, and access to tractors for smallholder farmers in the region is extremely limited. As a consequence of the loss of farm power and household assets, food security is quickly placed in jeopardy (Bishop-Sambrook, 2003). And poorer households will be more vulnerable to the loss of family labour and of access to DAP.

If farm power is to have a greater role in rural livelihoods and in achieving NEPAD's objectives, farmers have to be informed, educated, skilled, and financially empowered to enable them to purchase, repair and maintain farm power resources. The supporting infrastructure, such as extension and financial services, plays a key role in enabling farmers to make effective and sustainable use of farm power resources. There are five essential elements of action by supporting infrastructure as cited by Bishop-Sambrook (2005):

- i) providing farmers with access to knowledge and information about improved farm power technologies and supporting a drive towards the process of commercialization;
- ii) facilitating access to financial services, which many farmers require in order to purchase tools, DAP implements and tractors;
- iii) ensuring the availability of appropriate implements, manufactured either by local artisans or the formal sector, and supported by adaptive research;
- iv) fostering the development of a skilled and well equipped maintenance and repair service sector;
- v) promoting a supply of draught animals and veterinary services for farming communities using DAP.

## Chapter 4

# Farm power and technology options

This Chapter reviews the options for the application of power from humans, animals and tractors. The aim is to explore the potential for more effective and efficient application of power from these sources in smallholder agriculture. Farm power, whether from humans, draught animals, or from limited access to tractors in some areas, is the key non-biophysical resource for crop production in small farm systems (Twomlow, *et al.*, 1999).

### 4.1 HUMAN POWER TECHNOLOGIES

Hand tools are the most important implements for smallholder farmers throughout SSA. They are used everywhere for land clearing and primary soil tillage, and thereafter for a variety of agricultural jobs from weeding, to harvest, to tree felling. The area that can be cultivated using hand power alone will clearly depend on the family size, its make up, nutrition levels, the farming system, and a host of local environmental factors.

#### 4.1.1 Land preparation

Farmers in many SSA countries are obliged to clear land for planting with the hoe, a very

laborious and time consuming job. Furthermore, the timeliness of the operation is often critical if the crops are to be sown to make optimum use of the rains. Depending on soil type and compaction, it may be too hard to dig in the dry season before the rains; conversely, clay soils may make the job too difficult once they are wet. There is a severe limit on the area that can be prepared by hoe, with over 60 person days per hectare being required for the task. Soil conditions, the age, sex, and health of the worker(s) and the condition of the hoe will affect the time required, but it is always an onerous operation (Plate 4.1).

#### 4.1.2 Main types of hoe

Hoes may be made locally, manufactured nationally, or imported. The way the hoe blade is fitted to the handle, which is almost always wooden, varies from country to country, but there are three basic methods:

- The tang fitting, where a steel spike (or tang) at the top of the blade is burned through the bulbous end of the handle;
- The socket fitting, where the steel at the top of the blade is bent into a circular-shaped socket to take the end of the handle;
- The eye-ring fitting, where there is a forged ring at the top of the blade into which the handle is inserted (IFAD/FAO, 1998).

Blacksmith or industrially made hoes?

– Because the hoe is such an important tool for smallholder farmers, local manufacture by artisans has flourished in some parts of SSA, particularly in West Africa. Blacksmith-produced hoes, usually made from scrap steel, are generally cheaper than factory made products (a major attraction), and credit arrangements are easier to agree. At the same time, factory produced goods are generally of a higher and more uniform quality. The 1998 IFAD/FAO study in five SSA countries found blacksmith-made hoes typically cost \$US1.00–4.25, while factory made equivalents generally cost between \$US3–4, although the range found was \$US2.50–8.00.



Plate 4.1

*Manual land preparation, traditionally done by men in much of SSA, is now often a women's job.*



**Plates 4.2a and 4.2b**

When new, these Cock brand hoes weighed 1.4 kg. The hoes have been in use for 2, 4 and >5 years respectively (from right to left in the left-hand photo). They are fitted with handles of different lengths for the men, women, and children in the family. (Source: Holtkamp, 2003).



### 4.1.3 Weeding

Weeding is an absolutely critical operation in the cropping cycle. The penalty in crop yield for late weed control is heavy. Poorly scheduled or executed weeding can make the difference between a crop and no crop, but at very least it will always exact a yield reduction. More than 30 percent of yield is commonly lost as a result of weed infestation, which may be due to late and inadequate weeding. Smallholder families living precariously at the edge of subsistence cannot easily bear the cost of such an outcome. There is also a critical period of competition between the crop and weeds. For example maize in semi-arid Southern Africa should be kept free of weeds from 2–6 weeks after emergence (Twomlow *et al.*, 1999).

Weeding is generally a job performed by women, and they consider it to be their most onerous task, for it is both extremely time consuming and physically taxing<sup>5</sup>. Broadcast crops such as groundnuts can take up to 25 person-days/ha to weed; cassava or maize can take up to 50 person-days/ha (Bishop-Sambrook, 2003). Women generally work more comfortably with lighter hoes than those used by men, and this is often achieved by men passing worn-down hoes to the women (Plates 4.2a and 4.2b).

### 4.1.4 Herbicides for weed control

Apart from mechanical weeding using hand-hoes or rotary hand weeders<sup>6</sup>, chemical weeding with herbicides is another option<sup>7</sup>. The two main types of herbicides are pre-emergence and post-emergence. Pre-emergence herbicide is usually applied from one to three weeks ahead of planting. The accurate application of herbicides at prescribed rates requires knowledge of sprayer calibration. If the sprayer is not accurately calibrated, too little or too much herbicide may be applied, resulting in unsatisfactory weed control or damage to the crop seedlings. Various designs of hand sprayers are available in the market, and the most common one is the knapsack sprayer.

### 4.2 OTHER HAND TOOLS

Although the hoe for tillage and weeding is by far the most prevalent hand tool, there are others in use for agricultural production:

- *Planting tools.* Not commonly found, the planting tool (or pioche in Burkina Faso) resembles a short-handled hoe with a narrow steel blade for making small holes into which seeds are dropped.
- *Row markers.* A simple triangular frame with spikes attached at the required row-width for the crop to be sown. Pulling the frame across the cultivated ground scratches the positions of the planting lines.
- *Axes and mattocks.* Local blacksmiths are

<sup>5</sup> Land preparation demands high energy and hence power, as time is usually a limiting factor. Weeding demands less energy but over a longer time (O'Neill, 2000).

<sup>6</sup> These hand operated hoes are also known 'wheeled hand-hoes'. They are widely used for weeding and inter-cultivation of row crops.

<sup>7</sup> For more information on using herbicides for weed control see: FAO: Pesticide Safety and Application Equipment; Sprayer Operator Pocket Book, 2004 (available from AGST at: AGS-Registry@fao.org)

commonly the source of carbon steel axe heads that are fitted by tangs to wooden hafts.

- *Pangas and knives*. Used for clearing weeds, harvesting, pruning, and a host of other jobs around the farmstead, these tools are usually imported from countries with a large domestic demand that justifies commercial manufacture. Examples are Brazil, India and China.
- *Sickles*. Usually imported, but sometimes locally made, sickles are used for harvesting a variety of crops, including most small-grained cereals and grass.

### 4.3 ERGONOMICS CONSIDERATIONS

Ergonomics attempt to harmonise the work and working environment in order to raise productivity and work efficiency, and to promote well-being through optimising the effort of the worker (Jafry and O'Neill, 2000). The ergonomic implications of farm work are not, of course, confined to field work with hand tools. However, improvements in the use of these, made possible by fairly simple ergonomically sensible changes, could make a big difference to the health of farm families. This is particularly true in the case of women who, when weeding, are bent double for hours on end ... day after day.

*'It is weeding that almost kills women'*  
(Men's discussion group, Uganda. IFAD/FAO, 1998)

Manual operations, such as hoeing, are physically demanding because of their energy and postural requirements and are regarded as sources of drudgery (O'Neill, 1994). Approaches to identifying ergonomic problems and producing solutions – if genuinely participatory and inclusive of all important stakeholders, especially women – may hold the key to breaking out of the cultural ruts that often determine the design of hoes in SSA. This could reduce unnecessary drudgery and increase work output.

The case of the hand-hoe is particularly important because it is used so widely and for almost every cropping task. Work in Nigeria (Bassi, 1992) showed that increasing and varying handle length, and adjusting the blade angle according to the anatomical characteristics of the users, allowed people to work with improved posture and reduced energy demands.

### 4.4 REASONS FOR THE PERSISTENCE OF HUMAN POWER IN SSA

In many developing parts of the world, smallholder farmers have been making more rapid progress in breaking out of the limiting mould of human muscle as a source of farm power than they have in SSA. An analysis of the situation shows that the farming systems and conditions in SSA that tend to confine smallholders to human power are:

- farms on steep slopes cultivating perennial or semi-perennial crops;
- farms where high value animal production, such as milk, leaves little fodder for draught animals, or where the opportunity cost of setting land aside to feed draught animals is too high;
- areas where animal diseases (e.g. trypanosomiasis) prevent keeping livestock suitable for draught;
- humid zones where permanent or semi-permanent systems of multi-story cropping are practised;
- where very small farms predominate and draught animals cannot contribute to the timeliness of field operations;
- where limited market access and low rates of livestock ownership preclude investment in draught animals;
- where the farming system lacks intensity and is not integrated into the wider economy of the region.

This last point describes the situation for multitudes of smallholder, near-subsistence, or subsistence farmers in SSA. For mechanization to succeed in SSA, farmers may need to diversify into production of marketable crops, assuming there is a local demand for them. Their willingness to do this will be affected by access to information, seeds, and other productive technology, as well as by their perception of the risks involved.

### 4.5 SMALL-SCALE IRRIGATION TECHNOLOGY

Rainfall in arid and semi-arid areas of sub-Saharan Africa is usually insufficient to guarantee reliable and steady crop production, but as shown in Table 2.1, only 1 percent of SSA has irrigated agriculture. However, irrigation is developing in SSA at an average rate of over 1000 hectares per year in the 40 countries, and the total area presently irrigated is predicted to increase by 50 percent over the next 25 years. A wide range of





**Plate 4.3**  
*Treadle pump in Malawi*

rainwater harvesting techniques and small-scale irrigation practices are in use. Techniques such as bucket drip irrigation systems and human-operated treadle pumps have shown promising results on small farms of up to two hectares.

#### 4.5.1 Treadle pumps

For the past few years treadle pumps have been manufactured and adopted in several SSA countries. This follows their initial success in Bangladesh where over half a million units are in use (Kay and Brabben, 2000). Two types of treadle pump are made: the suction pump for pumping large volumes through low heads; and the pressure pump that has an outlet valve and can pump to higher heads. The rhythmic operation of the pump, which uses the strong leg muscles to operate the twin units, has been attractive to farmers. By 2001, some 10 000 units had been manufactured in Zambia, Zimbabwe, Niger and Kenya. Small-scale irrigation is seen as having major potential to improve livelihoods in SSA, where large-scale schemes have often failed (Kay, 2001).

Low cost but effective technologies like the treadle pump (Plate 4.3) can lift smallholder farm families out of poverty and into the cash economy through the production of cash crops where there is a market for them. Addressing the technology needs of small-scale farmers through the development of locally-made, low-cost and proven technology could accelerate the rate of progress.

#### 4.6 DRAUGHT ANIMAL POWER

As was shown in Table 2.2, the overwhelming source of farm power in SSA is human muscle.

#### BOX 4.1

##### **Agro-ecology, farming system, and choice of mechanization**

In the highland zones of East Africa (with the exception of Ethiopia) animal traction has not been widely adopted. This is because steep slopes and the crops cultivated (bananas, coffee and other semi-perennial crops) are difficult to mechanize, and because low wages, and small farms make it unattractive to substitute animal traction for labour (McIntire *et al.*, 1992). Where intensive dairy production is possible, fodder is best utilized for this enterprise rather than for draught animals, since the returns are higher. In humid and sub-humid zones where tree crop and root crop systems predominate (e.g. in the rain forest zones of West Africa) the potential for mechanization is limited by the permanent nature of the cropping system i.e. mixtures of trees and root crops as part of a multi-storied permanent system.

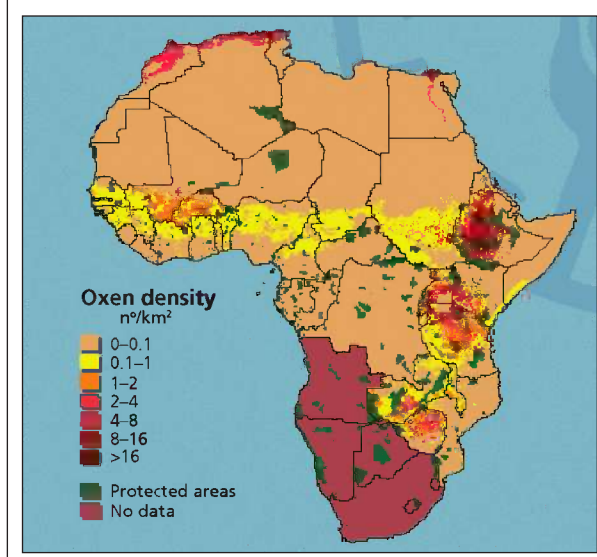
This has always been the case, although there are regions where draught animal power is predominantly used for initial soil preparation, i.e. ploughing. However, the use of draught animals is severely restricted by the presence of the tsetse fly (*Glossina* sp.), the vector of trypanosomiasis. Tsetse distribution has been mapped in SSA (Wint, 2002), and this permits predictions of where draught animals can be used. FAO has produced a distribution map for draught oxen in Africa (Figure 4.1), which reflects the influence of tsetse infestations (FAO, 2002a).

East Coast fever (theileriosis) is another lethal disease concentrated mainly in the east of southern SSA. (It is endemic in Burundi, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda, Zambia and Zimbabwe). Since it is transmitted by ticks, acaricide dips can be used to control it; however, local breeds can develop natural resistance.

In total, SSA has a population of some 16 million draught bovines, which are distributed as indicated in Table 4.1.

DAP is an appropriate, affordable and sustainable source of farm energy. It is increasingly being used in SSA and can become a major force for positive change in the region. In addition to tillage, weeding, transport, and other field operations, working animals can also be used

FIGURE 4.1  
Distribution of draught oxen in Africa



Source: FAO (2002a)

for forest logging operations, pond construction, and rural road maintenance. Compared with North Africa – and Ethiopia – the practice of using animal power in SSA is generally rather recent. DAP can more than double the area of crops that a smallholder family can plant, to somewhere in the region of 4 ha. However, only increasing the area of primary tillage simply moves the labour peak to weeding, and the hand labour for that task on the larger area will probably not be available.

*‘Animal traction makes the difference between night and day’.*

(Women’s group in Burkina Faso. IFAD/FAO. 1998)

#### 4.6.1 Types of animals used for work

**Bovines:** These are the most important source of draught animal power. They are principally local breeds that are adapted to the local conditions of climate, fodder and diseases, especially tick-borne diseases. Cows are also increasingly being used as the animal of choice for work in areas where there are not enough oxen and bulls. FAO (1972) gives a comprehensive review of the breeds to be found in use as draught animals in Africa.

**Equids:** Horses, mules, and donkeys are used for work to some extent, but are again limited by their susceptibility to trypanosomiasis and tick-

TABLE 4.1  
Draught bovine populations in  
sub-Saharan Africa (millions)

Ethiopia	Mali / Burkina Faso	Lake Victoria region	Zimbabwe / Zambia / Malawi highlands	TOTAL
>6	3.5–4	3.5–4	~1.5	~16

Source: Jan Slingenberg, FAO, personal communication

#### BOX 4.2

##### The benefits of working animals (after Simalenga and Joubert 1997)

- When promoted as a power option along with other technologies, animal traction can help lift rural communities out of poverty.
- Animal power provides employment and transport services, and promotes food production and security, thereby leading to a higher standard of living.
- In comparison to mechanical systems, animal power has the advantage to rural families of being available, timely, and affordable.
- Animal power makes marketing and trading easier.
- It relieves women of the burden of transporting firewood and water by hand, head or wheelbarrow.
- Animals are easy to use, and donkeys, specifically, can be handled by children and women.

borne diseases. Horses and donkeys are used for riding and packing, but mules are rare. Equids tend to be found mainly in temperate, semi-arid, or highland areas. They seldom flourish in the humid and semi-humid tropics (FAO, 1994).

Donkeys are increasingly being used in rural communities because of their advantages in terms of disease resistance compared to cattle. Donkeys are renowned for their exceptional survivability and longevity... they can live for up to 30 years. They have low costs and low management requirements. Their most common role is for transport although they can also be used for other farm operations.

The draught capability of working animals, suitably trained and in good condition, depends primarily on their body-weight, since this provides a fair indication of their muscle mass. As an aid to estimating the draught capability of a working animal, it can be assumed that a bovine can pull about 10 percent of its body weight

TABLE 4.2  
Sustainable power of individual animals in good condition

Species	Typical weight (kg)	Typical draught (N) <sup>1</sup>	Typical working speed (m s <sup>-1</sup> )	Power output (W)	Working hours per day	Energy output per day (MJ)
Bovine (ox)	450	500	0.9	450	6	10
Horse	400	500	1.0	500	10	18
Donkey	150	200	1.0	200	4	3
Mule	300	400	1.0	400	6	8.5

Note: 1kgf = 9.81N, so that a draught force of 500N is equivalent to approximately 50 kg force.

Source: Inns, 1992

throughout the working day; the figure for equids is higher, at around 12–14 percent. Table 4.2 gives some typical sustainable power outputs for animals in good condition.

#### 4.6.2 Harnessing arrangements

For an animal's energy to be converted into a useful draught force, a good yoking or harnessing system that avoids wastage and inefficiency is necessary. The possibilities are legion (for example, see FAO, 1994; Starkey, 1989), and here it is appropriate to confine the discussion to some general descriptions.

Head yokes are wooden yokes tied behind the horns. They are common in West Africa where they are mainly used with humpless (*Bos taurus*) cattle. Yokes made from tree species producing light, strong poles can be carved to fit the contours of the animals' necks, and they are attached with ropes or leather straps. The main advantage of head yokes is that the animals can apply a braking force on downhill slopes; this is especially important when pulling carts in hilly terrain. A possible disadvantage is that the animals' head movements are restricted, but in practice this does not seem to bother them.

