Conservation Tillage with Animal Traction

A Resource Book of Animal Traction Network for Eastern and Southern Africa (ATNESÁ)

Edited by P.G. Kaumbutho and T. E. Simalenga

MAWRD

Conservation Tillage
with
Animal Traction
A Resource Book
of
Animal Traction Network for Eastern and Southern Africa (ATNESHA)
Edited by
P.G. Kaumbutho
T. E. Simalenga
An ATNESHA publication
made possible by the assistance of
French Mission for Co-operation and Cultural Affairs in Namibia
through
Ministry of Agriculture Water and Rural Development of Namibia (MAWRD)

Citation of this publication:

The opinions expressed in this book are those of the respective authors and/or editors. They do not necessarily reflect the views of ATNESHA or the organizations that sponsored this publication.

Publication sponsored by: French Mission for Co-operation and Cultural Affairs in Namibia

Published on behalf of:
The Animal Traction Network for Eastern and Southern Africa (ATNESHA) by:

Book preparation to Camera Ready copy by P.G. Kaumbutho with the kind assistance of Fred Ochieng and Zena Ngorongo, Kenya Network for Draught Animal Technology (KENDAT) P.O. Box 61441, Nairobi. Kenya. Tel/Fax +254-2-766939 Email: KENDAT@Africaonline.co.ke

Cover Pictures: "Faces" of Conservation tillage in Namibia by P.G. Kaumbutho
Preface

The material presented in this book arose from an Animal Traction Network for Eastern and Southern Africa (ATNESA) Workshop titled: “Conservation Tillage with Animal Traction for Soil-Water Management and Environmental Sustainability” hosted by the Namibia government through the Ministry of Agriculture, Water and Rural Development (MAWRD) and held at Rundu, Namibia, in October, 1998. The workshop was co-sponsored by various organizations and its success was made possible by the hard work of many different people, of which the ATNESA steering committee and the workshop hosts will remain most appreciative. The local organizing committee was composed of officials from MAWRD, the University of Namibia, and the Rural Support Development Programme (RSDP) and ATNESA. A report of the workshop is available from both MAWRD and ATNESA. Deep appreciation is due to the Division of Agricultural Training and Mashare Agricultural and Research Institute who provided secretariat services and logistical assistance. The efforts of Team Leaders, P.W. Misika, E. Mwenya and E. Namalambo, backed by a most unique government ministry team, will always be remembered.

The workshop secretariat and other core costs of the workshop were provided by: MAWRD, NNRDP - Northern Namibia Rural Development Programme, RSDP - Rural Development Support Programme, Namibia, NOLIDEP- Northern Regions Livestock Development Programme, Namibia among others. Special appreciation is due to Dr. V.P. Shivute, the PS in MAWRD for his support and help in securing the funds. Several participants were sponsored by CTA - Technical Centre for Agriculture and Rural Co-operation, CF - Commonwealth Foundation and some by their own organizations or by agencies within their own countries. To all these, it’s a big Thank you.

The production of this ATNESA Resource Book and the Workshop Report that preceded it was supported by French Mission for Co-operation and Cultural Affairs in Namibia, under a contract to ATNESA. ATNESA provided tireless effort towards timely completion of this book, which joins at least 10 other resource books on this most important subject covering practical ways of empowering smallholder farmers and small-business transporters. The books are a true resource in this multi-disciplinary, multi-sector, individual and organizational initiative of sensitizing and main-streaming a most sustainable and versatile power source: animal traction. The books help in many ways and add flavour to the joyful art of networking by documenting the sharing of expertise, experience and practical solutions to everyday rural level livelihood problems. Often, it is the simplicity of the solutions available, that carries their efficacy.

Here is to better lives for our rural citizenry, the vulnerable and the humble, who do so much for their families and countries, in quiet corners of our God-given resource base.

May our farmlands be protected through conservation tillage systems and techniques, among other, ongoing initiatives, to preserve the environment.

It's for the children. It's for future generations, who probably deserve better than we have had …

Lets do it together…!

Table of contents

Preface

1.Overview of conservation tillage practices in East and Southern Africa by P.G. Kaumbutho, G. Gebresenbet and T.E. Simalenga

2.Conservation tillage with animal traction for soil-water management and environment sustainability in Namibia by Percy Misika and Emmanuel Mwenya


4.Investigating into soil fertility in the North Central regions by C. Rigourd and T. Sappe
5. Effect of socio-economic and gender issues on sustainability resource management by J.K. Rwelamira

6. Conservation tillage research and development in South-Africa by Richard Fowler

7. Role of draft animal power in Ghanaian agriculture by E.Y.H. Bobobee

8. Indigenous soil conservation tillage systems and risks of animal traction on land degradation in Eastern and Southern Africa by R.M. Shetto

9. The role of animal traction in soil and water conservation tillage practices among smallholder farmers in Malawi by W.F. Kumwenda

10. Socio-economic and gender issues in draft animal technology: A lady Farmer’s Commentary by T.B. Ngamau

11. Relationship between depth of tillage and soil physical characteristics of sites farmed by smallholders in Mutoko and Chinyika in Zimbabwe by R. Tsimba, J. Hussein and L.R. Ndlovu

12. Indigenous conservation tillage system in East Africa with an example of their evaluation from South West Tanzania by R. Kayombo, J. Ellis-Jones and H.L. Martin

13. Conservation tillage for sustainable crop production systems: Experiences from on-station and on-farm research in Zimbabwe (1988-1997) by Isaiah Nyagumbo

14. Soil fertility and minimum tillage equipment’s trials in the North Central, Namibia by C. Rigourd, T. Sappe and P. Talavera

15. IMAG-DLO and conservation tillage: Activities and Experiences by C. Kaoma-Sprenkels, P.A. Stevens and A.A. Wanders

16. Efforts and initiatives for supply of conservation tillage equipment in Zambia by Isaac Sakala

17. Conservation farming with animal traction in smallholder farming systems: Palabana experiences by Martin Bwalya

18. Minimum tillage for soil and water management with animal traction in the West-African region by Alioune Fall and Adama Faye

19. Soil-water and conservation tillage practices in Lesotho: Experiences of SWACAP by Letla Mosonene

20. Socio-economic and gender issues affecting the adoption of conservation tillage practices by F.B. Lubwama


Annex: ATNES A AND NETWORK CONTACTS

"The overall balance of success in combating soil degradation throughout the world is unsatisfactory. We can even talk about a worrying trend since not only the quality but also the quantity of soil - the basis of our lives - is continuing to dwindle. Apart from regional improvements, often achieved at considerable financial expense, we can say that the soils in many regions of the world are continuing to degrade. The consequence of this is that efforts to implement site-appropriate, sustainable forms of agriculture and for the development and trials of new, innovative approaches will have to be further intensified"
Overview of conservation tillage practices in East and Southern Africa

by

P.G. Kaumbutho¹
G. Gebresenbet²
T.E. Simalenga³

¹ Kenya Network for Draught Animal Technology (KENDAT), P.O Box 61441 Nairobi Kenya
² Swedish University of Agricultural Sciences, Box 7033. S-750 70 Uppsala Sweden
³ University of Fort Hare, Private Bag X1314, Alice 5700, South Africa

Abstract

Smallholder agriculture in East and Southern Africa (ESA) has special gains to gather from the agricultural mechanization endeavour, which is at different levels in different countries and which remains a major challenge for governments and farmers alike. While tractorization programmes in the region have hardly served the power supply needs of smallholders, animal traction has proved itself as a dependable and versatile source of agricultural power for tillage and transport. While soil and water conservation efforts in the region are not new, tillage for soil and water conservation has seen many shortcomings, ranging from professional redress to technological limitations, institutional support and socio-economic bottlenecks. Conservation tillage has been practised in largescale farms of the region for a while and is now receiving new focus for smallholder agriculture, within a new re-awakening in the interest of soil, water and general environmental preservation. The region is losing as much as 290 metric tonnes of soil per hectare per year and faces an average population growth rate of 3.2%. This situation does not augur well in a region which is facing agrarian stagnation though endowed with a wide range of economically utilizable, but derapidating natural resources. Various research, extension and development work has proved the gains of conservation tillage. The gains are however yet to become common knowledge and translated to utilizable techniques adopted en masse. The traditional ways revolving around tedious and high drudgery manual operations persist. New, specialized and relatively simple conservation tillage equipment is yet to challenge the common and destructive mouldboard plough which is used as a multipurpose tool by smallholders. For real and fast progress, future efforts must centre around end user led, aggressive promotional, networked activities that avoid the low impact and duplicated top-down efforts of the past. A culture of environmental consciousness needs to be developed as a way of getting conservation tillage to the fore. The issue to be addressed is how to balance the inputs required so as to maximize efficiency and cost-effectiveness of inputs, reduce risks of soil and environmental degradation, maximize the per capita productivity, and maintain or sustain an increasing trend in productivity. With regard to technology output, the range of equipment including simple light-weight tools which can be used with donkeys (preferred by women) as well as capacity to package them for completeness needs to be explored. Packages will make it possible to exploit the complementary capacities of animal traction. Such packages will bring about the much needed entrepreneurial creativity to make farmers implements serviceable as well as available for hire by those who cannot afford to own them. Among the recommendations made are farmer-centered, on-farm, participatory promotion methods and publicity, for sensitization, and environmental education; marrying traditional knowledge, ideas and practice, while addressing accompanying fears of users; farmer exchange visits; identifying suitable equipment and promoting the same nationally and regionally; field testing by farmers in multi-disciplinary and multi-sectoral research, geared towards quantifying the real gains of conservation tillage. Technology transfer efforts need to capture environmental protection through gender-sensitive soil management techniques and planning. Other complementary approaches like agro-forestry and water harvesting practices need to be brought on board if the socio-economic well-being of all parties is to be fully supported. Back-up support will include appropriate level capacity building at institutional and small industry level.

Introduction
1.1 Conservation tillage: an important worldly subject

The problem of soil water losses through surface runoff and evaporation is one of the major limiting factors in agricultural production today. Especially in arid and semi-arid lands, short intense storms coupled with prolonged dry spells make crop production difficult, if not impossible. A rainstorm brings about soil water conservation considerations, within the context of the surface storage, infiltration and water holding capacity of the soil and the capacity to minimise evaporation losses especially through the dry periods.

Tillage is defined as the mechanical manipulation of soil for any purpose. Manipulation involves soil disturbance and this can have great deteriorative consequences if not carefully or adequately incorporated. Tillage modifies the soil surface where the complex and crucial partitioning of rainfall into runoff, infiltration and subsequent evaporation. Tillage modifies soil surface structure, total porosity, macro-porosity, pore continuity and pore size distribution and therefore has great influence on the hydrology of an agricultural catchment (Mwendera, 1992).

Tillage influences the upward movement of moisture to the soil surface, vapour transfer from the surface to the atmosphere and heat transfer to the soil. Tillage therefore affects soil water evaporation and will do so differently in arid and humid environments. The properties of the plough layer and particularly the surface characteristics are time variant. Models of soil water transport can and have been used to help understand the effects of tillage (Klute, 1982).

Conservation tillage (Contil) is but one aspect of global, regional and national interest and importance in environmental conservation. For East and Southern Africa (ESA) the subject has special importance, considering that it touches directly on agricultural production and more so, in the majority semi-arid and arid tropics, which carry over 50% of the population. Additionally, ESA has about 80% of the population involved in smallholder agricultural production, utilizing traditional means of land preparation. The region also has some of the world's poorest population and it is unlikely that such people can have time for environmental preservation among other pressing needs, in a life of uncertain food security.

This situation makes Contil work and development in ESA to be incomplete, unless it addresses somewhat unusual or extra-thematic issues which are non-technical, economic and socio-political. Compared to the mechanized high input agriculture of the western world, conservation tillage in the tropics of sub-saharan Africa must be considered much more broadly, even if just to accommodate the highly variable eco-system.

Between the semiarid and arid planes of Namibia and the highly humid highlands of Cameroon and every climate and soil condition in-between, ESA is indeed a region of contrast. The region presents a highly defined ethnic and loosely structured and variable socio-political and other development scenario, which is highly influenced by practices or issues such as land tenure, pastoralism, shift-cultivation and others. Like the rest of Africa, ESA presents a complex system in which to address the Contil challenge. Indeed, in ESA the environment has become everybody's concern as well as frustration. Urban migration, movement to lower potential land in lower altitude locations, among other tendencies has brought in many factors of environmental sustainability, which have placed the region under great threat of total destruction.

In the region, environmental degradation is most likely to be associated with urban areas, while the erosion of large straits of idle semi-arid and arid lands goes un-addressed. High potential land is not spared as can be observed in streams and rivers which remain dark brown, throughout the rain season. Pollution by factories and motor vehicles which have recently been associated with subsequent global warming are small subjects in this region where there always seems to be more urgent problems in economically suppressed political economies.

In the agricultural sector soil and water conservationists have mostly addressed soil erosion and how mechanical approaches such as terracing, can be the answer. More recently, agroforestry efforts and promotion have brought in the tree as a structural aid and a source of biological wealth to the otherwise degraded land. The agroforestry approach has progressed a step into multi-disciplinary and multi-sector approach to agricultural land management. It also built on the indigenous techniques of soil conservation practiced for centuries by smallholder farmers in humid areas.
In less obvious ways, agricultural soil degradation and water losses have hardly been associated with tillage, its drudgery and power requirements. Tillage however remains, a great contributor if not the prime cause of soil degradation and erosion. In some ways the absence of special consideration for tillage as a prime issue may be associated with the young agricultural engineering profession in the region.

Traditional manual tillage or higher level, animal draft technologies have remained void of common-knowledge awareness of the importance of tillage and its practice. Technologically, neither the common hoe, nor the animal drawn mouldboard plough have offered much choice or creativity with regard to tillage. In largescale farming and especially so for wheat farmers, modern tractor based tillage has seen a wider level of choice, knowledge and creativity as these farming systems have borrowed directly from the developments of the Western World. In this regard, tine implements and single pass, minimum or no-till pneumatic seeders and other implements such as the prickle harrow have been introduced.

For example, in Kenya it is common to see a large scale wheat farmer in Timau area with a bumper wheat harvest when all the smallholders around them have a total crop failure especially in seasons when rainfall is scanty. The large farmers are able to use technology to break their hard pans and, in doing so build giant natural water "tanks", in which they store enough water for the season. At the same time the smallholder farmers, using the hand hoe or traditional animal drawn mouldboard ploughs find themselves busy expelling the little moisture that has been received to the thirsty sunshine. They do this by the traditional heavy soil manipulation in primary or secondary tillage operations.

1.2 The concept of sustainability

The concept of sustainable development emanated from the document developed by three international agencies: World Conservation Union, United Nations Environmental Programme (UNEP), and the World Wildlife Fund (WWF) in 1980 (Dieren, 1995). Later in 1983 the World Commission on Environment and Development (WCED) was established by UN General Assembly "to undertake a global enquiry on the prospect of combining social and economic
development with environmental protection”. It was anticipated that the Commission would work out proposals for long-term environmental strategies which would stimulate a sustainable development in the foreseeable future. The Commission compiled an important document (WCED, 1987) where the concept of sustainable development was formulated as were legal principles for environmental protection and sustainable development. The Commission defined sustainable development as:

"...development that meets the needs of the present without compromising the ability of future generations to meet their own needs..."

Box 2: Sustainable agriculture

The enthusiastic response to "sustainable agriculture" by scientific community and policy makers is due to severe problems of soil and environmental degradation, pollution of water and environment, and over-dependence on non-renewable sources of energy. However, sustainability is often perceived as a moral or an ethical issue which has taken on an emotional air. Consequently, the topic of sustainability has become a political issue rather than a practical science, a religious myth rather than a generalizable concept, and an interesting theme to discuss and debate rather than a measurable system to evaluate and quantify.

In view of perpetual food deficit and severe problems of soil and environmental degradation in sub-Saharan Africa, sustainable agriculture is not necessarily synonymous with low-input organic or regenerative agriculture in this region. Scientifically speaking, ecosystems utilized by human societies are only sustainable in the long-term if the outputs of the components produced balance the input into the system. Because demand for output from agricultural ecosystems is greater now than ever before, and it is rapidly increasing due to high demographic pressure, no-input or even low-input agriculture is a non-solution. The issue to be addressed, however, is how to balance the inputs required so as to maximize efficiency and cost effectiveness of inputs, reduce risks of soil and environmental degradation, maximize the per capita productivity, and maintain or sustain an increasing trend in productivity.

Lal (1993b)

It should be emphasised that the concept has "needs" as the key issue and particularly reaching the poorest parts of the world by eradicating poverty and planning for the needs of future generations by preserving natural resources and protecting the environment.

Following the Commission’s work, a series of international conferences on environmental issues have been held: the UN Conferences of Rio de Janeiro in 1992 and Kyoto (Japan) in 1997 on environment and the development. They were both meant to advance Agenda 21 whose content covers eradication of poverty and protection of environment, with emphasis on sustainable development in developing countries.

Soil conservation is important among global environmental and resource concerns. Sustainability in terms of soil conservation implies utilisation of soil without wastage or depletion, so that it is possible to have a continuous high level of crop production (Schwab et al. 1995). Soil and water resources of our planet are finite and are under already intensive use and misuse. Soil is being eroded at an extreme rate. Cultivated fields, overgrazed pastures, and deforested lands are suffering from erosion. An eroded soil is degraded chemically, physically and biologically. Two main problems are associated with soil erosion:

i. the very fertile top soil is washed away to rivers while,

ii. deposition of erosion is a major source of air and water pollution.

Soil erosion is therefore a potential environmental problem and erosion control is essential in maintenance of crop productivity of the soil as well as to control sedimentation and water
pollution.

2. Background

2.1 The sub-Saharan Africa situation

Sub-Saharan Africa (SSA) has a population estimated at about 382 million in 1982, 433 million in 1986, and 490 million in 1990. At an annual rate of increase of 3.2% per year, the population is expected to approximately triple from 433 million in 1986 to 1263 million by the year 2000. The population may eventually stabilize at 10 times its present number (Table 1).

The region is characterized by a huge diversity of climate, soils, geology, hydrology, topography, ethnic groups and cultural heritage. Using Thornwaite's classification, about 37% of Africa is arid, 13% is semi-arid, 23% is sub-humid, and another 13% is humid. Arid and semi-arid regions are characterized by low, erratic and highly variable rainfall. Depending on these ecological regions, the climax vegetation varies widely depending on the amount and distribution of rainfall.

Total arable land area of SSA is estimated at 131 million hectares (Table 2). The average per capita land area of 0.27 ha is only slightly lower than the world average of 0.33 ha. However, for the expected population of 1478 million by the year 2025, the per capita land area may be as low as 0.09 ha with no additional land brought under cultivation (Table 2), and 0.18 ha if new land is cleared at the rate of 0.6% per year of the existing rainforest (Lal 1993b).

Sub-Saharan Africa (SSA), is undergoing agrarian stagnation, becoming world famous as a region where natural resources are stressed to the limit and the place where food relief efforts have become routine. Concerns of accelerated erosion, desertification, deforestation and other human-driven destruction phenomena have placed SSA under recurrent threat of starvation and malnutrition.

Waterways and reservoirs continue to silt-up as rivers and lakes get polluted. From the agriculture perspective, and when tillage is given the broader meaning of "soil manipulation for any purpose" it is realizable that inappropriate tillage methods remain the major contributors to this trend.

Though loaded with high natural and economic diversity, SSA has 2231 million hectares of land, of which only 6% is arable. Annual rainfall amounts range from zero in the deserts to 5000mm in the highlands and all major soils are present.

Despite various but non-comprehensive efforts put in place at national and regional level ESA gains have been more in terms of economic and political togetherness and less so, by way of communally or regionally arresting environmental degradation. Environment preservation needs to be addressed across the borders as solitary efforts of individual nations simply do not do. It is noteworthy that, in ESA, human capacity is no longer as limiting as a few decades ago. Africa has the human capital needed to develop physical resources. Recent decades have seen the development of manpower with all the skills needed for the broad range of human needs. Technical manpower is especially strong in populous countries, like, Nigeria, Ghana, Kenya and Zimbabwe. In fact, unemployment and under-employment of trained personnel has contributed to mass exodus to European, North America and the Middle East (Lal, 1992).

The greater shortcoming is probably the general sense of environmental sustainability. With the potential adequately exploited, soil resources of Africa are adequate to support an acceptable standard of living for the current and future populations of SSA. FAO (1984) reported (see Table 3) that SSA could support 1120 million people at low levels of input, 4608 million at intermediate levels and 12930 million at high levels of input. The report was written at a time when the SSA population was only 400 million.

Table 1: Projected population of sub-Saharan Africa+

<table>
<thead>
<tr>
<th>Region</th>
<th>1986</th>
<th>1990</th>
<th>2000</th>
<th>2025</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Overview of conservation tillage practices in East and Southern Africa

Table 2: Arable land resources of tropical Africa assuming no further deforestation (calculated from FAO, 1986).

<table>
<thead>
<tr>
<th>Region</th>
<th>Total arable land in 1990</th>
<th>1990</th>
<th>2000</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10^6 ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Africa</td>
<td>62.0</td>
<td>0.29</td>
<td>0.21</td>
<td>0.10</td>
</tr>
<tr>
<td>Eastern Africa</td>
<td>37.7</td>
<td>0.25</td>
<td>0.18</td>
<td>0.08</td>
</tr>
<tr>
<td>Central Africa</td>
<td>10.8</td>
<td>0.20</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td>Southern Africa</td>
<td>20.5</td>
<td>0.29</td>
<td>0.22</td>
<td>0.10</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>131.0</td>
<td>0.27</td>
<td>0.19</td>
<td>0.09</td>
</tr>
</tbody>
</table>

+ Assuming no additional land is brought under cultivation, and that population continues to increase at 3.2% yr\(^{-1}\).

Table 3: Population carrying capacity of Africa for different scenarios (FAO, 1984).

<table>
<thead>
<tr>
<th>Carrying capacity at different input levels</th>
<th>People</th>
<th>Ratio to population of 1975*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low input</td>
<td>1120</td>
<td>3</td>
</tr>
<tr>
<td>Intermediate input</td>
<td>4608</td>
<td>12</td>
</tr>
<tr>
<td>High input</td>
<td>12930</td>
<td>24</td>
</tr>
</tbody>
</table>

* Actual population in 1975 was 380 million.

Despite the high potential and vast resources, it is ironic that the extent of soil and water degradation in Africa is equally alarming. Natural resources are severely degraded because of mismanagement, exploitation for short-term gains and widespread practice of low input
subsistence farming (Lal, 1988, 1990). Resource-based continuous cropping, even at low levels of productivity can lead to an average nutrient loss of 10 kg N, 1.8 kg P and 7.1 kg K ha$^{-1}$ yr$^{-1}$. The rate of nutrient loss is about twice as much in Eastern Africa, and is likely to increase because of the increase in demographic pressure and intense cropping.

Despite common belief, Africa has an impressive history of high-quality research data. Some of this research was initiated in early 1930s. History of research in soil and water management and crop improvement was summarised by Lal (1992).

2.2 The Conservation Tillage System:

The conservation tillage system can be viewed as composed of natural factors, which influence the various human and other capacities to manage soil. In this respect, soil is viewed as a small part of a larger system, made up of natural and management factors. Management factors are strongly influenced by various capacities, which in turn are dependent on the natural factors. Of essence, soil has to accommodate all and various needs imposed on it by both nature and humans.

For example, a soil in say, southern Sudan has certain natural qualities which will determine its conservation input level and needs. The manager may have strengths or weaknesses in capacity to manage soil and may for example need animal traction input and conservation tillage implements which may or may not be available. The same farmer may have the animals and equipment but have shortcomings in design, training, maintenance and other capacities. These capacities may be limited due to natural, technological or socio-economic factors. This vicious cycle may explain why conservation tillage is such a complex and multi-sectoral involvement.

Figure 1. The conservation tillage system

Natural factors can be visualized as:

- History and trends,
- Cultural complexities such as values, societal and gender-based roles,
- Weather and climate,
- Topography and cover,
- Soil type and distribution and
- Other phenomena such as global warming.

Capacities can be visualized to be:

- Experience and information,
- Training (formal and informal),
- Socio-economic well-being,
- Technology quality and accessibility,
- Research and extension and
- Government and non-Governmental institutional support including policy.

Management factors are such as:

- Role of people and their involvement,
- Natural resources, their place and rights,
- Land tenure, ownership and settlement,
- Leadership and natural resource policy,
- Legal base and establishment,
- Dynamic capacity to adjust to and address changes within development trends and
- Action and not reaction: where the tendency is to cure other than prevent environmental degradation.

Soil factors are such as:

- Basement material, structure and texture,
- Microbial capacity, profile and cover,
- Manipulation and compaction dynamics as well as sitting operational condition,
- Erosion stability, penetration resistance and water retention capacity and
- Tillage energy and other requirements.

2.3 Conservation tillage questions for East and Southern Africa

2.3.1 Crop yields and potential

Potential yield of most crops in SSA can be increased two to four times by judicious use of off-farm inputs such as chemical fertilizers, appropriate farm tools, improved varieties, etc. (FAO, 1978; see Table 4). With traditional systems of resource-based agriculture, agronomic yields of most crops are low. An important reason for low yields is the widespread system of no-input, resource-based, subsistence farming. For example, the average fertilizer use in SSA, although more than doubled over the decade ending 1987, was merely 8kg ha\(^{-1}\) of major nutrients. There is a potential for irrigation to mitigate the drought. However, currently only 5 million hectares of land is being irrigated. Furthermore, use of improved cultivators and of high production systems is currently limited to merely 5 to 6% of the arable land (Lal, 1993b).

2.3.2 Contil questions

In addressing the conservation tillage problems and progress in ESA, three basic questions need to be addressed:

1. What are the complexities of the general Contil effort and what are the real or specialized challenges the region and individual countries must contend with?
2. Are there adequate technologies and techniques available to manage soil and water resources for the much needed enhanced agricultural productivity?
3. Are the available conservation tillage technologies being adopted and what further action is needed to arrest the prevailing deteriorating situation and destruction of fauna and flora?

Box 3: Technology adoption in SSA

An important question that has repeatedly been asked is whether technically viable and station-proven technologies are being adopted. The answer to this question is no. Most technological innovations have proven successful in on-station experimentation and in research-managed on-farm trials. However, farmers of SSA have not abandoned the age-old traditional systems based on hoe, machete, and the match box. The absence of poor adoption of improved and apparently high-yielding technologies deserves the attention of sociologists, anthropologists, policy makers, and extension...
specialists. One of the principal reasons for the low rate of adoption is the topdown approach of research, without the participation of the farmer in prioritizing critical issues, defining research methods, and in validating and adopting the technology by fine tuning it to local conditions. Researchers often perceive a research problem according to their assessment of the farmer’s constraints to enhancing production. Researchers design methodology for on-station or on-farm experimentation, develop a hypothesis, collect and analyze data and publish results without interaction with farmers. It is not surprising, therefore, that the so called "improved technology" is often rejected by the farmers of SSA. Agricultural sustainability is extricably linked with recognition of the farmer being the premier research client and with the farmer’s effective participation. Has response by donor agencies been timely, adequate and effective in providing financial assistance to overcome the crisis and alleviate sufferings? An answer to this question is vividly presented by Lele (1991). It is argued that over the three decades ending in 1990, billions of dollars have been transferred from developed countries to Africa. It seems, however, that most of this aid has been rather ineffective in stimulating growth, breaking the vicious cycle, and alleviating poverty and human suffering. The problem lies both with national policies and donor perception. Furthermore, donors need to coordinate their assistance with regard to long-term development strategies and institutional building.

Overall, the success rate was about 25% for projects initiated in 1970s and 56% for those initiated in 1980s. Similar conclusions of low success rate (12-40%) were arrived at by a survey conducted by the World Bank (1984; 1985, p.38-43; 1986). He concluded that technology should be appropriate and tested locally; offer short-term, on-site benefits, and large increments (50-100%); require affordable inputs, especially labour; not include foregone benefits, e.g., giving up land; not include any increased risk; and be in tune with existing social factors, e.g., the separate roles of men and women in agriculture.

(Lal 1996)

2.4 Why conservation tillage?

Conventional tillage practice is one where the hand hoe is used each season to dig and turn the soil over, with an effort placed to break the clods and leave a fine tilth. When animal power is used farmers make several runs with the mouldboard plough, while they remain unaware of other equipment like harrows and ridgers. Where these equipment are known they remain out of reach due to supply shortcomings or cost. These farmers however still work to achieve the traditional fine tilth, which in most cases is unnecessary. With ongoing shortages hitting tillage, weeding and other labour needs, animal traction will continue to have a place in the smallholder farming system.

Table 4: Yield potential of crops*

<table>
<thead>
<tr>
<th>Land capability</th>
<th>Input</th>
<th>Millet</th>
<th>Sorghum</th>
<th>Maize</th>
<th>Soybean</th>
<th>Bean</th>
<th>Sweet Potato</th>
<th>Cassava</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mg ha⁻¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very suitable</td>
<td>Low</td>
<td>0.9</td>
<td>1.1</td>
<td>1.6</td>
<td>0.7</td>
<td>0.7</td>
<td>2.2</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>3.5</td>
<td>4.6</td>
<td>6.4</td>
<td>3.0</td>
<td>3.0</td>
<td>9.1</td>
<td>12.2</td>
</tr>
<tr>
<td>Suitable</td>
<td>Low</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>0.4</td>
<td>0.4</td>
<td>1.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*(Lal 1996)*
Conservation tillage has been defined in various ways which all capture the need for less soil manipulation, hence reduced energy requirement and capacity to leave crop residue on the soil surface during all tillage operations (primary or secondary). The common theme is one of reduced soil and water losses.

Due to continued use of traditional manual, animal drawn and even tractor drawn mouldboard ploughing, many farms in ESA have lost large amounts of soil to erosion. Especially where disc and mouldboard ploughs (both animal and tractor drawn) have been used consistently, hard pans have formed and soils no longer have capacity to allow easy percolation of rain or irrigation water. This situation is as bad for humid, as it is for semi- and arid areas. Reduced percolation leads to deprivation of water and nutrients from plants as roots are unable to dig into lower soil zones. Overall, a case of increased runoff results. Traditional tillage systems generally are energy intensive and leave behind overly pervourized soils with destroyed soil structure. The high energy tropical rain storms easily carry away soil from the desirable but vulnerable fine tilth seedbeds, which farmers insist on having.

Oldreive, (1993), a practising farmer helped show clearly the gains of higher input agriculture as well as conservation tillage. Chart 1 below shows how a higher investment in better farming standards can easily translate into higher profits per unit of land.

### Fewer hectares with higher standards mean more profits

**Example 1:**

- **2 ha @ 2 t/ha** = 4 t @ $900/t = $3600
- **Costs** = 2 ha @ $1578/ha = $3156
- **Gross Margin** = $444 profit

**Example 2:**

- **1 ha @ 4 t/ha** = 4 t @ $900/t = $3600
- **Costs** = 1 ha @ $1876/ha = $1876
- **Gross Margin** = $1742 profit

**Example 3:**

- **1 ha @ 6 t/ha** = 6 t @ $900/t = $5400
- **Costs** = 1 ha @ $2175/ha = $2175
- **Gross Margin** = $3225 profit

The areas here are only representative and will vary according to the situation.

Chart 1: **Examples of the gains brought by higher input agriculture (Oldreive, 1993)**

The effect of two simulated storm trials on water run off and soil loss.
### Table 1: Water Runoff and Soil Loss

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Water Runoff</th>
<th>Soil Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep ploughed and disced</td>
<td>90%</td>
<td>28.5 t/ha</td>
</tr>
<tr>
<td>Ripped and disced, 10% stover cover</td>
<td>70%</td>
<td>6.7 t/ha</td>
</tr>
<tr>
<td>Chisel ploughed and cultivated 30% stover cover</td>
<td>34%</td>
<td>1.6 t/ha</td>
</tr>
<tr>
<td>Zero-till, 80% stover cover</td>
<td>6%</td>
<td>1.0 t/ha</td>
</tr>
</tbody>
</table>

### b) Two consecutive day treatments; total of 125 mm applied in 2 hours

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Water Infiltrated</th>
<th>Tractor Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional till</td>
<td>52 mm</td>
<td>Tractor could only get in after 2 to 2 days</td>
</tr>
<tr>
<td>Zero-till</td>
<td>122 mm</td>
<td>Tractor could get in after 4 hours</td>
</tr>
</tbody>
</table>

**Chart 2: The advantages of conservation tillage illustrated (Oldreive, 1993)**

Chart 2 however helps to show that even with higher inputs such as fertilizer, tillage is an important practice for enhanced machinery and crop performance. The information on Chart 2 helps show the gains of conservation tillage.

The case is reported where no-till practice, where 80% stover is left on the surface is compared to reduced tillage, chisel ploughing and conventional disc tillage. It is shown that the higher energy tillage methods led by conventional tillage, led to increased runoff, hence soil loss, with dramatic difference, though on only 4% slope land. Section b) of Chart 2 shows how, with less or no tillage, machinery was able to go into the field and work, much sooner following a storm, while at the same time much more rain water infiltrated into the soil for the less-tillage case. It is common knowledge that machinery can be highly destructive of soil structure when used especially under soil conditions that are beyond the liquid limit.

### 2.5 Regional efforts towards conservation tillage and case studies

There have been several concentrated efforts towards eventual introduction of conservation tillage at farm level in the SSA region. These efforts have been in research stations and institutions while more recently, and on some cases they are reported to have moved to the farmers farms, adopting more participatory approaches. The efforts have seen various degrees of success. In turn the efforts have taken various forms of localized and national ventures with minimal regional integration for dissemination. Duplication of efforts has not been absent.

**Box 4: Striking the balance**

Although a comparatively large amount of research and development work has gone into various conservation tillage systems in Zimbabwe, farmers in both large and small scale sectors have been slow to adopt them. This reluctance can be attributed primarily to conservatism, rather than to technical or socio-economic factors, though the latter obviously play a part. It must be recognised that none of the currently available conservation tillage techniques are truly sustainable in terms of preserving soil, rainwater, nutrients, soil structure and the ecosystem. Nevertheless, some hesitant steps have been taken locally to reduce the environmental damage resulting from annual ploughing combined with mono-cropping and over-reliance on chemicals. Tine planting into residues has the potential to reduce losses of soil, rainwater and nutrients to levels close to sustainable ones, and significant improvements in soil structure have been recorded under this...
treatment; but the technology still depends on large inputs of chemicals and has been tested for only a limited number of crop rotations. The locally developed system called no-till tied-ridging is particularly suited to the communal areas as hardy residues are recommended to be fed to the cattle and would be a hindrance in land preparation if left on the surface. Losses of soil, rain and nutrients are reduced to very low levels under this system but no significant improvement in soil structure has been recorded. The experiment no-till strip-cropping system is the closest approximation to a sustainable low-external-input system yet devised locally. Negligible soil, rainwater and nutrient losses have been recorded with soil structure being maintained at levels similar to virgin ground.

Tillage increases water holding and transmitting properties of the soil. The more open the tillage-induced structure the greater are these increases. However, at high rainfall intensities the effect of tillage in enhancing these properties is undermined by the structural breakdown of the surface layer which results in greatly reduced water intake rates. The finer the tillage-induced surface structure, the more vulnerable it is to structural damage. The effect of tillage on evaporation depends on the surface structure and the level of atmospheric demand. At lower evaporation demands rougher than smoother surfaces. However, at high evaporativities, tillage tends to induce more evaporation losses. It appears that the argument that tillage reduces evaporation losses through the "soil mulch" theory tends to hold at relatively low evaporativities.


Work carried out in introducing conservation tillage research and management at both stations and farms includes that by: International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria; International Centre for Research in Semi-arid Tropics (ICRISAT) Sahelian Centre, Niamey, Niger; Zimbabwe's Agricultural and Technology Extension Services (AGRITEX) in collaboration with various European institutions such as Silsoe Research Institute; works of Kenya Agricultural Institute (KARI) and Regional Land Management Unit (RELMA), formerly Regional Soil Conservation Unit (RSCU) in Kenya, the Palabana, Zambia work on CONTIL equipment, the Improved Maresha prototype Contil project by University of Nairobi and Swedish University of Agricultural Sciences (Gebresenbet and Kaumbutho, 1997) among others.

At an FAO/FARMESA led meeting in Harare (June, 1998), the idea of forming a regional network on Contil was floated and intensely discussed. Where Contil studies have persisted in the ESA region and even better, gone from the research station to the farmers' fields, real progress has been recorded although mass adoption of technologies is yet to follow. Various technological advances have been made, with greatest impact where introduction of equipment has been backed by multi-disciplinary research teams looking at:

- the equipment, its design quality, sustained production and marketing,
- farm level crop yields as affected by the introduction and use of Contil equipment or practice,
- participatory approaches where not just technological but also socio-cultural and economic constraints to adoption have been addressed.

It may be argued that the most successful programmes have been those of Zambia and Zimbabwe. From these, complete animal drawn equipment packages covering the range of primary as well as secondary tillage operations have come to existence. In no-till and minimum tillage systems energy saving direct seeding equipment have been manufactured. Due to high weed infestation in these systems animal drawn cultivators have also been developed.

Examples of equipment developed are such as the Mogoye ripper and its wing attachments which easily make it a Contil ridger and weeder; or its planter attachment which makes it a direct seeder. The animal drawn subsoiler, one version from Zambia and another from Zimbabwe are but a few examples of the range of equipment developed in the region. Others are such as the tie-ridger, a most useful light equipment which helps conserve moisture in the driest areas. Some efforts have attempted to modify the traditional Ethiopian Maresha among other efforts.
2.5.1 Farmer management, soil and micro-topography

Working in Botswana, Harris et al. (1992) analyzed farmers' practices with regard to management and soils, micro-topography and tillage options. Farmers commonly grew a variety of crops with mixed stands of sorghum, maize, watermelon, cowpeas, and sweet sorghum. Most farmers broadcast their crops and this resulted in areas of high and low crop density. Row planting provided better control of plant population densities reducing the inter-plant competition and facilitating weeding.

The work in farmers' fields highlighted the importance of accessibility to draught animal power for timely cultivation and planting. Good crop establishment was clearly a key factor for good productivity. The spatial and temporal variability of the rainfall and the spatial variability of soil properties were confounding factors in comparing the influence of sites and soils on crop production.

Micro-topography (small differences in surface elevation, 0.2 –0.8m, over distances of 20-50m, not associated with the overall slope) was identified as a major scale of within field variability. The high areas were commonly associated with termite activity and the soils were generally more fertile with higher pH and clay content than low areas. However, the high areas (despite greater available water holding capacities) were always drier than low areas where runoff landed.

Several tillage options were tried including terrace and strip tillage. Cultivation was shown to improve the infiltration into the soil. Despite the complications introduced by micro-topography, double cultivation appeared to improve crop establishment. This was attributed to better soil moisture conditions early in the season through improved infiltration and weed control.

For tie-riding, the system did have effect of preventing redistribution of water within fields, while concentrating water in the furrow bottom. The seed was sown in the base of the ridge and was close to the subsoil as most of the top soil had been used to form the ridge. This positioning of the seed avoided the potential water logging effects of the furrow bottom and the dry conditions in the ridge top. The early development of the plants was always slower than in the flat row planted control, due to soil compaction in the root zone. Planting in the ridge top was not a feasible option as this was the driest soil. Although such a system could not be recommended a modified wide-bed, tied ridge and furrow system appeared more promising.

Extensive research was conducted into strip tillage systems, where alternate bands of soil were cropped and kept bare, both under well controlled experimental conditions and in farmers' fields. Water flowing through a series of such crop strips was likely to result in a cascade effect with consequent soil erosion problems.

2.5.2 Water harvesting and agronomic practice

Water harvesting from off-field sources was also explored. There was potential for such schemes to benefit other farmers. No specialist equipment was needed for construction of bunds. Each site would however have required specific investigation and design to fit socio-economic aspects.

Various agronomic and management factors were considered. The need for timely sowing with respect to rainfall was most important, more so for farmers who relied on contract cultivation. It was shown that even with optimum soil moisture conditions at sowing, subsequent conditions, if hot and dry, still reduced establishment. Seed soaking was shown to be one method of speeding up early growth and enhancing establishment and merits further investigation.

Agro-climatology studies were also conducted to provide an understanding of the spatial temporal variability of rainfall. While large differences in seasonal rainfall were evident between sites, the differences between years at a given site were much greater.

Among other points, the study concluded that:

1. Net runoff losses from cultivated fields were small and inconsequential in comparison with the effects on crops of inefficient management.
2. Runoff losses could be substantial from rangeland with sparse vegetation cover. Grazing could be managed to minimize runoff or to maximize runoff for use in a downslope crop.
area. The latter would however degrade the land.

3. Redistribution of rainfall within fields as a result of widespread micro-topography was a far more serious problem for arable agriculture. Large asymmetries in the system had important consequences for crop production because they reduced the level of control exercised by farmers over their operations.

4. Systematic variations in the micro-topography were associated with termite activity. These formed an environmental mosaic with large interactions between surface water mobility, available water-holding capacity, fertility and the destructive habits of the termites themselves. The system was extremely dynamic and relative cropping outcomes depended on a further interaction between rainfall pattern and sowing date.

5. Soils varied widely in the major components of available water holding capacity influenced by depth and texture. This variation was loosely correlated with position in the landscape, but also influenced by the nature of parent material.

6. Current cropping strategies involved minimal inputs by farmers who perceived arable farming to be a high-risk occupation. Crop production was not viewed as a high priority. Such an outlook was possible in Botswana because the buoyant economy offered alternative sources of income.

7. Levels of land management and crop husbandry were very low. Consequently, production was "sustainable" because off-takes were small. Improved management, which was a prerequisite for improving crop yields needed to be addressed.

2.5.3 Farmer-centred research

Working at Makoholi Experiment Station in semi-arid Zimbabwe Mashavira et al. (1997) described yield responses of commercial cotton to reduced tillage systems and the evaluation of innovative combinations of low-input tillage and weeding systems. The tillage practices adapted farmer practices and implements that were available to the communal area farmer, namely the mouldboard plough and the five-tine cultivator and ripper tine for maize production.

They concluded that open plough furrow planting (OPFP) with an ox-plough and ripping a planting line to a depth of 30 cm offered alternative crop establishment options that could be successfully implemented on ploughed or fallowed (reduced tillage) land without any yield reduction. In fact, for the scenarios they described, maize yield increased between 20 and 300% over hand planting. Although ripping to 30 cm required more labour than OPFP, the grain yield returns more than compensated.

2.5.4 Adding efficiency to current animal traction systems

Mbanje (1997) analyzed implement and selection factors with an aim of achieving practical opportunities to reduce draft demand. He did this by exploiting ways of having a multi-operation single pass, correct implement adjustment for right orientation, whereby, orientation referred to the position of implement in relation to the direction of movement of work animals (Gebresenbet, 1991). Other factors considered were ploughing speed and equipment hitching and harnessing, maintenance, and cleaning. Soil factors were such as choosing when and how to plough.

Caring for the soil, involved the way it was cultivated and the nutrients that were added to it. For example, addition of manure and organic matter helped reduce draught demand. The author however did not reach any quantifiable gains and recommended further work on this, much neglected subject of efficient tillage and use of animal traction.

2.5.5 Conservation tillage and erodibility

Chuma (1993) applied mulch ripping, clean ripping, no-till tied ridging and hand hoeing. No-till tied ridging and mulch ripping showed lower total soil loss than the other treatments. Checking the tillage effects five years (measured annually) after the treatments were applied, erosion and penetration resistance were evaluated by determining organic carbon content, percent clay in the upper root zone structural stability, infiltration and soil strength.

Conservation tillage treatments showed lower organic carbon reductions than conventional tillage, mulch ripping treatment however, showed slightly better structural stability than conventional tillage. Hand hoe treatment showed high soil strengths likely to inhibit root penetration.

Chuma (1993) concluded that minimal soil disturbance as by ripping operation combined with
improved soil fertility and ground cover could contribute to improved erosion resistance. He confirmed fears that present tillage practices were depleting (maybe up to 2.5 million tonnes per annum) organic carbon leading to increased erodibility.

2.5.6 Weeding, labour use and returns

Weeding is an important consideration in conservation tillage systems and can be a major shortcoming to the promotion and eventual adoption of Contil technologies. Riches et al. (1997) reported that weeding accounts for up to 60% of the labour used in maize production in semi-arid Zimbabwe (MLARR, 1992). Because of poor returns from cropping and an acute shortage of labour in many households, conservation tillage and weed control systems should be based on low-cost, labour-saving technologies (Ellis-Jones and Mudhara, 1995). While 76% of households in southern Zimbabwe own a plough, only 23% own an inter-row cultivator (MLARR, 1992). Weeding is undertaken by plough, cultivator, hand hoe or a combination of methods depending upon implement ownership, draught power and labour availability. If a plough is used, farmers usually remove the body (mouldboard) leaving the share as the operational weeding blade. They recognise that timely inter-row cultivation is important for weed control and for maintaining a rough soil surface which can retain subsequent rainfall (Ellis-Jones and Riches, 1992).

Table 5: Maize grain yields (kg ha\(^{-1}\)) labour requirements for weeding (h) and return to weeding labour (kg yield h\(^{-1}\)) for four weeding systems at the Makohli Experiment Station.

<table>
<thead>
<tr>
<th>Labour requirement for weeding</th>
<th>Return to weeding</th>
<th>1992/93</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>Mechanical</td>
<td>Total</td>
</tr>
<tr>
<td>Hand weeding</td>
<td>5195</td>
<td>132.5</td>
</tr>
<tr>
<td>Cultivator</td>
<td>4552</td>
<td>52.2</td>
</tr>
<tr>
<td>Plough with body</td>
<td>4345</td>
<td>26.8</td>
</tr>
<tr>
<td>Plough less body</td>
<td>2766</td>
<td>45.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labour requirement for weeding</th>
<th>Return to weeding</th>
<th>1993/94*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>Mechanical</td>
<td>Total</td>
</tr>
<tr>
<td>Hand weeding</td>
<td>2251</td>
<td>126</td>
</tr>
<tr>
<td>Cultivator</td>
<td>2092</td>
<td>45.3</td>
</tr>
<tr>
<td>Plough w/ body**</td>
<td>3047</td>
<td>20.3</td>
</tr>
<tr>
<td>Plough less body</td>
<td>1636</td>
<td>45.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labour requirement for weeding</th>
<th>Return to weeding</th>
<th>1994/95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>Mechanical</td>
<td>Total</td>
</tr>
<tr>
<td>Hand weeding</td>
<td>3670</td>
<td>155.6</td>
</tr>
<tr>
<td>Cultivator</td>
<td>3990</td>
<td>42.6</td>
</tr>
<tr>
<td>Plough w/ body**</td>
<td>3896</td>
<td>0</td>
</tr>
<tr>
<td>Plough less body</td>
<td>2590</td>
<td>41.4</td>
</tr>
</tbody>
</table>

*labour for hand weeding estimated from on-farm records;
** ridges were tied after weeding in 1993/94 and 1994/95.

Weeding by mechanical systems required less labour than hand hoeing (Table 5). With the body removed the plough had an effective working width of only 25cm so three passes were needed to weed each inter-row. The plough with body system gave the greatest return in terms of maize grain yield per weeding hour (Table 5), even when the plough system resulted in lower yields than hand weeding or the cultivator system.

Mid-season ridging at the time of weeding, which could be used in combination with widely used plough and planting systems, was a versatile method of preparing a water conserving landform. It could also provide timely weed control following tine tillage, that is planting along a rip line (Shumba et al., 1992). Farmers would then have a low draft system of plant establishment without the requirement for additional weeding labour caused by early weed growth in the untillled interrows. This approach to reduced seed-bed preparation may allow conservation tillage to be introduced where other systems such as mulch ripping (for example, Anazodo et al., 1991) are impractical because the crop residues are used for livestock feed. Other potential benefits, as yet unquantified, were the effects of the previous season's tied ridges on the conservation of early spring rainfall, prior to spring tillage.

2.6 Technology advancement

Conservation tillage and technology needs to be defined in the broad sense. Contil technology is much more than animals and their care, implements and equipment, crop varieties and their management and even soil and water management techniques. In recent days the broader approach to technology and its transfer calling for multi-disciplinary and multi-sector approach has become necessary.

The need for systems approach to conservation tillage and management needs emphasis. Technology includes sustainable soil and crop management options available to farmers in the region. Among the various equipment that have been introduced in ESA, the range of practices include technology for seedbed preparation, planting and erosion control. Biological conservation technologies are such as agroforestry, mulch farming, contour and strip cropping, legume-based crop rotations, cover crops and green manures, mixed farming practices based on controlled grazing, use of farm-yard manure and others.

Conservation tillage technology needs to be seen and defined to include these and what may be called physical technologies such as no-till, minimum-till, vegetative hedges, sod-seeding, contour ridges, tie ridges, mulch farming, terracing, rough-ploughing, deep sowing and pot-holes, among others (see Chart 3). Time when these various technologies, or accompanying operations are applied is of prime importance. Time determines not only what is possible when, but also the energy requirements, operational efficiency and yields.

Dry-planting and pre-season hard pan breaking are some of the practices which are of great significance especially in areas of limited rainfall amounts.

Generally, physical technologies involve implements and tools which, in many applications add work and energy efficiency towards applying the biological technologies.

2.6.1 Research Findings versus traditional practice

Most field operations particularly by small-holder farmers are performed manually thereby limiting the area cultivated per person. The fact that most operations are performed by hand limits the extent to which farmers can adopt certain conservation tillage practices as draught power or mechanisation is almost always a requirement.

Thus the development of mechanical power has been related to scales of production associated with the colonial history of the respective countries. The adoption of conservation tillage systems is related to the resource ownership of the farmers particularly draught power. In Zimbabwe for instance it is estimated that 5-10% of the commercial farms are under true conservation tillage whilst the use of conservation tillage in the small-holder farming sector is estimated to be below 1% (Nyagumbo, 1998).

Assessing the potential for adoption of advancing technology and specifically on weed control in
the region Nygumbo (1998) reported that weeding effort which accounted for more than 60% of the labour used for maize production, was greatly eased by animal drawn cultivators and ploughs used to control weeds. The efficiency of weed control was also found to greatly improve where farmers used re-ridging with the plough as a weed control measure under no-till tied ridging in the sub-humid north of Zimbabwe (Nyagumbo, 1993). The technology utilization remained low. Comparatively in the larger scale commercial farming sectors of Zimbabwe, Zambia and South Africa the spread of Contil technologies could be attributed to the availability of suitable machinery and the herbicides which have tended to be unaffordable to small-holder farmers in Zimbabwe.

### Conversion of Lal 1993a

**Chart 3: The broad definition and aspects of conservation tillage technology**

**Table 6: Sources of power for primary land preparation in 5 SADC countries**

<table>
<thead>
<tr>
<th>Country</th>
<th>% of cultivated land</th>
<th>Draught animal power</th>
<th>Mechanical power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botswana</td>
<td>20</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Kenya</td>
<td>84</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>South Africa</td>
<td>10</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>Tanzania</td>
<td>80</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>15</td>
<td>30</td>
<td>55</td>
</tr>
</tbody>
</table>

Source: Ellis-Jones, 1997

Farmer management capabilities will remain an issue in gauging possible progress as conservation tillage systems call for higher levels of management and this has tended to contribute towards low adoption rates. Small-holder farmers own less than 5 ha of land in most...
countries in the region and because of this they do not want to risk crop failure by using technologies they are unfamiliar with, especially considering their labour and resource limitations.

2.6.2 Contil initiatives and efforts by nations in the ESA region

Nyagumbo (1998) summarized some of the Contil activities of selected countries in the ESA region:

In Zambia the currently practised soil conservation measures include contour ridges and grass strips across the main slopes. The lack of effective enforcement laws after independence led to a complete collapse and abandonment of conservation measures particularly by smallholder farmers. The traditional CHITEMENE system of shifting cultivation also contributed to accelerated rates of soil erosion due to shorter fallow periods and longer cropping cycles caused by increased population pressures (Mukanda, 1993). Some research work on tied ridging has been undertaken at Lusitu Research Station with some encouraging results.