Withers, or neck, yokes are most frequently used in SSA. Again they are usually made from

#### BOX 4.3

##### Harnessing and hitching systems

For oxen, bulls and cows: use (a) head or horn yokes; (b) neck or withers yokes

For horses, mules and donkeys: use breast-band harness or collar harness.

For making a breast-band harness: use canvas belting materials, leather, or thick cotton webbing.

light, strong poles. The main pole is usually shaped to some degree to accommodate the curvature of the animals' necks. There are two vertical pegs, of wood or metal, which pass on either side of the neck and may be secured beneath the neck with loose chain, rope, or hide. The implement to be pulled by the draught bovines is attached to the central point of the yoke, either by a wooden beam, a rope, or a chain.

For equids, withers yokes are used in some countries for simplicity and economy, in the sense that the yokes already exist. However, this arrangement is not favoured because equids have a strong chest, and **breast-band harnesses** are more suited to their anatomy (Plate 4.4). Equally effective – but more expensive – are collar arrangements, which provide a greater contact surface area. In both cases, the implement to be drawn is attached to a cross member pivoted at the middle (swingle tree), which in turn is connected to the traces that run on either side of the animal to transmit the pull. Cart shafts can be attached directly to the collar or can be supported by a back strap in the case of the breast-band harness. Appropriate hitching methods have been elaborated by Pearson *et al.* (2003)

There are a myriad of local adaptations and additions to these basic types of yokes and harnesses (Starkey, 1989; Goe, 1990), and local preferences and skills should always be given priority.



Plate 4.4

Example of a breast-band harness





Plate 4.5 (left)

*A Magoye (Zambia) ripper with ridger attachment*

Plate 4.6 (right)

*Expandable DAP cultivator with ducksfoot tines (at rear) and chisel tines (in front)*

## 4.7 IMPLEMENTS USED WITH DAP

The commonest agricultural implements for use with DAP in SSA are for primary soil tillage. Other equipment has been adopted for shaping the soil, establishing the crop, weeding, and harvesting. The other major use of animal power is for transport, but a detailed consideration of this application is beyond the scope of this document. The following section does not pretend to be exhaustive but aims to present the equipment most commonly encountered in SSA.

### 4.7.1 Primary tillage implements

The ard (Goe, 1990) and mouldboard plough are the two main implements for primary tillage. The ard has evolved over thousands of years and has been perfected by constant trial and error. It is made of wood with a steel share, and it opens a furrow without inverting the soil much. It is attached to the withers yoke via a wooden beam and leather straps. Perhaps the greatest advantage that ards have over other ploughs is that they can be locally made with local materials and cost little.

Mouldboard ploughs, on the other hand, are either imported or manufactured centrally in commercial factories. They differ from ards in that they are designed to cut, raise, and invert a prism of soil: the steel share undercuts and raises the prism which is then moved laterally and inverted as it passes over a curved mouldboard.

The mouldboard plough is a good tool for weed control, but it does not have much else to recommend it. It leaves the soil surface loose and unprotected, which makes it vulnerable to erosion while also accelerating the oxidation of organic matter. It is probably the greatest cause

of soil degradation and crop yield decline in SSA. Nevertheless, it remains a very popular and widespread implement, and its demise is not imminent. Mouldboard ploughs, which can be pulled by chain, rope, or fixed beam, are available in a variety of sizes and mouldboard types. Share widths are in the range of 7–10 inches (180–254 mm).

Narrow-tined chisel ploughs, or rippers, have a mode of action very similar to that of the ard. Their carbon-steel shares burst the soil in a narrow furrow and leave the remainder of the soil protected with surface organic matter. Their use, although still not widespread, is generating interest for their dual attributes of saving time and energy and of reducing soil erosion (Jonsson, *et al.*, 2003).

### 4.7.2 Secondary tillage implements

Ridgers are essentially symmetrical twin mouldboard implements used for shaping soil into ridges, or for earthing up a crop grown on the ridge as a weed control measure (Plate 4.5)

Growing crops on ridges, or in the furrow, is a widespread practice and has advantages for controlling rain or irrigation water, as well as for easier inter-row weeding. Connecting the ridges with cross ties at intervals along the furrow length can trap rainwater and encourage infiltration rather than run-off – an advantage in semi-arid conditions.

There is a range of harrows, infrequently encountered in SSA, that can be used for producing a fine tilth seedbed or for gathering surface vegetation. Examples are zig-zag harrows, peg-toothed harrows, and disc harrows.

Cultivators are commonly used in many SSA countries, mainly for inter-row weeding of a crop that has been planted in lines. They are multi-tined implements, usually with five or so tines that can be rigid or flexible and vary between narrow chisel points, through ducksfoot tines, to wide V-shaped sweeps. Cultivators can be adjustable, via pivoting frame members, or have rigid frames which allow width adjustment through some means of moving the position of the tines on a cross member (Plate 4.6).

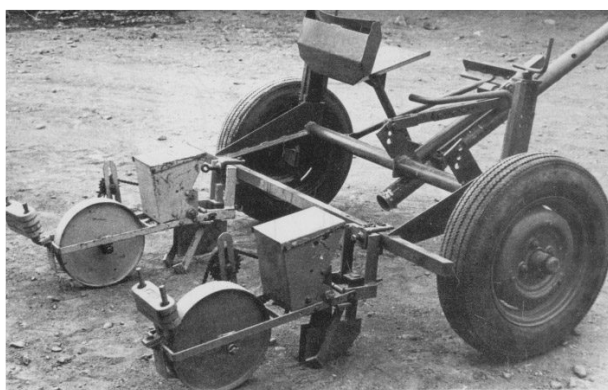
### 4.7.3 Seeders

With few exceptions (e.g. Senegal and Mali) animal drawn seeders are not widely used. This is probably because farm families often prefer to do the job by hand to be sure the seed is placed more or less correctly. It is also perhaps because of the cost and complexity of mechanical seeders and their need for a fine seedbed. However, the light soil conditions of the two West-African countries

mentioned lend themselves to mechanical seeding, and the popular inclined plate seeder is used by thousands of farmers (Plate 4.7). Inclined plate seeders have an advantage over the horizontal plate seeders manufactured in southern Africa in that they can deal better with un-graded seed.

#### 4.7.4 Harvesters

Crop harvesting with animal traction is not a common activity, but crop lifters are regionally important, for example in Senegal. They are most commonly used for lifting groundnuts and consist of a wide V-shaped, triangular, or straight sweep attached to a tool frame. The sweep works at a depth below the groundnuts, which are lifted and left on the soil surface to dry.



**Plate 4.7**  
*Inclined plate seeder*

#### 4.8 LIMITATIONS TO DRAUGHT ANIMAL USE

Although DAP can increase labour and land productivity and can help to lift poor smallholder farmers out of poverty, but there are limitations to its availability and appropriateness. In section 4.6, the problems of the tsetse fly-borne trypanosomiasis and East Coast fever (theileriosis) were discussed with reference to their effect on limiting the use of DAP.

Nevertheless, interest in DAP is generally on the increase, and the profitability of its use – as discussed in Chapter 5 – has been widely recognized by smallholder farmers. However, investment in DAP does bring greater risk to the farming operation. There are areas where numbers of draught animals are on the decline due to disease, drought, forced sale, ceremonial slaughter, dowry payments, and rustling.

In semi-arid conditions, the provision of fodder in the dry season can be a major obstacle to the possibility of maintaining draught animals in good condition. Grazing becomes difficult as natural vegetation dies back and becomes lignified, although draught animals will normally regain weight loss quickly with the beginning of the rainy season. Pearson and Smith (1994) assert that the key issue faced by farmers when keeping draught animals is the provision of sufficient feed, in both quantity and quality, at the time when the animals are required to do the most work.

In addition, the production of fodder crops has

#### BOX 4.4

##### **Some constraints to the adoption of DAP**

The following are some of the constraints to the adoption of DAP:

- A short growing season, which results in low rates of use and, consequently, high costs per unit of work, i.e. per hour or per hectare.
- Poor access to capital or credit may prevent many near-subsistence or semi-commercial farmers from investing in the technology.
- Labour is required to maintain animals in non-work periods, which in semi-arid areas can be for much of the year, even if animals are used for weeding.
- The potential labour savings associated with adopting DAP, plus any extra benefits such as an expansion in the cultivated area, must compensate for the extra time and money spent

maintaining these animals year round, mostly for fodder, labour and veterinary services/drugs. These benefits need to be competitive with possible non-farm uses of time and money. This may be less of an issue in agro-pastoral societies where cattle production/accumulation is socially and economically favoured. However, if non-farm activities provide much of the household income outside cultivation seasons, the labour tied to maintaining draught animals may have a high opportunity cost. The use of this labour must therefore be included in any calculations of the impact of adopting DAP.

- An unstable agricultural economy and environment may result in distress sales of oxen, especially during shock events such as drought.
- Other constraints include: the need for training and the availability of animals, implements, and services.

the disadvantage of displacing food or cash crops. For example, in the highlands of East Africa there is often a comparative advantage in the production of tree crops and milk, rather than annual arable crops, and DAP has not been adopted there.

Overall there have been slow rates of adoption of DAP in SSA over the past three decades. As Jaeger and Matlon (1990) pointed out, to adopt DAP requires both an initial capital investment and the development of new skills. During the early years of adoption, farmers can face severe cash flow difficulties. Exacerbating factors such as drought – which affects animals as well as crops – poor harvests, limited access to markets, livestock disease, theft of draught animals etc., can force asset-poor households into financial loss and distress sales of their draught animals (Bishop-Sambrook, 2003). Not surprisingly, many programmes to promote DAP in Africa have found it necessary to provide credit for DAP adopters.

#### 4.9 POTENTIAL FOR DIVERSIFICATION AND SUCCESSFUL INVESTMENT IN DAP

As briefly mentioned in Chapter 3, there is considerable potential for diversifying the use of draught animals, thereby enhancing a family's livelihood asset base. This diversification can be brought about in some of the following ways:

- Widening the range of jobs that animals can do. This can include more crop production tasks, but it can also mean water lifting, milling, and other stationary power devices.
- Using single rather than multiple animals, and providing them with appropriate implements, usually lighter in weight.
- Using animals that have hitherto not been used for farm work. This could include horses, donkeys and mules, which hitherto may have been restricted to transport.
- Using animals for non-farm work, e.g. road maintenance, dam construction.

Perhaps the greatest potential for diversification is in transport (Box 4.5). Farm work tends to take place intensively for short periods. For example, ploughing may be done in a week and then the animals are not needed for a few weeks until the first weeding, and so on through the farming year. This makes the cost of these operations very high because the investment in draught animals and equipment is not being spread over a range of activities and time. If transport is added to the range of activities performed, the opportunity for year-round work

becomes a possibility (Box 4.5).

A degree of commercialisation of agricultural production will usually be essential to allow farmers to invest in animals – where they are not already owned – and equipment for DAP, such as ploughs, cultivators, carts, etc. Successful introduction of DAP into West Africa, for example in Senegal, The Gambia, and Mali, was associated with the promotion of cash crops, such as cotton and groundnuts, and the provision of subsidized credit for the purchase of animals and equipment (ILCA, 1981). Once up and running, farmers adapted the available implements to suit their specific needs. Many in The Gambia and Senegal developed innovations such as minimum tillage with direct sowing, and weeding with animal drawn planters and cultivators, dispensing with the mouldboard plough altogether (Sumberg and Gilbert, 1992). They have also innovated with the use of cows for draught and with the integration of draught animal and beef production, partly facilitated by ample supply of groundnut hay as reasonably good forage.

Supplies of equipment and spare parts are important to the development of DAP, and shortages of these are sometimes assumed to be serious enough to prevent the spread of the technology. However, markets are often quick to respond to demand for products, and more important constraints are probably a shortage of credit and of extension and training. Manufacturers have often looked to government,

##### BOX 4.5

##### Diversification of DAP in transport

An example from Malawi (Starkey, 1994) illustrates the potential of diversification in transport: *A farmer reported the purchase of a pair of oxen and a plough as his first investment in DAP. After three seasons of ploughing with his animals, he bought a cart. The following season he reverted to manual cultivation (using hired labour) because his oxen earned him more as transport animals than the cost of the hired labour. At harvest, income from carting can be particularly high since hire rates, such as "one bag kept for six bags carted", may represent more than 15 percent of the harvest value, just for transport. The ability to transport large loads, rather than head-carrying, means that markets can be better exploited, and this can be a stimulus to produce more profitable cash crops.*



donor, or NGO-supported projects and programmes as their principal market, rather than developing networks of agents in rural areas to distribute and sell equipment. This reliance on outside support is considered less risky, but it results in little market research or in the development of linkages with users of equipment. Manufacturers, therefore, may often have little knowledge and understanding of the needs of the users of their products.

It has been argued that as farming systems intensify, land becomes scarcer for growing fodder for draught animals (Boserup, 1981). However, in practice finding fodder may not always be a major constraint to the adoption or use of DAP. Crop residues may provide greater quantities of fodder than natural pasture (McIntire *et al.*, 1992); they can sustain draught cattle, if they are appropriately managed with supplements.

#### 4.10 RURAL TRANSPORT OPTIONS

An important activity in agricultural production is the movement of inputs and farm produce from one location to another. Inputs such as fertilizer have to be transported from the point of sale to the farmstead, and manure has to be transported from kraals to the fields. After harvesting, the crop has to be moved from the field to the homestead, and any surplus has to be taken to the market.

##### BOX 4.6

##### Successful investment in DAP

The following are some of the key factors associated with successful investment in DAP:

- Good returns on land and labour, which suggests reasonably good yields and access to markets. In other words, in relatively low-risk agriculture where farmers are confident that investments in draught animals and machinery will provide a reasonable return. Such areas may often have rather high population densities and good access to nearby urban markets (Ehui and Polson, 1993).
- Some tradition of keeping livestock, particularly cattle. This gives agro-pastoralists an advantage over societies without cattle management skills.
- Fertile soil and favourable climatic factors.
- High rates of use (number of days of work per year), which give better returns on investment.

Thus, transport is a major element in rural life, as well as in urban communities. Efficient transport, apart from ferrying agricultural produce, can facilitate other income-generating activities, and also lessen the women's burden of carrying firewood and water. Transport means in SSA range from the most basic of all, head-loading – usually by women – to pick-up trucks and other road vehicles, while in between lie the intermediate means of wheel- barrows, hand-carts, bicycles, and animal-drawn carts.

Transport using draught animals can take place in the form of:

- Pack transport – donkeys and camels are the most common animals used for carrying loads on their backs. Different load carrying devices, such as panniers, baskets, canvas bags, and sacks are used to ensure better balancing of the load on the animals' backs.
- Carting – with cattle, donkeys, camels or horses: animal-drawn carts can be 2-wheel or 4-wheel, using pneumatic, steel, or wooden tyres.

#### 4.11 TRACTOR POWER: SCOPE FOR USE AND PRINCIPAL OPERATIONS

Currently there are approximately 160,000 tractors in use in the region (FAOSTAT). However, this number may be an overestimation of the number that are truly serviceable; and in any case, their use in smallholder agriculture is very limited. Government hire services have been dramatically reduced as a result of the failure to re-capitalize for replacement. Typically, the schemes were not financially viable because travelling distances were too great, and because smallholders were unable to afford realistic hire prices. Any access to tractor power that is available is now mainly through district schemes, NGOs, or private sector hire.

It will generally not be economically viable for a small-scale farmer with a typical land holding of up to 5 ha to own a tractor. Rarely, if ever, have subsidized, government-run, tractor hire schemes been sustainable; nor have they helped to alleviate poverty or increase farm production (Twomlow *et al.*, 1999). On the other hand, the rental market for locally owned and operated tractors does have a role that may be increased in the future.

In the past, – and sadly sometimes today – the application of tractors and heavy mechanization in unsuitable situations has led to heavy financial losses, lower agricultural production, and

## BOX 4.7

**Business opportunities in rural transport**

There are business opportunities linked to animal-powered transport. These include: the manufacture of panniers, carts, and spares; supply and distribution networks; repair and maintenance; and contracting (hiring out) services.

Entrepreneurs in the numerous small-scale factories and rural craft workshops can take advantage of profitable opportunities to participate in the manufacturing of carts and in the fabricating of spare parts.

Contracting out of DAP services is fairly common in the rural communities in the region. An estimated 30–60 percent of the farming community, including the poor and others who do not own oxen, benefit substantially from accessing the technology through direct hire or other social arrangements within the society.

It has been established that DAP is more profitable, and the payback to investment is fastest, when animals are hired out. Farmer/contractors have recorded increases in income of more than 50 percent, and in many cases a cart can be repaid within six months (Panin and Ellis-Jones, 1992; Mkomwa *et al.*, 1996).

environmental degradation (Clarke 1997; Mrema and Odigboh, 1993). In these circumstances, tractor mechanization can easily become a burden to national economies and to individuals, rather than being an essential input with the potential to increase productivity. A similar situation has occurred in some centrally planned economies. With the advent of trade liberalization, the subsidized application of tractor power can no longer be economically justified. In Cuba, for example, there is currently a renewed and vigorous interest in the expansion of DAP for work that does not require high inputs of power (Ríos and Cárdenas, 2003).

The principal uses of tractors in smallholder farming are to supply the high power needed for primary cultivation, and for transport. Primary cultivation is overwhelmingly performed by disc ploughs, and transport by a variety of two- and four-wheeled trailers.

**4.11.1 Factors affecting the adoption of tractor mechanization**

Tractor mechanization appears to be most profitable where land is abundant and labour is scarce relative to land, and where labour is moving rapidly off the land to non-farm employment. Tractor mechanization will contribute little to agricultural productivity in countries where the land frontier has been reached and there is densely populated farmland, unless labour, attracted by higher wages, is rapidly moving to non-farm employment. Where the cost advantages of employing machines are large because agricultural wages are rapidly increasing, adoption of the technology is likely to be swift. In SSA, rises in wages, or a significant growth in non-farm employment, have not occurred or kept pace with population growth.