The use of conservation tillage systems in Zambia has mainly been spearheaded in the last 3 years by efforts of the Zambia National Farmers Union (ZNFU) Conservation Farming Unit in the Southern province of Mazabuka as reported by Aagard and Gibson, (1996). Zambian links with Hinton Estates in Zimbabwe culminated in ten commercial farmers establishing 20-70 ha under conservation tillage with encouraging results. Since December 1995, the conservation farming unit was established to promote conservation tillage in both large and small scale farming sectors. Some work on the promotion of various animal drawn rippers which have been extensively tested with farmers through extension brochures is in progress through a programme known as Smallholder Agricultural Mechanisation Promotions (SAMeP).

In Botswana it was reported (Nyagumbo, 1998) that tillage research has been undertaken since 1970s. However up to the present the most common form of tillage practise is mouldboard ploughing carried out on the day of planting. More recent research on different tillage methods (Persuad et al., 1990) recommends two methods namely double ploughing i.e. spring ploughing followed by another ploughing at planting and spring ploughing followed by tine cultivation at planting. Some work was also carried out on strip tillage on sandy loam soils and shallow tillage or herbicides on vertisols as reported by Willcocks and Twomlow (1991).

In Malawi the ridging constructed by handhoes is the most common practise used by about 95% of the smallholder farmers (Mwinjilo, 1992). Zero tillage or no-till are not used at all due to cost of herbicides and lack of draught and labour resources (Kumwenda, 1990). Some effort is being made to reduce labour requirements for construction of ridges by the use of permanent ridges as compared to annual ones. Other forms of conservation practices include maize-legume inter-crops and rotations.

In Southern highlands of Tanzania 95% of the farms are less than 5 ha in size. Land preparation is mostly manual (Ley, 1990). In addition to standard mechanical structures such as channel terraces conservation tillage systems are in use with implements capable or retaining 70% crop residues on the surface after tillage operation. Weed control is achieved with the use of herbicides such as round-up. Problems cited included lack of appropriate machinery, experience and grazing of stover by livestock.

Traditional techniques locally developed in the southern highlands of Tanzania and suitable for use on steep slopes include the Matengo pit or Ngoros (a series of pits 2.4m long x 2.1m wide x 0.14 – 0.30m deep) and the Matuta ridge systems (vegetation slashed and aligned across the hillsides and buried with soil thrown down-slope (Temu and Bisanda, 1996). These techniques have shown immense benefits in terms of soil and moisture conservation for crops as well as fertility improvements.

In Kenya the traditional conservation technique is the fanya juu terrace. In a recent study on traditional techniques mobile trash lines at 1.5-7.5m spacings significantly out-yielded (maize and cow pea) and reduced soil loss and run-off levels compared to the control (Okoba et al., 1998). The use of these trash lines in combination with static structures such as fanya juus and stone bunds is a recommended system especially for lower Embu in eastern province.

3. Socio-economic issues of conservation tillage
Apart from the many technological concerns and proven gains of conservation tillage, the few exposed farmers in the region are still not adopting the techniques en masse. The non-technical reasons for the low adoption rates range from costs of equipment when they are available to the socio-cultural features such as fear of change and weaknesses in promotion and qualities of extension services.

Socio-economic issues of conservation tillage in ESA centre around the traditional African customary approach to issues revolving around land its use and ownership. The value attached to land as a sign of worth and wealth can be a major source of caution, if not conflict in development.

Nyagumbo (1997) analyzed the socio-cultural constraints of smallholder technological dissemination and their impact on development projects. The observations were centred around the Contil project in Zimbabwe, which had faced varying degrees of success. It was observed that:

- Farmers were victims of a receiver mentality, brought about by previous government and donor subsidized projects. They immediately lost interest each time they were told that the project had nothing to offer materially or financially. Longer term gains were more difficult to comprehend. Previous subsidies had been such as interest-free money to commence projects, with little contribution from the locals themselves.
- Emanating from the receiver attitudes highlighted above, was suspicion between participating and non-participating farmers, with those not participating feeling those participating had certain material or financial gains. This caused tension between them, resulting in jealousy, envy and even hatred.
- In Zimbabwean customary law following the death of a member of a family, close relatives of the deceased get a small share of the deceased’s belongings, such as clothing. Contil research equipment quickly became wealth to be shared, following the death of participating farmers. Issues and concerns of witchcraft soon set in.
- Many farmers indicated that they spent as many as 30 days (25% of their working time), attending funerals and were therefore unavailable for participatory research.

It was therefore clear that development of new technologies in small-holder farming areas was affected by serious non-technical problems and constraints. Awareness of these constraints led to farmers being adequately informed and accommodated to feel true ownership of research projects. It was noticed that when farmers knew the objectives of the research, they were more co-operative and useful.

Box 5: Gender roles in conservation tillage and technology transfer

The implication for extension would be to facilitate the problem and needs identification with the presence of both, men and women, rank the priorities together and according to gender and then develop the extension programme together. A choice of technological options should be developed together in order to correspond to farmers (male and female) criteria which are very diverse and situation specific.

In a time of rapid socio-cultural change gender roles and relations are highly dynamic. Therefore, it is important to build a platform on which rural people themselves can negotiate for new roles, functions, norms and for new power relations. It is more favourable to negotiate roles via technical issues rather than via discussions on gender as the advantages of any changes must be concrete and obvious in real life-situations. The process requires skilled facilitators at various-levels. This new competence is a real challenge to the conventional agricultural research and extension institutions.

Hagmann et al. (1997)

3.1 Gender issues in conservation tillage and technology transfer

Hagmann et al. (1997) reported on an assessment of socio-cultural constraints in agricultural research and extension. They noted that this is often a male-dominated domain and that the
introduction of the gender perspective was frequently taken as a fashion rather than as a substantial contribution to rural development. They highlighted the reality that, in many societies in Africa south of the Sahara, male labour migration into towns had resulted in a situation where more female than male-headed households prevailed in the rural areas.

Among the many facets of gender weaknesses and as they affected efficiency in development the following points were put forward:

- **Weak communication between the Actors**: where communication within the families, within the communities and between farmers and extension workers turned out to be weak.
- **Communication in the families**: where extension workers chose male farmers who often were also members of the farmers' club and extension training programmes. The male head of household was not obliged to inform the other household members, whereas the wives and the children etc. were accountable to the male head and therefore information flowed smoothly in this other direction. The same applied to communities, where farmers complained that their leaders never report back from meetings and courses they attended. It was also realised that communication among female members of the household was better than the flow between the sexes.
- **Problems of a Male-Dominated Extension**: where male domination in extension limited the attraction of extension for women.
- **Decision making**: where men and women stressed that the husband makes most of the decisions in the family, but it turned out to be the opposite.

The study concluded that:

- Training for Transformation (TFT) was a method to be recommended as it empowers local people to control their lives through active participation in their own development and sharing of ideas and knowledge. TFT stresses the importance of participation and co-operation of both, male and female members in organisational development in order to build institutions which enable people to become self-reliant.

4. Conclusion and the way forward

In conclusion it is noted that many efforts towards conservation tillage practice in ESA has been put in place although impact is yet to be felt. A wide variety of factors have worked against research and extension efforts for technology transfer, and traditional practice has continued to persist and dominate. In many cases poor technology transfer techniques have been tried and farmers are yet to adopt conservation tillage practices en masse.

For progress to be attained, the definition of the path to be followed can only be based around the wide range of literature items cited, the experiences therein and that of these authors. The appropriate approach for Contil promotion in the region can therefore be defined and subscribed as one to include the following components:

1. Farmer-centered, aggressive, on-farm, participatory methodologies in demonstration and practice as well as publicity for sensitization, with all parties (researchers, extensionists, farmers, support service providers, government and non-government operators) applying their appropriate and adequate roles.
2. Marrying traditional knowledge, ideas and practice, while accommodating fears and experiences about technologies, with socio-economic and other concerns of end-users. Farmer exchange visits will be most important in this endeavour.
3. Identifying suitable equipment and promoting the same nationally and regionally while merging resources and eliminating duplication of efforts within and between nations.
4. Applied field testing with farmers as more research findings are made, especially to quantify the real gains of the use of various equipment while accommodating the natural and other development trends and narrowing the gap between research & end-users.
5. A systems approach, to multi-disciplinary and multi-sector research and technology transfer efforts which capture environmental protection and soil management techniques, agro-forestry practices and economic well-being of all parties involved, and especially smallholder farmers.
6. Formal Contil networking, collaboration and co-ordination backed by training, support for equipment supply, including simplification for local manufacture and other support.
7. Shortcomings in technology and equipment development is not unique to conservation
tillage but subject to the many general as well as specific shortcomings and gaps in agricultural mechanization endeavour.

8. Efforts towards capacity building in terms of institutional back-up, training, personnel, equipment and other support are faced with shortcomings in disciplinary commitment & time allocation, which calls for adequate remuneration of professionals.

Improved agricultural technologies should be directed to alleviating soil-related constraints of accelerated soil erosion, rapid fertility depletion, nutrient imbalance, and drought stress. Furthermore, essential inputs must be made available at affordable prices and on time. Beyond these, farmers must be adequately rewarded for their produce and be assured of returns.

Work with farmers – especially to build on their traditional ways to give real meaning and confirm indicators brought about by research is recommended. For example, mulch ripping has shown great promise for soil structural stability while the hand hoeing has shown soil strengths that could inhibit root penetration but probably hand-hoeing and no mulch ripping will continue to be the practice in reality.

Africa is endowed with a wide diversity of climate, vegetation, geography, terrain and soils. Yet the range of species grown is rather narrow. Introduction of new species could spread risks and increase options. There is no justification for ignoring cash crops.

References


Giles G.W. 1975 The re-orientation of agricultural mechanization for developing countries. Proceedings of FAO/OECD expert panel meeting on effect of mechanization on production and employment, FAO, Rome.

Hagmann J. E. Chuma and O. Gundani 1997. Is he the farmer or the farmer’s husband? Gender in agricultural research and extension in Zimbabwe. Entwicklungsethnologie, 6 (2) 1997 pp 100-119


Krause R. (undated). Mechanization contribution to high level sustainable production:
Overview of conservation tillage practices in East and Southern Africa


Shumba, E.M., S.R. Waddington and M. Rukuni 1992. Use of tine tillage with atrazine weed control, to permit earlier planting of maize by smallholder farmers in Zimbabwe, Experimental Agriculture 28:443-452


Conservation tillage with animal traction for soil-water management and environmental sustainability in Namibia

by

Percy Misika¹ and Emanuell Mwenya²

¹Deputy PS, MAWRD Namibia ²Mashare Agricultural Institute, Namibia

Abstract

This paper is based on the outcome of a national workshop on conservation tillage with animal traction for soil-water management and environmental sustainability held 16-18 June 1998, Okashana, Namibia. The Ministry of Agriculture, Water and Rural Development (MAWRD) conducted the workshop. The information gathered through paper submission and presentations reviewed indigenous knowledge on the subject both in the commercial and small-scale farming sectors, implements available, rainwater harvesting techniques and the use of draft animal technology. The status of conservation tillage in Namibia is mixed. In the commercial farming sector conservation tillage has been practised for over 15 years during which several tine implements have been introduced and conventional tillage implements such as ploughs and discs replaced. The trend with small-scale farmers is more towards conventional tillage where nearly all farmers using draft animals, mouldboard plough their fields and those who have access to tractors disc plough and harrow. A handhoe is most common and has been used by some farmers to prepare their fields for dry planting (minimum tillage), a method that has been reported to be restricted to very small portions of land. It is a tiresome operation as it is performed during hot season and farmers only use it because they have no other option. Planting on ridges and broadbeds has also been observed but the practice seems to be a traditional land preparing method that eases planting and weeding. Ridges are rarely made across the slope. Recently, draft animal power projects have introduced animal drawn tine implements such as rippers and results from the two-year trials appear promising. These implements work the soil faster than the mouldboard ploughs and hoes, however, there are also negative outputs associated with their use. They do not allow incorporation of manure into the soil and weeds tend to grow faster than in conventional tillage systems and weeding is constraint if cultivators are not applied.

1. Introduction

Namibian climate can be described as semi-arid to arid. The climate is influenced by two deserts, the Namib in the west and the Kalahari in the east. Of the total area, desert region is 22%; arid land, 33% and semi-arid land, 37%. The climate has a definite bi-modal pattern with rain season normally beginning in October through the end of April. Most rain normally falls between the end of December and the middle of April (Hydrology Division, 1998). In the Northern Communal Areas the mean annual rainfall ranges from 300 mm in the west to 700mm in the east. January and February are usually the wettest months (Hutchison, 1995). In other parts of the country such as the coastline the mean annual rainfall is generally less that 50mm. In the south the mean annual rainfall is 50-160mm and dryland farming with this amount of rainfall is very difficult (Goagoseb, 1998). The mean annual evaporation normally exceeds precipitation by a factor of 5 to more than 10 in most parts of the country. For example the mean annual evaporation is estimated at 2750 mm and 2530 mm for the North Central Divisions and Kavango respectively. These areas have less than 700mm mean annual rainfall. The evaporation values in central-southern areas go up to 3700 mm, this is where rainfall is the lowest (van der Merwe, 1983; Hydrology Division, 1998).

Soils particularly where crop production is practised, are generally sandy with low water retention capacity. Reliable crop production under rainfed conditions is only possible in areas receiving an average of over 400 mm rainfall annually, representing 34 per cent of the country. It is reported that 97 per cent of the soils in these areas have clay content of less than five percent (MAWRD, 1995). These soils have very low organic matter, poor water holding capacity and are generally poor in several nutrients except calcium. Only approximately 1% of the total land has soils with (medium to high) potential for irrigated arable production (Alweendo, 1998).

2. Animal traction: Status and strategies
There is already a tradition of using draft animals for ploughing and transport in various parts of Namibia. Several farmers have used oxen and donkeys for ploughing and transport. This practise can be traced to over 100 years ago. Currently, indicative estimates are that 60-89% of farmers in the Northern Communal Areas use draft animals. Even though crop production in communal areas such as Erongo, Kunene and Omaheke is very limited, draft animals still play a very important role in transport. In these areas probably 80-90% of the rural households use donkey carts for water collection, human transport and trade.

The ex-government of the Republic of Namibia has recognised the importance of draft animal power technology and policy statements relating to DAP have been pronounced in the National Agricultural Policy (MAWRD, 1995). In collaboration with some donor-funded projects, implementation of the DAP technology have been undertaken by establishing the National Draft Animal Power Programme centre at Mashare Agricultural Development Institute (MADI), (Misika, 1998).

An ox-drawn plough is the most common animal drawn implement available in the northern communal areas. Nearly all farmers owning draft animals particularly oxen own at least one plough. Farmers have expressed confidence in working with a plough and many feel that they are satisfied with their ploughing operations. Implement stockists appear to have no problem in selling ploughs and farmers know where to find them, even in remote areas. Generally there are no repair facilities in these areas and some farmers end up purchasing new ploughs as sources of worn out parts (Mwenya, 1998).

The interest in weeding with draft animals is increasing in communal areas. Some cultivators have been tested and tried with farmers. The light Senegalese, BS41 and Maun cultivators have been accepted by several farmers and need effective strategy for farmer adoption. In some parts of North Central Division there is already a steady increase in the number of cultivators in use. However, stockists also demand assurance of business when contacted to take interest in stocking cultivators. This is particularly because implement distributors do not know the actual demand for cultivators yet. Moreover, not many farmers have shown "real demand" for importers to enter this market.

A ripper is another implement being promoted in Namibia. There are approximately 100 rippers available in Namibia. These implements have been mainly on trial basis and very few farmers know about their usage. Where rippers are promoted they are mainly used as tools to open up furrows for planting in dry lands.

2.1 Rural transport

Rural transport by use of sledges and carts is common in rural areas. There are more sledges than animal drawn carts being used in Northern Communal Areas especially the Caprivi and Kavango Regions. In the Northern Communal areas, farmers normally make sledges themselves while carts are manufactured by small workshops in towns. This is not the case in the South, West and East of the country where farmers manufacture the carts themselves. There has been no deliberate intervention from projects or the National Draft Animal Power (DAP) Programme to promote rural transport through training or supply of components. Unlike land preparation and weeding, transport is an activity conducted throughout the year and should be seen as an integral part of farming systems in the communal areas.

2.2 Management issues

Management of draft animals is normally a major concern by farmers, financing institutions and promoters of draft animal power technologies. The productivity of draft animals is normally questioned in some areas where grazing land is poor and usually the animals in these areas are weak at the beginning of the land preparation season when they are needed most. This situation threatens the success of the DAP technology as financial institutions sometimes fear giving loans to farmers for reasons that farmers may not pay back. This in some cases leads to late land preparation. Strategies to improve care and nutrition are being formulated to guarantee productivity of draft animals. Conservation of feed resources that are abundant during rainy season and after crop harvest is one way of addressing the situation. The Northern Namibia Rural Development Project (NNRDP) has in the past season (1997/98) initiated treatment of millet straws for supplementary feeding of draft animals. Initial results appear to be positive but more work needs to be done. Another strategy could be to encourage a few farmers getting credit from financial institutions to enter into production of fodder under irrigation. These farmers could supply feed to other farmers who may not afford irrigation systems (Misika, 1998). Moreover, in the commercial farming sector feed conservation is already being practised in Namibia. Strategies to explore this practice...
and adapt it to communal farmer level are also being investigated.

3. Conservation tillage methods

3.1 Indigenous knowledge

Conservation tillage has been acknowledged as a more productive technology for crop production in the commercial farming sector. The commercial farmers in Namibia are reported to have started shifting towards conservation tillage practices over 15 years ago and results have been well-appreciated (Maltzahan, 1998). Some farmers have benefited from increased soil productivity and increased yields due to expanded crop fields. The technology has allowed the farmers to prepare their fields much faster than the conventional tillage systems. Methods used to conserve soil-water include minimum tillage, zero tillage, ridging, mulching and timely weeding.

On the other hand, indigenous knowledge on soil-water management by small-scale farmers in the communal areas appears to be mixed. Some farmers in this category have practised dry planting, planting on ridges, minimum tillage and zero tillage. However, not all of them are aware that their tillage systems conserve soil-water for crop production and to others these practices were passed traditionally, from one generation to another. According to Matanyaire (1993, 1998) the majority of farmers in the North Central Division (81%) planted on ridges and broadbods while those in Kavango (94%) planted on flat land. This is a strategy out of indigenous ingenuity to facilitate drainage and increase the crop-rooting zone in shallow profiles. The ridges are generally made up and down the slope and are rarely across the slope. Most farmers in the North Central Division (NCD) were using this system as a traditional land preparation method that eased planting and weeding. This suggests that the practice is not connected to conservation tillage for soil-water management nor connected to soil erosion prevention. Other farmers are planting on ridges to encourage drainage. Nonetheless, several communal farmers have used minimum and zero tillage practices simply because they were late to prepare their fields. These farmers are mainly using hand hoes (dry hoeing) to open up planting holes at desired spacing. Dry hoeing does not allow rain water to seep too far beyond the root zone. Equally important, is that seeds sown at shallow depth benefit from the first rains and get a chance to establish early (Naunyango et. al. 1998). However, the practice is labour intensive and cumbersome. Poor germination is also common due to insufficient rains at the beginning of the season.

In the Caprivi Region crop farming systems may be divided into river-lands and dry-land farming systems. Some conservation tillage practices that can be acknowledged in dry land farming are such as animals being left on the field to graze after harvest. Animal droppings spoil some stover, which they cannot eat. The spoilt stover together with the dung partially form some mulch on the top of the soil and this is reported to give soil sponge-protection during the first rains. It also helps in water retention. However, the contribution from this practice is minimal. In most cases, stovers are not grazed because harvesting is usually done after animals have been taken to the upper lands. The stover rots in the field and acts as a water collector and retainer.

3.2 Implements used for conservation tillage in Namibia

The early 1980’s marked a shift, in the commercial farming sector, from conventional tillage to conservation tillage practices. Very few practised conservation tillage before 1980. From 1980 tine implements were introduced and these slowly started replacing conventional implements such as disc harrows, disc ploughs and mouldboard ploughs. With small-scale farmers the trend has been more towards conventional tillage. Ploughing with tractor drawn discs and animal drawn mouldboard ploughs has been most common. These implements work the whole land and in some cases has been reported to cause negative effects to the soil. A few farmers, particularly in Kavango Region have observed accelerated loss of soil fertility because of the use of animal drawn ploughs and tractor disc ploughs. They believe that in fields where hand hoe is used the soil takes longer time to show signs of infertility compared to where a plough or disc had been used. This is normally confirmed when a certain weed called esusu becomes prominent.

Since 1996 the trend to use tine implements with draft animal power has been observed. Draft animal power projects have introduced chisel tines attached to cultivators and rippers attached to the mouldboard plough beams. So far the Magoye ripper and the Zimbabwean curved ripper have shown good results in various soil types. The improved "manipulated" chisel tine adapted on the Senegalese cultivator is also promising but needs modifications for deeper penetration.
Conservation tillage with animal traction for soil improvement has been used mainly to open up furrows for planting while the manipulated chisel tines on the Senegalese cultivator were used to loosen soil without inversion. Some conclusions in land preparation with regard to the use of chisel tines and rippers by NNRDP (1996/97 and 1997/98 seasons) include the following:

- Minimum tillage speeds up soil preparation
- Dry sowing increases yields in case of terminal droughts
- With minimum tillage weeds grow earlier and faster than in conventional tillage
- Dry sowing with DAP results in a better germination than dry sowing with a hand hoe; more water is easily captured in the furrow.
- Ripping does not allow incorporation of manure into the soil, thus, conventional tillage should be allowed after a few years.

4. Rainwater harvesting for crop and livestock production

Namibia has developed an extensive infrastructure for bulk water supply from large dams, aquifers, canals and pipelines throughout the country though very little for crop irrigation. In rural areas there are several small dams, wells and boreholes. Except for some of these small dams that enhance recharge to boreholes and for storage dams, few water harvesting methods are in practice. The most common rainwater harvesting methods in Namibia include harvesting rainwater from the roof, runoff and floods. In the North Central Division it can be said that water harvesting is achieved through the natural “pans” called Oshanas. Water harvested on roofs from rainfall, in rural areas, has limited application. Much smaller quantities are harvested for crop production, particularly vegetables. Rainfall water collected even in small dams is usually too little for sustainable crop production. It is however most useful for livestock.

The runoff potential in most parts of Namibia is approximately 2% of the rainfall (Hydrology Division, 1998). The major zones of potential runoff can be distinguished as follows:

- Central strip which has little or no top soils, underlying impermeable geology, covering mostly hilly and mountainous terrain and at the most, moderate vegetation. This area has well developed drainage systems and a relatively high runoff potential with average runoff/rainfall ratios between 1 and 10%.
- Areas where there is no surface runoff due to sand dunes with a high infiltration capacity (Namibia and Kalahari deserts in the south); very flat terrain covered by soils with a good water absorption capacity (Eastern, north-eastern and Central which include Sandveld, Cuvelai, Kavango and Eastern Caprivi areas).

Runoff in the interior of Namibia occurs as a direct response to rainfall during the few heavy showers in the rainy season. The main reasons for this direct response phenomenon include erratic rainfall patterns. The main reasons for this direct response phenomenon include erratic rainfall patterns and high river bed losses. The physical features of the terrain are such that they have little potential for surface or subsurface storage, which would enhance delayed runoff.

5. Agroforestry as a conservation tillage technique

In Namibia, there is a very strong case for dry land agroforestry systems which are basically aimed at the deliberate management and introduction of high value trees on farm land, be it cultivated farm land or pasture or bits of uncultivated land between settlements. Examples include trees, to conserve soil fertility and also improve crop production by acting as windbreaks, shade crops and Nitrogen fixers.

5.1 A Case of riverline agroforestry

The present practice observed along rivers such as the Kavango and Zambezi, is that huge areas are used mainly for the production of rainfed annual crops. This means that in any year, there is little production on the riverline fields which are within a few meters of permanent water. In addition, no attempts have been made to trap or harvest flood waters to be used in the dry season to grow crops. The clearing of natural riverline vegetation for cultivation of mainly annual crops, represents not only a bio-diversity loss but also loss of the total productivity of riverline belts. Riverline agroforestry would attempt to mitigate this by integrating some perennial, biannual and annual crops to be produced along rivers. The philosophy is to maximise the production of these types of lands for the benefit of farming communities, while protecting the soil and maximising the use of available ground and river water.
5.2 Environmental sustainability and conclusions

The significance of soil and water loss in itself is not immediately obvious in areas where yields are very low. This is because it may be more efficient for an individual farmer to face a yearly loss of a small percentage of produce than to invest substantial amounts of money or time in methods that reduce environmental damage. Therefore there may be two sources of motivation for promoting conservation tillage from a sustainability point of view:

Firstly, the costs of learning a new technique must be low enough to justify doing so for the individual farmer. This is particularly likely to be true in areas that are already degraded and where the farmer either has to invest in new crops or face the expense of moving elsewhere. This is a conventional economic justification of extension generally.

Secondly, the remnants of riverline vegetation in Northern Namibia are likely to have much higher marginal values than they would in a virgin state due to the irreversibility of their loss. Hence conservation tillage will have value in reducing the need to convert woodlands into croplands. These values include bio-diversity generally and in particular, wildlife, in areas of high tourism such as Kavango and Caprivi. One key source of value of woodlands generally is in coping with drought, both providing materials for human use (for food and crafts) as well as browse for livestock. Again marginal values will rise as the amount of the resource falls.

References


Conservation tillage in Zambia:
Some technologies, indigenous methods and environmental issues

by

Joyce M. Siacinji-Musiwa

NRDC Zambia

1. Introduction

It is well documented that efforts over the past 2 decades to improve the performance of the traditional agricultural sector in Zambia have largely failed. Results of the 1995 IAS/UNZA Agricultural Sector Performance Analysis are particularly alarming as they point to a decline in both yields and gross area under production. Maize yields in Southern, Central and Eastern Provinces for example have declined by about 300,000 hectares from a peak of 1.2 million hectares in 1988. At the farm level, incomes have shrunk and families are generally less food security than previously. A recent World Bank Survey indicates an increase in poverty levels in the rural areas from 70% in 1994 to 90% in 1995.

At the institutional level, ineffective extension and research services and inappropriate agricultural policies, which have relied excessively on maize production, have been cited as contributory factors. However the recent sharp decline in the performance of agricultural sector is more likely to have arisen from major changes in climatic and economic circumstances. These changes include:-

1. The severe droughts experienced recently, particularly in the southern regions characterised by both a decline in overall precipitation and increasingly erratic distribution patterns.
2. The liberalisation of agricultural marketing under the Structural Adjustment Programme involving the withdrawal of subsidies for farm inputs and commodities
3. The collapse of institutional credit organisations
4. A sharp rise in interest rates on seasonal loans and a severe decline in lending operations.
5. A severe decline in the availability of draft power in communal farming areas as a result of Corridor disease and the attrition of active farm labour through urban drift and widespread incidence of Aids.

The IAS/UNZA Agricultural Sector Performance Analysis Study identified these trends as the major cause of a reduction in smallholder cropped land.

Excessive soil erosion and a decline of fertility in the traditional cereal production regions of Zambia particularly, Southern, Central and Eastern Province was recorded.

1.1 The farm level

1.1.1 Coping strategies

At the farm level the picture has been particularly bleak. The decimation of draft oxen, the reduction in active farm labour, and recent disruptions in input supply and marketing arrangements have all had a negative impact on productivity, income and most importantly, food security. On the positive side there is evidence that farmers themselves are attempting to adopt strategies to cope with these problems. These include attempts, at crop diversification, the use of drought tolerant varieties, the adoption of reduced tillage methods and an increase in off farm income generating activities. It is also evident that farmers are more receptive than ever before to ideas that will increase their self reliance and reduce their susceptibility to the recent negative influences of the climate and the economy. Outgrower schemes in Zambia are also playing an increasingly significant role in the smallholder sector. In 1996 for example LONRHO had over 70,000 farmers producing cotton. The total number of farmers producing for small and corporate outgrower schemes is likely to rise beyond 120,000 in 1997 representing 18% of all small farmers.

1.1.2 Degradation of the agricultural resource base
Farmers are less aware that conventional farming systems are destroying the land upon which they depend. Most farmers notice the inexorable decline in the productivity of their fields, however they generally believe this is a natural and irreversible process. ‘My land is old and worn out’. Furthermore ‘landuse’ technologies which have up to now been advocated to protect their soils are extremely labour intensive, and farmers have therefore been unwilling to adopt them.

Overwhelming evidence from research in Zimbabwe and Malawi over the past 12 years has underlined the negative effects of conventional husbandry practices on the immediate, medium and long-term productivity of the smallholder sector. The statistics are alarming and can be applied equally to most of Zambia’s agroecological Regions I and II. Furthermore, the extreme seasonality of agriculture in Central Africa and the consequent pressures placed upon small farmers who adhere to conventional practices has long been overlooked.

1.1.3 Immediate effects of conventional tillage and husbandry practices

i. Smallholders who practice conventional tillage will always plant late because they have to wait for the rains before they can start. For each day of delay after the first planting rains have fallen, farmers will lose 1.3% of their yield. Subsequent husbandry practice, no matter how effective cannot compensate for this loss. Farmers who are 18 days late for example will lose 25% of their production.

ii. ‘The rains always surprise us, everything has to be done at once, we cannot cope and so our work is done late, in a hurry and badly’. There is no better axiom than this farmers remark to describe problems all smallholders face with the onset of the rains. Activities such as land preparation, planting and weeding which should be sequential become concurrent and the farmers are driven by events, which overwhelm them.

iii. Unless farm land is contoured with bunds 30% of seasonal rainfall (300 mm in a normal year in Central Province) will be lost as runoff, and will be unavailable for crop growth.

iv. Unless farm land is perfectly flat up to 50 tons of top soil will be lost from each hectare annually.

v. On conventionally tilled and exposed land, up to 50% of applied fertilisers are lost in storm flow.

vi. The surface layers of soils exposed to the energy of rain drops are pulverised and soon become crusted and sealed. This affects crop germination and further accelerates runoff and erosion.

vii. Hoeing and ploughing each year produces hard pans, which restrict crop root volume and make crops more susceptible to dry periods.

1.1.4 Medium to long term effects

Conventional tillage, coupled with monocropping and bad husbandry practises lead to degradation and to a situation where the soil can no longer support crops. In Zimbabwe it is estimated that 30% of smallholder farmland is now totally degraded. In the densely populated areas of Malawi such as the Lilongwe plains, the situation is worse. Recent statistics gathered from a visit by the CFU to Malawi underline the problem in stark terms:

1. annual loss of topsoil 35 tons/ha or 160 million tons in total.
2. annual loss of nutrients 339,000 tons of nitrogen and 25,000 tons of phosphate valued at USD300,000 million; and
3. average maize yields declined by 4% to 11% annually. Present yields average 1.0 to 1.2 tons/ha.

The pattern of decline is similar in both Zimbabwe and Zambia, and there is no doubt that the accumulative effects of inappropriate and unsustainable farming methods have exacerbated the effects of recent droughts in southern Zambia.

2. Agro-ecological zones of Zambia

2.1 Climatic overview

The Zambian climate is sub-tropical and strongly seasonal, characterised by three distinct seasons:

Mean annual temperatures are between 19-22°C reaching their maximum annual range in the extreme south-west (14-26°C in Sesheke). The mean annual rainfall decreases from over 1000mm in the North to less than 700mm in the South.
2.2 Agro-ecological regions

Zambia has been classified into 4 broad agro-ecological region zones:

1. Region I The Luangwa - Zambezi River valley zone.
2. Region IIA The Central, Southern and Eastern Plateau
3. Region IIB The Western, semi-arid plains
4. Region III The Northern, Northwestern high rainfall zone.

Sometimes the zones are referred to as:

a. low rainfall areas (Zones I and IIB);
b. medium rainfall (high agricultural potential) areas (Zone IIA); and
c. high rainfall area (Zone III).

3. The benefits of conservation farming

Production, not soil conservation as such, is the priority for small-scale farmers. They do not deliberately set to degrade their land resources, but in their struggle to survive, they often have to concentrate on immediate short-term needs at the expense of sustainable soil use. Farmers give priority to those practices that best meet their family’s immediate needs for food, fuel, shelter and cash as well as to meet their social and cultural obligations to the community in which they live.

The benefits of Conservation Farming methods are proven and they offer smallholders the opportunity to increase their productivity, safeguard their land and reduce the risks of total crop failure in drought years. Sustainable agriculture means a series of farming operations that take care of the “whole” system in such a manner that farming can be sustained over a long period of time.

3.1 Conservation farming definitions

Minimum Tillage (MT) refers to reducing tillage operations to the minimum required for crop development. For hoe and animal draft farmers producing cotton for Lonrho for example it usually means scratching or ploughing out the row where the crop is to be established and leaving the rest of the land untouched before planting. MT is not a new concept and has always been a traditional way of planting for hoe-farmers in many parts of Zambia. Any farmer who waits for the rain then makes planting holes with a hoe to plant a crop is an MT farmer. However ox-draft MT is a new concept and came as a survival tactic by farmers to cope with the effect of Corridor Disease on their cattle.

The main benefits of MT are that farmers can plant a larger area and can plant early.

Conservation Tillage (CT) are all operations which: (a) protect the soil from the damaging effects of rain splash; (b) reduce runoff and keep more of the rain on the fields (rain harvesting), (c) make the best use of costly fertiliser and seed and (d), allow farmers to finish land preparation well before the rains.

Conservation Farming (CF) incorporates MT and CT and is a term used to describe a range of husbandry and conservation practices which when used in combination bring about the benefits already mentioned. Conservation Farming also means crop diversification and rotations so that at least 30% of the land is occupied each year by a legume. Farmers who do Conservation Tillage and also use rotations are doing Conservation Farming. Essentially, CF combines sound husbandry and management practices, which arrest soil exhaustion, increase productivity, and enable farmers to spread out labour demand and get their work done on time. The technology can be applied to a wide range of farming groups from resource poor to commercial with good results.

3.2 Key conservation farming and tillage practices

- Crop residues are retained on the land and not burned. If residues are scarce they are raked into ‘trash lines’ across the slope to capture rainfall and reduce run off. Ideally a minimum ground cover of 30% residue is recommended. Residues reduce soil temperatures, protect the soil, minimise runoff and improve fertility.
- Land preparation commences in August or even earlier. The labour requirement can be spread over a period of 3 to 4 months. In this way the farmer is ready to plant his/her crop as soon as the
Conservation tillage in Zambia

When the first planting rains fall. Planting is quick and easy weeding can commence as soon as weeds emerge.

- Planting basins of 30cms x 15cms x 15cms are dug with the hoe (these may be smaller in higher rainfall areas). These basins are permanent and are never moved. Successive crops are planted in the same basins each season. Carefully measured applications of basal dressing and/or manure are applied in these basins well before the onset of the rains. The crop inter-rows are never cultivated and apart from weeding operations the inter-row is not disturbed. This approach has many advantages. The basins remain concave after planting and concentrate the early rain around the seed and help to reduce runoff. Fertiliser and manure are placed where needed and wastage is minimised. Successive crops can take advantage of the root channels and residual fertiliser applied the previous season. Because the inter-row is not ploughed and weeds are not allowed to seed, the weed bank diminishes in time.
- Basins are spaced so inter-row weeding can be done by hand or oxen.
- Ox farmers using the new low draft, Shaka tine rip in the dry season and then establish their basins over the rip lines using the hoe. Alternatively they can use the Palabana Furrower to open planting furrow over the rip lines as soon as the first planting rains have fallen. Ripping reduces compaction, breaks plough pans and reduces the crop susceptibility to poor rain distribution.
- In the drier areas of Zambia, farmers use the hoe to make potholes in the inter-row during the first weeding. This technique harvests rainfall, improves infiltration, and reduces crop stress during dry periods.
- Legumes occupy 30% of the cropped area and are rotated with cash crops such as maize, cotton and sunflower. The legumes fix nitrogen and reduce the requirement for synthetic fertilisers. Deep rooting crops such as pigeon pea benefit successive weaker rooting crops by penetrating pans.

3.3 Establishment of the conservation farming unit

It is now commonly agreed that Conservation Farming (CF) systems provide the best opportunity for farmers to reduce their costs, increase their productivity, ameliorate the effects of drought, improve their food security, and protect the agricultural resource base from further degradation.

Accordingly, discussions between Donors, the Ministry of Agriculture, the National Farmers Union and the Golden Valley Agricultural Research Trust (GART) in late 1995 centred on the need to establish a cost effective and proactive unit to co-ordinate and promote the adoption of Conservation Farming Systems (CF) among smallholders initially in the more drought prone regions of Zambia. In November 1995 with interim support from the World Bank and the EU a Conservation Farming Unit and Conservation Farming Liaison Committee was established under the Zambia National Farmers Union.

The Committee has representatives from ZNFU, Palabana ADP, MAFF, SCAFE, GART, and LONRHO. The Committee meets every two months and has the following responsibilities:

a. ensure standardisation of technical messages, methods and approach;
b. act as a forum for exchange of ideas and experiences;
c. recommend priorities for research and seasonal demonstration programmes;
d. maintain liaison with all local and international research organisations involved in CF and summarise latest findings for end users;
e. assist and summarise latest findings for end users;
f. publicise and promote the conservation "effort" through the media; and
g. identify potential sources of finance to support the Conservation Farming effort.

The Committee is chaired by the Conservation Farming Unit (CFU) Co-ordinator. The Unit works with private sector outgrower companies such as Lonrho and with NGO’s by training staff and demonstrating CF practices with farmers. Such agencies provide the necessary services (extension, input supply and marketing) that enable farmers to exploit new CF technologies.

3.4 Conservation farming for ox farmers

Ox farmers cannot maintain the accuracy of planting in the same holes every year like hoe farmers, however weeding is easier for these farmers because they can use ox drawn cultivators. The advice to ox farmers to adopt Conservation farming include the following:

- keep residues in the field
- use minimum tillage; and
- train oxen to move in very straight lines so that the planting rows can be maintained year after year.

The common ox-plough is not a good implement to use for Conservation Tillage. Ox farmers therefore need an implement that can break up pans and not clog during land preparation.

The *Shaka Tine* is a ripping implement that can easily be fitted to a standard plough beam. It requires low draft and two small oxen (350kg each) can easily pull the tool. The tool is best used during the dry season to maximise shattering of the soil. The idea is to rip out the lines where the seeds will later be sown so that plant roots can penetrate the pan. The rip lines help enhance infiltration and they should be applied across the slope.

From work done by Conservation Farming Unit it has been found that a farmer can rip 2 acres per day as compared to ploughing one acre per day in the wet season. When farmers use Shaka tines they have at least 3 months in which to rip. The increased work pace allows larger areas to be cultivated. If the rip lines are made 90 cm apart, the farmer can even use oxen with a cultivator to remove weeds later.

The CFU is promoting the use of this tine with their demonstration farmers. So far, LOHNRO and CLUSA have ordered 200 tines each to give their farmers for the 1998-99 season.

The Palabana Subsoiler is a new implement to break up dry soil. It digs deep into the soil (25cm) and therefore breaks the plough pan. This will help improve the infiltration.

The attachment can easily be fitted to any standard plough or ridger frame found in Zambia. Depending on the soil type and depth or work, animal drawn sub soiler can work with satisfactorily results at different times of the year.

The Magoye Ripper and furrower is used for minimum tillage in the preparation of land for planting. It has advantages over the standard plough of low draft requirement, and it produces a furrow of even depth. The Magoye Furrower can be used to open a planting furrow as soon as the first planting rains have fallen. If the Shaka tine has been used, the furrower should follow the rip line.

The Palabana Ripper is becoming the most widely accepted implement. The ripper is used to make planting furrows either in dry or moist soil. Only along such furrow is the soil disturbed. Such an operation makes it possible to do dry planting and ripping with reduced draft while leaving the ground undisturbed.

The Palabana Ripper Planter Attachment saves time and labour. It is a planter unit added to the Magoye Ripper which makes it possible to rip, plant and cover the furrow in a single pass. Planting in this case is done even faster and much earlier than is done with just ripping.

In lighter soils, dry planting can be done before the onset of the rains. For heavier soils this equipment can only be used soon after the onset of the rains. Inter-row weeding can be done using an inter-row with a cultivator immediately after planting.

The Ridger body used on plough bodies or ridger beams has a clear point for good penetration. The wings turn soil upwards (like a plough) to form well shaped ridges. When a farmer needs to make ridges before planting e.g. sweet potatoes this implement can be used. This ridger can be used for tillage, weeding, split ridging and most important, conservation tillage, ripping.

### 4. Traditional methods

#### 4.1 Hand hoe

Since time immemorial the hand hoe has remained the predominant method for crop establishment in most parts of Regions I and II with the exceptions of Eastern Province. At the onset of planting rains farmers dig random holes into which they plant their cereals. Interplanting of pumpkins, okra, cowpeas and other crops may be undertaken later using the same method. Since the introduction of cotton and soyabeans in Central and Southern Province by the Lint Company (LINTCO) in the late 1970’s, farmers have been obliged to modify this approach to achieve the required plant population by scratching continuous planting lines with the hoe prior to or at the onset of planting rains.

#### 4.2 Hand hoe-ridge culture
Conservation tillage in Zambia

The Hand hoe-Ridge Culture is common practice in Eastern Province and Malawi. Ridges are split each year usually before the onset of the rains and new ridges are formed in the previous season’s furrows. Contour ridging was introduced by the colonial Government in Nyasaland as a measure to control erosion and to accommodate the production of hard fired tobacco. Unfortunately, the majority of farmers do not ridge on the contour.

4.3 Ox-ridging

Farmers in Eastern Province who grow tobacco or groundnuts wait until the onset of rains and then use ridger bodies to build up ridges, often by splitting the previous seasons ridges. Alternatively, ridges are built up during the growing season after ploughing and crop establishment, by using ridger bodies to weed.

4.4 Ox ploughing minimum tillage

This is a relatively new method adopted by cotton farmers who have lost draft animals but wish to maintain their cropped area. A recent survey undertaken by the World Bank revealed that 18% of all farmers had converted to this method to establish their cotton. The plough shear is generally removed and the trek chain stoned. The plough point is then used to open planting furrows after the onset of the rains.

5. Achievement of the CFU over the past two seasons

In 1997/1998 the CFU undertook 881 demonstrations with smallholders, up from 395 in 1996/1997. There is no doubt that many farmers have recognised the benefits of the technologies demonstrated and adoption by non-assisted farmers is already picking up. Particularly, they have understood the opportunity it provides for early and rapid crop establishment, and the moisture retention benefits in seasons of poor rainfall. Ox farmers have already noticed the effect of dry season mulch ripping in cotton yields.

Conservation Farming is becoming well known in Zambia and some agencies like DAPP and CLUSA have adopted Conservation Farming as the recommended practice for all their farmers.

The demand for advice and support from the CFU from a wide range of agencies is extremely encouraging.

6. Problems and constraints

Despite the reported successes in Zambia with conservation farming, the following have been identified as the problems faced in the adoption of Conservation Farming.

6.1 The absence of farmer groups and associations

This is regarded as the biggest problem. In practise the vast majority of farmers are fragmented, disorganised and geographically dispersed. The absence of cohesive and well organised farm groups is the most significant constraint facing the development of smallholder agriculture in Zambia. The transaction costs in dealing with a disorganised farming community is prohibitive whether it is for the provision of loans, extension services, markets, or the dissemination of appropriate technologies.

CLUSA’s Rural Group Business Programme is currently facilitating the formation of farmer groups in Mazabuka, Monze, Mumbwa and Chibombo and the CFU is working with these groups with very good results. CLUSA’s demonstration farmers in Mumbwa have achieved the best results in the 1997/98 season.

LONHRHO remains a major CFU client and presently has about 90,000 smallholders producing cotton. The structures established by LONRHO are based on administrative priorities to enable the dissemination of extension and provision of inputs, loans and marketing services. Although LONRHO recognises the potential benefits of Conservation Farming, its major focus is the growing of cotton.

6.2 Continuity

CFU works with demonstration farmers for 3 years in order that the medium term benefits can be
realised. Because of the high standard required by CFU, only 28% of the 395 demonstration farmers in the 1996/1997 achieved an adequate standard of management to warrant continued support. This means that with the drop of demonstration farmers, the inclusion of other farmers will mean a destruction in the demonstration programme.

6.3 Technology dilution and impact monitoring

Non-assisted farmers will not necessarily follow the complete package of measures. For example burning residues in a deeply entrenched practice, and in communal areas where cattle grazing is uncontrolled, residues are consumed well before the onset of the rains. Alternatively, the benefits of conservation farming are limited for farmers who cannot afford fertiliser and do not keep livestock.

The CFU does not have the capacity to assess uptake rates and the broader social, financial and environmental implications. Recently USAID has pledged support for a three-year independent monitoring and evaluation consultancy to undertake this work and it is hoped that this will be forthcoming.

6.4 Liming

The acidification of soil is a major problem in Zambia and is not only confined to the acid leached soils of Region III. A considerable amount of research has been conducted on this subject, including attempts to seek alternative means of arresting or reversing the acidity. These have largely failed and lime appears to be only short-term solution. Commercial farmers lime their land as a routine measure but due to the cost (application rates of 4 tonnes/ha), the vast majority of small holders cannot use lime.

References


Investigating into soil fertility in the North Central regions

by

Christopher Rigourd and Thomas Sappe

Northern Namibia Rural Development Project, P.O. Box 498, Oshakati

Abstract

This paper is a report which intends to identify and investigate some of the fertility problems in the North Central Regions of Namibia. The report first highlights the major features and constraints of three farming systems, with special focus on fertility problems at regional and area levels. It then presents the major soil types identified by farmers and those identified by technicians at plot level. The paper aims at building a basic soil classification. Farmers’ strategies to match their crop with their soils, and their fertility management practices are dealt with at farm level. The place for animal traction in fertility management is spelt out.

1. Introduction

In agronomy fertility is understood to comprise the functioning of a biological system with few but interacting components namely; soil, climate and the plant. Subject to technical, economic, social and historical determinants fertility is assumed to embrace the suitability of an environment for agricultural production (Boiffin and Sebille, 1982).

Although the climate and the soil may be the main components of fertility, a more global perspective is required, which encompasses:

- Physical environment: climate and soil;
- Economic environment: production systems, farmers’ integration into input and output markets;
- Social environment: role of livestock (farmers’ strategy in keeping livestock);
- Institutional environment, property rights and regimes (for fields and pastures)

According to Memento de l’agronome, (1991) two concepts of fertility must also be presented:

- the current fertility resulting in the current yields achieved by farmers and
- the potential fertility that must be related to the maximum yields farmers could possibly achieve, with no concern for economics and risk.

Some constraints within the farming systems can be alleviated, others cannot and these prevent farmers from achieving the maximum yields.

In North Central Regions (NCR) of Namibia, both soil and climate limit agricultural production and the fertility of the biological system is relatively low.

In general soils are poor in nutrients and organic matter. Alkalinity, salinity, sodality, poor water retention capacity and water-logging are all common features. Rainfall is erratic and low, direct sunlight is extremely intense.

Plants, the third interacting component, are local drought tolerant crops such as millet, cowpeas and bambara nuts. Drought tolerance or short duration plants cope with this environment and are popular with farmers. The drought tolerance of the local millet variety should be stressed. New improved short duration varieties have been developed and widely adopted by farmers such as Okashana No.1. Other improved millet and cowpea varieties are forthcoming.

Fertility is generally decreasing in the NCR. One of the causes lies in the socio-economic environment. The population and livestock pressure on the land has increased as the labour available on the farms has decreased. Other causes are related to farming practices.
Although decreasing fertility is a general trend in the NCR, different areas face different problems related to fertility, hence the need to be area specific.

This report intends to identify and investigate some of the fertility problems in the North Central Regions.

2. Methodology

The management of fertility determines the functioning of farming systems. Namibia has an history of a farming crisis which saw the collapse of the former system and the emerging of a new one to fit new conditions.

Following the defined global approach to fertility analysis, the approach adopted for this research was to bring together two perspectives:

- a farming system point of view and
- a soil science approach.

Practically this meant recognising the existence of both farmers' and technicians' knowledge in defining fertility. In the "Action Oriented Research (AOR)" approach adopted by the Northern Namibia Rural Development Project (NNRDP), farmer’s point of view was paramount, and the farmer and the technologist were equal partners.

Another approach issue was that fertility could not be dealt with purely by soil sampling and soil profile, plot level analysis. If fertility was to be understood within the farming system, it had to be addressed at different levels. The levels adopted were:

- Regional level; for instance to cover cattle movement between posts.
- Farm level; notably looking at farmers’ strategies.
- Plot level; to cover say, soil heterogeneity.

Practically, to complete this research in line with the approach presented, the following activities were carried out:

- 22 interviews, specifically on soil fertility, with farmers from 4 NNRDP pilot communities in Central, Western and Eastern areas.
- 15 sites analysed, with 42 soil samples analysed by the agricultural laboratory in Windhoek and soil profiles drawn.
- Interviews with farmers, related to soils, while conducting minimum tillage and weeding tests.
- Literature review.

Actually semi-interviews and sampling mostly covered two areas and two different farming systems identified: the one on the Western area and the one on the central Cuvalai area. Information regarding the eastern area was mostly collected "by the way" and reference is made here to a NNRDP report: "farming system study in Ekolala (next to Enhanha)" by Jocelyne Delarue.

This report first highlights the major features and constraints of the 3 farming systems, with special focus on fertility problems (regional level, area level). It then presents the major soil types identified by farmers and those identified by technicians (plot level), and aims at building a basic soil classification. Farmers strategies to match their crop and their soils, and their fertility management practices are then dealt with (mainly farm level).

3. Results and discussion

3.1 Farming system perspective

3.1.1 Common problems related to soil fertility in the three farming systems

The following fertility problems were encountered in the North Central Regions:

- Soils are sandy.
- Soils are poor in nitrogen & phosphorus.
Soils are poor in organic matter.
Soils have a very low structural stability.
Soils have a poor water retention capacity.
Soils tend to form hard pans: some inherent to the soil, others formed by repeated ploughing at the same depth.
Although farmers are well aware of the benefits of applying manure, they do not always have the means to do so: cattle are at the cattle posts, donkeys are not kraalled and labour is not available.
Water-logging is common although rainfall is limited.
The water content of some soils may change tremendously over short periods from water-logging to hard crusting on the surface
rainfall is low, erratic and falls in heavy storms, direct sunlight is intense and temperatures are high.
farmers practice continuous cereal cropping.
land is completely bare during the dry season.
most of the current practices to manage fertility are labour intensive although labour is scarce in the farming system.

The first bottleneck in the farming systems is weeding. One possible solution to tackle that problem is the use of the cultivator for weeding with draft animals. It had indeed been successfully tested in pilot communities and its use is now an extension message.

Once the weeding constraint is tackled, soil preparation, harvesting and threshing will be additional bottlenecks needing redress. Possible solutions with regard to land preparation are currently on test in Namibia.

Further problems are fertility and marketing of both inputs and produce.

3.1.2 Specificity of the three farming systems

a) In Eastern areas (pilot community: Ekolala), a forest is established on deep sandy soils. Rainfall averages 450mm. Most of the farms are recently cleared. The population density is still low. This is a pioneer front. Cattle posts are close to the farms.

Area specific problems related to fertility are:

- the sandy soils are particularly poor in nutrients.
- the water retention capacity of these soils is very low.
- the size of the field is initially limited by the labour available for slashing and burning the forest, and also by the stumps in the field.

b) In the Central Oshana Area (pilot community: Eefa and Onamutanda) soils are relatively better, rainfall average. The fields are old with typical Oshana system and dark "clayish" soils. The population density is high. Cattle posts are far from the farms, and cattle tend to stay longer in them.