Some SSA countries committed themselves to programmes of tractor mechanization at independence, notably Uganda, Tanzania, and Zambia. These were mostly government run hire schemes, since individual ownership by smallholders was not feasible. As early as 1967, De Wilde was reporting that Ugandan tractor hire schemes were not covering their costs: 20 percent of all operating costs were incurred travelling between farms where small, awkwardly-shaped and poorly cleared fields reduced the efficiency of tractor cultivation. Bishop-Sambrook (2005) reported that tractors have all but disappeared from the agricultural landscape in Uganda, at least in the east of the country.

Most government hire schemes have folded, and private tractor ownership is the now the norm in SSA. In Ghana and Botswana, tractor ownership is often associated with access to non-farm income from employment, business, or remittances (Bishop-Sambrook, 2003; Panin, 1995). However, many owners find it difficult to maintain tractors in rural areas where the supporting infrastructure of repair shops and spare parts is weak. The general picture is one of gradual decline of tractor hire services, whether public or private, which may also reflect a general decline in the profitability of agriculture (Bishop-Sambrook, 2003). Nevertheless, private tractor hire services can be viable in areas of high population density and high value agricultural production, for example of tea and or high yielding maize varieties.

#### 4.11.2 Problems associated with tractor use

**Spare part and fuel supply:** The key operational considerations for the tractor owner or service provider are the availability, accessibility and retail price of genuine spare parts and of fuel. The availability of parts is dependant, on the one hand, upon whether they are common items such as filters, fan belts, batteries, tyres, etc. that will fit a wide range of tractors; or on the other hand, repair parts that are items specific to one particular make and model of tractor. Evidently, the former will be more readily available from a wide range of retail outlets located in both rural and urban areas; whereas the latter are only available from the local distributor of the particular make in question, who is usually located in a major urban centre. In addition, because of the limited numbers of makes and of specific models of tractors usually sold in a single developing country, the distributor will not be prepared to hold repair parts in stock. This is because the random demand for them, and the cost associated with maintaining inventory, have negative effects on the company's balance sheet. Consequently, when a farmer requires a part to repair – rather than service – his tractor, it is highly likely that it will not be in stock with the distributor. He will normally have had to travel for at least a day to reach the distributor located in the nearest large urban centre in order to find this out, and then to place an overseas order.

When the part finally arrives, months later, the farmer will be faced with a bill that is made up of six cost components: the basic price of the part, the government imposed import duty, sales tax, exchange rate commission, dealership handling charges, and a profit mark up. On top of that, the farmer will have had to bear the cost of lost time and travel to and from the distributor ... not to mention the down time on his tractor if it was unusable pending the arrival of the repair part. Similar frustrations may apply to the supply of the diesel fuel that makes up as much as 70 percent of the tractor's operating cost. Except that in the case of diesel fuel, there will be an additional fuel tax to pay.

**Organizational difficulties:** Tractor hire services from the private sector are the most likely sustainable source of tractor power for smallholder farmers in the future. Owners are likely to possess only one tractor and will usually attend to their own needs before offering a service to others. So, timeliness of crop establishment and

its effect on yield becomes an important issue. Small and scattered plots also pose a difficulty and make contract ploughing unprofitable, in spite of the high charges usually levied. Tractor hire services are only likely to be profitable if they are used for a range of services, e.g. maize shelling, transport, milling, and so on (Lyimo, 1999).

**Environmental damage:** The tractor mounted disc plough is responsible for immense environmental damage. FAO has produced abundant literature on the causes and effects of soil erosion and degradation, and it is inappropriate to repeat that information here. Fortunately, there is currently a ground swell of interest worldwide in increasing efforts to reduce the environmental degradation caused by the use of unsustainable agricultural practices. Ploughing leaves the soil surface in a vulnerable condition in which it is easily eroded by wind and water. The FAO Manual on integrated soil management and conservation practices (FAO, 2000) explains that rain on soil exposed by tillage suffers structural collapse of the aggregates on the surface, with the subsequent formation of soil crusts that reduce water infiltration and impede seedling emergence. The destruction of surface aggregate also promotes increased runoff and erosive transport of soil particles. Furthermore, Shaxson and Barber (2003) explain that the continual use of ploughs, and especially of disc ploughs, frequently results in the formation of dense hardpans just below tillage depth. These plough pans often have smooth upper surfaces with sealed pores that impede the penetration and development of plant roots.

**Access:** Small holder access to tractor power can come from three sources:

- national government tractor hire schemes;
- local government small-scale hire schemes;
- NGOs or other groups working at grassroots level and providing a service from donated funds;
- private sector entrepreneurs.

The likely scenario with regard to government tractor hire schemes has been discussed: they are in decline everywhere. And private sector entrepreneurs offer a service that can tend to be a high-priced and untimely. Grassroots NGOs are able to supply tractor services, but probably not on a sustainable basis. One example of a local government council entering the scene is the purchase, by Bondo County Council in Kenya, of a tractor and trailer in 2001 to supply a local service (Bishop-Sambrook, 2003). Time will tell if this approach is sustainable.

## 4.12 POSSIBLE WAYS TO REDUCE POWER NEEDS: CONSERVATION TILLAGE AND CONSERVATION AGRICULTURE

The vital importance of farm power to increase agricultural productivity and improve livelihoods has been firmly established. One approach to satisfy the demand for power is, on the one hand, to increase its supply, while on the other hand, a second approach is to seek ways of reducing the need for it.

As has been seen, the greatest demand for farm power is for land preparation, and as has also been seen, this is also the source of the greatest soil degradation. However, there now exists abundant and crucially important evidence, particularly from Brazil (Landers, 2001), that traditional land preparation methods are unnecessary. It has been shown that conservation tillage, including zero tillage, can provide a sustainable solution that brings many benefits. These include reducing the need for farm power, while at the same time halting and even reversing soil degradation. The fully integrated system that reduces or eliminates tillage and applies a number of other measures to protect the soil, conserve moisture, and control weeds is known as conservation agriculture. The following sections will provide more detail.

### 4.12.1 Energy-efficient farming that conserves and enhances natural resources

Historically, most industrially developing countries have given greater importance to economic growth than to environmental protection. And yet ‘sustainability’ is included in the lexicon of most national planners when formulating their plans. Global warming is with us, forest destruction continues unabated, and we still continue with agricultural practices which impoverish one of our most valuable assets – the soil – while at the same time using large quantities of energy.

The principal components of conservation agriculture are the reduction of soil manipulation and the maximization of the vegetative soil cover to protect the soil surface. Tillage can be reduced with the use of implements with chisel points that can be either DAP or tractor-powered. Plate 4.5 shows such a ripper which, with the ridging wings detached, is capable of making a narrow cultivated slot in the soil where seeds can be deposited. This is still, however, a job requiring high draught. Even greater reductions in energy input can be made with direct sowing, i.e. without any prior

cultivation or ripping. A study of the energy cost of tractor-powered crop production with conventional tillage and direct seeding (Doets, *et al.*, 2000) estimated that total energy inputs are 40–50 percent lower for conservation agriculture.

Thankfully, the acceptance of traditional agricultural production that uses high inputs of energy shows signs of changing. And paradoxically, it is the demise of government tractor hire schemes, for economic reasons, that may be heralding a transformation towards more sustainable and less energy-intensive agriculture. If, indeed, national policies go in this direction, they will have a profound effect on our soils and on our agriculture. The positive aspects of conservation agriculture, as discussed at macro and micro levels in FAO (2002b), argue a strong case for national policies to promote the system.

However, leaving the soil protected with surface vegetation requires a change in mind set, and it will demand greater management ability, especially for weed and cover crop control (de Freitas, 2000). Managing surface vegetation includes both mechanical and chemical measures. The mechanical equipment is principally DAP or tractor-powered.

### 4.12.2 Direct seeding

Options exist for direct seeding by hand, DAP or tractor. There are many simple tools already in use that enable crop seeds to be sown through vegetation on the soil surface. These range from the planting stick with a sharpened point or a metal tip to the pioche or pick, which is a small hoe designed to make a hole big enough for seeding (IFAD/FAO, 1998). Many more

#### BOX 4.8

#### Definition of conservation agriculture and of conservation tillage

Conservation agriculture is generally defined as a farming system that aims at minimising the loss of soil and water through the least possible soil disturbance, completely avoiding soil inversion tillage; applying crop rotation principles; and providing permanent soil cover on the surface.

Conservation tillage, on the other hand, covers a broad range of non-inversion tillage systems. It is often associated with zero tillage, reduced or minimum tillage, and ripping, among other techniques.



sophisticated jab planters have been developed over the years, but they have not been widely adopted. One exception is the *matraca* (Plate 4.8) which has enjoyed widespread adoption in South America. The *matraca* has recently been introduced into SSA and has generated enthusiasm among farmers and artisans. Time will tell if it achieves the same popularity as it enjoys in the American continent.

DAP direct seeders have been developed by farmers and commercial manufacturers over the last fifteen or so years in Brazil. Plate 4.9 shows one example that has performed particularly well in SSA. Direct seeders for tractors, both large and small, have also been developed by farmers and entrepreneurs. They generally incorporate both seed and fertilizer metering units and cut the surface vegetation with a fluted disc. Plates 4.10 and 4.11 show two examples of tractor mounted direct planters.

Figure 4.2 compares the tillage and soil cover situation with conventional, plough-based tillage and conservation agriculture. Conventional agriculture leaves zero soil cover whereas direct seeding leaves the maximum amount. Intermediate systems, for example ripping, leave variable amounts of cover. Tables 4.3 and 4.5 show some of the conservation equipment that can be used with different sources of farm power for various field operations.

#### BOX 4.9

##### Advantages and benefits of conservation agriculture

Conservation agriculture offers several important advantages in the context of farm power and environmental protection. These include:

- direct planting with no tillage saves energy, labour and time;
- weed control with cover crops and herbicides saves energy, labour, and time;
- soil erosion is practically eliminated;
- leguminous cover crops fix atmospheric N and so fertilize the following crop, reducing the need for additional fertilizer, and thereby reducing costs and labour;
- permanent soil cover conserves soil moisture, which can make the crop more resistant to spells of drought;
- productivity and livelihoods are improved, with less risk.



**Plate 4.8**  
*Hand jab planters. A Brazilian made matraca on the left; and a version made by a Kenyan artisan on the right*



**Plate 4.9**  
*DAP direct planter made in Brazil and under trial in Zambia*



**Plate 4.10**  
*Direct planter adapted to a single-axle tractor*



**Plate 4.11**  
*Brazilian made direct planter at work in Kenya*

### 4.12.3 System approach to the introduction of conservation agriculture

The transition from conventional farming to conservation agriculture involves a complete change in mindset and in production systems. Such a fundamental change may even involve throwing out the ploughs and harrows (Landers, 2001). However, conservation agriculture involves more than just a change of implements: it normally involves changes in cropping system, timing of farm operations, management of weeds – including the introduction of herbicides – and management of crop residues and soil cover crops.

In small-scale farming systems, tractors – especially small, single-axle tractors – can play a role in conservation agriculture, as indicated in Table 4.3.

When conservation agriculture is practised correctly, using cover crops and crop rotations, pest and disease incidence will often be less than with conventional tillage. Consequently, the costs of treatment will also be reduced. In a system where the use of herbicides replaces land preparation work, the production costs can be reduced as shown in Table 4.4.

The positive impact of conservation agriculture on the distribution of labour during the production cycle and, even more important, the reduction in overall labour requirements, are the main reason for its adoption in Latin America, especially for farmers who rely completely on family labour (Montoya, 1984). In areas of SSA where family labour is becoming a constraint because of migration, HIV/AIDS, etc., conservation agriculture could be a good solution. The reduction in on-farm labour requirement would allow farmers to:

- extend the cultivated area;
- hire themselves out in off-farm employment;
- diversify their activities, including processing

of agricultural products;

- reduce the cultivated area – possible because of increased yields – and allow marginal areas to regenerate.

Table 4.5 shows how the number of farm activities can be reduced under conservation

TABLE 4.3  
Options for different operations in conservation agriculture

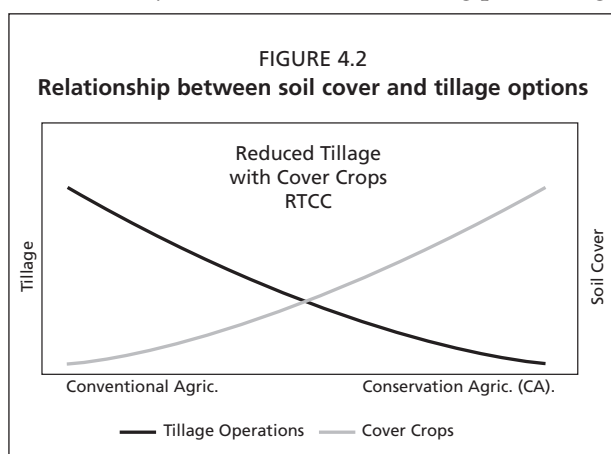
Field Operation	Implements	Farm Power
Sub soiling	Chisel plough, sub-soiler, ripper	Tractor DAP
Weed control	Ripper, ridger Hand-hoe, sprayer	DAP or tractor Manual
Tillage and Planting	Ripper/planter	DAP or tractor
Cover crop management	Knife roller, sprayer	DAP or tractor
Soil-water management	Ridger, tie maker Ripper with wings	DAP or tractor DAP

TABLE 4.4  
Relative values of production costs in tractor/plough-based system and conservation agriculture (in percentages)

Production cost	Relative values of production costs (% total costs)	
	Plough-based agriculture	Conservation agriculture
Mechanization (fixed and variable costs, less fuel)	23	19
Fuel	8	5
Fertiliser and seeds	55	50
Herbicides	9	21
Insecticides	4	4
Labour	1	1

TABLE 4.5  
Mechanized operations and the time required (hours/ha) for each of them under different production systems (Rego, 1998).

Operation	Conservation agriculture	Conventional tillage
Knife roller	0.89	–
Direct seeding	0.76	–
Spraying	1.2	0.6
Harvest	0.93	0.93
Ploughing/disking	–	1.37
Levelling	–	1.38
Conventional planting	–	0.89
Earthing up	–	1
Total	3.78	6.17



Source: Bishop-Sambrook et al, 2004

agriculture and gives an overview of the savings in hours per hectare with conservation agriculture compared to conventional tillage. The saving in hours/ha is almost 40 percent with conservation agriculture.

#### 4.12.4 Line planting

Although conservation agriculture can most certainly offer the greatest reduction in farm power requirements, even the relatively simple introduction of row planting in conventional farming systems can bring important reductions. For whenever seed is broadcast, all weeding of the crop must be done with hand-hoes. As already noted, weeding causes the longest periods of drudgery, especially for women, and when done badly or in an untimely fashion, severely affects crop yields.

The labour demand for weeding can, and does, limit the area sown to crops. If, however, crops can be sown in lines, DAP can later be used to pull a cultivator along the inter-row space. There will still be the need to do some manual weeding within the row, but the total time taken to weed will be very much reduced.

Line planting can be achieved by several methods. Perhaps the simplest is to select a yoke that obliges the animals to walk at a distance equivalent to twice the desired row width. During the planting operation, a furrow will be opened with a plough, chisel, or ridger and the seed dropped in and covered, probably manually. One animal will walk on the previously sown furrow whilst the next line is planted. An alternative, once the land has been prepared – either manually or with DAP – is to pull a simple, three-pronged marking rake across the prepared field to scratch the lines where the crop is to be planted.

#### 4.13 SELECTING THE BEST MECHANIZATION OPTIONS

It should be remembered that farmers are constantly making decisions about whether or not to adopt a new technology. A number of factors can guide a farmer towards his decision (Table 4.7).

However, in addition to the basic factors laid out in Table 4.7, there will be a number of other background considerations that may well require support from an extension agent to help the farmer towards the fullest possible understanding of the environment surrounding the decision he needs to make.

Firstly, it will be important to take into account the physical aspects of farm power, the social and economic conditions in which farm households

TABLE 4.7

**Basic factors that will influence a farmer's decision on a technology**

a) Technical performance:	Work rate and impact of technology on timeliness of operations.
b) Financial returns:	Gross margins, break-even analysis, source of finance, individual or group ownership.
c) Social implications:	Total labour requirements, division of tasks between household members, and impact on quality of life
d) Environmental implications:	Impact on soil structure and water use efficiency (conservation of natural resources).
e) Machinery support services:	Ability of existing infrastructure to maintain and repair new technologies, access to spare parts, technical information, training and advisory services.

Source: Bishop, 1997

#### BOX 4.10

#### **Pre-conditions for adoption of conservation agriculture (CA)**

The following are some of the pre-conditions for adoption of CA:

- A farmer should have a thorough understanding of the new technology and especially be aware that the full benefits of CA take some time to show. It is not an overnight transformation, and farmers will probably need training and observation of other farmers practicing CA to grasp its full implications and benefits over time.
- Soil chemical and physical properties that may be limiting maximum plant growth should be corrected. This may involve liming, improving nutrient status, and most important, sub-soiling to remove any hardpan.
- Gradual and planned adoption of: minimum tillage techniques (ripping); use of herbicides to control weeds; and the introduction of crop rotations.
- Sowing in permanent planting lines and the introduction of soil cover crops.
- In livestock production areas, crop/livestock management systems need to be put in place to avoid competition for crop residues to be left as soil cover or to be used as fodder for livestock.