Area specific problems related to fertility:

- Population and livestock pressure on the land is high.
- The size of the field is limited by high population. Labour is available for soil preparation and weeding.
- Cattle posts are far and cattle tend to stay longer there: horizontal fertility transfer is low.
- There is a shift in draft animal power from cattle: that used to be kraalled, to donkeys, that are not kraalled.

c) In the West (pilot community: Eunda) soils are relatively better and less sandy than in the East. Mopane bush covering a very hard soil is extensive. Rainfall is poor and averages 300-350mm. Population density is low and cattle posts are relatively close. The fields are younger than Central Oshana area.

Area specific problems related to fertility are:

- Rainfall is very poor.
- A Mopane bush with its associated hard soil is widespread: it is assumed that fallow cannot be a fertility management strategy.
• Fields, though young (1-3 years) are said to be less fertile by farmers.

3.1.3 Identification of the major soil types

Scaling the analysis down to the local level (plot/site level), two important characteristics were considered and are stressed

• at the regional level, the soils are generally poor
• at the field/farm level, the soils are extremely heterogeneous: farmers face extremely different soil types on their farm and must adjust their strategy accordingly.

It is sometimes difficult to make a soil classification with regard to soil fertility since a major determinant may actually be the site and topography. There is need to report both soil types and sites in fertility classification.

3.2 Identification by farmers

This section is based on interviews conducted with farmers and presents a simple classification of soils and sites as seen by farmers.

Farmers do not always differentiate soils and sites: hence names given by farmers may characterise either a soil or a site.

To assess the quality and fertility of a soil or a site, farmers are conscious of:

1. the soil reaction towards water: farmers consider soil water and not just rainfall to be the first determinant of farm yields. Water percolation and retention are important factors.
2. Location of land, hence its water, retention, runoff and drainage characteristics.
3. Colour of the soil. Dark and red soils are often considered good.
4. Hardness of the soil and texture. Soft soils are often preferred to hard soils.
5. Soft and Deep Sandy Soils are Type No. 1. These are deep sandy and soft soils which rarely form a surface crust or hard pan. Their colour is clear to dark red. Water penetrates easily, but retention capacity is poor. These are mostly found in the highest parts of the field.

The following names are used by farmers:

<table>
<thead>
<tr>
<th>Oshiwamboa name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ehenge (1A)</td>
<td>Eunda, Onamutanda</td>
</tr>
<tr>
<td>Omuthitu (1A)</td>
<td>Eunda</td>
</tr>
<tr>
<td>Efululu (1B)</td>
<td>Ekolala</td>
</tr>
</tbody>
</table>

b) Low Ground and Swamp, Loamy Sands are type No. 2. These are soils with clay content of 5 to 10%; high by Namibian standards. Their colour varies from dark grey to brown and very dark. Water does not penetrate them easily and tends to flood. These are found in the lowest parts of the field in small to large areas.

<table>
<thead>
<tr>
<th>Oshiwano name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okashana (small area)</td>
<td>Eefa, Eunda, Onamutanda, Ekolola</td>
</tr>
<tr>
<td>Edhiya (small area)</td>
<td>Eunda, Onamutanda</td>
</tr>
<tr>
<td>Okatenhegue (small area)</td>
<td>Eunda</td>
</tr>
<tr>
<td>Oshana (large area)</td>
<td>Eefa, Eunda, Onamutanda, Ekolola</td>
</tr>
</tbody>
</table>
c) Waterlogged and hard-dry soils are Type No.3. These are relatively shallow soils whose hard pan is between 20 and 30cm deep. Their hard pan forms a hard crust on the surface when water evaporates and their colour varies from clear to clear grey. These soils have important drainage problems. They waterlog even after small showers. The water content of these soils varies tremendously over a short period and the water retention capacity of the soil is low. These soils have poor fertility according to farmers and are found in the low to middle parts of fields. They are common in central Cuvalai areas and in the West.

<table>
<thead>
<tr>
<th>Oshiwambo name</th>
<th>Location</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethenene</td>
<td>Eunda,</td>
<td>Eunda,</td>
</tr>
<tr>
<td></td>
<td>Onamutanda,</td>
<td>Onamutanda,</td>
</tr>
<tr>
<td></td>
<td>Eefa</td>
<td>Eefa</td>
</tr>
<tr>
<td>Olundanda</td>
<td>Eefa</td>
<td>Eefa</td>
</tr>
</tbody>
</table>

d) Very hard soils in new fields are type No.4. These are mostly characterised by their hardness and are found in recently cleared fields. The soils tend to be very clear (white) in colour. Water does not penetrate them and this causes water logging. These soils have poor fertility from farmers’ point of view. They are found mostly in the Western areas.

e) Good Deep and Dark Soils are Type No.5. These are deep, relatively soft soils, without hard pan and hard crust. Their colour varies from grey, to dark grey and very dark. Water penetrates easily and these soils have the best water retention capacity. These soils are considered the best for cultivation and tend to receive more manure, ashes and food residues.

<table>
<thead>
<tr>
<th>Oshiwambo name</th>
<th>Location</th>
<th>English translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omutunda</td>
<td>Eunda, Eefa, Onamutanda, Ekolola</td>
<td>NA</td>
</tr>
<tr>
<td>Elunda</td>
<td>Eefa, Eunda</td>
<td>Former homestead, the heap of ashes and rubbish together</td>
</tr>
</tbody>
</table>

f) Other Unclassified Soils are such as *Oshivanda* (termite hills), which are very hard and impenetrable by water. These are especially good when mixed with other soils, a labour intensive operation.

*Oshitunu* refers to old termite hills, after being eroded by water and wind. They are considered to be of medium potential by farmers.

*Omulonga* is a soil where water settles.

Although farmers name many different soils and sites in different ways, the above groupings are considered encompassing.

### 3.3 Identification by technicians

A general feature of soils in the NCR, apart from those in the *Oshanas* or next to it, is their light texture which ranges from sand to sandy loam and loamy sand. On average the sand content is 87%, clay is 9.5% and silt is 3.5% respectively.

Typically, these soils:

- have a poor water holding capacity
- have a low cation exchange capacity and are generally poor in nutrients except in Calcium.
These sandy textures alone cannot explain the observed soil properties and must be considered in connection with compaction and surface crusting, which are important features determination of soil hardness.

Typically, clay content is low in the first horizon of the soil and tends to accumulate in deeper horizons. In turn the pH of soils always increases with depth alongside the increase in clay content. Within a field the pH of the "soft and sandy soils -Type No.1" (acidic) is lower than the one of the "good deep and dark soils - Type No.5" (neutral), and lower than the one of the "water-logged hard dry soils - Type No.3" (alkaline).

The buffering capacity must also be looked at, of which it is noted that due to low organic matter content and low clay content, most soils easily get buffered. The pH is easily altered upward or downward by acids or alkalis. This is true of non-calcareous sandy soils. Thus, although they may be slightly acidific (pH 6-6.5), the pH may be lower or higher around plant roots.

Soils that are calcareous (notably type No. 3 which contains calcium carbonates) may have low clay and organic matter content but may be well buffered. The very high pH soils are also well buffered due to a mixture of carbonates (including sodium). There is nothing that can be practically done to reduce the pH of the saline, sodic calcareous soils. They are very poor in organic matter and this facilitates leaching of nutrients hence a poor chemical fertility, and decline in structural stability of the soil.

Phosphorus is very low and averages 6 ppm, whereas an optimum for grains would range between 15 and 35 ppm. Ca, Mg, P, and K are often unbalanced. Moreover, these nutrients are always leached and concentrated in the deeper horizons, sometimes with accumulation of carbonates and salts in a compacted layer.

a) Soft and deep sandy soils (Type No.1) are always poor in K, P, Ca and often in Mg. They may have the lowest chemical fertility but this does not imply the lowest agricultural fertility since they do not tend to waterlog as Type No.3 does. They are rather acidic, although the pH increases with the depth when the percent sand decreases.

The combination of a low pH and low concentration of both Ca and K makes the availability of these nutrients for the plants low. The low pH results in a low availability of Mg for the plants.

Sodicity may be found in the deeper horizons. These soils are located in high parts of the field. Typical characteristics are:

- Sandy texture
- Low pH (acidic soils)
- Poor in nutrients (low chemical fertility)
- Found in High part of the field

They may be classified as arenosols.

b) Low ground and swamps, loamy sand soils (Type No.2) have a fair amount of silt (around 6-10%) and a high fraction of clay (for NDR) of about 20% in the deeper horizons as major characteristics. Deeper horizons are sandy clay loam soils. These soils are located in the lowest part of the fields and pastures.

Typical characteristics are highest clay content while deeper horizons are sandy clay loam. They are found in lowest areas

c) Waterlogged hard and dry soil (Type No.3), have one horizon or a thin layer where carbonates accumulate. High concentration of Ca may hamper the absorption of other nutrients. These soils have a drastic change in the profile with a hard compacted layer with a higher clay content. Carbonates tend to be accumulated in this horizon. Some possible reasons for hard crusting and hard pan formation are:

- Compaction of clay rich soils,
- Evaporation of salts and salt movement upward in profile,
- Presence of gypsum (CaSO4),
- Soluble silicates such as Sodium and Magnesium (gypsum – sodium silicate + sand would form a cement),
- Presence of Oxides of Fe, Al, Mn etc
Presence of other soluble minerals

All waterlogged sites, and only them, have a high electrical conductivity in the deeper horizons. That reduces salinity. Although the surface horizon has a neutral pH, suitable for cultivation, deeper horizons are alkaline (from pH 8.5 to 10.5).

Deeper horizons are also saline due to high concentration of Na, which will limit some plant ability to absorb water. Furthermore, the high Na concentration induces a low structural stability hence the soil turns to mud easily and becomes very hard consequently. The combination of alkalinity and salinity gives these soils little potential for cultivation.

Typical characteristics are:

- The presence of a compacted layer that prevents water to penetrate (the soil is not deep),
- An accumulation of carbonates,
- Hard crusting on the surface when water evaporates,
- Very low water retention capacity,
- Very low structural stability,
- Alkalinity and sodicity in the deeper horizons, and
- Salinity.

They may be classified as solonchak.

d) Good deep and dark soils (Type No. 5) have relatively neutral pH and this does not hamper the absorption of most of the nutrients, and is suitable for local crops.

Apart from too little P their common feature is they do not suffer from excess or lack of other important nutrients such as Ca. A major characteristic of this type is the gentle differences in characteristics between the horizons. With little hard crusting on the surface and no compacted layer, water penetrates easily down to the deeper horizons and the soil has a relatively good water retention capacity.

Typical characteristics are:

- Neutral pH,
- Relatively good concentration of the different nutrients (except P), and
- Gentle transition between the horizons allowing a good water penetration and retention.

No sample of very hard soils on new fields (Type No. 4), were analysed. Neither were any other ("non-identified") types.

3.4 Linking farmers and technician’s knowledge:

Four of the soil types investigated technically can be linked with those identified by farmers.

- Type No. 1: Soft and sandy soils
- Type No. 2: Low ground, swamps and sandy loam soils
- Type No. 3: Water-logged/hard dry soils.
- Type No. 5: Good deep and dark soils.

Since no soil samples were available of the "very hard soil on new field (No. 4)" and "non identified types", (identified by farmers), it is not possible to confirm or deny the existence of such types from a technical point of view. Since, within a farm the soils are highly heterogeneous, all these different types may be found, plus some sort of transitional soils. Farmers manage their soils according to suitability for cultivation and that, they judge according to "sandyness", waterlogging qualities and other practical aspects like hardness.

Since soils and sites are linked, these can be indicated on a transect (see Figure 1). Figure 2 exposes possible assumption explaining soil evolution.

4. Farmers’ management of fertility

4.1 Use of manure
Cattle and goat manure are well used by farmers to improve the fertility of their field, but donkey manure is hardly used. From the kraal to the field, manure is mostly transported in baskets and sometimes on donkey carts. The "permanent kraal" is displaced every few years to spread the fertility. At the time, the poles used for the kraal are changed and the former kraal site is cultivated. Often there is a "small temporary kraal" moved every few months over the field. This kraal was mostly be used for goats. In this case of study, manure was always applied on a site as a curative measure (when yields were poor) and never as a systematic preventive measure.

Manure was often applied as dry powder. Only a few farmers reported mixing it with straw or grass to increase its quantity. Straw and grass were preferentially given to livestock as fodder. Manure was first applied to millet plots, rarely to cowpeas and never to bambara nuts and groundnuts. When the "permanent kraal" was shifted maize was cultivated on the site to benefit from a very high organic matter content. When the "temporary kraal" was moved, either cereal (preferentially millet) but rarely cowpeas were cropped.

Farmers face two problems that limit the use of manure:

- Application is labour intensive. This is probably the major reason why farmers do not apply manure more often. Manure can only be applied before ploughing to avoid losses because of the wind.
- The availability of the manure itself. Cattle tend to stay longer in the cattle posts, which sometimes develop into secondary farms.

Donkeys are hardly kraalled and common thinking is that donkey manure is not good for the soil. This in turns does not facilitate the use of donkeys as draft animals. Goats are always kraalled at night, but produce little manure compared to the needs of the farm.

Nevertheless, on some farms goat manure may be the only source of manure.

4.2 Movement of the house and use of household residues

Ashes are always spread around the homestead. This brings some nutrients to the soil, but little organic matter. Food residues, if not given to livestock, can also be spread around the homestead and this contributes to some organic matter. The homestead and its surrounding are places where nutrients and organic matter are accumulated. Every few years it is shifted and the site having a good fertility is preferentially cultivated with millet.

Since brick houses are increasingly common, labour intensive, shifting cultivation is on the decline.

4.3 Ridges and soil preparation

For the last twenty years, ridges have been common in Eefa. Fewer were observed in Eunda and none in Ekolola where sandy type soils make them less necessary and more difficult to erect. Unlike western and central areas where crops are cultivated on the top of the ridges to avoid excess water, in the sandy eastern areas, farmers cultivated their crops in the furrow. Whereas in many other countries ridges are often used to concentrate chemical fertility at locations where the crop actually grows, it was not the case in the areas studied. The major reason for erecting ridges was soil water management.

Traditionally, farmers ridged the ground into small mounds. These were few square meters large and erected using a hand hoe. This practice is still in use by farmers not having animal draft power. Ridges other than mounds are increasingly in use, and this is facilitated by the use of animal power and the plough. The biggest ridges are often perennial (30-40cm high and 1.2m wide) and are maintained by a combination of the plough and the hand hoe. The medium sized (20-30cm high, 1-2m wide) are temporary and are made with the traditional plough. The smallest (20cm deep and 0.5-1m wide) are temporary and either made with the traditional plough or the hand hoe. Some furrows are simply those left by tractors which disc the fields. Ridges are important for soil and water management. The orientation of the ridges may change from one year to the other in sites with a flat or even sloppy topography. Regarding soil water management, ridges have the effects illustrated on Figure 3.

The use of animal power facilitates the erection of these ridges with an efficiency and economy not comparable to the hand hoe or tractor with disc plough. Farmers did not favour the tractor due to fear of it bringing poor soils from high depths to the soil surface.
Nevertheless farmers who want to prepare their fields early, so as to benefit from the first rain, when their draft animals are still weak, favour the tractor, provided the waiting list for tractor is not too long.

4.4 Use of fertiliser

Fertilisers are hardly used by farmers since they are not available in remote areas. The use of fertilisers on sandy soils and with low erratic rainfalls is controversial. The following arguments have been raised:

- If farmers invest in fertilisers and the rainfall are very poor, the benefit in term of extra production may not be worth the cost as it decreases marginal returns.
- Since the organic matter content of the soil is very low, the nutrients brought by the fertiliser are leached to the deeper horizons and do not benefit the crop.
- Unbalanced fertiliser, notably with a too high nitrogen content may adversely affect plant growth: the aerial part may develop too quickly compared to the root system.
- Application of fertilizers in case of drought may have negative effects on the soils.

Nevertheless one obvious fertility problem in the NCR is the very low Phosphorus content. Phosphorus may therefore be acceptable.

Potassium and Magnesium may only be necessary for some "soft and deep sandy soils (Type No. 1) having a poor chemical fertility. Calcium may not be required.

Very little information is available with regard to micro-nutrients, hence it is not possible to conclude. Eventually, fertilisers may not be applied in the absence of manure.
5. Conclusions and follow-up

5.1 Conclusions

The soils in the North Central Regions tend to be very poor in nutrients and organic matter. Furthermore some nutrients are unbalanced. This induces a poor chemical fertility. The physical fertility of many soils tends to be very low. Being mostly sandy soils their water retention capacity is low. Moreover, they tend to have a very low structural stability.

Other more specific characteristics should be stressed such as salinity, sodicity, alkalinity, and water-logging.

A basic classification would be into five soils types, soft and deep sandy soils, swamps and loamy sand soils, water-logged/hard dry soils, very hard, new field soils and good deep and dark soils. A major finding
was that soils are extremely heterogeneous.

Farmers would then rather think in terms of relative properties rather than absolute properties of soils. They relate better to conditions such as, hardness, water retention, water logging etc.

Technicians should than most probably also consider these types in more relative terms than absolute terms. Thinking in these relative terms, farmers decide on their coping pattern to firstly secure their millet production. Each plot is used for the crop it is most adapted to.

Some fertility problems are general to any type of soil, such as the limited organic matter content. Some others are type specific, and should receive a special interest. This calls for follow-up work.

5.2 Future work

Farmers have been involved in this research, and the results should now be presented to them. Notably, the soil classification should be presented to them and they should either confirm it, modify it or reject it. The same should be done for the other conclusions. This would ensure that technicians have good understanding of the situation and the problems.

Moreover, this investigation was conducted mostly in the western and central Cuvalai areas. One must now check to what extent the conclusions can be extended to the Eastern areas.

Ground has been laid as a first step for farmers and technicians to begin to discuss as equal partners with common understanding.

Farmers and technicians can focus on some of the problems related to soil fertility. This requires, ranking these problems with farmers. The knowledge that the ranking by farmers may be different from that by technicians is well placed.

The main problems to be discussed could be little organic matter content, lack of phosphorus, problem of poor water retention capacity, problem of water-logging, decreasing fertility trends and how to address them.

Further investigation through interviews, soil profiles, laboratory analysis could be conducted as necessary.

Conducting such tests should help the technician in refining, diagnose and better answer farmers’ constraints.

Acknowledgement

The authors would like to thank Dr. M. Rowell (Agricultural Laboratory/MAWRD) and Mr. Jorry Z.U. Kaurivi (University of Namibia) for their extremely valuable contributions to this report, in bringing a more soil scientific perspective, in helping analysing the laboratory results, and discussing and commenting on the early draft of this report.

The authors would like to thank as well Ms. Anny Hyllier, from the plant science project, for the support provided and the time spent to correct the first draft of the report.
Effect of socio-economic and gender issues on sustainable resource management

by

J.K. Rwelamira

Land and Agriculture Policy Centre

P.O. Box 243, Wits 2050

Johannesburg, SOUTH AFRICA

Abstract

The key to sustainable environment and natural resource management is to integrate marginalised rural people into the formal economy. The majority of such people are the women of Africa, who have virtually no access to farm-based resources, except through their male relatives. The lack of access to or rights over land and other resources among African women reflects itself in failed rural development schemes. The notion of natural resource management is intrinsically linked to rural development, because the allocation of resources is important in generating sustainable livelihoods. Without access to resources there cannot be enough incentive for sustainable natural resource management and consequently rural development is curtailed. Thus, there needs to be equality in the allocation of resources and support mechanisms, which encourage people to use their resources sustainably. This paper attempts to relate the socio-economic, cultural and gender issues of natural resource management, to environmental sustainability as it applies to Eastern and Southern African generally, and to the New South Africa in particular. The rationale is to relate resource access, ownership and control to the efficient and sustainable use of natural resources in agricultural production.

1. Introduction

As stated in the UNICEF Progress of Nations Report (1998):

"The day will come when nations will be judged not by military or economic strength, nor by the splendour of their capital cities and public buildings, but by the well-being of their people: by, among other things, their opportunities to earn a fair reward for their labour, their ability to participate in the decisions that affect their lives; by the respect that is shown for their civil and political liberties; by the provision that is made for those who are vulnerable and disadvantaged".

Of all the issues that influence society, none is more profound than gender: the countless, unspoken cultural rules that differently govern the behaviour of female and male persons in every country in the world, from the day they are born. The difference between men and women show up clearly in the division of responsibilities at home and in their communities.

In the farming sector, the situation is not different. While women are considered to be producers of food their male counterparts concentrate on cash crop and livestock production. Women constitute the main agricultural labour force in Africa., and indeed in the Eastern and Southern African region (ESA). Ironically, men cultivate larger areas and produce more agricultural goods, because they have access to more resources and better technology. This gender bias is an important cause of poverty, because it limits the women’s capacity to contribute to food production and economic growth. Greater impact and overall improvement in sustainable agricultural production brought about by the use of improved technology, such as animal traction (AT), can only be truly accomplished if gender issues are addressed in the process of rural development.

More than one fifth of humanity live in poverty while nearly two-thirds of humanity subsist on less than 3 dollars per day. The numbers of the poor are increasing. At the same time, the world is hurtling away from environmental sustainability.

1.1 Definition of environmental sustainability
According to the World Bank, environmental sustainability (ES), is defined as: maintenance of natural capital. Of the three forms of capital – human made capital, human capital, and natural capital, environmental sustainability falls in natural capital. Natural capital is the natural environment, which is the stock of environmentally provided assets, such as topsoil, deposits, atmosphere, tropical forests, ground and under-ground water, wetlands, fisheries and biodiversity. All these provide a flow of either renewable or non-renewable useful goods or services.

Sustainability means maintaining environmental assets, or at least not depleting them. It means maintaining global life-support systems. The rapid depletion of these essential resources, coupled with the degradation of land and atmospheric quality indicate that the human race has not only exceeded its current social carrying capacity, but is actually reducing future potential and biophysical carrying capacities by depleting essential natural capital stock.

The importance of sustainability arose because the world is recognising those current patterns of development are not generalizable. Present levels of per capita resource consumption in any one place cannot be generalised to all the people living currently, or future generations. ES became a widely espoused goal in the late 1980s and early 1990s. It was reinforced by the Brundtland Commission of (1987), and the United Nations Earth Summit of 1992 (World Bank, 1993).

Africa faces an environmental crisis, manifested by rapid deforestation, loss of soil fertility, low agricultural productivity, disappearing biodiversity, and unmanageable urban environment. These have thwarted the continent's social and economic factors. Some external influences have also contributed but these are not discussed in this paper.

The ESA region has considerable diversity and similarities. It is a region that is endowed with a variety of natural and human resources. The most important similarity is the dominance of agriculture and its contribution to national development. Agriculture employs 70% - 80% of the total labour force and contributes substantially to the region's gross national product and foreign exchange earnings.

Various studies have confirmed that this region is rich in renewable natural resources of land, water, forestry, wildlife and marine life (Rwelamira and Kleynhans, 1996).

Studies have been undertaken by the African Development Bank (1993) and regional institutions such as the defunct Southern African Centre for Co-operation in Agricultural Research (SACCAR) and the Southern African Commission for Conservation and Utilisation of the Soil (SARCCUS). These studies recommended various ways of solving agricultural problems affecting smallholder and large-scale farmers and those that deal with the conservation and utilisation of natural resources.

2. Key issues of environmental conservation and development.

2.1 Environmental issues related to agriculture in Eastern and Southern Africa

It is neither possible nor advisable to generalise about the extent of environmental degradation and natural resource management and mismanagement in ESA region. However, a pool of key environmental issues affecting sustainability of agriculture in the region is summarised below.

1. Population pressure, in some areas, has necessitated utilisation of marginal grazing land for food and cash crop production, leading to overgrazing. This problem is common in Tanzania, Botswana and Zambia. Resource use conflict is common in the smallholder agrarian systems, which is associated with the allocation of land between livestock rearing and crop production. Even among commercial-farming communities, long-term environmental consideration is sacrificed for short-term profits. This is true among commercial farms in South Africa and Namibia.

2. Pressure on the land created by population concentration due to conditions of war. This has been the case in Angola, Mozambique and now in the Democratic Republic of Congo.

3. Soil erosion: caused by over-exploitation of natural resources and and poor land management practices through over-cultivation, overgrazing and deforestation. This problem is prevalent throughout the region, but is more severe in some countries such as Lesotho and Botswana.

4. Water resource pollution, contamination of land and ground water due to industrial and agricultural activities. Pollution of water resources is a serious problem in Swaziland, Tanzania. Zambia and Malawi. Some countries have established environmental protection and pollution control bills, but enforcement is a problem.
5. Siltation of rivers and dams is increasing due to the population pressure, as people cultivate increasingly steep slopes, resulting in more soil erosion into rivers and dams.

6. Tsetse fly infestation, which limits grazing land per livestock unit and potential arable land. This problem is still serious in Tanzania, the Congo and to a lesser extent in Botswana.

7. Poor land management practices by peasant farmers which do not promote sustainability of resources. An example is bush burning to clear fields which exposes the soil to the sun and the impact of raindrops.

8. The communal land tenure system, which allows free grazing and accumulation of livestock. This undermines the concept of land carrying capacity and promotes environmental deterioration.

9. Natural problems like drought and aridity affecting environmental sustainability. In countries like Botswana and Namibia, drought underlies many of the problems encountered in the utilisation of land based resources.

2.2 Socio-cultural and economic issues

Environmental considerations affect virtually all aspects of social, cultural and economic development. While international and national development activities are organised along sectoral lines, environment is cross-sectoral, touching all areas of development. Also peoples lives and traditions are closely related to environmental conditions. People must be involved in environmental decision making and actions.

While the impact of environmental problems, such as deforestation, erosion and loss of soil fertility is being assessed, the underlying causes of such problems needs a closer look. Growing populations and the resultant stress on land requires special attention. Policies and incentives, which affect natural resources management, as well as traditional practices, land tenure, access to and control over resources, and other social and cultural factors, need to be reviewed. Likewise, the economic factors and political will necessary to make changes have to be assessed.