TABLE 4.6

Conservation tillage equipment for both human power and DAP (Bishop-Sambrook *et al.*, 2004)

Equipment	Features
<p>DAP knife roller</p> 	<ul style="list-style-type: none"> <li>• bends and crushes crop residues and cover crops prior to planting. The crushed material remains on field as soil cover.</li> <li>• saves the removal of crop residues by hand</li> <li>• residues act as cover to suppress weeds</li> <li>• requires two draught animals and two operators</li> <li>• imported but could be made locally</li> <li>• cost Tsh 300,000 (US\$ 300)</li> </ul>
<p>DAP direct planter</p> 	<ul style="list-style-type: none"> <li>• plants through crop residues and cover crop with no tillage</li> <li>• removes the need to prepare the land for planting</li> <li>• requires one or two draught animals and two operators</li> <li>• imported from Brazil</li> <li>• cost Tsh 120,000 (US\$ 120)</li> </ul>
<p>DAP ripper (Magoye). Has optional planter attachment)</p> 	<ul style="list-style-type: none"> <li>• cuts furrow rather than inverts soil</li> <li>• requires two draught animals and two operators</li> <li>• planter attachment places seed directly in ripper furrow</li> <li>• wings can be attached for ridging and weeding, reducing time by half because does both sides of row in one pass</li> <li>• originally imported from Zambia, now manufactured in Moshi</li> <li>• ripper tine cost Tsh 60,000 (US\$ 60) excludes plough beam</li> <li>• planter cost Tsh 75,000 (US\$ 75)</li> </ul>
<p>Hand jab planter</p> 	<ul style="list-style-type: none"> <li>• plants through crop residues and crop cover with no tillage</li> <li>• eliminates the need to prepare the land for planting</li> <li>• also used to apply fertilizer</li> <li>• imported from Brazil; also manufactured locally (CAMARTEC)</li> <li>• cost for locally made Tsh 10,000 (US\$ 10); imported version Tsh 15,000 (US\$ 15)</li> </ul>

operate, and the profitability levels of farming operations, as outlined in Chapter 5. The best option, whether powered by humans, animals, or engines, will depend upon the following factors:

- relative costs of labour and capital;
- credit availability and interest rates;
- market(s) for increased crop production;
- availability of machines;
- rates of use of machines;
- farm size;
- in case of DAP, fodder availability and the incidence of animal diseases;
- the maintenance costs of animals versus tractors;
- the value of producing alternative livestock products;
- the availability of spare parts, fuel, and repair services during the early years of engine-powered mechanization.

Few smallholders in SSA are in a position to consider outright purchase of tractors, although they can choose to hire tractors if the service is available. For most, the choice will be between human and animal-powered technology. However, private sector operators may consider whether it is feasible to invest in tractors for hiring out to others. Although cost is a major consideration, other factors must also be considered when selecting the best options for agricultural mechanization. Table 4.8 outlines some of the constraints associated with the different forms of mechanization that will need to be considered.

Given the limited number of constraints associated with human-powered agriculture, it is easy to see why this continues to predominate throughout SSA. Although DAP is considered an intermediate form of mechanization, it does need significant financial resources and the acquisition

of many new skills, particularly where cattle are not an existing part of the farming system. Without some form of external donor funds or of public investment in training, extension, adaptive research, and the development of links with private-sector machinery manufacturers and artisans, there is unlikely to be a spontaneous and widespread adoption of DAP technology in SSA.

It appears probable, therefore, that human power will continue to predominate in agriculture in SSA for some time to come. However, the use of human power in farming systems such as conservation agriculture, which reduces labour demands and drudgery, may be appropriate for improving the productivity and livelihoods of poor smallholders, while at the same time preserving and even improving their natural resources. But it should be borne in mind that conservation agriculture, and the forms of mechanization that go with it, are a major departure from traditional practice. From the farmers' viewpoint, it may be more affordable than DAP, but even so, the shift to it too will require public support and much commitment.

TABLE 4.8

**Potential constraints to the adoption of different forms of mechanization**

Hand tools	DAP	Tractors
<ul style="list-style-type: none"> <li>• labour availability</li> <li>• availability of manufacturers and suitable tools</li> <li>• socio-cultural traditions</li> </ul>	<ul style="list-style-type: none"> <li>• animal diseases</li> <li>• limited tradition of using DAP</li> <li>• security (likelihood of theft)</li> </ul> <p>Availability of:</p> <ul style="list-style-type: none"> <li>• suitable animals</li> <li>• animal husbandry skills</li> <li>• feed/pasture</li> <li>• veterinary services</li> <li>• implements and spare parts</li> <li>• artisans/blacksmiths</li> <li>• extension services for training</li> <li>• timber for yokes</li> <li>• harness makers</li> <li>• financial services</li> <li>• socio-cultural traditions</li> </ul>	<p>Availability of:</p> <ul style="list-style-type: none"> <li>• appropriate tractors, machines and implements</li> <li>• repair and maintenance services, spare parts</li> <li>• trained operators</li> <li>• supplies of fuel, lubricants etc.</li> <li>• implements for weeding and harvesting</li> <li>• financial services</li> </ul> <p>Other factors include:</p> <ul style="list-style-type: none"> <li>• suitable plot sizes</li> <li>• reasonable access to fields</li> <li>• shape of fields</li> <li>• reasonable distances between fields</li> </ul>

## Chapter 5

# Financial evaluation of mechanization options

The purpose of this chapter is to help readers analyze the costs and likely benefits of smallholder mechanization and thus determine its economic viability. It begins with the economic viability and rationale for mechanization and goes on to illustrate how fixed and variable costs can be calculated. Sections on gross margins and farm profits, household cash flows, and financing of mechanization follow.

### 5.1 ECONOMIC VIABILITY OF THE DIFFERENT LEVELS OF MECHANIZATION TECHNOLOGY

In the SSA context, where smallholder farmers predominate, the important questions to pose before embarking on any programme of mechanization will be:

- Are there labour shortages that restrict agricultural production and/or have labour costs increased?
- Will mechanization increase profit so that the cost of the investment can be paid for?

Labour shortages, and hence labour prices, may be growing as a result of illness, malnutrition, and/or non-agricultural economic growth. Even when labour shortages and labour prices are increasing, the agricultural mechanization sub-sector may be still be relatively undeveloped with few support services and limited private sector activity. This, combined with shortages of capital on smallholder farms, will limit uptake of mechanization technologies. Indeed, agricultural mechanization will not be successful if the local economy is unable to deliver – or gear up to deliver – maintenance, repairs, spare parts and fuel for machines and implements, whether they be imported or manufactured locally (see section 4.11.2).

An important feature of any machine is its operating capacity in terms of the quantity of work it can do, for example, the area of land that can be ploughed in a day or the amount of rice that can be de-husked in an hour. The fixed costs per unit of work output of a tractor (usually measured in terms of its annual rate of depreciation) decline as use increases. In other

words, the nearer a machine attains its theoretical maximum working capacity, the cheaper it is to run per unit of output (i.e. the fixed cost per hectare or per hour is decreased). On the contrary, if utilization rates fall, the operator or owner will confront rising costs per unit of work output.

Draught animals also have a theoretical maximum operating capacity, for example, the area of land that can be ploughed in a day. However, they may provide other social and economic benefits that a tractor does not; for example, they can often be sold at the end of their working life at a price greater than that for which they were purchased as young animals. But an important consideration related to DAP is the opportunity cost of maintaining animals during periods when there is no agricultural work – during the dry season, for example – which requires both labour and fodder, and probably some veterinary services and drugs too.

Investment in tractors can only be justified when farm sizes are large enough to generate profit, or when good hire out (contracting) rates are ensured ... and of course, when there are contracting opportunities on other farms. Where small farms predominate, four-wheel tractor ownership may be uneconomic unless farm sizes increase or contracting services can be sold.

It is generally agreed that mechanization options using animal or engine-powered technologies will only be viable in SSA if they contribute to fulfilling the five conditions laid out in the following sections 5.1.1 to 5.1.5:

#### 5.1.1 Increase labour productivity

As has been shown, a family relying totally on hand-hoes is severely restricted in the area that can be cropped and cared for (see section 2.2.2). Similarly, post-harvest processing operations are often time-consuming, labour intensive, and repetitive. The addition of animal or engine power to agriculture significantly increases the output of the human energy put into crop production and processing.

The adoption of improved hand tools, DAP, or tractor-powered cultivation techniques improves

labour productivity, that is to say, a similar output is produced with less labour, or more is produced with the same amount of labour. This is true for both cultivation operations and power-intensive activities such as threshing and milling, which are usually powered by stationary engines. For example, the increases in productivity resulting from the introduction of motorised mills are often large, and they are of particular benefit to women.

The labour savings resulting from the adoption of DAP in Zambia have been estimated to be in the region of 25–35 percent. Similarly, the adoption of DAP in Ghana has been shown to contribute to increased financial returns per unit of human labour. Conservation tillage in Tanzania, using either hand tools or DAP, has been demonstrated to reduce labour demands for land preparation, planting and weeding: no ploughing is required, seed is sown directly with jab planters, and cover crops inhibit weed growth (Kienzle, 2003).

Table 5.1 shows the major savings in labour achieved with the adoption of DAP weeding in North-East Uganda. Extending the use of DAP to most farm operations, such as ploughing, cultivating, weeding, and carting, improves labour productivity; and it has the concomitant benefit that family labour may be able to engage in other income earning tasks, either agricultural or non-agricultural.

### 5.1.2 Expand the area under cultivation.

When farmers in SSA adopt DAP, they generally expand the area they cultivate. Pingali (1987) reporting from 17 country case studies noted that farmers shifting from hand-hoes to DAP usually doubled their area of cultivation. Whether there is an aggregate area expansion for a country or region as a whole will depend upon the availability of fallow or uncultivated land.

However, as mentioned previously, and as bears repeating, applying DAP or tractor power just to expand the area of land prepared for

sowing often creates a labour bottleneck for subsequent weeding. A study in Burkina Faso showed that the adoption of an animal-drawn plough alone, with no DAP weeding equipment, had little effect on area cultivated, precisely because of the limited amount of labour available for weeding. One result was that the oxen were only used for 60 hours fieldwork per year. On the other hand, the adoption of ploughs *and* weeding implements resulted in the cultivation of an additional 4 ha, significantly increasing the use of the draught animals to 400 hours/year (Jaeger and Matlon, 1990). Clearly, the higher the rate of use of draught animals, the lower the unit cost of work, and the greater the return on the investment in DAP. The mechanization of more than one cultivation operation is therefore crucial if area expansion is to result from the introduction of the new power source, and if the return on the investment in DAP is to be maximized.

### 5.1.3 Increase land productivity

Animal and tractor-powered mechanization only leads to increased yields when it improves timeliness of land preparation and weeding, or perhaps when deep tillage before the onset of the rains can enhance water infiltration and provide moisture for crop growth. It is possible to attain similar yields under the same environmental conditions from crops cultivated by hand, DAP or tractors. Available evidence suggests that, in most circumstances, mechanization is a labour-replacing rather than a yield-enhancing technology. Research comparing hand-hoe and DAP farmers in Africa failed to discern an effect on yield associated with the use of DAP (Pingali, 1987).

### 5.1.4 Improve profit and reduce costs

Mechanization, to be successful, must normally contribute to the improved profitability of agriculture, generate adequate returns to justify investment in machines or implements, and

TABLE 5.1

Labour costs and returns with respect to weeding in NE Uganda (Teso Farming System)

	Sorghum		Groundnuts	
	DAP weeding	Hand weeding	DAP Weeding	Hand Weeding
Weeding (hr/ha)	34.7	157.8	31.8	73.2
Cost of weeding (\$)	6.12	27.85	8.07	18.07
Return per day of weeding labour (\$)	11.40	2.19	135.78	18.42
Weeding as % of total costs	13.2%	51.3%	7.7%	21.5%

Source: Barton et al. (2002)



provide a reasonable profit for the enterprise as a whole. If labour productivity can be increased (see section 5.1.1), this will reduce labour costs per unit of output. The introduction of DAP weeding to replace hand weeding, for example, will normally reduce labour costs substantially. Table 5.1 clearly shows how DAP weeding of groundnuts and sorghum in the Teso Farming System, North-East Uganda, reduced weeding costs for groundnuts by a factor of about three, and for sorghum by a factor of four, resulting in higher returns for both crops (Barton *et al.*, 2002). Removing the need to plough altogether and using cover crops to suppress weeds, under a conservation agriculture system, can significantly reduce labour costs even further (Kienzie, 2003).

Farm incomes in SSA are often linked to family size or access to labour (Bishop-Sambrook, 2003). It is these larger farm-households, in terms of land, labour, and capital that are most likely to be early adopters of mechanization technology, for they have the capital with which to make investments in draught animals and machinery. This investment allows them to expand their farming operations further. Large household labour forces also have the advantage of spreading animal husbandry chores and the tending costs needed to maintain draught animals during and outside the cultivation season. In effect, those households with more assets will generally be the first to mechanize.

The possibility of earning income and reducing the costs of mechanization by hiring out draught animals or tractors will be an incentive to those wishing to invest in these technologies. However, the possibility of hiring out is likely to be greatest where ploughing is not severely time-bound, for example, where dry-season, post-harvest or winter ploughing is possible, or where delays in planting do not seriously affect the final yield of the crop. Where the growing period is short, or in semi-arid conditions of say 500 mm of annual rainfall, and where a delay in sowing can seriously affect yields, the opportunities for increasing the use of DAP or tractors through hiring out to others are limited because all farmers require the service at the same time. The operations most suited to contracting out are those that need not be carried out concurrently on all farms, for example, threshing, milling and transport.

The overall aim should be to use mechanization to reduce the labour costs of cultivation, transport and processing, thereby providing improved returns and profitability.

### 5.1.5 Reduce drudgery

Human-powered farming, transport, and processing is wearisome and tedious toil. For example, primary tillage with hand-hoes requires some 500 hours per hectare of human labour, whereas ploughing with draught animals requires only about 60 hours per hectare (FAO, 1981). In SSA it is usually the most labour intensive operations, such as ploughing, threshing and milling, that are the first to be mechanized. The effects of introducing motorized milling are often impressive: grinding a week's supply of maize meal can be reduced from 8–15 hours by hand to a mere 10 *minutes* with a motorised mill (Miracle, 1967). These types of improvements generate significant demand for milling services, for they not only reduce drudgery, especially for women, but also produce high returns for those able to afford the investment.

Reducing drudgery for women is of major importance since they play a crucial and increasing role in agricultural production, particularly in SSA. In addition to their many tasks, which include carrying water and firewood, weeding, processing and preparing food, processing harvests for the market, caring for family members, and marketing surplus food, they are often required to grow crops to satisfy the subsistence needs of their household. Many of these tasks are time consuming, repetitive, and exhausting ... in a word, they are drudgery. So, enhancing the power available for women's tasks will often have social as well as economic benefits.

## 5.2 ESTIMATING THE COSTS AND BENEFITS OF MECHANIZATION

For the farm household considering investment in mechanization it will be essential to make some simple calculations of the financial implications. At the outset, especially in areas and regions with little knowledge or experience of mechanization, poor farm households may need assistance to make these calculations. Although it may not always be necessary to calculate precisely, it is important that extension workers and farmers understand the major aspects of the costs of mechanization, for only when the costs are known can provision be made for replacement or for establishing a hire out charge. The costs are of two types: fixed costs and variable costs.

### 5.2.1 Fixed costs

These are not dependent upon the annual working hours of tractors, draught animals, stationary engines or implements, and must be covered by the owner, even when the machines or animals are idle (FAO, 1990).

Fixed costs include:

- Depreciation caused by wear and ageing. In effect, this means a sum put aside, or that will need to be spent, to replace an item when its useful life is over. For example, if a tractor has a working life of five years and a negligible residual value at the end of that period, it depreciates at the rate of 20 percent each year. Draught animals are quite different, however, because their residual value will be relatively much higher than that of a tractor. In much of SSA, a mature, eight-year-old ox may have a similar – or perhaps even greater – value than an untrained two-year-old one.
- Interest on capital used to purchase animals, tractors or implements, or the opportunity cost of using these savings, or in other words, the interest forgone. For communities without access to formal banking services, this may be irrelevant since savings tend to be held in the form of livestock or other tangible assets. A working ox or cow may also have a higher value than other animals in the herd.
- Taxes imposed by government, for example, property or machinery taxes. These are probably of limited importance to smallholders, but large commercial producers may be affected by them.
- Insurance to protect the owner of animals or machinery in the case of loss due to theft, fire or flood, and including cover of liability for damage to third parties. In practice, few SSA smallholder farmers have access to formal insurance services. They do self-insure by holding assets – often livestock – that can be quickly liquidated in the event of a crisis.
- Shelter, including housing to protect machines and animals from the weather, etc.
- Other fixed costs include veterinary care, fodder, and labour for tending draught animals outside of the cultivation season.

Annual fixed costs are divided by the working hours per year to estimate the fixed costs per hour. In practice, for estimating the fixed costs of tractor ownership it will be necessary to consider all the factors outlined above, except the last.

For draught animals only the initial costs – if animals are not already owned – any additional labour costs, and veterinary costs need to be calculated. The labour costs for feeding and tending draught animals outside of the cultivation season can be substantial, especially where cattle are not traditionally owned and oxen cannot be grazed with the existing herd. In the past, unpaid children often tended animals, but so many are in now school that they can no longer do this work. Paying for labour will add to the costs of investment in DAP.

### 5.2.2 Variable costs

Variable costs are associated with the working hours of the animal, machine, or implement and will not be incurred if the asset lies idle. These costs are usually expressed as costs per working hour and include:

- Fuel, lubricants, oil filters etc. calculated as consumption per hour multiplied by the cost per unit, for example litres of fuel consumed per hour times the cost per litre.
- Operator's wages. This may be the hourly wage of the operator. However, if the operator(s) are permanent employees on a fixed wage, the cost will be the portion of their time, and hence their salary, charged to driving the tractor or draught animals, divided by the annual working hours of the machine/animals.
- Repair and maintenance of mechanical items, usually estimated as a percentage of the purchase price of the implement or machine.
- Extra rations required by draught animals during working days if these are purchased. These are likely to be negligible as working periods are often quite short, particularly in semi-arid farming systems, and only land preparation is energy intensive.

In practice all the above, except the last, must be considered for tractor owners.

The annual fixed costs divided by the number of hours worked, plus the variable costs per hour or per hectare added together, determine the overall cost of owning and operating machinery per hectare or per hour. It is necessary to know this total cost per hour or per hectare to determine the hours or area that need to be worked to break even, and the minimum hire out rate that can be charged without incurring losses.

Tables 5.2 and 5.3 are worksheets/checklists showing how one can estimate the hire out or

TABLE 5.2

Example of a worksheet for estimating DAP costs and hire-out rate

Basic Information required	Donkey	Ox	Implement
1. Purchase price or current value (\$)	50	300	150
2. Estimated working life (years)	20	10	10
3. Interest rate (i%)	5	5	5
4. Annual use (hours)	200	200	200
5. Trade-in value or residual value (\$)	0	200	50
<b>Estimated Fixed Cost/year</b>			
6. Annual depreciation (straight line method) <sup>1</sup> (\$)	2.5	10	10
7. Annual interest cost <sup>2</sup> (\$)	1.3	12.5	5
8. Annual insurance cost (\$)	0	0	0
9. Annual housing/shelter cost (\$)	0	0	0
10. Annual tax cost (e.g. registration etc.) (\$)	0	0	0
Total Fixed Cost per year (\$)	3.8	22.5	15
<b>Total Fixed Cost per hour (\$)</b>	<b>0.02</b>	<b>0.11</b>	<b>0.08</b>
<b>Estimated Variable (operating) Cost/hour (\$)</b>			
11. Repair and maintenance costs (for donkey and oxen will be veterinary costs)	0.5	1	1
12. Feed cost/hour (supplementary feed)	–	0.5	–
13. Lubrication cost/hour	–	–	0.5
14. Labour cost/hour	0.5	0.5	–
<b>Total Variable Cost/hour</b>	<b>1.0</b>	<b>2.0</b>	<b>1.5</b>
<b>Total Cost (Fixed + Variable)/hour</b>	<b>1.02</b>	<b>2.11</b>	<b>1.58</b>

Notes:

<sup>1</sup> Annual depreciation = (purchase price – residual value) ÷ useful life<sup>2</sup> Annual interest = [(purchase price + residual value) ÷ 2] × i%

TABLE 5.3

Example of a worksheet for estimating tractor/implement costs and hire-out rate

Basic Information required	Tractor or Engine	Implement
1. Purchase price or current value of machine (\$)	30,000	3000
2. Estimated economic life (years)	10	10
3. Interest rate (i%)	5	5
4. Annual use (hours)	500	200
5. Trade-in value or residual value (\$)	3000	300
<b>Estimated Annual Fixed Costs (\$)</b>		
6. Depreciation	2700	270
7. Interest cost	825	83
8. Insurance cost	700	0
9. Housing/shelter cost	0	0
10. Tax cost (e.g. registration etc.)	300	–
Total Fixed Cost per year (\$)	4525	353
<b>Total Fixed Cost per hour (\$)</b>	<b>9</b>	<b>1.8</b>
<b>Estimated Hourly Variable (operating) Costs</b>		
11. Repair and maintenance cost	5	2
12. Fuel cost/hour	15	–
13. Lubrication cost/hour	1	–
14. Labour cost/hour	2	–
<b>Total Variable Cost/hour</b>	<b>23</b>	<b>2</b>
<b>Total cost (Fixed + Variable)/hour</b>	<b>32</b>	<b>3.8</b>

contract rate for DAP or tractors. These tables are provided for illustrative purposes only and their values should *not* be used for any real situation. It is very important that cost calculations always be based on local sources of information, and especially information from farmers.

It can be seen that the total cost per hour – animal plus implement – is about \$2.6 for donkey and \$3.7 for ox. Thus, these are the break-even costs per hour for using the implement with a donkey or ox respectively. One can now determine a hire out rate by simply adding a profit margin, of say, 10 or 20 percent over and above the break-even cost per hour.

As can be seen, the total cost of tractor plus implement is \$36/hour. This is the break-even cost. From this one can estimate a break-even cost per hectare by dividing the total cost per hour by the field capacity. Assuming the field capacity is 2.4 ha/hour, the break-even cost is \$15 per hectare.

Adding 10 or 20 percent profit margin to the break-even cost per hectare will give a reasonable hire-out rate. However, it must be remembered that local contract work rates are very often determined by the ability to pay. A comparison of actual rates with the theoretical break-even rates will give an idea of the likelihood of decapitalization and the ability or not to replace the assets at the end of their useful life.

### 5.2.3 Calculating gross margins and farm profits

Some simple calculations will be needed to see how any investment in mechanization will

contribute to output and profit margins, whether the investment is in improved hand tools for conservation agriculture, traditional DAP to expand the area of cultivation or a DAP weeder to reduce the time and costs associated with hand weeding. The following example considers the impact of introducing draught oxen into a traditional farming system in The Gambia.

In the analysis in Table 5.4, it should be noted that the area under hand cultivation, at 1.75 ha, was somewhat more than the norm for human-powered farming in SSA. This was because the holding was run by an extended family. Even so, when DAP cultivation was introduced, the cultivated area were doubled.

The gross output of millet and groundnuts for the enterprise doubled with the introduction of DAP, while the gross margins – the gross outputs minus the variable costs – more than tripled for millet and doubled for groundnuts.

In this case, DAP was used for land preparation, planting, and weeding, and this explains the sharp reduction in the cost of hired labour, despite the much larger area cultivated.

The data presented in Table 5.4 suggest that the advantages of using oxen are large since gross margins of the enterprise were increased from \$448 to \$1233.

### 5.2.4 Household cash flows

The analysis outlined in section 5.2.3 may be useful for district planners, but extension workers may need to adopt a household-level approach to assist farmers develop an understanding of

TABLE 5.4

Comparing the income from human-powered and animal draught-powered farms in the Gambia

	Hand cultivation		DAP cultivation	
	Millet	Groundnuts	Millet	Groundnuts
Area cultivated (ha)	1.75	1.75	3.5	3.5
Yield (kg)	1312	1487	2625	2975
Farm gate price per kg (\$)	0.25	0.35	0.25	0.35
<b>Gross Output</b> (yield x price/kg) (\$)	<b>328</b>	<b>520</b>	<b>656</b>	<b>1041</b>
<b>Variable costs (\$)</b>				
Seed (\$)	10	45	20	90
Fertilizer (\$)	35	45	70	90
DAP variable costs (Table 5.2) (\$)			2	2
Hired labour (\$)	140	125	100	90
Total Variable costs (\$)	185	215	192	272
<b>Gross Margin (\$)</b>	<b>143</b>	<b>305</b>	<b>464</b>	<b>769</b>
<b>Total Gross Margins</b>	<b>448</b>		<b>1233</b>	
<b>Gross Margin/hectare (\$)</b>	<b>82</b>	<b>174</b>	<b>133</b>	<b>220</b>

the costs of running their operations and their home over the whole year, and the likely costs and benefits associated with mechanization. The concept of cash flows – income and expenditure – can be introduced to poor farm households as a means of demonstrating to them:

- whether there is sufficient surplus income to be able to invest in mechanization;
- whether it will be necessary to save or sell assets to purchase mechanization inputs;
- whether there will be a need for some form of credit for the investment;
- whether the potential impact on cash flow of the investment makes it worthwhile.

There will often be cases where the cash flow before mechanization, although positive, is not generating sufficient income to allow the household to invest in DAP immediately. The options then are to hire in DAP, save for a number of years before investing, or seek some form of credit with which to purchase the technology.

### 5.3 FINANCING AGRICULTURAL MECHANIZATION

Mechanization is costly: there is the initial investment in purchasing a tractor, or a pair of oxen, and the implements to go with them; and then there are running costs, maintenance costs, and the need to have sufficient capital ultimately to replace worn out equipment. How can this be financed?

All businesses, including small-scale farmers, constantly have to take decisions about finance – about what to buy, when, and how to pay for it. Most purchases are financed out of cash inflows, e.g. from sales of produce, from payments for services rendered, or from wages earned. This is how spare parts, fuel, or veterinary costs would normally be financed, but finding the initial investment to buy equipment is more difficult because it is a large lump sum of money that is required at one time. To finance lump sum investments from cash inflow requires saving up, and this is only possible if the business operations are sufficiently profitable to leave a margin that can be saved, after meeting household and routine business expenditure. Alternatively, a member of the family may be working away and sending back remittances that can be saved.

The important thing to remember, always, is that the first source of investment finance is the retained profit or savings of the business owner. A practical difficulty for most small farmers in SSA is finding somewhere safe to keep such savings

... as well as having sufficient self-discipline to make and keep the savings in the first place. It requires great vision and a long term plan to save up for investing in fixed assets such as machinery, especially in social environments where it is not the normal thing to do. It also requires strong managerial competence to save and then use the resources in an orderly way. The motivation to invest in cattle, including draught oxen, is often great because it is familiar and usually brings social status. Whether it is feasible to self-finance mechanization or not, the crucial thing is that the farmer should have the desire and belief that s/he should invest in it, and be prepared to sacrifice present consumption and save money to do so.

It may well be that a farmer operating on the margins of subsistence has no surpluses that would enable accumulation and investment. In this situation, however, mechanisation is unlikely to be the best strategy for the family: they would undoubtedly need first to deal with access to land, production and market opportunities, cultural constraints, family health and many other issues contributing to their current personal circumstances.

When a business operator wants to mechanize but operates on such a small scale that it is impossible to save sufficiently to finance a mechanization input alone, an option is to share the ownership. Essentially, this involves getting other people to contribute their savings and to purchase the equipment jointly. In the case of oxen, it could be that two households agree to purchase one ox each and then work them as a team.

#### 5.3.1 Joint ownership

Joint ownership and sharing suffer the same constraints as contracting services – there is only a limited time span available to undertake crop establishment operations on several different farms, and delays reduce yields. Therefore, to make joint ownership successful, the farmers must understand each other very well and be prepared to plan carefully how to organise the work on their land. They must agree an equitable procedure for sequencing the work and for maintaining the equipment. In general, joint ownership should be confined to a small number of people, all of whom have a common interest in making the arrangement work and who have accepted the financial commitment involved. It is not suitable for a loose confederation of people such as a ‘community group’.

If a small group of farmers have decided that



joint ownership is realistic it is important that:

- the membership of the group be decided by themselves and not by outsiders;
- they have a clear set of rules regarding financial contributions, care and maintenance of the machine, how work will be scheduled, how a member can withdraw from the group, etc.;
- a bank account is set up with nominated signatories so that contributions can be deposited there and withdrawn as needed for maintenance and replacement;
- a system of record-keeping is set up to monitor machine use, on-going expenditure, receipt of contributions, etc.

As already mentioned, community groups, village associations, or associations that exist for other purposes, are not suitable vehicles for joint ownership of machinery. In these instances, ownership should rest with a specific person or an entity such as a cooperative, and it should be run as a contract hire service. There may be good reason to assist small groups of women in SSA jointly to acquire draught animals, which will improve cultivation and enable them to support their families better. If cultural constraints are not a limitation, the key issues are, as always, how the animals and equipment will be managed and how financial costs of acquisition and maintenance will be handled. It could be that access to a hire service is a better option.

### 5.3.2 Borrowing

When it is impossible for people to accumulate sufficient funds to be able to invest in machinery or DAP – either individually or jointly and within a reasonable time frame – borrowing the money may be considered. Borrowing is a way of using future income now. As soon as someone takes a loan, they incur a commitment to repay that money from their future income. So borrowing does not remove the necessity to save: it merely enables someone to have the benefit of the equipment now while continuing to save so that they can pay off the debt and gain full ownership of it. Furthermore, it increases the cost of the investment because most lenders require payment of interest on the loan, and therefore the savings will need to be commensurately greater.

The obvious benefit of borrowing is that the potential advantages of mechanizing can be realized earlier. If there is an increase in crop yield or quality, which results in higher income, the results of taking a loan should be positive. The

crucial relationship is that the extra profit should be greater than the cost of borrowing. If this is the case, it should not be difficult for the borrower to repay the loan and still benefit from an increase in disposable income. It is relatively easy to produce budgets which show the enormous potential benefits of mechanizing or moving to DAP from hoe cultivation, but it is much more difficult to realize these improvements in practice. The simple acquisition of fixed assets, such as machinery or DAP, does not lead alone to increased income: they have to be used correctly; production targets have to be achieved; the extra crop has to find a market, and so on. If income is not increased, loan repayments have to be made from existing income, and that means less consumption than at present. It is important for people to realize this.

From their side, lenders are normally well aware of the risks. A lender has to evaluate the person who is asking for a loan and decide whether that person will be able and willing to repay. Here are some of the issues that a lender will normally take into account before agreeing to a loan:

**Character** – the personal integrity and characteristics of the business owner(s) and family:

- Are they honest and trustworthy?
- What is the physical and mental health of the person(s) running the business?
- Have they repaid bills and previous loans on time?
- Do they have family problems e.g. alcohol, frivolous spending, etc?

**Capacity** – the ability of the business to repay the loan:

- How is the business managed?
- What does the business plan indicate about income and profitability of the business?
- Can the business generate enough cash to make the loan payments with interest, including a margin of security?
- What is the innovation and creativity of the business in creating new growth opportunities?
- What are the family needs?
- What are the effects of seasonal fluctuation and production and price variations?
- How does the business compare to others within the same sector or activity?
- When can the loan be repaid?

**Capital** – the money invested in the business:

- What money and assets are invested in the business?
- What is the family contribution to the business?



**Collateral** – the backup resources for the repayment for the loan:

- Are the assets of the business and personal guarantees adequate to cover the loan if necessary?
- Are the personal guarantees offered by the person trustworthy?

**Conditions** – the key economic factors that impact on the ability to repay the loan:

- Is there an adequate and stable market to sustain the business?
- What are the price and production risks?
- What are the general market trends of the sector?

Even the village money-lender will think about some of these issues. A responsible banker will definitely check them all. The larger the loan and the longer the period needed to repay, the greater the risk of changed circumstances. Thus, lending for machinery or DAP is normally considered risky, and the lender demands more security in the form of guarantees or pledged assets.

Clearly, for many small farmers there is an obvious and considerable difficulty in borrowing to mechanize. The interest rates of informal lenders may be prohibitive, while the procedures of formal institutions may be equally prohibitive.

### 5.3.3 Improving the Options

The first and most important step in improving the possibility for farmers to finance agricultural mechanization is to help them plan. They need to be able to review their current farming practices, to assess alternatives, to compare prices, to calculate costs, to understand depreciation and to estimate profit. They need to be able to assess the impact of a large investment on their cash flows and current and future saving patterns. They need to know if they can expect to improve their income, what they have to do to achieve this, and what would happen if they did not. This is a clear role for extension or advisory officers, and steps should be taken to improve their skills in this area.

If someone has a clear and sound plan, the prospect of borrowing from the formal sector increases dramatically. It is further enhanced if a farmer has evidence of regular saving, and every effort should be made to encourage people to open savings accounts in credit unions, savings and credit cooperatives, rural banks, post office savings banks, or deposit-taking microfinance institutions. Evidence of past business is the best guide to future business. Someone's commitment

to reinvesting in their business can also be demonstrated by providing a balance sheet of assets and liabilities. Most small farmers in developing countries do not produce accounts, but it is not difficult to put together a balance sheet, and advisory officers ought to be able to facilitate this. The relationship between assets and liabilities will clearly show whether there has been reinvestment of profits in the farm over the years.

All the above suggestions will help to offset the critical need for collateral. Bankers will still prefer to have some form of security for long term loans, however, and governments can help this situation by improving land registration and provision of title deeds, or by creating the legal framework for banks to accept alternative forms of collateral. Lessons from the microfinance sector have shown how joint liability or personal guarantees can act as substitutes for pledged assets, and the legal environment should be created to ensure such guarantees can be enforced. This would increase the confidence within the banking sector.

### 5.3.4 Leasing

Another strategy that financial institutions may consider is leasing. Leasing is a medium term financing instrument that can be used for financing fixed and moveable assets, such as farm machinery, equipment, buildings, land, means of transport, etc. The core principle of leasing is the separation between the ownership of the production asset and its use: the owner of the asset, or lessor, hands it over to the lessee for an agreed period of time against a periodic payment that covers capital costs, depreciation and a profit margin.

The key benefit of leasing is the relaxation of collateral requirements because the leased asset itself stands as the main security. A second advantage is that the asset is disbursed in kind form, and this avoids the risk of diversion of funds. Disadvantages are that rural lessors face high transaction costs for supervision of lessees; there is a lack of secondary markets for repossessed equipment; and there is a lack of appropriate insurance products and awareness amongst all stakeholders about the legal and operational features of leasing.

The extent to which financial institutions increase their willingness to finance longer term investment on farms will also depend partly on their own skills in developing products and procedures that lower their risks. This applies to all types of financial service providers,

whether cooperative, banking, or microfinance institutions. In particular, they should consider being a channel for insurance products that are suited to small-scale farmers and help to offset some of the many risks they face.

A final point is that governments should not increase risk levels by misguided policies that cancel farmers' debts for political reasons or enforce low interest rates that prevent financial institutions from covering their costs. They should concentrate on improving advisory services, reducing obstacles facing equipment dealers, and ensuring that the legal system is implemented in a competent manner to back the contractual arrangements of financial institutions.

### **5.3.5 Micro credit**

With governments under pressure to reduce public expenditure, subsidized credit schemes are unlikely to be considered a viable option for most countries in SSA. By contrast, microfinance has been demonstrated over the past two decades to be a sustainable means of providing financial services to poor households, without the need for collateral. The Grameen Bank in Bangladesh, for example, has demonstrated that small farmers and poor households can save on a regular basis (weekly or bi-weekly), and that linking this saving with borrowing is feasible and sustainable. These financial systems are based on:

- Group lending and group, or collective, responsibility, including penalty for default. Other members of the group are refused loans if one member of the group defaults. This results in powerful social pressure to repay and overcomes the problems associated with a lack of collateral on smallholder farms.
- Tight control over administrative costs, bureaucracy, and paperwork, coupled with incentives for employees and the decentralisation of decision-making to local officers.
- Women as the prime beneficiaries of microfinance, since they have demonstrated that they are more credit-worthy than men.
- Interest rates as close as possible to the market rate prevailing in the commercial banking sector, without sacrificing sustainability.
- The development of an organisation that is owned by the borrowers, who are also savers and therefore have a stake in the success of the organisation.

The process of transferring this experience

to SSA has begun, and there were estimated to be 5.7 million microfinance clients in Africa in 2002 (Daley-Harris, 2003). However, changes to the established format may be necessary if such finance is to be used to purchase agricultural mechanization inputs, for weekly or biweekly repayments would not be appropriate for farmers making lump sum investments in machinery.