The 1990’s have seen environmental sustainability becoming a priority of economic development almost entirely due to social concerns. Lack of environmental sustainability harms people, and is inequitable and non-democratic. It requires social sustainability by way of scaffolding of people’s organisations that empower self-control and self-policing in peoples’ management of natural resources.

2.2.1 The cultural environment and animal traction

There are socio-cultural factors within the production environment, which comes into play in the overall decision process. In most countries of ESA region, animal traction technology is dominated by men. Where AT work involves oxen, there are additional gender related limitations and traditional roles where women involvement becomes limited. Studies in countries such as Tanzania, Zambia and Malawi support this observation. In countries like Lesotho, women, by tradition, cannot handle oxen. Livestock ownership in most of Sub-Saharan Africa, is deeply rooted in culture. For example, livestock, especially cattle are considered a sign of wealth and are the responsibility of men.

In recent years women in ESA region have become actively involved with animal traction, and especially as a means of transport. Through hiring and borrowing, women have had more access to animal power for cultivation, even though at the convenience of the hirers. This may cause poor timeliness and may affect productivity.

2.2.2 Land and women

Throughout Africa, empowering women, to reach at least parity with men, is overdue. Aspects such as equal access to land, job creation for women, health, social security and education for girls have raised concerns. Women empowerment is nothing more and nothing less than increasing women’s control over their own lives. This, according to Goodland (1993), includes increasing the choices open to women, especially in land ownership and women’s access to resources and credit.

Women, especially in the rural areas, see access to land as central to their role in social reproduction and the domestic economy. Women throughout the region are the food producers and land is important to them as a resource.

Fewer women than men are commercial farmers. Also, in conditions where there is a keen interest in stock farming among men, relatively few women aspire to become stock farmers. In the rare cases were women own stock, they are not part of stock owner’s organisations, where these exist, which excludes
them from decision-making processes.

In most rural communities, community politics and local governance are still largely structured by an overarching ideology and practice of male authority. Rarely do women participate in the committee or traditional governance structures of the community, except for women groups. This is despite the fact that they are deeply involved in community affairs and actively participate in social networks beyond the household. How can a community effectively address issues of environmental sustainability without involving women?

In South Africa where a Land Reform program is currently ongoing, the concentration is on the needs for land, as they apply to men and women differently. There is limited focus on the crucial questions of the relations of power that determine women’s participation in, access to and control over land and other resources.

2.2.3 Water, fuel-wood and women

Women, helped by children spend an un-proportionate amount of time and energy on two activities essential to all households, water and fuel. More time spent on these activities means less time is available for other productive activities. Thus, any facilitation of water and fuelwood supply will be beneficial especially to the poorest of the poor women.

A number of ways have been tried to alleviate the problem. Cheap rooftop collectors are used for harvesting rainwater. Where possible hand pumps on bore holes are helpful. Women use plastic containers for headloads of water, some use wheel barrows, animal drawn carts, or rudimentary wheeled urns, to lighten the burden. More innovative use of animal power should be looked into, to help in borehole pumping of water instead of limited hand and expensive diesel pumping.

Heavy reliance for cooking and heating by the majority of the people on fuelwood collected from natural woodland, has led to severe and worsening deforestation hence environmental degradation through soil erosion. Most African households in the rural areas use wood for cooking and other purposes. In most areas, fuelwood contributes over two thirds of the total energy used in the rural areas (Goodland, 1993).

While it is difficult to disaggregate causes of deforestation and erosion, fuelwood collection and overgrazing are major factors. Other factors such as forced overcrowding and poverty, as is the case in Angola, Mozambique, Namibia and the former South African homelands, add to the already serious problem.

Over time, fuel-wood is becoming scarce and is not within easy reach by communities. Wood collectors now have to go further into the forests to obtain wood. Scarce household money has started to be allocated to buying commercial fuels, mainly wood and paraffin, thus impoverishing rural households further.

Rising energy and cost for fuel-wood collection, like water, penalizes women. Raw fuel-wood is less expensive than charcoal, coal, electricity, paraffin or gas. Practically, all fuel-wood used in rural areas is collected by women. Due to woodfuel scarcity more women’s time is spent in collection. One headload may cost over 3 – 5 hours collection time. Depending on the size of the family and the different uses for the woodfuel, 2 – 3 loads may be needed per week, which needs 6 – 15 hours. Many women walk 6 – 19 kilometres per headload, weighing between 21-38 kilograms. Heavier loads have been recorded.

The possibility of cheap handcarts and animal drawn carts for wood and water is already being promoted. However, more innovative ways of using animal traction for this purpose needs to be looked into.

2.3 Who is responsible for environmental degradation?

Environmental degradation is exhibited by irreversible soil erosion, deforestation, gullying, sedimentation of farms, flooding, droughts, and other effects. While there is fair agreement on the severity of environmental degradation there is less agreement on the causes.

As partly described above, the main causes of environmental degradation can be summarised as:

1. Fuel-wood collection.
2. Artificially concentrated population; exacerbated poverty and denied access to resources.
3. Inappropriate land use, deforestation and soil loss.
4. Overgrazing.

2.3.1 Lack of access to resources

In a world of limits and scarcity, the affluence of the rich has an opportunity cost on the poor. Likewise, the powerful tend to dominate the powerless and take over the better resources from the country or area. Landless poor people are usually forced onto marginal soils that are difficult or impossible to work sustainably.

Ironically, it is the poor and powerless who become impoverished and this leads to environmental degradation. Most of the benefits of development, such as agricultural extension, technology and access to credit are enjoyed by rich and the powerful.

The lack of access to and rights over land and other farm based resources among most African women places them in a disadvantaged position and renders them victims of environmental damage. Inequality, poverty and sewed land tenure systems increase the usage of marginal agricultural lands, intensifying environmental damage by deforestation and encroachment on less fertile soils.

3. What can be done?

A strategy to combat environmental degradation and ensure proper natural resource management has to be all-inclusive and holistic in nature. All the stakeholders, whether peasants small-scale or commercial farmers have to be involved in order for such a strategy to succeed.

A rural restructuring program (RRP) to reduce artificial population densities and to rehabilitate existing damage is needed.

A program to rationalise land use via suitability zonation is necessary.

3.1 Women empowerment

All steps taken to eliminate or slow down environmental degradation must be accompanied by empowerment of women. Empowerment may include non-environmental issues such as effective health and reproductive health services such as the means of choosing to limit reproduction, a pre-requisite for population control.

According to Chimere – Dan (1993), women empowerment is "the ability to take control over their own lives". For this to happen, women need opportunity for informed decision-making on matters affecting them and their families. The means towards fulfilling women’s goals should be under their control. Women are agents of economic and environmental change, and must be recognised for their role in managing resources and families. Equal rights for women on wages and resource ownership is essential.

In South Africa, the new constitution guarantees equal gender rights to all land-related issues. However, in practice communities operating on tribal lands still adhere to traditional rules and regulations. In the traditional authority system, land continues to be allocated to men who in turn allocate it to their wives to use. In KwaZulu Natal, for example, since 1987, the law allowed women household heads to acquire land in their own right, although there is little evidence, so far, that this provision has become practice.

3.2 Destocking

Current patterns of overstocking are widely and graphically documented in most countries of the ESA region. There are no incentives to undergraze and there are compelling incentives to overgraze. Communal grazing on community rangelands always leads to overgrazing. Grazers do not count the often-irreversible reduction in productivity brought about by overgrazing. Unfortunately women do not have much say in this arena as most of them do not own livestock.

The significant savings, social security, sociological and prestige role of cattle ownership have to be balanced against the widespread degradation they cause. Women can play a vital and meaningful role in environmental groups that discuss program-wide cattle policy. Women are already involved in the stall-feeding of stock. They usually participate in collecting fodder and water and bringing it to the stock into the stalls. Rotational grazing by paddocking and seasonal herding away from deteriorating range and
to better range should complement this effort. The latter strategies have to be implemented by men and boys.

3.3 Tree planting

The Food and Agriculture Organisation (FAO) of the United Nations advocacy for tree planting is already observed annually in many countries of Sub-Saharan Africa. The benefits to rural development and the environment brought by trees include:

i. Restoration of degraded sites in high density areas.
ii. Watershed management.
iii. Fuelwood.
iv. Reduction of wind erosion.
v. Hedges for weather improvement.
vi. Provision of fruits, nuts and shade.
vii. Reduction of evaporation.
viii. Habitat for pollinators and honey sources.
ix. Green manure and mulching.
x. Traditional medicines.
xi. Provision of timber, poles and other wood products.

In places where tree plantations have been successfully established (e.g. in Swaziland), women have managed to play a major off-farm role in seed collection, seedling management, distribution, nursery management and participation in training thereoff.

There is still scope for more employment creation in the dry land trees sector such as wattles, dates, nuts, fruits, jojoba, cashew, leguminous and other indigenous tree species. The labour absorptive capacity of, tree based, smallholder agriculture is environmentally and economically significant.

3.4 Community, household gardens and agroforestry

In countries where land is extremely limiting, with a significant proportion of people being landless, kitchen or urban gardening and raising of small stock is already common. Community gardens, village ponds, or agroforestry are promoted as a means of alleviating poverty. Community gardens are entirely by elderly women and their female relatives. Gardens are irrigated either by bucket carried from a well, dam or a stream; occasionally by hosepipe or sprinkler. Women, thus, have the experience needed for replicating such labour intensive, poverty reducing and environmentally sustainable agriculture. Even peri-urban and urban gardens are often cultivated by women and women seem to be more willing to associate with each other for the common good. Such experiences have been widely documented (for example by: Roth, 1992; Rwelamira, 1997; King, et al. 1993 and others).

3.5 Appropriate technology

In view of the need for employment creation, poverty alleviation and better natural resource management, appropriate technology regimes have to be promoted. Expensive machines have usefully been replaced by solar, wind and animal traction as power sources. This change is a crucial step towards environmental sustainability and progress. It is an important step from subsistence to a modest surplus. The two most urgent needs for women in this regard are in:

- Easing fuelwood supply, and
- Water collection

4. Recommendations

Below is a summary of actions towards environmental sustainability for Eastern and Southern African, in order of priority:

1. Empowerment of women to accelerate the transition towards population stability and sustainability in rural as well as urban communities.
2. Increasing government and NGO assistance for water supplies and renewable energy sources.

3. Promoting human capital formation, with a particular emphasis upon improving education, training and employment creation for girls and young women.

4. Supporting technologies, which provide increased employment opportunities for unemployed individuals in rural and urban areas. Training on-the-job, apprenticeships, and tutoring.

5. Provision of improved health care for mothers, infants and children; social safety nets for the rural poor, and targeted assistance to low-income groups.

6. Providing increased support for rehabilitation of degraded ecosystems conservation and management of natural resources such as forests croplands and water.

4.1 International level needs for environmental sustainability

For completeness, at the international level, environmental sustainability needs:

1. Focus upon direct assistance to the poor, rather than expecting general economic development efforts to alleviate poverty.
2. The concept of sufficiency, rather than over-consumption.
3. Internalizing environmental costs in energy prices and accelerating the transition to renewable energy sources.
4. Internalising to the manufacturer of municipality the costs of disposal of toxic and non-toxic (e.g. sewage) wastes. Halting exports of such waste to our region. Such measures provide incentives to minimise toxic waste generation where it is produced.
5. Hastening technology transfers to rural areas, such that they may leapfrog environmentally-damaging stages of rural economic evolution.
6. Broadening conventional cost-benefit analysis to internalise environmental costs.
7. Increasing grants for rural areas to reach global environmental standards.
8. Supporting the maintenance of biophysical infrastructures upon which all-economic activity is built, and


<table>
<thead>
<tr>
<th>Countries able to support 1-5 times its 2000 population under subsistence level farming:</th>
<th>Countries unable to support 2000 population under subsistence level farming:</th>
<th>Not able to support 2000 population under intermediate level farming:</th>
<th>Country able to support 1 – 5 times its 2000 population under intermediate level farming:</th>
<th>Country able to support 1 – 5 times its 2000 population under intermediate level farming:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botswana</td>
<td>Angola</td>
<td>Lesotho</td>
<td>Botswana</td>
<td>Angola</td>
</tr>
<tr>
<td>Lesotho</td>
<td>Mozambique</td>
<td>Malawi</td>
<td>Mozambique</td>
<td></td>
</tr>
<tr>
<td>Malawi</td>
<td>Tanzania</td>
<td>Namibia</td>
<td>Zambia</td>
<td></td>
</tr>
</tbody>
</table>
Zimbabwe | Zambia | Tanzania
---|---|---


NOTE: These estimates are based on the available land, including potential cultivable, and the anticipated population increases.

Conclusion

Political will is a scarce resource in ESA. In some countries of the ESA region, it is still difficult to face up to the need for gender equality, income redistribution and population stability. If the concept of environmental sustainability has to be achieved, then each state has to commit itself to face these harsh realities. Empowerment of women is an inevitable first step towards population stability and sustainability.

It is easy to blame problems of environmental degradation to over-population. However, it is not population numbers that threaten the environment, but the lack of access to resources on one hand and over-consumption of resources on the other.

Massive information campaigns, directed to both men and women, particularly addressing the links between women's empowerment gender roles and economic impoverishment are necessary.

In order to achieve environmental sustainability and alleviate poverty throughout our region:

1. Human capital formation and social services, through education and training, employment creation, particularly for girls and women, to match that of boys and men, is necessary. Gender awareness is essential.
2. Conservation and prudent management of natural resources such as wetlands, water cropland and forests is paramount to environmental sustainability.
3. Appropriate technology has to be transferred to the rural areas to enable them to leap frog environmentally damaging stages of rural economic evolution. Such appropriate technology should be affordable, labour intensive and environmentally friendly. Animal traction has a special place in this regard.

References


Conservation tillage research and development in South Africa

by

Richard Fowler

ARC-Grain Crops Institute P/Bag X 9059,
Pietermaritzburg 3200, SOUTH AFRICA

Abstract

South Africa has a wide range of soils and climates. Extensive studies, especially over the past 25 years, have been conducted into practices and systems which could conserve the soil, water, energy and other resources required for sustainable crop production under various of these soil and climate combinations. Some of the results obtained and ongoing or envisaged work is outlined. It is hypothesised that, given the co-operation and support of international agencies and in co-operation with other African countries, the South African research system, spearheaded by the National Department of Agriculture and its Agricultural Research Council, could play a major role in achieving sustainable national and household food security in the sub-continent.

1. Introduction

South Africa has a total area of 122 341 000 hectares, of which only one third is level to moderately sloping and only 14% is arable. Appropriately 1.2 million hectares is irrigated, accounting for almost 30% of crop production and 4% of the Gross Domestic Product (Scooney & van der Merwe, 1992; Goodland, 1995). The cold Benguella (Atlantic ocean) current running up its west coast and the warm Mozambique (Indian Ocean) current running down its east coast account in part for the climatic extremes in South Africa – ranging from semi-desert in the west to semi-tropical in the east. The Southern tip, including most of the deciduous fruit and some wheat producing areas, receives most of its rain in winter. In the remainder of the country, erratic, spaced storms of high intensity, normally commence in September-October and continue, apart from a frequent mid-season break in January-February, to March-April. The mean national annual rainfall is appropriately 450 mm, with 75% of the country receiving less than 600 mm.

Only 3% of the arable area of the country is classified as being of high agricultural potential, almost 60% of the soils having a very low organic matter content conducive to land degradation and low productivity (van der Merwe & de Villiers, 1998). Maize is both South Africa’s staple food and most extensively (1.7 – 4 million hectares) grown field crop, followed by sugarcane and wheat. Maize in particular is often grown in areas of marginal rainfall or soil depth, together with sorghum and cotton.

In the past a net exporter of food, increasing population densities and past mismanagement of arable and pasture lands are threatening South Africa’s natural resource base and national and household food security. Major causes of soil degradation are organic matter depletion and soil sterilisation. These in turn cause acidification or alkalinesaturation, compaction or crusting, runoff, erosion, infertility and desertification (van der Merwe & de Villiers, 1998). Conservation tillage has the potential to arrest or reverse these processes, and its wide scale advocacy and adoption is therefore of national importance.

2. Background and conceptual basis

2.1 Conservation tillage pre-1950

Dominated by Euro-American thinking and the drive to "modernise" by maximising production utilising increasing quantities and types of external inputs, South African researchers and extensionists have only recently attempted to discover and understand indigenous conservation principles and practices (Oettle et al. 1998). An example of these is the terracing used by Venda farmers in the Northern Province (Critchley & Netshikovehla, 1997), but there are undoubtedly many more.

In the main, however, South African tillage principles and practice this century (except possibly in the past 5 years) have been almost exclusively derived from those expounded or utilised in Europe and North America. Thus Leppan & Bosman (1923), although they define tillage as "the manipulation of the soil by means of implements so that its structural relationships may be improved for crop growth", state that two of the objectives of tillage are ‘to pulverise the soil’ and ‘to place beneath the surface manure, stubble, stalks and other organic matter, where it will be out of the way’. The most important function of tillage was to prepare a good seederbed, inter alia ‘free from weeds and surface trash’.

Tillage implements fall into two categories – those that loosen the soil e.g. ploughs, and those that compact it e.g. rollers. The primary functions of the plough were to shear off, split the furrow slice vertically and horizontally, resulting in the complete pulverisation of the soil, and ‘put any rubbish beneath the surface’. Of the three types of plough available, the disc plough had a slightly lighter draft and was especially effective on very hard dry soil and for covering trash. The Lister Plough was a double mouldboard which left the ground with ridges.

Even then, however, it was recognised that moisture was the chief factor limiting crop production in South Africa, and winter ploughing was advocated so that the soil would face winter in a ‘rough condition’, conducive to weathering and receptive to the spring rains. Soils would then be ‘pulverised’ into a fine tilth, although the efficacy of preventing evaporation by dust mulches was much disputed.

Mundy (1923) advocated working land in both directions. Ploughing, he believed, was the most important tillage operation,
although there was little African evidence in favour of sub-soiling or deep ploughing. The low maize yields obtained were often due to the postponement of autumn ploughing. To counter erosion new land would be on as gentle a slope as possible, and ploughed and planted on the contour. If the size of land permitted, 'a useful practice was to leave natural roadways of unploughed veld parallel to the slope'.

Saunders (1930) believed the primary objective of tillage was to make the soil 'a place of hold-fast or anchorage for the plant', although other objectives included the soil incorporation of surface organic materials so they could be readily converted into humus. The ox was still the main source of tradition in South Africa. The main tillage operation was ploughing, but large heavy tine cultivators had recently been introduced 'to take the place of the plough in certain cases'. On the heavy black 'turf' soil of the Springbok Flats some farmers were ploughing only once every 2-3 years, using tines in the other seasons. The cultivator loosened the soil sufficiently but 'the only effective method of turning under organic matter was ploughing'.

Wind erosion, especially on the sandy soils of the (now) Free State, could be reduced by not winter ploughing, winter ploughing but leaving in a very rough state, or using the Lister plough to throw up ridges. Trials at Pietersburg (1923-28; Nothern Province) and Glen (1922-27; Free State) on red sandy and dark clay loams had indicated increasing yield advantages from 7 inch (180mm) or 10 inch (250mm) ploughing compared to 4 inch (100mm). This, it was felt, was due to the 'burning out' of shallower incorporated organic matter. Soil mulching required further investigation.

Thompson (1936) concluded that, the creation of a soil mulch had doubtful value in South Africa. Evaporation appeared to be the principal dissipating factor of rainfall, and was minimised by the presence of a dense soil cover.

Van Reenen (1935) found the most prolific cause of water and soil loss on ploughed land was ploughing up and down the slope. Ploughing should be done along the contours and, in (now) KwaZulu-Natal, the use of contour strips of grass had been found effective. In 1935 the Government had agreed to assist farmers check erosion, and local soil conservation committees were being established.

The first half of this century was undoubtedly a difficult period for all farmers, the rapidly increasing demand for agricultural products at often uneconomic prices leading to a systematic overtaxing of both grazing and arable lands. The silt load of some of the country's principle rivers during the 1919/20 season was estimated to be 187 million tonnes, which grew in the 1950's to an estimated average per annum soil loss of 300 million tonnes (Ross, 1957). Soil depletion became more and more pronounced, giving rise to widespread erosion and desiccation which the Soil Conservation Act (No.45 of 1946) was introduced to help, through subsidy and regulation, to curb. A new era of Conservation Farming was borne.

2.2 Conservation farming in South Africa post-1950

Klintworth (1957) identified the three most important factors contributing to the physical decline of soils as surface pulverisation raindrops; solar desiccation and heating; and trampling by stock (Figure 1). All these could be reduced by the maintenance of a mulch of straw or semi-decomposed compost on the soil surface, which would also encourage the build-up of soil organic matter and the penetration of soil roots.

Early work on conservation tillage in maize production involved stubble mulching and reduced tillage with tine of ‘chisel’ ploughs. Maize tillage research at Potchefstroom (now North West Province) over the 9 seasons 1955/56 – 1963/64 showed that reduced tillage had little or no adverse affect on yields. On a sandy soil at Viljoenskroon (now in North West Province) ripping to a depth of 450mm under the row produced significantly higher maize yields during the low rainfall years 1978/79 and 1979/80, while mouldboard plough treatments caused compacted layers below their working depth (Mallet, Koch, Visser & Botha, 1985). Owens, 1984 reported that sandy soils were particularly susceptible to compaction, as were heavier soils if worked wet or with heavy equipment.

2.3 Wind erosion

Approximately 2.5 million hectares in South Africa is prone to wind erosion. This is observed mainly by maize and wheat producers on sandy soils in the North West and Free State Provinces. Wind may remove soil from bare areas, and may in the process damage young plants. At a wind erosion symposium in 1974, four measures for the control of wind erosion were identified, namely:

i. Mechanical measures – the use of share ploughs or tine implements to create a coarse or cloddy soil surface;
ii. Organic measures – cover crops, or the strewing of crop residues or other organic matter on the surface;
iii. Stubble cultivation – leaving stubble on the surface;
iv. Strip cultivation – leaving the previous season’s crop standing, or cutting off high when harvesting and planting between the old rows. (Joubert, 1979).

2.4 Soil-water and tillage interaction

The most important elements of weather, which influence crop performance, are radiant energy and moisture (Mallet & de Jager, 1974). The amount of either which reach or remain in a soil can be influenced by the vegetative cover and especially the crop residues on the surface of the soil, which in turn can be influenced by the type and intensity of tillage.

Thompson (1965) working with sugarcane in (now) KwaZulu-Natal showed that the trash blankets improved soil moisture levels which resulted in increased yields. Mallet & Johnston (1983) compared the effect of conventional tillage and direct drilling on maize yield and the physical characteristics of a Doveton series soil (30% clay). After 8 years continuous maize they found direct drilled plots showed slightly higher compaction in the top 120 mm, but below this conventional tilled plots were more compacted. Organic carbon was higher in the surface layers of the direct drilled plots. Soil moisture in the direct drilled...
plots was much higher at planting, resulting in significantly higher yields in seasons of below-average rainfall.

Berry, Mallett & Johnston (1985) confirmed these findings in experiments incorporating four tillage treatments, with % maize stover cover at planting (shown in brackets):

i. Direct drilling (with 71% cover);
ii. Chisel plough (120mm deep) x 2 (with 55% cover);
iii. Offset disc (100mm) & Chisel plough (120mm) x 2 (with 29% cover);
iv. Mouldboard plough (250mm) & offset disc (100mm) x 2 (with 8% cover).

These trials showed that tillage practices which maintain higher levels of surface residues retained more water.

Figure 1: The consequences of inappropriate land use (Klintworth, 1957).

At the commencement of the second season of one of these experiments the plant available water (PAW) in the top 600mm of the soil profile of each tillage treatment was not significantly different. However, following primary tillage, PAW decreased with increasing tillage, attributed to the reduced evaporation prior to planting under the increased soil cover and in the less disturbed soil. Maximum soil temperatures at 50mm increased with decreasing residue, resulting in quicker seedling emergence and leaf area development during the early vegetative growth (Berry et al., 1987).

2.5 Surface residues and soil loss

Land & Mallett (1982) investigated the effects of various methods of primary tillage and seedbed preparation on surface residues. They found flail equipment to be more satisfactory than discs to cut up maize stover, as when the discs were set sufficiently aggressively they buried too much stover. The chisel plough left the most surface residue, twisted shanks being less affected by speed of operation but burying more trash than straight shanks.

A swanson-type rainfall simulator at Cedara in KwaZulu-Natal was and is still being extensively used to compare the effects of simulated rainfall events on soil and water loss from soils under different soil covers and subjected to different tillage treatments.
Land & Mallett (1984) compared the effect of six levels of maize stover providing 0-75% soil cover on a clay loam with 3.5% slope. Increasing percentage cover increased infiltration and reduced soil loss, with a minimum 30% cover required to keep both within acceptable limits.

A number of natural runoff plots were set up at Cedara in mid-1982. Soil type was a 2 metre deep Inanda clay (48% clay), slope 6.9 - 8.8%. Acceptable soil loss was 6.75 t/hectare (Table 1).

2.6 Weed control

Numerous workers have noted the tendency for weed spectrum to change under reduced tillage. Weed control in the long term tillage trials at Cedara became a major constraint, and it inspired investigations by P.E.L. Thomas. This study produced a system of control. In brief, the slower emergence and initial growth of direct drilled maize occasioned by the lower soil temperatures under mulch early in the season, together with the interception of pre-emergent herbicides by the mulch, allowed weeds such as Digitaria sanguinalis and Cyperus esculentus to successfully emerge over a longer period. Higher doses of the pre-emergent herbicides or slow releasing formulae (such as some granules) were of assistance. Direct post-emergent sprays of what came to be termed the ‘Cedara Blitz’ (paraquat mixed with a triazine with or without a top-up of the pre-emergent in high potential maize) provided the final solution.

The application of post crop-senescence herbicides to reduce weed seed set and the control of winter weeds to conserve soil moisture were also studied.