Extension workers seeking sources of finance for farmers wishing to mechanize should seek to develop relationships with existing microfinance providers in the private or NGO sectors.

## Chapter 6

# Participatory planning and evaluation for mechanization

In this Chapter, we describe the process of participatory development of mechanization technology. The aim is to guide people involved in such development programmes and to help them resist the temptation to impose their views. Instead, they need to involve all of the stakeholders in a consultative process from the earliest possible point in the programme.

### 6.1 THE RATIONALE FOR PARTICIPATORY PLANNING

Until the mid-1970s, the blame for the failure of smallholder farmers to adopt improved technology packages was usually attributed to their ignorance and conservatism. Only in a few cases was it recognized that the technology on offer had not combined the characteristics necessary to be attractive to the so-called beneficiaries of the initiative. The centrist model did not take into account the innovative talent of farmers, a resource developed throughout thousands of years of informal research (Biggs, 1980). In private, some agricultural scientists even now continue to blame peasant conservatism for the lack of adoption of new technologies; they overlook the fact that peasants have a deep understanding of their own reality, and that this has allowed them to survive for millennia, often in very difficult circumstances and with primitive tools.

Development programmes frequently include technology that is novel, at least to the region they are working in. There is always a strong temptation amongst managers of development activities to make decisions about the “most appropriate” technology without involving those who will be affected by the adoption of new practices or equipment. The participatory planning and research concept has its roots in the recognition that, if smallholder farmers do not perceive the relevance of the results of the research, and feel some ownership of them, they will not adopt them.

Participatory approaches transfer the initiative and the power of decision to farmers who, in the

final analysis, have a significant advantage over scientists: they have detailed knowledge of their production systems. Indeed, smallholder farmers are constantly modifying and exploiting micro-environments and making adaptations that are difficult to reproduce in experimental stations. They adapt and innovate to survive in marginal conditions (Chambers and Jiggins, 1987).

Although there are variations on participatory methods, in general, participatory research starts with a process of consultation and collaboration between technical specialists and farmers as partners or colleagues. Firstly, the technical specialists act as a catalyst in a process in which farmers identify and prioritize the technical problems they are facing. The technical specialists then formulate appropriate research strategies to overcome them. The results and their interpretation and application are managed by the farmers, with technical assistance from the technical specialists. The benefits of the collaboration reside in the application of the different perspectives, knowledge, and styles of both parties (Sims and Bentley, 2002).

Over the years, FAO and other leading agencies have promoted a Farming Systems approach to rural and agricultural development (FSD). The thrust of FSD has been to develop an understanding of the farm household, the environment in which it operates, and the constraints it faces, together with identifying and testing potential solutions to those constraints. At farm household level, the focus of FSD involves the interactions of two major elements:

- farming systems analysis
- farming systems planning, monitoring and evaluation.

The details of these elements have been explained in the FAO Farm Systems Management Series of publications, Numbers 6 and 10 (Dillon and Hardaker, 1993; Norman *et al.*, 1995).

Recently, the concept of ‘people-centred development’ has been emphasized by FAO. A key ingredient in this is the use of participatory

development approaches and practices. The objective in all participatory approaches is that projects – from planning, to the implementation stage, and to evaluation – should be participatory and consultative. That is to say, they should: involve all stakeholders, be flexible, empowering, gender sensitive, and sustainable (Baumann *et al.*, 2004). Comparisons of various participatory methods have been documented by the FAO Livelihood Support Programme (LSP) (Cleary, 2003).

## 6.2 PARTICIPATORY APPROACHES IN MECHANIZATION PLANNING AND EXTENSION

The last fifty years have seen a large amount of investment in research and development aimed at producing equipment for smallholder farmers. Regrettably, however, adoption by farmers was often disappointing to the developers, and so numerous items of ‘improved’ equipment have ended up on the scrap heap. The fundamental reason for the failures of the past has doubtless been the lack of active participation of the stakeholders in the process of developing mechanization technology. *All* of the stakeholders (Box 6.2) must be induced to participate actively in the planning and implementing of mechanization strategies if they are to be successful. The role of farmers is paramount, for

participatory planning builds upon the indigenous knowledge that already exists in the community and blends it with the ideas and knowledge of the other stakeholders ... the researchers, policy makers, private sector, etc.

Farmers already do research and planning at their own level. Every season has a planning time. Farmers are not blind followers: they are constantly testing, adapting, and evaluating new ways of doing things. Participatory planning taps into this enormous potential of indigenous knowledge and experimentation.

Participatory planning has several other advantages. Firstly, the participating farmers, manufacturers, input suppliers, and all of the other stakeholders involved, feel ownership for the results. Secondly, it is effective in reaching consensus and, overall, the sustainability of any mechanization strategy is enhanced.

Agricultural extension and advisory efforts are central to the success of any mechanization and sustainable agriculture programme. However, the hitherto common and conventional ‘top-down’ approach to extension has not yielded positive results. This is because it is too directive and based on the erroneous notion that the research and extension community enjoys a monopoly on knowledge and wisdom. People-centred approaches are a way of improving the effectiveness of rural extension efforts. Their ‘farmer first’ focus aims to empower farmers to plan, manage and implement agreed activities.

### BOX 6.1

#### People-centred approaches (after Baumann *et al.*, 2004)

According to the Sustainable Livelihood Approach, the key principles of people centred development should be:

- people-centred – focusing on what matters to people;
- holistic – identifying constraints and opportunities regardless of the sector, geographical space, or level at which they occur;
- responsive and participatory – stakeholders themselves must be the main actors;
- multi-level – working at all levels and building on the linkages between them. Conducted in partnership with both the public and the private sectors;
- sustainable – economically, institutionally, socially, and environmentally;
- dynamic – recognise the dynamic nature of livelihood strategies and respond flexibly.

### BOX 6.2

#### Stakeholders in mechanization planning

The following are the main stakeholders that have to be involved during a mechanization planning process:

- farmers and community organizations;
- research, extension and training institutions;
- manufacturers;
- artisans and blacksmiths;
- providers of repair and maintenance services;
- veterinary services;
- importers and distribution networks;
- relevant NGOs and government departments, such as agriculture, finance, trade and industries, etc.;
- retailers and wholesalers.

### 6.3 GENDER ISSUES IN PARTICIPATORY PLANNING AND IMPLEMENTATION

The term ‘gender’ refers to the social construction of female and male identity. It goes far beyond the biological differences between men and women: it includes the ways in which those differences, whether real or perceived, have been valued, used and relied upon to classify women and men and to assign roles and expectations to them.

A “gender analysis” refers to the variety of methods used to understand the relationships between men and women in a particular setting, their access to resources, their activities, and the constraints they face relative to each other. Gender relations may be changed by political, economic, and opinion-shaping influences, and also when an economic transformation is in process.

A gender analysis, by examining the differences in women’s and men’s lives, including those that lead to social and economic inequity for women, informs policy development and service delivery and aims to achieve positive change for women. Box 6.3 highlights some of the key issues which should be considered and included during gender analysis of development policies, programmes, and projects. These will help to ensure that all development efforts address the needs and priorities of both men and women. The identification of gender roles in a given situation provides the criteria to appraise and evaluate the extent to which actions and interventions may succeed. In particular, an analysis of the flow of resources and benefits is essential to understanding how a project – in this case mechanization – will affect women and men.

Ignoring gender issues during planning and implementation stages often leads to unwanted consequences for women and a failed development effort. An example of an unexpected and unwanted gender reaction to the introduction of a new technology took place in Senegal when an improved groundnut lifter was introduced that left fewer ground nuts in the soil. By tradition, any groundnuts that women could glean by hand after the main harvest were theirs to sell. The new and more efficient lifter would reduce that gleaned income, so they resisted it (IFAD/FAO 1998). In conclusion, gender issues should be considered and main-streamed in all aspects of mechanization development.

For further information on gender issues, readers are referred to the series of guides on gender in development produced by

#### BOX 6.3

##### Gender analysis tools

Key issues in a gender analysis include:

- **The division of labour** – identification of the division of labour: who does what type of work, for both reproductive and productive activities.
- **Access to and control over resources** – identification of the resources available to men and women to carry out their activities: who can use them and who controls them?
- **Benefits from work done** – analysis of the needs, both practical and strategic, and who gets the income from the resources and work?
- **Constraints and opportunities** – how might appropriate interventions be targeted to overcome the identified constraints and realize the opportunities?

#### BOX 6.4

##### Points to remember about gender issues during mechanization planning

- Emphasize gender awareness at all levels and in all the activities of a project;
- include women in all aspects of project design, implementation, and evaluation;
- recognize the need for gender sensitization among project personnel and other stakeholders involved in mechanization;
- use gender analysis tools in training processes for gender awareness;
- look for ways of including women and letting their voices be heard... listen to their needs and priorities.

FAO’s Socio-Economic and Gender Analysis (SEAGA) programme.

### 6.4 THE PROCESS OF TECHNOLOGY DEVELOPMENT

In the context of farm power and the development of mechanization technology, the process will usually follow the sequence described in the next sections.



#### 6.4.1 Technical specialists and farmers as partners or colleagues

Given that the ultimate goal of developing a technology is to achieve its adoption by farmers, increase agricultural productivity, and improve livelihoods, it seems odd that the most important specialist of all – the farmer – has been missing for so long. In fact, the farm family is an absolutely vital element in the process of development and evaluation, and the farmer and technical specialist should work as partners. There are many levels of participation (Biggs, 1989), but the fundamentally important part is placing the farmer squarely in the role of colleague (Ashby, 1990).

##### *Step 1. Identifying the problems:*

Those involved in planning the development of mechanization will naturally have some preconceived ideas about what the objectives should be, but the farming community *must* be fully engaged in discussions. This will involve helping them, through well facilitated group work, to articulate their main problems as they see them and to list them. The process then moves on to discussing the priority problems and agreeing on which can and should be investigated. It is also important to clarify the issue of how farm power and mechanization relate to other preoccupations and production constraints that the farmers are facing.

The initial impressions that the technical specialists make on the farmers is very important. The technical specialists should be open, friendly, and show their willingness to listen in detail to what the farmers have to say. They must be frank in expressing their comments, ideas, and possibilities, but *never* overbearing or showing that they feel in any way superior to their farmer colleagues or clients. Humour, used judiciously, relaxes people, helps to level social differences, and goes a long way towards creating a good working relationship. It is very likely that at this stage some familiar participatory research techniques will be appropriate, for example, rapid surveys, focus group discussions, technical workshops, and inter-community visits (Velduizen *et al.*, 1997; Thies and Grady, 1991).

##### *Step 2. Selecting possible technical solutions:*

The technical specialists will probably play a greater role at this stage because they will have access to worldwide information and will be able to select promising technologies that have been

successful elsewhere. A good example would be the possibility of reducing the burden of manual land preparation and weeding with conservation agriculture technologies that have been developed by farmers and proven in South America.

##### *Step 3. Construction of prototypes:*

If technical solutions are not available elsewhere, or if they need some adaptation for local use, prototypes will have to be constructed. There can be at least two sites for this work, either the development project's own workshop, or a commercial workshop or manufacturer. It is preferable to involve the private sector as early as possible because potential manufacturers are vital stakeholders in the development process. Novel prototypes – rather than lightly modified equipment – should be subjected to preliminary evaluation 'on-station'<sup>8</sup>. Only when the technical problems, inherent in most initial prototypes, have been ironed out should the technology move on to the next, on-farm phase.

##### *Step 4. On-farm evaluation of the technological options:*

The phase of on-farm evaluation of the technology by farmers is now begun. It is important to realize that farmer evaluation is quite different from the technical evaluation (see section 6.5). Both types of evaluation should take place on-farm under as wide a range of typical farming conditions as possible. Farmers who are evaluating a technology that has been generated to solve a technical problem that *they* have identified are likely to be very active in their comments on the performance of the prototype. Nevertheless, some suggestions for 'improvements' may need to be rejected as technically unfeasible or likely to result in equipment that is too expensive. It is important to involve manufacturers and artisans in these on-farm evaluations (Plate 6.1). Their suggestions will have implications for achieving low-cost manufacture (Box 6.5).

##### *Step 5. An iterative process:*

Farmer evaluation and modification of the prototype is an iterative process. Suggestions for

<sup>8</sup> Participatory R&D does not eliminate the need for work on experimental stations, or at least away from the public gaze. Prototypes should only be taken on-farm when they have been shown to perform satisfactorily from a technical viewpoint. Not to do so may invite ridicule and an early loss of interest.

modifications are agreed in the field, and these are incorporated in the workshop, preferably by a commercial manufacturer. This to-and-fro process continues until the prototype meets the approval of all stakeholders.

**Step 6. Pre-production prototype:**

Manufacturers are the critical stakeholders at this juncture. It is sometimes a temptation for a development project to retain control of the development process longer than is desirable. Manufacturers will make a product that is technically feasible and can be put on the market at a price that will be attractive to farmers.

**Step 7. Final field tests:**

The pre-production prototype is subjected to further on-farm evaluation by farmers so that any final adjustments can be made to the design.

**Step 8. First commercial batch production:**

A first batch of, say, 30 units, is manufactured and distributed to farmers. A useful intervention at this stage is for the development project to purchase the units and sell them on to farmers. It might be appropriate to apply a subsidy on the price to farmers for this batch on the clear understanding that it will not continue after final approval of the design and performance of this first batch.

**Step 9. Batch production:**

The stage of commercial production in the hands of commercial manufacturers has now been reached. The project may continue to be involved through promotional activities, such as field days and demonstrations, but the equipment is sold at an unsubsidized price. In the current climate of free market economics, the continued application of price subsidies is unlikely to be sustainable and will jeopardize the viability of the commercial operation.

Depending on the local circumstances, the process described above may be modified. Technical transfer from one industrially-developing country to another (south – south cooperation) facilitated by a development agency, would be one example. The formation of strong coalitions that promote rural change by means of research and technology development are more effective than any specific method applied. Box 6.5 traces an example of the development process related to DAP weeders in Uganda.



**Plate 6.1**

*Manufacturers are vital stakeholders in the development process. In a development project in Uganda (Box 6.5), this commercial manufacturer participated with his technical staff in the on-farm evaluation of the technology.*

## 6.5 FARMER EVALUATION AND TECHNICAL TESTING

Historically, changes in equipment have often been made by innovative farmers working with local artisans or manufacturers (Starkey, 1989). This evolutionary process has usually led to the production of equipment ideally suited to the farming systems in which they work. Farmer evaluation of mechanization technology could be conducted as part of the Farmer Field School (FFS) methodology that FAO has been successfully promoting. Originally developed in Asia for Integrated Pest Management, but now operational in a number of SSA countries, FFSs are an experiential learning process in which groups of farmers meet once a week in a small study field. With a well-trained facilitator – who is also an agricultural specialist but much more likely to raise problems for group discussion and reflection than he is to answer questions – the group engages in a participatory dialogue and a discovery/learning process that sharpens the members' observation and reasoning abilities. The methodology is based on the notion that farmers have a wealth of knowledge that they can be helped to articulate and build on. It is also based on the principal that no technology will necessarily work in a new location, and that it must always be tried, validated, and adapted. This last point is, of course, the opening for involving the FFSs in farmer evaluation of mechanization technology.

However, an on-farm evaluation with farmers is not the same as technical evaluation or testing from an engineering point of view<sup>9</sup>. FAO's

Bulletin on testing and evaluation of agricultural machinery and equipment (Smith *et al.*, 1994) gives detailed procedures for testing a wide range of implements, including hand-hoes. The procedures in the Bulletin are not meant to be fixed recipes; rather, elements of them are meant

<sup>9</sup> The term 'testing' is usually used to describe a process of assessing the performance of a machine under repeatable conditions. 'Evaluation' includes performance under variable (and often non-repeatable) field conditions and includes economic and ergonomic assessments. However, machinery test centres frequently make no distinction between testing and evaluation.

to be used as required for specific purposes. In the process of equipment development, there will be a technical requirement to test specific parts of a machine and, finally the machine as a whole. This technical testing is likely to take place at various stages during the development of the technology. It should be undertaken by trained technical staff: it is not a job for farmers, who would apply their own, and different, criteria. Conscientious and thorough testing during technology development is an important part of the programme and can lead to improvements in performance, durability and ease of use. Unfortunately, it is

#### BOX 6.5

##### Participatory technology development for DAP weeding in Teso, Uganda

The Teso area of North-East Uganda was affected by war and civil disturbance up until the early 1990s. As farmers returned to their homes and began to restock with draught oxen, it became apparent that weeding of the annual crops of sorghum, millet, groundnuts, beans, and cassava was a major constraint to increased production. This was confirmed by a participatory needs assessment during 1998 when communities were consulted about the production constraints they faced. Broadcasting seed at planting makes weed management extremely laborious and slow. The traditional work groups (*alea*), no longer exist, and weeding becomes late or prolonged with associated yield loss. Few farmers can afford to hire labour for weeding because labour prices rise during periods when demand is high. Expansion of the area cultivated, following the re-introduction of oxen for ploughing, exacerbates an existing labour constraint for weeding.

In partnership with communities in Teso, a participatory technology development project funded by DfID and managed by the National Agricultural Research Organization (NARO) was initiated to address the labour constraint of weeding. Following farmer training in line planting and DAP weeding, four different DAP weeders were tested on farm. Two of these implements, the SAARI and AEATRI weeders were produced as prototypes by NARO. Another, the SG2000, was imported from Kenya. The fourth implement tested was the local plough, which was adapted for weeding by removing the mould-board. The implements were tested by 63 farmers in nine different locations on their own farms and on

two crops – sorghum and groundnuts – in two different seasons. The SAARI weeder had several advantages over the others: it was cheaper because it bolted on to the existing plough frame, had possible output and speed of work advantages over the plough, and was better at removing perennial grass weeds.

The SAARI weeder was subjected to wider on-farm trials that also involved two commercial manufacturers in Soroti. The manufacturers took the basic design and modified it for ease of production before returning to farmers' fields for further evaluation. NGOs and the farmers themselves had promoted further extension and training in the DAP weeding technique. The first commercial batch production – 30 units from each manufacturer at a price of 30 USD – was produced in October 2003. Further development of DAP weeding is in the hands of government and NGO extension and training organisations, with the private sector producing weeders as demand grows for them.



**Plate 6.2**  
The DAP weeder produced for farmers in Teso, Uganda via a participatory development project



an aspect of technology development that is often not performed as thoroughly as it should be. Although the crucial importance of farmer participation, ergonomics, and economics inputs have been noted, the need for careful technical testing by specialists remains as important as ever.

## 6.6 SELECTING BETWEEN ALTERNATIVES

A development programme seeking to improve agricultural productivity and family livelihoods will often be able to offer a range of alternatives as solutions to technical problems. These must perform effectively, especially in comparison with the existing methods and technology, and be acceptable to farmers. The on-farm evaluation with farmers and the testing process described in section 6.5 will normally result in a small number of preferred options from among the alternatives.

Economic evaluation, *from the farmers' perspective* (as discussed in Chapter 5) will guide the final choice of technology. Usually, a comparison between current practice and a proposed technological change, applying the criteria most important to farmers, will be the most relevant. If farmers invest in technology, they expect it to generate returns over and above its costs. They expect to receive benefits that may, for example, increase income, increase food security, or even provide time to pursue other interests. Returns on time invested, for example, could be a high priority, for it could present the opportunity to earn cash income through other activities. The farmers' priorities should be discussed with them at the time of making an economic analysis of the options.

Social and cultural implications will play a part in the selection of appropriate technology. Again, the participation of all stakeholders in the process should avoid the pitfalls that have often blighted efforts in the past. Such things as women ploughing with draught bovines may not be acceptable in parts of SSA, and if so, it could be better to promote the use of donkeys to increase women's access to farm power. In some countries, a connection between standing upright to work and laziness is firmly rooted in people's minds. Men, in particular, believe that if women are not bent double with a short-handled hoe while weeding, they are not working properly; they would not allow their women to use the longer handles that might reduce the toil and discomfort of the weeding season. In one country 1,000 jab planters were distributed to farm families, and

840 of them had to be taken back. Perhaps they were rejected because they could be used standing upright by 'lazy people'. Unfortunately, no one thought to find out why they were rejected (IFAD/FAO, 1988). Such sensitive issues will be regionally important and must be researched through discussion within communities.

Change of technology may require a change of management capability and an increase in knowledge and skills. There are clear shifts in management levels between the use of human, animal, or tractor power, and suitable training will have to be given. The same can be true of shifts that do not necessarily include a change of power source. A good example would be the adoption of conservation agriculture and the need to apply herbicides precisely, and at the right time. There may also be social and cultural problems related to conservation agriculture: for example, leaving vegetation on the soil surface may easily invite local criticism from those uninitiated in the practices; and keeping grazing animals away from crop residues and cover crops in the fields after harvest may go against traditional custom and cause social problems, however necessary it is, especially in the early stages of adopting CA.

## Chapter 7

# Creating an enabling environment

This Chapter we shall examine a number of aspects of creating an enabling environment for mechanization for smallholder farming families in SSA, including: policy implications; quality standards for tools and implements, consumer protection, enabling national manufacture; and the roles of the government and private sector. A section is devoted to district-level considerations and actions, including some proposals for emergency and hardship situations. There is a check-list for mechanization planners and finally, some concluding remarks.

### 7.1 POLICY ASPECTS IN AGRICULTURAL SECTOR DEVELOPMENT

Under its Comprehensive Africa Agriculture Development Programme (CAADP), the New Partnership for Africa's Development (NEPAD) aims to reverse Africa's agricultural crises by fostering increased productivity and efficiency in the sector (Minoiu, 2003). Improving the provision of farm power and mechanization to small-scale farmers has been clearly identified as one of the key elements in achieving NEPAD's goals. Since it is African leaders who are behind the NEPAD initiative, political commitment to its goals should be high, and it follows that there should be support for mechanization initiatives that have the potential to enhance productivity. It is therefore logical that mechanization strategies should be an integral part of all comprehensive agricultural development plans.

### 7.2 THE ROLES OF GOVERNMENT AND THE PRIVATE SECTOR IN MECHANIZATION DEVELOPMENT

The principal role of the government is to provide the conditions, that is to say, an enabling environment, for a largely self-sustaining development of the agricultural engineering sector. With the widespread move towards market economies, policies must be aimed at removing the most damaging forms of market constraints, leaving market forces to operate where they can be effective in promoting growth in agricultural productivity, as well as in rural poverty alleviation.

#### BOX 7.1

#### Some possible roles for government in development of mechanization

- Training (including R&D)
- Market information
- Land tenure policies
- Provision of credit facilities
- Business promotion and development
- Fiscal policies
- Industry policies and marketing infrastructure
- Agricultural extension

Many of the activities to promote and develop mechanization will take place in the private sector. The main role of this sector is to facilitate the delivery of inputs and services. Other roles will include the provision of appropriate information and training, and also participation in networking activities to achieve an efficient balance between supply and demand. Efforts need to be made by governments to ensure this sector can function effectively, supported by the necessary training and extension, favourable fiscal policies, and research. Box 7.2 shows a check-list of the basic considerations for government policy-makers and planners concerned with mechanization strategy.

### 7.3 CONDITIONS THAT CREATE AN ENABLING ENVIRONMENT

#### 7.3.1 Facilitating national manufacture

The growth of supply chains for hand-hoes sold to African farmers is an example of the effects of

#### Remember:

*The purpose of an agricultural mechanization strategy is to create a policy, institutional and market environment in which farmers and other end-users have the choice of farm power and equipment suited to their needs within a sustainable delivery and support system.*

(Bishop, 1997)



## BOX 7.2

**Basic considerations for mechanization planning: a check-list for government policy-makers and planners (after Bishop, 1997).****Policy Review**

- Do agricultural policy instruments influence the use of farm power and equipment?
- Do industrial and fiscal policy instruments influence local manufacture of farm machinery and equipment?
- Do trade policy instruments influence the importation of farm machinery and equipment?

**Farming System**

- Does the existing level of agricultural mechanization restrict agricultural production?
- Does the existing level of mechanization perpetuate drudgery and poverty among farming communities?
- Does the existing level of agricultural mechanization restrict the performance of household tasks?
- Does the existing level or type of agricultural mechanization have adverse environmental impact?

**Agricultural machinery industry and distribution networks**

- Does the local manufacturing industry meet the needs of the farming community?
- Do the imports of farm machinery and equipment meet the demand of the farming community?
- Do distribution, repair and maintenance services support the efficient use of farm machinery and equipment?

**Supporting institutions**

- Are there adequate credit facilities for local manufacture, importers, distributors, and farmers?
- Is there adequate training for farmers in the operation, and maintenance of farm machinery and equipment?
- Does the extension service provide adequate support?
- Is there adequate training and extension support for using draught animals?
- Do manufacturers, importers and farmers have access to sufficient market information to make informed choices?
- Is there adequate protection for consumers from poor or illegal business practices?

globalization (Holtkamp, 2003). It is estimated that more than 10 million hoes per year are imported from Asian countries. In the 1980s and 1990s, all the industrial manufacturers in the Eastern and Southern countries of SSA, under pressure from cheaper imports, were forced to abandon the production of hoes; some stopped production of all agricultural hand tools. The Cock brand of hoes has replaced the Crocodile brand, which was formerly produced in Africa and widely known.

Industrially developing countries obviously need industries, and the growing populations of those countries need employment. There is always a market for the tools and implements used in agriculture, and so it might appear logical for the government of an industrially developing country to protect its local manufacturers of agricultural tools and implements matter of policy. However, globalization and the growing importance of agreements reached under the aegis of the World Trade Organization make such protectionism increasingly difficult.

Local manufacturers will generally use

high-grade materials when they are readily and reliably available at reasonable prices. This may require a government policy to ease the import barriers that often still exist, despite trade liberalization. For example, in some countries, high government import duty on steel has been an economic handicap for the local production of farm implements at prices that are accessible to smallholder farmers. The import duties are levied on an across-the-board basis and usually on the assumption that the steel it is destined for the building trade, a relatively prosperous sector compared to small-scale agriculture. Perhaps governments could adopt of a system of rebates of import duty for manufacturers of agricultural tools and implements when they can show how they have used the steel.

Furthermore, in some SSA countries, complete implements that are imported attract a lower import tariff than raw steel, another major handicap for local manufacturers.

In the light of the above, it seems that the most important measures that governments could take to facilitate national manufacture of farm tools

and implements would be:

- Ensure the regular supply of good quality materials, notably steel, at a competitive price. As mentioned, this implies that import tariffs on such materials should be regulated, or abandoned, to enable locally-made products to compete financially with their imported equivalents.
- Protection of the local market against the import of inferior products through a more effective policing of quality (see sections 7.3.2 and 7.3.3).

### 7.3.2 Quality assurance and national product Standards

The purpose of quality Standards is to ensure that manufacturers correctly use high grade materials and techniques to produce a reliable product with a good service life, assuring consumers of the 'fitness for purpose' of the item on sale (Inns, 1995). Standards generally serve to bring together the best existing design and construction practices; they should reflect best existing practices without attempting to get ahead of them.

The two most important standards that are applied to tools and equipment for smallholder farmers are their dimensions and the quality of materials. A test procedure may also be included as a way of assessing the functional characteristics. By way of illustration, these are shown in Box 7.3, which is a specification for a hand-hoe. Quality assurance and specifications/standards, to serve as a guide to end users, can also be developed for other technologies.

It may seem that Standards, by definition, are desirable, but it should be noted they can also stifle innovation. For example, developing mechanization for small-scale farmers, as proposed in this publication, would include the innovative design of hand tools, and it would clearly be most unhelpful to disqualify design improvements simply because they did not confirm to national Standards. It also seems that Standards have the potential to exclude modifications for the special needs of specific groups. In the hand-hoe example given, the weight may be excessive for women, who are its principle users. Evidence suggests that women prefer hoes that are lighter than 1 kg for weeding, and so, if the Standard were applied, they would have to wait for a worn-down tool before being able to work with less fatigue. The debate on the desirability of Standards is a matter of judgement for policy makers.

#### BOX 7.3

#### Specification for a hand-hoe Standard (after Armstrong, 1980)

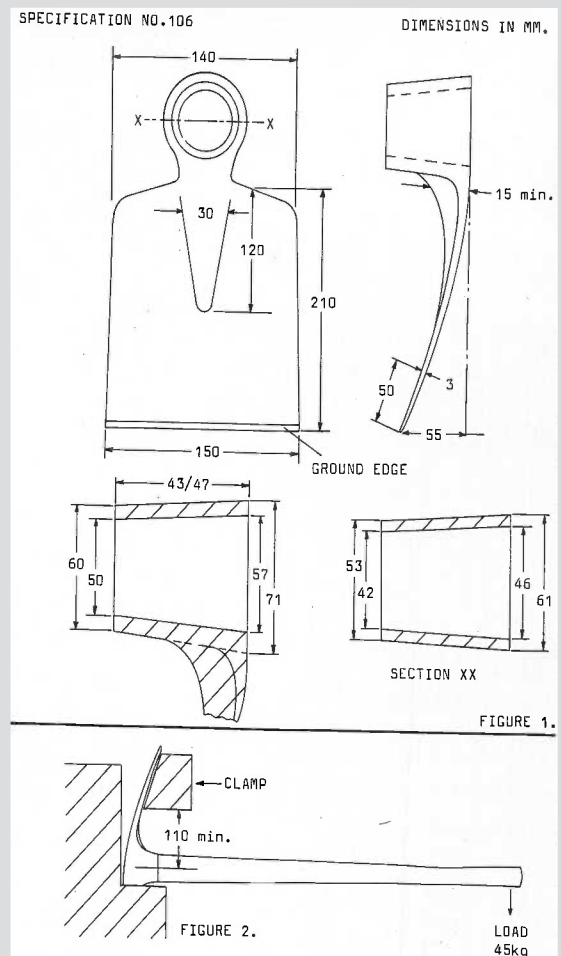
**Weight:** 1.5 kg (+10%, -5%)

**Steel:** C (0.4/0.5%); Mn (0.5/0.8%); P (0.05%, max); S (0.05% max)

**Heat treatment and hardness:** lower part hardened and tempered up to half way up the blade. 40/46 Rockwell C.

**Construction:** Forging to be symmetrical and free from flaws. Eye to be smooth internally and uniformly tapered. Must lie centrally. Cutting edge ground sharp.

**Strength test:** Clamped as in Figure 2 (below), apply 45 kg gradually and maintain for 2 min. On removal there should be no damage, loosening or permanent set.



*Critical dimensions and test procedure*  
Source: Armstrong, 1980

### 7.3.3 Consumer protection

The story of the Cock brand hoes<sup>10</sup> that are possibly fake and being imported into Eastern and Southern Africa was mentioned in section 2.2.2. It is difficult for a farmer to distinguish different quality of materials in hoes, or in any other tool or implement. Furthermore, local suppliers seldom replace broken equipment. So, the application and enforcement of a hoe Standard would protect the consumers' interests. The reality seems to be, however, that the acceptance of trade liberalization, coupled perhaps with the lethargy often associated with some government departments, means that there is little realistic likelihood of Standards being used to protect consumers. In an attempt to guide farmers and retailers in their choice of hand-hoe, or *jembe*, FAO produced the poster design shown in Figure 7.1. After testing in rural communities, it is planned to reproduce the posters in local languages and display them prominently in areas where there is trade in hand-hoes. Similar posters for other technologies should be developed, where appropriate, to guide end users.

### 7.4 DISTRICT-LEVEL INITIATIVES

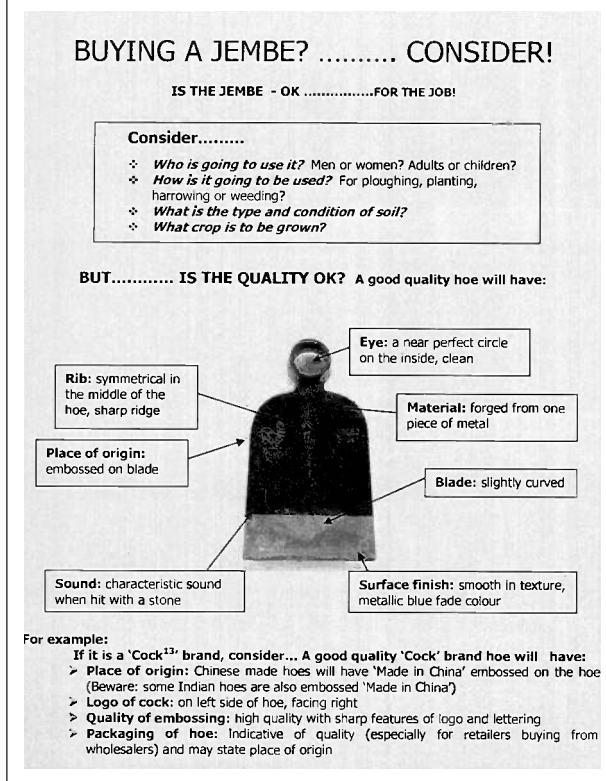
Once a national policy has been established to promote farm power and mechanization for smallholder farmers, effectively recognizing them as a national priority, action plans will need to be formulated and executed at district level. The issues highlighted in section 6.2 should be taken into consideration during mechanization planning and the selection of the appropriate options. Further issues and challenges in mechanization planning were highlighted in the check-list in Box 7.2.

#### Remember:

*The process of mechanization is not neutral. There are many stakeholders, ranging from individual farmers, artisans, and retailers to businesses within the regional and national economy. It is essential to identify and bear in mind who the beneficiaries of mechanization are, who can afford it, and who will be disadvantaged. Furthermore, are new opportunities being created? If so, for whom?*

<sup>10</sup> There are several legitimate factories of Cock brand hoes in the People's Republic of China and these are imported into SSA. But there are also counterfeit Cock brand hoes emanating from other markets (Holtkamp, 2003).

FIGURE 7.1  
Poster to guide farmers and retailers  
in the selection of hand-hoes



(Mention of this particular brand name does not imply endorsement by FAO)  
Source: Bishop-Sambrook, 2003

#### 7.4.1 Participatory development and evaluation of technology

The most important message to impart to people at district level who are working with farming families is: *Do not impose technology by following the traditional top-down model.*

Participation of all stakeholders is essential in the development process – lip service will not do! Following the strategy discussed in Chapter 6 will give a high probability of:

- making available technology that answers a priority local need and, therefore, has a high likelihood of being adopted;
- encouraging local manufacturers and artisans to have a closer relationship with the farming community, thereby becoming able to respond to their needs more readily;
- improving the livelihoods of all stakeholders ... farm families, manufacturers, distributors, and repairers;
- ensuring that equipment produced is compatible with locally available power sources.

## 7.5 THE PROCESS OF MECHANIZATION PLANNING AND STRATEGY FORMULATION

The main purpose of formulating a mechanization strategy is to create an environment in which agricultural mechanization will develop from the existing situation to a desired future state. The strategy is formulated paying specific attention to the roles of government and the private sector. The output is a suite of policy and institutional recommendations, supported by programmes and by projects, when appropriate (Bishop, 1997).

Initially, the district-level team driving the strategy must be familiar with the present situation: What are the principal farming systems and their use of farm power, tools and equipment? What are the current manufacturing activities and distribution system? What are the opportunities for repair and maintenance services? And so on.

Next, the strategy team and the stakeholders must plan and establish a vision of the future and determine how these future mechanization requirements will be fulfilled. Figure 7.2 illustrates the stages that can be followed during the planning process.