2.7 Long-term effects

A severe rainstorm in February 1985 caused severe lodging in all the maize on Cedara except that planted by no-till. Investigation showed this was due to the firm anchorage of the no-till plants (Lang, Mallett & Berry, 1986).

After 8 years, direct drill maize, on a Hutton/Doveton clay loam, it was found that the top 120 mm had become denser, and that organic carbon levels in the top 20mm was higher than in conventionally tilled plots. Four years later it was found that densities had stabilised but organic carbon levels had increased from 3.8 – 4.7%, compared to 3.3% in the conventionally tilled plots. Surface pH levels were lower and P, K and Al levels were higher in the direct drilled plots. Earthworm counts were significantly higher (Mallett, Lang & Arathoon, 1987).

Agenbach & Maree (1989), working in a winter rainfall area on a shallow sandy-loam soil with a gravel and stone content of 45%, compared the effects of no-till, tine and mouldboard based tillage systems in wheat monoculture and wheat-after-legume pasture systems. Most soil parameters were improved by less intensive tillage. Lawrance et al. (1998) analysed the long-term tillage trial at Cedara. Over the 13 seasons, the average yields from the reduced tillage treatments differed by only 10 kg/hectare, but exceeded the conventional tillage by 100 kg/hectare.

Table 1: Average annual soil loss (adjusted to a 9% slope) and grain yield from the Cedara runoff plots for the period 1983, and soil organic matter percentage in the top 150mm after ten years Continuous maize (after Russell & Gibbs, 1995).

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>SOIL COV%</th>
<th>MAIZE YIELD (t/ha)</th>
<th>SOIL OM%</th>
<th>AV. SOIL LOSS/yr (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Till</td>
<td>70%</td>
<td>5.7</td>
<td>5.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Chisel</td>
<td>30%</td>
<td>6.6</td>
<td>4.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Mouldboard Spring</td>
<td>0%</td>
<td>6.7</td>
<td>5.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Mouldboard (autumn)</td>
<td>0%</td>
<td>6.1</td>
<td>3.9</td>
<td>9.9</td>
</tr>
<tr>
<td>Control (rotavated only)</td>
<td>0%</td>
<td>-</td>
<td>3.8</td>
<td>61.9</td>
</tr>
</tbody>
</table>

Production costs were lowest for the direct drill treatment due to higher yields as well as fuel, labour and machinery savings. Other factors favouring reduced tillage systems were reduced soil erosion, increased moisture retention and the ability to plant earlier.

2.8 Conservation tillage research 1988-1998

The ARC-Grain Crops Institute Tillage Trial reported above was split to include a lime and a paraplough treatment in 1988. The acidification of the surface in especially no-till was attributed to excessive nitrogen applications, especially in drier years, and some subsoil compaction was apparent (Table 2). Subsequently the importance of crop rotation was noted and the trial again split to incorporate soya beans.

The growing awareness in South Africa of the importance of animal traction led Fowler (1996) to split another similar tillage trial two ways. The trial had been established in 1983 and incorporated No-Till, Chisel, Chisel & Disc and Mouldboard & Disc
(conventional) tillage treatments. In 1994 the trial was split both ways, all the maize crop residues being removed from two sub-plots and the others cultivated with similar equipment drawn by a 70kW John Deere tractor or 4-6 oxen. The mean yields from the two traction methods were identical, but the removal of the crop residue 5 months prior to planting reduced yield and plant density. Unfortunately the trial site had then to be vacated. Other workers however, from IMAG-DLO of Netherlands, ARC-IAE at Silverton and Fort Hare University, are pursuing animal traction based conservation tillage research.

On-farm conservation tillage trials based on tractor, animal draft and manual means are being conducted in the KwaZulu-Natal Department of Agriculture. The writer is working with them in a Monsanto funded project. No-Till crops like maize, cotton, and possible rotation crops such as soyas, cowpeas and dry beans are being tried. It is hoped some 200 on-farm demonstrations will be co-operatively established.

2.9 Conservation tillage adoption and research needs

One major constraint to the adoption of conservation tillage is the possibility of pest and disease surviving over-winter on the crop residues, especially if no crop rotation is practised. This led to an extreme reluctance on the part of wheat farmers to adopt conservation tillage practises and two major reversals in conservation tillage adoption by maize farmers due to diplodia cob rot and grey leaf spot (GLS) outbreaks. Tolerant cultivars to both these diseases are, however, available.

Table 2: The effect of lime and paraplough treatments on the ARC-Grain Crops Institute Tillage trial (after Berry, 1998).

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Control</th>
<th>Lime</th>
<th>Paraplough</th>
<th>Lime &amp; P/Plough</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-Till</td>
<td>5129</td>
<td>7246</td>
<td>5868</td>
<td>7670</td>
<td>6478</td>
</tr>
<tr>
<td>Chisel</td>
<td>7455</td>
<td>8141</td>
<td>7967</td>
<td>7974</td>
<td>7884</td>
</tr>
<tr>
<td>Chisel &amp; disc</td>
<td>7772</td>
<td>8318</td>
<td>7693</td>
<td>8239</td>
<td>8006</td>
</tr>
<tr>
<td>M/brd &amp; disc</td>
<td>8918</td>
<td>9044</td>
<td>8854</td>
<td>8345</td>
<td>8790</td>
</tr>
<tr>
<td>Mean</td>
<td>7319</td>
<td>8187</td>
<td>7596</td>
<td>8057</td>
<td></td>
</tr>
</tbody>
</table>

Other constraints include deficiencies or gaps in the information available to conservation tillage farmers. This occurs due to poor communication between farmers, advisers, researchers or because work under South African conditions is still required. Notable deficiencies include:

1. the introduction, proliferation and protection of earthworms;
2. the allelopathic and other effects of crops and weeds, growing or residues;
3. crop rotations;
4. cover crops;
5. surface acidification prevention and redemption;
6. the identification and development of appropriate implements, both tractor and animal powered;
7. the draft requirements for implement; soil type: moisture content permutations;
8. the immediate and long-term effects of the nature, amount and cover of various crop and weed residues.

Additional practitioner queries are presented in Table 3.

Table 3: Queries listed by the No Till Club, KwaZulu-Natal, South Africa in an adviser-defined order of priority and circulated to members for their comment in September 1998.

1. How effective are earthworms in moving fertilisers and lime?
2. Does lime move of its own accord through the profile under No Till?
3. What crop rotations are recommended for No Till?
4. Can a guide be presently published on the research results to date, for both the commercial and the small-scale farmer?
5. How does one identify the type of earthworm in the soil?
6. What is the best way of building up earthworm populations?
7. What is the best form of lime or gypsum to use, bearing in mind the loss through wind action, and the problem of applying small quantities at a time?
8. What is the safest way to change from conventional to no till?
9. Are earthworms necessary in our cropping soils?
10. Who has done research on No Till, and what are the findings?
11. What are the most eco-friendly pest control chemicals to use?
12. What effect does No Till have on soil and plant diseases?
13. Can there be a Nitrogen negative period under No Till?
14. What additional N is required to counter a Nitrogen negative period?
15. Does species variety make any difference under No Till?
16. What overall profit difference could one expect from No Till compared to Conventional Tillage?
17. What advantages does No Till have over Conventional Tillage in the context of machinery and machinery costs?
18. How will oats in a crop rotation perform in counteracting diseases?
19. What should the biological status of soils be (microbial, fungal, worm, mole, hums, etc)?
20. What are the best types of fertiliser to use?
21. What economic advantage does No Till have over Conventional Tillage in terms of diseases, pests, weed control, irrigation costs, labour requirements and fuel costs?
22. Is there a need to look at strip tillage?
23. How does the choice of crop or variety affect the use of No Till?
24. What are the machinery requirements for No Till?
25. Does a compacted layer form under No Till?
26. What information is available regarding the removal of residue by the grazing animal?
27. How serious is crop residue toxicity, and how is it overcome?
28. Could No Till be practised ad infinitum?
29. What methods of application of the various types of fertiliser may gain the greatest benefit?
30. What is a simple method of identifying soil structure in the field?
31. What are the effects of different types of Nitrogen?
32. Can No Till support denser plant populations than conventional Tillage?
33. What are the power requirements for No Till on different soil types?
34. What is the definition of No Till for our purpose?
35. Is there evidence that it sustains yields over the long-term?
36. What are the best machinery systems to reduce compaction at affordable prices?
37. How can machinery induced soil disturbance in No Till be further reduced?
38. Does No Till improve soil structure and, if so, how long will it take to do so?
39. Does it improve soil organic matter?
40. Does it harbour/preserve insects; can these insects be controlled under a continuous No Till?
41. Can an economic benefit be realised on these insects be controlled under a continuous No Till?
42. Does No Till reduce the irrigation demand of the crop?
43. Does it decrease the effect of drought on the crop?
44. Could it increase the interval between irrigation’s?
45. To what degree per soil type does it improve soil moisture relationship?
46. How do yields compare between No Till and Conventional Tillage?
47. Does it have any effect on the length of the period to crop maturity?
48. Can it be recommended for dryland cultivation?
49. To what extent does it encourage/discourage weed infestation and growth?
50. Will No Till increase soil fertility?

Berry (1998) emphasised the unsuitability of no-till for sandy soils (Table 4). Partly due to the constraints outlined above, but also due to the conservatism of advisers and practitioners, no-till has had extremely limited acceptance. Reduced tillage is however practised by many large scale commercial farmers, especially those cultivating sandy soils. No-till for vegetables and cotton producers is virtually nil, with the only adopters of any significance being some sugar farmers in KwaZulu-Natal. This is the case for wheat, medic, lucerne and canola farmers in the Western Cape, and maize, wheat; soya farmers in KwaZulu-Natal. In both these cases, only 2-3% of the area is under no-till.

### Table 4: Probable maximum number of seasons of no-tillage intervention required (after Berry, 1998).

<table>
<thead>
<tr>
<th>Clay content Top 150 mm</th>
<th>Grain crops</th>
<th>Silage crops</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dryland</td>
<td>Irrigated</td>
</tr>
<tr>
<td>1 - 8%</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>9 - 16%</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>17 – 24%</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>25 – 32%</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>33 – 40%</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>&gt;40%</td>
<td>32</td>
<td>11</td>
</tr>
</tbody>
</table>

### Conclusion

Considerable research and development of conservation tillage techniques has been conducted in South Africa, especially in the past 25 years. Much of this knowledge has still to be effectively digested and presented to potential practitioners, especially small scale farmers. Much work, especially on animal traction, crop rotation and acidification, remains to be done.

The reduced research capacity in notably the Agricultural Research Council (ARC), combined with the lack of motivation of many workers to engage in non-income generating research, or to recognise or try to understand the unique problems inherent in small scale farmer systems, may severely limit the investigative capacity of the South African system in the future. However, the prioritization by the South African Government of National Unity and its National Department of Agriculture of the protection and proper utilisation of the country’s natural resources, and its expressed desire to be of service and assistance to its neighbouring countries and own resource poor farmers will help. This, combined with the enthusiasm and commitment of the newly formed No-Till Club in KwaZulu-Natal will make the difference. The club has senior officials and
researchers in the KwaZulu-Natal Department of Agriculture; Vice-President Frans Hugo and various Directors and researchers in the ARC; and other individuals in the universities and other departments in South Africa. They will ensure that conservation tillage receives the support it needs.

This support is effectively linked to international experience and funding and is backed by the information and the requirements of our fellow Africans. The research and development capacities of South Africa will therefore play a major role in the rapid sustainable adoption of appropriate conservation tillage practices and systems in the sub-continent. Such adoption will have a major impact on ensuring national and household food security. It could also stabilise the natural resource base of the region and reduce production and living costs. This will lead to reduced unemployment and conflict. It will in turn facilitate the African Renaissance and Peace.

References


Lang, P.M. & Mallett, J.B., 1984. Effect of the amount of surface maize residue on infiltration and loss from a clay loam soil.


Pretoria.


Role of draft animal power in Ghanaian agriculture

by

Emmanuel Y.H. Bobobee

Agricultural Engineering Department

University of Science and Technology

Kumasi, Ghana

Abstract

Draft animal power in Ghana was first introduced into the dryer north of the country in the 1930’s to support the production of cereals and other export crops. Today there are over 35,000 pairs of work oxen out of a total cattle herd of 1.2 million. Nearly 15,000 donkeys are being used as draft animals especially for carting. The use of animal traction as an efficient means of production to save labour and reduce drudgery is concentrated in the Northern region which holds about all of the national work oxen. There are only a few other areas in the central part of the country where animal traction is being introduced. Most work animals are oxen, but in the Upper East Region many farmers use bulls. Donkeys for ploughing and ridging are used especially by women groups and farmers in the upland areas, and along the borders where cattle rustling is on the increase. No horses or cows are used for traction. This paper discusses the current status and potential of animal draft power utilisation in the country and the role played by the various stake-holders; scientists, extensionists, blacksmiths, farmers and development workers. Churches and non-governmental organisations (NGOs) have been in the forefront in pushing the technology among resource poor farmers over the years. Tamale Implement Factory (TIF) and a host of village artisans (some trained by TIF) have been manufacturing implements for farmers use. Among the many constraints associated with animal traction, dry season feed and water, cattle rustling, lack of spares, poor quality implements, lack of animals and cultural practices are reported by farmers as most important.

1. Introduction

Animal traction (AT) technology was introduced in Ghana by the British colonial government in the 1930s. The technology is widespread in the North of the country especially in the Upper-East, Upper-West and Northern regions where the tradition is deeply rooted. There are few places in upper Brong Ahafo, parts of Ashanti, Volta, Greater Accra and Eastern regions where animal traction is being gradually introduced.

Animal traction is mainly employed for ploughing, ridging and transport of farm produce. Little animal power is used for planting, weeding, harvesting and threshing. In many parts of the country animal traction is seen by many farmers, researchers and policy makers as an appropriate, affordable and sustainable technology, requiring few internal inputs. Work animals are providing farmers with vital power for crop production and transportation to reduce the drudgery and intensity agricultural production, so raising living standards throughout the communities to benefit men, women, young and old.

It is believed the efficiency of labour in Ghana’s agriculture could be increased several fold if animal traction and animal-drawn implements would replace the current method of land preparation and crop cultivation. Current practice is for most smallholder farmers to use the hand hoe and cutlass. The regional distribution of animal traction farmers, local artisans producing and repairing the animal-drawn implements has many shortcomings. Availability of animals for work, research facilities, management and health constraints and socio-economic problems are not well known or documented.

1.1 Objectives

The main objective of this paper is to report the findings of an animal traction technology resource mapping study carried out to establish a complete databank on numbers and distribution of draft animals and related infrastructure as well as promotional policies and strategies in Ghana.
Specifically, the project sought to document identifiable animal traction technology infrastructure in Ghana in the areas of:

- work animals availability in the country,
- implements in use and repair needs,
- ox-carts and donkey carts in use and repair needs,
- blacksmith and artisanal support,
- breeding centres and local sources of work animals,
- research work in animal traction and training centres,
- constraints facing animal traction development in the country.

The results of the study are intended to assist in the development of animal traction policy and technology generation in areas that are viewed as critical in pushing forward the frontier of the technology.

Important beneficiaries include district and regional agricultural development programmes, manufacturers, importers, distributors of animal-drawn implements and spare parts, non-governmental organisations, researchers and extension staff involved in the development and promotion of animal traction.

2. Historical perspective and developments

2.1 Animal traction history in Ghana

Animal traction technology was introduced as an alternative farm power source for tillage and transport in the Northern regions in the 1930s. Training centres were established at Zuarungu (Upper East Region) in 1934. Bawku, Navrongo and Tamale had centres built in 1938. The use of the technology was catching up well with farmers until the advent of independence in 1957. At this time the Government’s agriculture expansion programme saw tractors imported in large numbers, into towns and surrounding areas where AT training centres had been set up. The relative speed for doing work with tractors and the government subsidized lower cost of tractor services reduced interest considerably in the use of the AT technology. Since then, the promotion of AT technology has been left to be promoted by Churches and other NGOs. They provide training and credit facilities to farmers to acquire animals and implements.

The situation remained unfavourable until 1974, when the Ghana-German Agricultural Development Project (GGADP) intervened to give it a new boost. This project was set up initially as a fertiliser project, with the primary objective of distributing and encouraging the use of chemical fertiliser. Realising the existing tillage problems in the regions, the GGADP decided to encourage animal traction. In this regard, training stations were opened and stocked with the necessary training materials, and implements to train interested farmers. Bullock banks and an implement factory were established by the project to assist interested farmers.

2.2 Present situation

Until recent times, cattle in Ghana have been raised for meat and have not been improved for milk production or draft. The Ghanaian local cattle, the N’dama and the West African Short Horn (WASH) have much lower nutritional requirements, are more resistant to diseases and can withstand periods of feed scarcity and drought. Important draft cattle breeds in Ghana are reared by Fulani nomads who are not settled agriculturists. Most of the zebus coming from the drier sahelian regions are able to withstand the heat stresses, but find it difficult to survive in areas of high tsetse challenge.

The dwindling stock of old tractors in private hands, coupled with high prices of tractors and the high interest rates compel many farmers to opt for draft animal power services in the Northern part of the country. Animal traction is mostly used in upland areas where the soils are fragile. There are over 35,000 pairs of work oxen, and nearly 15,000 donkeys being employed by Ghanaian farmers (see Table 1).

Most work animals are bullocks (oxen), but in Upper East Region some farmers also use donkeys. Donkeys are mainly used for transport on single donkey carts, but there is an increasing interest to use donkeys also for ploughing and ridging. Working cows are not employed by farmers especially in the predominant muslim communities in the North.

2.2.1 Transitional zone and Coastal Savanna
In Greater Accra, Volta, Brong, Ahafo and Ashanti Regions together, there are less than 60 pairs of working bullocks and less than 50 working equines. Constraints include limited ownership of cattle, hence, small number of bullocks to select from, lack of knowledge of animal traction, extensive farming systems based on shifting cultivation, and heavy clayey soils in certain locations.

### Table 1. Summary of cattle and work oxen census in Ghana (1996).

<table>
<thead>
<tr>
<th>Region</th>
<th>Oxen pair</th>
<th>Bulls</th>
<th>Young bulls</th>
<th>Bullocks</th>
<th>Cows</th>
<th>Heifers</th>
<th>Zebu</th>
<th>Sanga</th>
<th>Ndama</th>
<th>WASH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper West</td>
<td>5000</td>
<td>14037</td>
<td>19917</td>
<td>19735</td>
<td>90127</td>
<td>58358</td>
<td>25226</td>
<td>37538</td>
<td>5614</td>
<td>157692</td>
</tr>
<tr>
<td>Upper East</td>
<td>21065</td>
<td>23213</td>
<td>23184</td>
<td>26354</td>
<td>76104</td>
<td>34387</td>
<td>9510</td>
<td>6032</td>
<td>2327</td>
<td>196848</td>
</tr>
<tr>
<td>Northern</td>
<td>9088</td>
<td>26422</td>
<td>43856</td>
<td>27246</td>
<td>90127</td>
<td>70891</td>
<td>31657</td>
<td>42112</td>
<td>3830</td>
<td>350236</td>
</tr>
<tr>
<td>Brong Ahafo</td>
<td>15</td>
<td>105</td>
<td>4351</td>
<td>1246</td>
<td>22261</td>
<td>8662</td>
<td>7235</td>
<td>11652</td>
<td>3843</td>
<td>27262</td>
</tr>
<tr>
<td>Volta</td>
<td>15</td>
<td>3293</td>
<td>10189</td>
<td>5148</td>
<td>48536</td>
<td>22367</td>
<td>6434</td>
<td>54082</td>
<td>1900</td>
<td>50510</td>
</tr>
<tr>
<td>Ashanti</td>
<td>5</td>
<td>1535</td>
<td>1922</td>
<td>825</td>
<td>8959</td>
<td>4064</td>
<td>3243</td>
<td>8482</td>
<td>3009</td>
<td>6800</td>
</tr>
<tr>
<td>Greater Accra</td>
<td>15</td>
<td>1710</td>
<td>7242</td>
<td>1928</td>
<td>29732</td>
<td>13686</td>
<td>5124</td>
<td>51809</td>
<td>1545</td>
<td>9151</td>
</tr>
<tr>
<td>Eastern</td>
<td>3</td>
<td>1639</td>
<td>6314</td>
<td>1324</td>
<td>22016</td>
<td>12492</td>
<td>6206</td>
<td>21381</td>
<td>2256</td>
<td>23851</td>
</tr>
<tr>
<td>Central</td>
<td>0</td>
<td>329</td>
<td>819</td>
<td>341</td>
<td>3635</td>
<td>1461</td>
<td>534</td>
<td>4640</td>
<td>551</td>
<td>1917</td>
</tr>
<tr>
<td>Western</td>
<td>3</td>
<td>254</td>
<td>344</td>
<td>355</td>
<td>2016</td>
<td>924</td>
<td>194</td>
<td>847</td>
<td>142</td>
<td>3607</td>
</tr>
<tr>
<td>Total</td>
<td>35209</td>
<td>77537</td>
<td>118138</td>
<td>84502</td>
<td>393513</td>
<td>227292</td>
<td>95363</td>
<td>238575</td>
<td>25017</td>
<td>827874</td>
</tr>
</tbody>
</table>

Several projects being funded by International Fund for Agricultural Development (IFAD), are promoting the use of animal traction in the transitional zones at Techiman (Brong Ahafo) and Nkwanta (Volta), but the adoption rate is low. As the technology is relatively new, support services including implement supply and repair, proper selection, training and re-training of interested farmers as well as financial assistance seems to be necessary for sustainable animal traction development. The few farmers who have been assisted to obtain animal drawn carts have found them profitable mainly because of hiring services to others.

### 2.2.2 Northern, Upper East and Upper West regions

The three regions contain nearly all the 35,000 pairs of work oxen and all the donkeys being used by the farmers (see Table 1). In these regions there are sufficient cattle and animal traction has been used for many years. The adoption rate in certain areas especially Upper East and the Sissala areas in Upper West is very high. The Technology suffered severe set-backs in the region during the periods immediately following independence in 1957 when government embarked on tractor mechanization schemes.

From 1985 to date, many farmers have embraced animal traction. Cotton production which is concentrated in the North is one cash crop that is increasingly dependent on draft animal power especially for land preparation. Bobobee et al. (1997), confirmed that of more than 35,000 ha under cotton, animal power is used to cultivate 25% of the area. Tractor and manual labour contributed 74.4% and 0.6% respectively. There are indications that with increases in the cost of tractors, their spare parts and imported fossil fuels, many more cotton farmers will be adopting animal traction for crop production in future. Animal traction activities in the Eastern part of Northern Region suffered a set-back due to the recent ethnic conflict.
2.2.3 Animal drawn implements

The majority of the available animal drawn implements are copies of the Eberhardt implements imported from Germany. Few Bourgignon ploughs from France and Emcot ridgers are also available with the farmers. Copies of the popular Eberhardt ploughs are made by the Tamale Implement Factory (TIF) and also by many blacksmiths in the Northern regions. The implements made by the TIF have bent beams to which ploughs are fitted with imported shares and mouldboards. The type of bent beam does not allow correct depth adjustment, especially when hitched to the small WASH bullocks.

Implements made by blacksmiths have similar problems, but also lack good workmanship. Ploughs and ridgers are manufactured in preference to weeding implements which are hardly seen in the country. Ploughs are popular in all the regions except the Upper East Region and the East and West Mamprusi districts of the Northern Region, where ridging is the popular primary tillage practice. The widest range of implements including peg-tooth harrow, row market, planter and weeding cultivator are used by the Sissala ethnic group in the Tumu and Lambussie districts of Upper West Region.

So far region-specific implement development based on the actual farmers' needs taking into account the agro-ecological conditions have not taken place. It seems that the drafts of the available implements (ploughs and ridgers) are too high for the small WASH bullocks. Other implements like weeders and groundnut lifters, as well as light implements suitable for small bullocks and donkeys are not available.

2.2.4 Tillage practices

Ploughing and ridging are the main tillage systems. Ridging as a primary tillage practice is well adopted in the Upper East Region. More appropriate soil and water conservation tillage practices based on tied-riding, ripping and direct planting technologies are less common.

2.2.5 Animal drawn transport

Single donkey carts are widely used in the three Northern Regions, much more than bullock carts. Many women and children use single donkey carts to transport building materials, water and the farm produce. Animal drawn carts have proved effective and economically attractive for rural transport. This is evident by a high demand and supply of carts from the Tamale Implement Factory, and many artisans in Kumasi. The two-wheeled bullock and donkey carts are somehow standardized and partly made of scrap materials, particularly the axle. The more expensive double-axle carts are being promoted by few projects, but production has not been taken over by local artisans.

2.2.6 Research

There has been some socio-economic research relating to animal traction in Northern Ghana. Systematic testing and durability trials, research and development of animal drawn implements have not developed. Imported collar harnesses for donkeys and bullocks have been modified and promoted by the Animal Traction Centre under the Agricultural Research Station, Nungua. The adoption rate is low. The innovative double collar harness developed by blacksmiths and farmers at Kalijisa and other parts of the Builsa districts needs support for widespread adoption among the emerging donkey users. Improving the widely used uncomfortable double withers yoke for bullocks is also attracting research attention.

2.2.6 Training and extension

The rising interest in animal traction farming calls for expanded training programmes on the technology at all levels including farmer training. Animal traction at Farm Institutes and Agricultural Colleges is frustrated by lack of facilities such as animals, implements teaching manuals, literature and experienced instructors.

With the exception of few extension staff frequently involved in training farmers and bullocks, and often supported by NGO's most of the frontline staffs have limited skills and exposure in training farmers and animals. Besides, there is a need for animal traction extension materials.

Most artisans have only few basic tools and equipment to manufacture the implements and spares. They copy the existing implements especially the bent beams without knowing the effects of the design on the animals. Teaching of basic agricultural engineering requirements for animal drawn implements is needed...
Role of draft animal power in Ghanaian agriculture

http://www.fao.org/ag/ags/agse/agse_s/3ero/namibia1c7.htm

3. Constraints

Animal traction farmers are facing several constraints. Problems identified by farmers and ranked in order of seriousness are as follows:

1. scarcity of draft animals, implements and spares.
2. theft of animals,
3. death due to poor health of a work animals during peak working period,
4. lack of dry-season feed and water,
5. limited use of animals throughout the year,
6. high cost of implements and spares,
7. lack of durable accessories and spares.