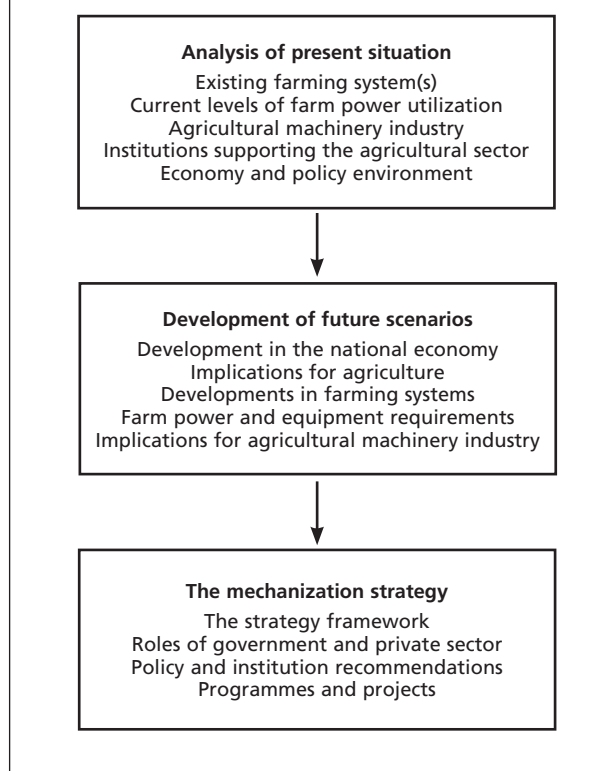
## 7.6 PROVISION FOR EMERGENCIES AND CASES OF PARTICULAR HARDSHIP

Poor households that are continuing to lose labour as a result of sickness and/or migration are particularly vulnerable; they run the risk of ever decreasing production, with less food and less income, a decline that may become irreversible and have tragic consequences. District development plans may attempt to address the problem of such families as an emergency, and therefore, some guidance on possible strategies is relevant here.

In some areas of SSA there is a situation of 'chronic emergency'. This is created by one or more of several destabilizing factors: civil strife, floods, drought, climate change, disease – especially HIV/AIDS – and others. Because of this chronic emergency situation, there is a need to consider assistance to farm families with poor asset bases that goes beyond the usual 'more hoes and more seeds'. Obviously, debilitated human capital will not be able to use more hoes, so other interventions must be initiated at the district level.

It is illogical to suppose that vulnerable families with eroded asset bases could contemplate investment in labour saving technology with their own resources. In these cases, other possibilities should be explored in participation with the communities affected (Bishop-Sambrook, 2003

FIGURE 7.2  
Stages in the formulation of a mechanization strategy  
(after Bishop, 1997)



and 2005). Initiatives that could be considered are:

- Support for the formation and functioning of self-help groups or labour brigades. The main purpose of these would be to ensure that crop production continues at times of severe stress, such as caring for the sick or after bereavement.
- A development of the previous concept is the formation of groups to hire farm power, whether from animals or tractors. Such groups will require training, access, and a payment mechanism.
  - Provision of grants or vouchers to households for hiring farm power services and other labour saving technologies, e.g. carts for fuel-wood and water collection (Box 7.4).
- Help prolong the active and productive life of people afflicted with HIV/AIDS through the supply of drugs and medicines, food, and health care instruction.

## 7.7 CONCLUDING REMARKS

It cannot be repeated too often that farm power is a critical issue in sub-Saharan Africa. Without paying due attention to it, along the



**BOX 7.4****Vouchers for seeds and farm power in emergencies**

During the rehabilitation phase after an emergency situation, a lack of seed may threaten the establishment of future food crops. This can be because of the loss of seed stocks – perhaps starving families had to eat them; a fall in quality of seed available; or a disruption of local markets. One measure to overcome such a situation has been pioneered by the NGO Catholic Relief Services (CRS): it is the establishment of seed fairs.

A seed fair is a market where households purchase the seed that they choose through a voucher system. This is in contrast with donating seed and other inputs, which is the traditional way of administering emergency relief. The fair is announced on a specific day at a specific location, and vulnerable households are issued with vouchers worth a specific cash value. These are used to buy seed from registered sellers in the community. The same approach has been used

for hand tools. In this way, farmers choose what they want – not what an external donor thinks that they should want. In addition, the local community participates fully, and so local trade is stimulated. CRS has been able to make seed available to many thousands of disaster affected families in five east African countries in this way.

A similar approach has been tried by FAO for farm power inputs in Serbia. Until a full cropping season has passed, it will be too early to say with certainty how effective the scheme has been. However, in essence, the scheme works as follows:

A set of vouchers for cultivation and irrigation services is issued to each potential beneficiary. Each voucher is worth either one cultivation or one irrigation of 1000 m<sup>2</sup> of land (so 10 vouchers are good for 1 ha) and is handed to the service provider when the work has been done (Gordon Biggar personal communication). A similar system can be envisioned that would supply farm power, using DAP and tractors, to smallholder farmers in emergency situations in SSA.

lines described in this document, agricultural productivity in the smallholder sector will continue to stagnate, or more probably decline further because of the increasing labour constraints that have been discussed here. The implications for Africa's hundreds of millions of people already living in poverty, and for the Continent as a whole, are horrific to contemplate.

Unfortunately, a wasteful and frustrating aspect of the farm power problem in SSA is that international aid programmes for mechanization continue to import large amounts of equipment that is not suited to the specific SSA circumstances. This adds to the graveyard of junked machinery for which the only use is as a source of good raw material. But the errors could easily be avoided by the proper selection of equipment to be imported, based on all of the participatory, technical, ergonomic, economic, and socio-cultural approaches that have been mentioned in this publication:

The conclusion from so much work done on the ground in SSA by the authors of this publication and by others is that DAP will probably be the most appropriate and sustainable source of power under small-scale farming conditions, at least for the foreseeable future. Its ownership requirements are less demanding than that of tractors. Repair and maintenance services for tractors are not readily

accessible in most rural areas, whereas draught animals can be sourced within rural areas, and the basic repair services for implements are available from local artisans. DAP offers opportunities for entrepreneurship through hiring out of DAP services, especially for transport.

However, DAP from bovines cannot be used in some regions of SSA where diseases affecting them are prevalent, or because of socio-cultural norms. Donkeys could perhaps be a viable alternative, but in any event, for these and other reasons described earlier, human muscle will continue to predominate as a power source on smallholder farms for years to come. The most efficient possible use of that human power source is of paramount importance. Certainly, greater efficiency could be achieved through judicious ergonomic work to design more effective hand tools for different types of farm worker under various working conditions.

Probably the most important option for smallholder farmers in SSA, however, lies in reducing the requirements for farm power through systems such as conservation agriculture, which allows the most energy-demanding tasks of land preparation and weeding to be avoided almost entirely. It can be powered by humans, animals, or tractors, and it protects and enhances the natural resource base. However, as mentioned earlier, the



promotion of conservation agriculture and its mechanization options in SSA will require political will and policy decisions, coordinated public and private sector support and action, and orientation and training for small-scale farming families.

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## FAO AGRICULTURAL AND FOOD ENGINEERING TECHNICAL REPORTS

- 1 Production and processing of small seeds for birds, 2005 (E)
- 2 Contribution of farm power to smallholder livelihoods in sub-Saharan Africa, 2005 (E)
- 3 Farm power and mechanization for small farms in sub-Saharan Africa, 2006 (E)

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## Chapter 1

# Introduction

### 1.1 BACKGROUND

The eradication of extreme poverty and hunger is the first of the United Nations' Millennium Development Goals. By 2015, as a first step, the objective is to have reduced by half the proportion of people living on less than a dollar a day, and also to have reduced by half the proportion of people who suffer hunger, in line with the World Food Summit Resolution of 1996.

In sub-Saharan Africa, the escalating levels of poverty and underdevelopment, and the continued marginalization of the African continent in general, constitute enormous challenges that call for urgent and energetic actions if the 2015 objectives are to be met. Indeed, the prospects for doing so are already looking grim, with the UNDP Human Development Report of 2003 stating that the 2015 objectives would probably only be attained well into the 21st century in sub-Saharan Africa (SSA).

It was precisely because of this gloomy outlook and the need for energetic action that a number of African leaders, and the OAU, took the initiative of creating the New Partnership for Africa's Development (NEPAD). This amounts to a radical intervention, spearheaded by African leaders, to develop a new vision and strategic framework for that will ensure Africa's renewal.

Agriculture is one of NEPAD's six priorities, and agriculture is seen as the engine of NEPAD-inspired growth, beginning with the aims of improving the livelihood of people in rural areas, achieving food security, and increasing exports from the sector. It is explicit in NEPAD's strategy that growth in the agricultural sector will stimulate growth in other economic sectors.

Agricultural productivity needs to be greatly enhanced if the sector is to play the role expected of it by NEPAD. Some figures illustrate the magnitude of the challenge being faced. NEPAD's documentation states that in 1997–99, there were 200 million chronically hungry people in Africa, representing 28 percent of the total population. Furthermore, the situation is deteriorating, for in the seven or so years (from 1990–92) leading

up to 1997–99 there was an increase of 27 million hungry people.

During the 1990s, only ten African countries reduced their number of chronically hungry people. At the end of the 1990s, 20 percent of the population in 30 countries were undernourished, while in 18 of those countries, as much as 35 percent of the population was similarly afflicted. In 2001, 28 million people were facing food emergencies.

Since the 1960s, food imports into Africa have been rising steadily, and the continent became a net importer of agricultural produce in 1980. Agriculture in Africa employs 60 percent of the labour force and produces just 20 percent of exported merchandise, while it was 50 percent in the 1960s.

NEPAD sums up its view of the importance of the agricultural sector in these words:

*Until the incidence of hunger is brought down and the import bill reduced by raising the output of farm products, which the region can produce with comparative advantage, there is no way in which the high rates of economic growth to which NEPAD aspires can be attained.*

(From the summary of NEPAD Action Plans)

### 1.2 THE CRUCIAL ROLE OF FARM POWER

The review and guidelines presented in this publication are the result of several recent studies on the farm family power situation in small-scale agriculture in sub-Saharan Africa (SSA). These reports reconfirm many earlier studies to the effect that the farm power situation is deficient almost everywhere and that urgent measures are needed to correct it. In fact, the increases in agricultural productivity required in SSA to meet the MDG and NEPAD objectives will not be achievable without giving very serious attention to the issue of family farm power in small-scale agriculture.

Farm power is a vitally important component of small farm assets, and a shortage of it lies at the heart of many of the problems of small-scale farming in SSA. If the major constraint of farm power cannot be lifted, there will be little



increase in agricultural productivity, stagnation in farm family income, more hunger, and less food security. Nor will it be possible for agriculture to become “the engine of NEPAD-inspired growth” that will also “stimulate growth in other economic sectors”. In brief, unless the farm power shortage is overcome, there is a danger that rural people in SSA will face a further slide into poverty and hunger, while their national economies remain stunted. Studies in SSA (Bishop-Sambrook, 2005; Kienzle, 2003; Ribeiro, 2004) have revealed in a graphic manner that unless the issue of farm power is addressed in a practical way, with solutions that are accessible to small farmers, the region is at risk of increasing poverty and hunger.

Labour shortages in the agricultural sector of SSA have been a growing problem in recent decades. One factor creating those shortages is migration – mainly of men – to seek work in towns because their farming activities have been unable to provide a decent livelihood for them and their families.

A second factor is HIV/AIDS, which started out as a mainly urban problem in SSA, initially affecting more men than women, and those with relatively high incomes. Now, however, it has moved rapidly into the rural areas. It is estimated that by 2020, the epidemic will have claimed the lives of 20 percent or more of all those working in agriculture in many Southern African countries (FAO, 1995). Clearly, since AIDS mostly devastates the productive age group – people between 15 and 50 – it has a severe effect on a household’s labour availability, and hence on its productive capacity. But it is not only the loss of life to AIDS that affects labour availability and agricultural productivity. Some of the other effects of the AIDS epidemic are: AIDS sufferers often cannot work during bouts of related sickness and need care and support from another household member; once households experience labour shortages caused by AIDS, they are often unable to participate in the labour groups that are commonly mobilized for key farming operations; and finally, in extreme circumstances, households sell their productive assets, such as draught animals, tools, and implements, to raise cash (FAO, 1995).

Another serious problem affecting agricultural productivity in SSA is that of soil degradation. The level of degradation varies considerably across the region and is difficult to quantify. However, some figures for soil erosion in Ethiopia

have been documented, ranging from 16 to 300 tons of soil per year being washed away, with an average for the country of over 40 tons/year on cultivated land (Hurni, 1988). A World Bank/FAO study four years earlier estimated that even if the erosion rate were halved, there would still be a 2 percent per year reduction in total grain production in the Ethiopian Highlands. Erosion also carries away plant nutrients, as does cropping without replacing soil nutrients with fertilizer, sometimes termed “mining” of nutrients.

An influential body of opinion holds that the fertility of soils in SSA is declining, and it is true that crop yields per hectare are falling. However, there can also be political and social reasons for this, as well as the expansion of crop production into less favourable areas. There is considerable debate on the subject (DDPA, 2005; Campbell, 2005). Nevertheless, there is abundant anecdotal evidence in many parts of Africa from smallholder farmers themselves who state that they are obtaining much smaller yields from a particular plot than were being obtained by their fathers and grandfathers.

There can be little doubt that conventional methods of farming, with much soil disturbance for seedbed preparation, leave the soil prone to erosion. Conventional soil tillage also speeds the depletion of soil organic matter and nutrients, contributing to soil degradation. Any interventions concerning farm power and farming systems need to take into account the issue of soil degradation; at very least, they must contribute to halting the degradation process, or better still, to reversing it.

### **1.3 MECHANIZATION FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT**

Agricultural mechanization has been defined in a number of ways by different people. Perhaps the most appropriate definition is that it is the process of improving farm labour productivity through the use of agricultural machinery, implements and tools. It involves the provision and use of all forms of power sources and mechanical assistance to agriculture, from simple hand tools, to animal draught power (DAP), and to mechanical power technologies.

Mechanization is a key input in any farming system. It aims to achieve the following:

- improved productivity of labour;
- a reduction of drudgery in farming activities, thereby making farm work more attractive;

- an expansion of the area under cultivation where land is available, as it often is in SSA;
- increased productivity per unit area as a result of improved timeliness of farm operations;
- accomplishment of tasks that are difficult to perform without mechanical aids;
- improvements in the quality of work and of products.

Based on the source of power, the technological types of mechanization have been broadly classified as hand-tool technology, DAP technology, and mechanical power technology. Sophistication, capacity to do work, costs, and in some cases precision and effectiveness, determine the levels of efficiency that can be achieved in each system.

One of the major reasons for the disappointing performance and contribution of mechanization to agricultural development in SSA has been the fragmented approach to it (Rijk 1989; Mrema and Odigboh, 1993, Simalenga 1997). This often arises from poor planning and an over reliance on mechanization inputs that are provided as aid-in-kind from donors and prove unsuitable for local conditions. Poor co-ordination within and between government agencies and the private sector dealing with mechanization have compounded the problems. The formulation of national agricultural mechanization strategies can help to overcome these constraints. A holistic or system analysis approach is required in the planning process, and all the key players in the economic and cultural environment in which development is to take place must be considered.

The type and level of mechanization in a particular area should initially be guided by the producers of mechanization inputs, both to suit their business and to meet their clients' particular needs and circumstances. However, the process of making mechanization choices should bring farmers in as the focus of policy, planning, and development.

#### 1.4 THE SCOPE AND PURPOSE OF THIS PUBLICATION

The purpose of this publication is to provide information and guidelines for policy makers in agricultural and rural development and for regional and district staff with responsibilities in this area. The Executive Summary will perhaps be the most appropriate for policy makers, while the rest of the publication provides more detailed information and guidelines for planning and implementing farm power and mechanization initiatives.

#### BOX 1.1

##### **Mechanization: the salient points**

Agricultural mechanization is not an end in itself; it is an input in agricultural production and rural development.

Mechanization is NOT only tractors and other mechanically-powered equipment. Tractor power is just one of the options in mechanization, which involves the use of all manner of tools, equipment and machinery.

The most appropriate machinery and power source for any operation depends on the work to be done. However, the affordability, availability and technical efficiency of the selected option need to be established and taken into account in the planning process.

In sub-Saharan Africa, some of the successful mechanization introductions have used draught animal power (DAP).

The sustainable development of mechanization depends on the existence of markets where prices guide the supply and the demand of equipment.

The power sources and operations covered in this document are the following:

- human, animal, and tractor power sources
- land preparation, weeding, ridging, crop harvesting, and threshing
- small-scale irrigation technology based on human-powered water pumping.

The publication does not address the whole spectrum of farm power and mechanization options for smallholder farmers in SSA. Such a document would need to be greatly expanded and would include pest control, crop processing, transport, and irrigation, as well as a consideration of alternative power sources, such as water, wind, and sun.

The document is structured to provide an overview of farm power and farming systems in sub-Saharan Africa (Chapter 2), followed by an examination of how farm power affects agricultural productivity and rural livelihoods (Chapter 3). These considerations set the scene for a discussion on technological options in farm power, covering means of increasing its availability but also of reducing the need for it through agricultural production systems that call for low inputs of energy (Chapter 4). The household-level financial and economic implications of farm power options are then explained (Chapter 5), followed

by a description of participatory approaches to mechanization planning and evaluation (Chapter 6). The publication ends with policy and operational guidelines, and also considerations for creating an enabling environment for fostering solutions to the problems power on small-holder farms in SSA (Chapter 7).

## Farm power and mechanization for small farms in sub-Saharan Africa

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Many previous publications on farm mechanization, draught animal power, hand tool technology, etc. have tended to be narrowly focused. They dealt with tractors, or with draught animal, or with intermediate technology. The topic of farm power and mechanization also tended to be separated from the actual process of growing crops. As a result, there was a widespread lack of understanding of the topic and there were many widely held misconceptions regarding the essential contribution of farm power and mechanization to small farmers' livelihoods and living conditions.

This manual breaks away from this rather narrow approach by putting the different sources of farm power, mechanization, machines, equipment and tools into a much broader context. Farm power requirements need to be viewed with reference to rural livelihoods and to farming systems as well as to the critical area of labour saving in HIV/AIDS-hit populations. No one particular type of technology is advocated. The publication considers the broad picture and the options that may be most appropriate. This manual provides an overview of options for farm power and technologies that could be suitable for smallholder farmers who are trying to make decisions with regard to the different types of farm power sources available. It also lays out the importance of the farming systems and the economic context within which mechanization takes place. Special emphasis is given to economics and finance as well as to the environmental impact of inappropriate mechanization.