The available durable implements like the ones from the TIF produce high draft for the animals to pull and this makes the animals to be tired faster especially at the start of the season.

4. The future of animal traction development in Ghana

4.1 Outlook for animal traction development

Draft animals have been important in Northern Ghanaian farming systems for a long time and are expected to become more important in the Transitional and Coastal Savanna agro-ecological zones in the future. However, there is a need for a number of strategies to systematically promote and improve the use of animal traction. Some of the strategies are:

a. The establishment of animal traction research centre within the Ministry of Food and Agriculture. This would be affiliated to the Council for Scientific and Industrial Research (CSIR), to co-ordinate activities and to lead the necessary, on-farm testing of implements and development activities.
b. Demand driven approach to animal traction problems with farmers playing active roles.
c. Human resource development at all levels including training and support to blacksmiths.
d. Effective involvement and use of universities, agricultural colleges and farm institutes to carry out necessary research and the training of extension staff.
e. Systematic development of animal traction training manual and national standards.
f. Applied research and extension efforts to increase the efficiency of the existing yoking system for bullocks, and the use of animal power for planting and for weeding.
g. Gathering of more information on the profitability of animal traction in farming and rural transport and, where applicable, to include the use of animal traction in the cropping budgets.

4.2 Animal traction technology generation priorities

Animal traction use over the years has been limited to ploughing, ridging and carting. Tillage with animal power has enabled farmers to increase the land under crop. However due to lack of planting, weeding and harvesting technologies with animal power, these operations are still carried out with manual labour. As a result the seemingly large expanse of land under crop does not produce commensurate yields because other operations suffer from timeliness cost depending on availability of manual labour during peak periods.

To avert this yield decrease and to close the technology gap to enable farmers derive maximum benefits from the animal traction technology, the following technologies need to be developed:

• animal drawn planters,
• weeding and harvesting technologies.

4.3 Planting with animal power

Delinted cottonseed produced by the Plantations Development Limited at Wa in the Upper West Region, and the policy of all the major cotton producing companies to plant delinted instead of fuzzy seeds, has brought to the fore the need for animal-drawn cotton planters to be developed and extended. This planter
will be used on fields prepared by both tractors and animal power.

4.4 Weeding technology

With the exception of re-shaping of ridges with animal traction in the Lambussie and Tumu areas, presently all fields ploughed with animals are weeded by hand. There is therefore the urgent need to develop and promote animal-drawn weeding technology with either the rigid or spring tine cultivators. The use of the ridger to re-shape ridges should also be promoted.

4.5 Harvesting technology

Animal-drawn groundnut lifters need to be developed, tested and promoted in groundnut producing areas.

4.6 Comfortable yokes and harnesses

The present withers yoke produced from wooden planks have been reported to be uncomfortable to the animals. The point of contact on the neck of the animal is so small that the pressure developed causes harness sores and restricts the animals from giving out their best. New and improved yokes using the traditional wooden planks with the contact points made to fit the shape of the neck of the animal should be promoted. The existing yokes could be modified through the removal of excess material at their present points of contact. The use of cushion and rags for lining contact areas could also be investigated. Additionally, the use of the lighter bamboo for withers yoke should be investigated and promoted.

The innovative collar harness developed by farmers in the Bulisa district for harnessing a pair of donkeys needs further investigation and promotion. Since donkeys are not prone to rampant theft like the oxen, additional to the fact that they are equally hardy and can be used for field work, this new and innovative collar harness needs more attention.

4.7 Wear resistant soil engaging parts of implements

The implements made by TIF have ploughs fitted with imported cast shares, while those made by local blacksmiths have shares forged from mild steel without any hardening process. Locally manufactured soil engaging parts like shares and heels wear fast. Farmers sometimes change these parts about three to four times in a season cultivating under 15 hectares (Dibbits and Bobobee, 1996).

On-farm testing and durability trials are proposed for improved shares and heels to ascertain the wear and reliability of these plough parts. The imported cast shares used by TIF have average Rockwell Hardness ‘C’ values of 49 (HRC), compared to 70-80 HRB values obtained from the locally forged parts. There is the need to investigate and improve upon the hardness and durability of the local products to enable the farmers derive maximum benefits from their implements.

4.8 Curved versus straight beams of implements

The original imported Eberhardt implements were designed and manufactured to suit the big animals of the temperate regions. With the small WASH and Ndama bullocks being used in the country, this original designs are not suitable. The curved beam makes the hitching points to be too high thus pushing the theoretical centre of resistance of the implements far behind the implements. This has the resultant effect of the implement to be unstable, making the implement to virtually ‘walk’ on the share point with the heel hanging in the air. This imposes undue pressure on the operator and high draft on the animal, leading to early tiredness of both. It is advisable that the Ministry of Food and Agriculture (MoFA) raises the issue with TIF, which is the leading manufacture to change its present design to a straight beam to raise the productivity of both animal and operator. The other blacksmiths will follow TIF’s example in producing the straight beams.

5. Conclusion

Animal traction, like electricity, education, rural road networks and communications, can empower rural communities. If one studies the history of farm power evolution in Ghana, one draws the conclusion that animal traction development has been neglected over the years. Despite the years of neglect, animal traction is still a major farm power component by farmers in the northern part of the country.

Notwithstanding the problems associated with the adoption and use of animal traction in the agriculture of
Northern Ghana, animal traction still offers the best option and opportunities for increase in farm sizes, reducing drudgery in farm work, reducing labour costs, raising yields and farm production in general. However, these opportunities can only be utilised if farmers are assisted to acquire working animals and accessories at reasonable prices. The availability of quality spare parts to ensure sustainability in the use of implements is also a condition for success.

Finally the need to research into the design and development of comfortable harnesses and more appropriate and durable implements for planting, weeding and harvesting should be supported and promoted.

References


Indigenous soil conservation tillage systems and risks of animal traction on land degradation in Eastern and Southern Africa

by

R.M. Shetto
Senior Research Agricultural Engineer, MARTI Uyole
P.O. Box 400, Mbeya, Tanzania

Abstract

Traditional agriculture in the past was compatible with the level of population, ecological environment and intensity of cropping. Long bush fallow periods restored soil fertility effectively while tillage practices such as pit cultivation; mounding, ridging, mulching and earth-bunding successfully conserved the soil. The indigenous soil conservation systems evolved over the course of time to suit certain environments. They are usually location specific and have designs that reflect their multiple functions such as fertility management, erosion control, drainage and water harvesting. Moreover, most indigenous soil conservation tillage systems are labour intensive and are difficult to mechanise, thus severely limiting the cropped land. In some areas they have been replaced with conventional flat cultivation. Conventional flat cultivation whether done by the hand hoe, draft animals or tractors, needs to be accompanied by appropriate soil conservation measures, or it will encourage soil degradation. The adoption of the ox-plough is usually associated with extension of cultivated land which may need clearing. Plough pans may form with continuous cultivation and the extensive use of sledges increases risks of soil erosion. Therefore in order to protect the soil for sustainable agricultural production, land conservation should be integrated in the normal crop and livestock husbandry practices. Smallholder farmers can relate to the land husbandry concept, which should be emphasized. In areas where animal traction is on the increase, minimum tillage using animal drawn ripper tines and wheeled cart transportation should be encouraged to reduce risks of soil erosion. Participatory community based approaches should be used to create a more ownership attitude and the "free for all" livestock range management system should be revisited to increase personal responsibility on the land and increased investment on soil conservation activities.

1. Introduction

Agriculture is the dominant sector in the economies of Eastern and Southern Africa providing up to 75% of the total export earnings. Agriculture contributes between 15 and 50% of the Gross Domestic Product (GDP) and provides employment to 80% of the over 150 million people living in the region (FAO, 1991). Moreover agricultural production is predominantly subsistence and the productivity of the smallholder farmer is generally low. The potential for lateral agricultural expansion, to meet the food security needs of the growing population is mainly constrained by a combination of low soil fertility, poor production systems and erratic, unreliable rainfall. Most soils have high acidity, poor structure, low water holding capacity and low organic matter (Ofori, 1993), quality constraints that have to be overcome in order to improve productivity for sustainable agriculture.

Traditional agriculture in the past was compatible with the level of population and ecological environment. Long bush fallow periods were effective in restoring soil fertility for the prevailing level of crop yields and intensity of cropping. Pressure on land has resulted in drastic reduction of the fallow periods and in some countries they have disappeared completely. Intensive land cultivation – albeit with low use of inputs due to the farmers’ inability to purchase what is necessary has set in. This leads to nutrient "mining of the soils" which is manifested in degraded soils and reduced crop yields.

Indigenous tillage practices such as pitting, mounding, ridging, mulching, earth and stone bunding successfully conserved the soil but in recent years, conventional flat cultivation, which is associated with modern agriculture has set in. Mechanized conventional tillage encourages splash and sheet erosion as it leaves the soil surface bare, under sporadic tropical downpours.

This paper briefly reviews the indigenous soil conservation tillage systems and discusses the risks of...
animal traction on land degradation. It also looks at the challenges of soil conservation in the region.

2. Tillage systems and land husbandry

2.1 Tillage and land degradation

Land degradation is the process that leads to the loss of biodiversity and productive capacity of the land (Box 1). Land degradation is therefore a major environmental concern for sustainable agriculture in Africa.

Box 1: Land degradation

Land degradation starts with the impoverishment of, and reduction in vegetative cover, exposing the soil surface to accelerated erosion and leading to reduction in soil organic matter and nutrient content (IFAD, 1992).

2.2 Conventional tillage practices

Tillage is defined as physical, chemical or biological soil manipulation to optimise conditions for germination, seedling establishment and crop growth (FAO, 1993). The primary objectives of tillage are seedbed preparation, provision of a good medium for plant roots, water infiltration and retention, erosion and weed control.

In Eastern and Southern Africa, conventional flat cultivation systems are commonly practised. In this practice, the soils are cut, inverted and pulverised, burying most of the crop residues underneath, leaving a clean fine seedbed. Under the impact of raindrops, the soils may cap or crust. This reduces infiltration and increases water runoff, accelerating sheet erosion.

Box 2: Reduced yields due to plough pans

In Njombe district in the Southern Highlands of Tanzania, the grain yield in maize dropped from 5 tons/ha to 1.2 ton/ha in ten years. This was caused by the formation of plough pans. 2-10cm below the surface due to continuous conventional tillage, using 34 discs trailed harrows year in year out. (Shetto and Kwilingwa, 1989).

Conventional tillage is energy intensive and results in a limited rooting volume due to plough pans formed at shallow depths which restrict root growth and development (Box 2). It also results in a decline in organic matter content and increased soil erodibility.

2.3 Conservation tillage

Conservation tillage can be defined as a crop planting system that allows minimum disturbance of the soil to allow seeds to be sown while ensuring maintenance of crop residues on the surface (FAO, 1995). The crop residue left on the surface, cushions rain drop impact and reduces water movement, hence soil erosion. As water runoff and evaporation are reduced, water penetration is improved. The crop residues and roots build up in the long term, improving soil structure. Draft power requirements are also minimised ensuring timely planting (Box 3).

In Eastern and Southern Africa, soil conservation measures have been undertaken since time immemorial. This indicates that, conservation tillage was probably among the major preoccupations of farmers in ensuring sustainable crop production.

Box 3: No-primary tillage and animal power

Farmers in Chunyu district in Tanzania have trebled their area under cotton production (some up to 20 ha units) with the adoption of the ox-weeder. Ox-ploughing is now becoming a constraint to further expansion because of the short planting time. To hasten planting, the less energy no-till system is now practised where only planting holes are dug with the hand hoe, followed by very
early weeding using the ox-weeders, a few days after the emergence of the cotton. (Shetto and Mkomwa, 1996).

2.4 Indigenous soil conservation tillage systems

These are mainly traditional soil conservation tillage systems evolved by farmers over the course of time to suit certain environmental conditions (Box 4). It appears that indigenous conservation knowledge has accumulated particularly in areas where the natural resource base is under severe pressure from local communities, the ecosystems are fragile and there is a long history of adaptation to adverse conditions.

Box 4: Indigenous technologies

Technologies evolved as a result of a gradual learning process and emerge from a knowledge base accumulated by rural people by observation, experimentation and a process of handing down across generations peoples’ experiences and wisdom. Apparently the technology is dynamic and not static in nature, frozen in time or stuck in history (Hans-Joachim Kruger, et al. 1996; Reij, 1996)

Most local soil and water practices are location specific and accordingly vary in purpose. They may conserve soil in situ such as stone and earth bunds; conserve soil while simultaneously improving soil fertility such as mixed cropping, ridge or pitting; harvest water such as tied ridges; and dispose off excess water from crop lands such as traditional ditches or cut off drains. Thus indigenous soil conservation systems may be agronomic, vegetative or physical in nature and some of these are discussed in the following section.

2.5 Agronomic and vegetative techniques

Agronomic techniques may be biological or cultural. They include such practices as crop rotations, mixed cropping and trash lines. Crop rotations and mixed cropping are traditional systems that are widely practised in the region. Good crop rotations such as maize followed by legumes facilitate the conservation and addition of humus, restoration of soil structure and fertility and reduction of pests and diseases.

In mixed cropping, two or more crops are grown in the same field in the same season. In most cases grains and leguminous crops are mixed. The fast growing legumes provide soil cover early in season, shielding the impact of raindrops. They fix nitrogen too, and thus help to maintain soil fertility.

In slopping hillsides, maize stover is sometimes used to make trash lines, which help in slowing down the flow of runoff, and traps eroded soils. The technique is used both for erosion control and fertility improvement.

2.6 Physical tillage techniques

2.6.1 Pit cultivation

This is essentially a soil and water conservation system as well as a fertility restoration technique, through refuse decomposition. Grass is cut and laid out in strips forming square grids. Soil is then dug from the centre of the grid, covering the grass and leaving 30-60 cm deep and 100 cm in diameter pits. The pits, from a distance resemble a honeycomb or chessboard. The pits control runoff while conserving moisture simultaneously. The rainwater collected in the pits, percolates into the soil slowly while the incorporated crop residues improves soil fertility. The practice is fairly common in the Matengo highlands in southern Tanzania where they are popularly known as "Ngoro". Pits are laid even on steep slopes ranging from 10-60% (Temu and Bisanda, 1996).

2.6.2 Mound cultivation

Mound cultivation is essentially an in situ composting system for fertility management. Mounds are prepared by heaping soil and grass from an area of about one square metre, ensuring that the grass is covered completely. A leguminous crop is planted randomly on the mounds that are 40-60 cm high and 50-60 cm in diameter. In the following rainy season, the mounds are flattened and the main crop is grown. These mounds are locally known as "Fundikila" in Kenya while in Tanzania they are called "Ntumba".

http://www.fao.org/ag/ags/ags/se/agse_s/3ero/namibia1/c8.htm
2.6.3 Earth bunds

This is essentially a soil and water harvesting technique. Earth bunds are used mainly for water harvesting in rice production in the drier parts such as the lake zone in Tanzania. Earth bunds about 0.5m high are constructed around rice fields in order to collect runoff water from the higher slopes. In some other parts like Ethiopia, earth bunds are used for slowing down runoff in maize and sorghum fields where they are usually constructed along the contour after planting the crop. The bunds are constructed by digging a trench about 25cm deep with the scooped soil forming embankments or ridges.

2.6.4 Stone bunds

These are barriers of stones placed at regular intervals along the contour. They have been used for generations in Ethiopia where they are locally known as "dhaggaa" and in some parts of South Africa. The size of the stone bunds varies between 0.5-2m and may be 5 to 10m apart, depending on the availability of stones and the topography. Stone bunds retain or slow down run off and hence control erosion. They also allow the accumulation of soil, which may be redistributed after the bunds are dismantled.

2.6.5 Traditional ditches

Traditional ditches may be made to allow excess water to infiltrate easily and drain out of cultivated land, to the side of an artificial or natural waterway. A ditch may sometimes be dug on the upper side of the cultivated land to act as a cut off drain to protect the field from the runoff coming from the higher land. Thus traditional ditches drain excess water from the field, protect the soil from being washed away by runoff and reduces surface runoff generated within the cultivated land. They are commonly made throughout the region and in Ethiopia they are constructed using a ‘maresha’ ard plough pulled by oxen.

2.6.6 No primary till or pot holing

This is essentially a dry planting slashing and burn system. It involves slashing the vegetation or stover, leaving it on the ground to dry and burning it to leave a clean seedbed. Sowing is then done without disturbing the soil, except for the planting holes that may be made by using a digging stick or hoe. The practice is common in the central plateau of Tanzania where it is known as “kuberega”. In Zimbabwe, Zambia and Kenya it is known as "Muro".

2.6.7 Ridges

Ridges have traditionally been associated with the growing of specific crops such as beans, groundnuts, sweet potatoes and cassava. Ordinary ridges are 20-50 cm high and are usually spaced between 60-80cm. When they are laid across the slope they control the soil erosion. Ridges also improve the soil fertility through in situ composting of vegetation that is buried under during ridge formation. In some areas, broad-based ridges have evolved, furthering more the concept of soil fertility restoration with the incorporation of more grass, and trash. The system is commonly practised in Tanzania and Zambia.

2.7 Mulching

Mulch farming maintains surface residues on tilled land. Crop residues are useful in conserving the soil, controlling water runoff, improving soil physical conditions and increasing soil fertility. In situ mulching was fairly commonly practised in the region. The practice has declined as a result of other competitive use of the crop residues such as feed for livestock, fuel and building materials. Mulching however is still practised in banana and coffee areas and in horticultural crops, in areas of high rainfall.

2.8 The iraqw system

This is an intensive crop management system practised by the Iraqw tribe in northern Tanzania. In this hilly area, all the crop residues in the field and manure from stall fed cattle is incorporated into cultivated ridges. Terraces are made to control soil erosion, and fodder is cropped on the edges of the terraces for the cattle, being supplemented by grass from fallow fields. Trash lines and cut off drains are also used to slow down surface runoff and to increase infiltration.

3. Animal traction and land degradation
3.1 Historical perspective

With the exception of Ethiopia and South Africa, the history of animal traction in Eastern and Southern Africa started with the introduction of ox-ploughs by the missionaries and white settlers in the early 1920s. Whereas in Ethiopia, animal power has been used for thousands of years, in South Africa it dates back to the 1600s (Starkey 1995).

Apart from the initial efforts by the then colonial governments, increased utilisation of animal power before the 1960s has been more or less spontaneous, being closely associated with the commercialisation of crop production to serve the then mushrooming trading centres, the mines and the export market to Europe. However, with the coming of independence, most countries moved to tractorisation in the hope of increasing crop production to meet their domestic food needs; and raising the much needed foreign exchange through export of cash crops.

As a result animal traction was completely neglected and its development stagnated. Moreover, new interests cropped up again in the early 1980s following the failure of many tractor mechanisation schemes. Animal traction is now increasingly becoming important throughout Eastern and Southern Africa, with the number of draft animals increasing, complementing both hand labour and tractor power. For example, the number of draft animals has almost doubled in Tanzania and Zambia in the last twenty years.

Animal power is mostly utilised in the fairly extensive systems of grass fallow cultivation and semi-arid areas in the region. These include southern Kenya, the cotton zone of northern Tanzania and the southern highlands, the maize belts of southern Zambia and central Malawi, the communal areas of Zimbabwe, southern Mozambique and northern Namibia (Starkey, 1994).

3.2 Risks of animal traction on land degradation

There is very little documented information concerning the environmental implications of animal traction. However, like any other conventional flat cultivation, whether by hand or tractor, animal power has the potential of promoting land degradation. For smallholder farming in many countries in the region, proper soil conservation measures are rarely practised, leaving the tilled land at the mercy of the weather.

3.3 Area expansion and deforestation

The adoption of the ox-plough is usually associated with extension of cultivated land. With the possession of more farm power, more woodlands are cleared and put under cultivation, thus increasing deforestation. This exposes more land to the hazards of soil erosion. An increase of cropped land of 100-300% has been observed in Tanzania and Zambia with the adoption of animal draft technology (Francis, 1988; Harder, 1989).

As more farmers move to animal traction, traditional soil conservation practices such as mound farming, ridge and zero cultivation give way to flat cultivation with the ox-mouldboard plough which is potentially disastrous especially in the semi arid areas (Shetto and Mkomwa, 1996).

3.4 Conventional flat cultivation

Traditionally in Eastern and Southern Africa, tillage by draft animals is done by using the single furrow mouldboard Victorian plough. It is in Ethiopia only where the non-inverting ‘maresha’ plough is used. The mouldboard plough cuts, inverts and pulverises the soil burying most of the crop residue. The practise might not be appropriate especially in the semi arid areas, as the tilled land is left fairly exposed, making it more vulnerable to splash, sheet and wind erosion.

Also when ploughing is repeatedly done on the same land, plough pans a few centimetres below the top-soil. Plough pans hinder good development of roots, resulting in declining yields. In many cases, ploughing is done parallel to the slope and not along the contours. Some farmers claim that it is faster to work the animals up and down the slope rather than across the slope especially when the configuration of the field is difficult (BACAs, 1996; Shetto and Mkomwa, 1996). Sometimes in ploughing, width adjustment on the plough is not done properly, leading to many plough furrows being left in the field. When it rains, water runs in the plough furrows accelerating rill erosion especially in sloping fields.

3.5 Sledges
A sledge is a "V" or "Y" shaped wooden plank cut from a forked tree branch or trunk. The two trailing planks are joined with short pieces of timber to form a loading platform. The single end of the "Y" trunk is then hitched to the animals by means of a chain. Sledges slide on the soil surface as the animal pull, leaving rutted tracks on the ground. These sledge tracks act as waterways when it rains, accelerating soil erosion. Sledges are a common sight in most rural areas especially in Tanzania where, almost every household owning a pair of oxen, owns a sledge too. In some SADC countries such as Botswana and Zimbabwe, sledges have been banned completely as they are considered an erosion risk.

4. Other sources of land degradation

Apart from inappropriate tillage practices, deforestation and overgrazing have been identified as the other major causes of land degradation in Eastern and Southern Africa.

Deforestation is mainly a result of agricultural land expansion and provision of building materials and fuel wood for domestic requirements. It is estimated that 90% of the domestic energy used in the region is from fuel-wood (Box 5). Bush fires are also rampant in the area, especially in the dry season reducing further the forest cover. The long-term consequences are changed rainfall pattern, decline in soil fertility and increased surface runoff.

On the other hand, the number of livestock has also been increasing, almost doubling in the last three decades. The "free for all" extensive free range grazing system of livestock encourages soil degradation. Overgrazing depletes the land of its vegetation cover exposing the soil to water and wind erosion. Excessive trampling by the animals destroys the soil structure, reducing infiltration rates, thus increasing run-off that accelerates soil erosion. Free grazing of crop residues makes conservation tillage difficult even for those who would have liked to practice it.

Box 5: Fuelwood and land degradation

About 300,000 – 400,000 ha of forest and woodlands disappear each year in Tanzania. Iringa town alone with a population of 85,000 people in the Southern highlands requires approximately 79,000 tonnes of fuel-wood annually that equals clear felling of approximately 3,000 ha of natural standing miombo woodlands each year [De Pauw 1994; HIMA, 1994].

5. Constraints and challenges

Traditional or indigenous conservation tillage has been a major pre-occupation of subsistence farmers since time immemorial. During the pre-independence era, the colonial governments instituted wide mechanical soil conservation measures in the region. However, they became unpopular with the farming community as they were implemented by force. After independence, most of these measures were ignored, leading to severe land degradation in some countries.

While indigenous soil conservation methods still play an important role, they are highly location specific. Some of these measures are labour intensive and are difficult to mechanise, thus severely limiting the cropped land. Agronomic and vegetative measures alone have not been very effective where marginal lands like steep slopes are put under cultivation as a result of land pressure.

Where animal traction is becoming important, some indigenous soil conservation systems have been replaced with conventional flat cultivation that increases the risks of soil degradation. As the use of animal traction is on the increase in the region, then the incorporation of appropriate soil conservation measures in such systems is important so as to ensure sustainable crop production. These measures should be integrated into the normal crop-livestock husbandry concept, where care and improvement of land resources comes first and control of degradation is part of the caring and improvement process. Minimum tillage using animal drawn ripper tines should be encouraged to protect the soil from hazards of erosion especially in the semi arid areas.

Transport on the wheel using animal drawn carts should be promoted to reduce risks of soil erosion with the extensive use of sledges that trail on the ground.

Participatory community based approaches involving the stakeholders in planning and implementation...
Indigenous soil conservation tillage systems and risks of animal tracti...  http://www.fao.org/ag/ags/age/age_s/3ero/namibia1/c8.htm

are necessary in order to create a higher ownership attitude. Clear messages on conservation tillage
should be included in the normal extension packages and training of both village extension workers and
farmers should be emphasised so as to improve their understanding and skills.

The livestock “free for all” range management system should be revisited so as to increase personal
responsibility on the land and increase investment on soil conservation activities. Conservation measures
tend to be more acceptable to farmers if they serve multiple objectives and help to increase production.
Indeed, to many smallholder farmers, resource conservation cannot be an end in itself, but it is an integral
part of efforts to improve and sustain livelihoods. Improving productivity is the underlying rationale.

References

Bacas, 1996. Land Conservation Programme for Southern Highlands zone. Consultancy
Report prepared for the IFAD/Southern Highlands Extension and Rural Financial Services
Project.


Italy.

Francis, 1988. The impact of Ox-draught Power on Small scale Agriculture in Mpika district
of Northern Zambia. ILCA.

Inventory of Indigenous Soil and Water Conservation measures in Ethiopia. In Reij, C.;

Harder, J., 1989. Institutional Incentives and Technology Adoption: the case of Animal

Southern Highlands, Tanzania. Consultancy report for IFAD/SHERFS Project.

production by the Rural Poor. A Report prepared for IFAD by CDCS. Amsterdam.

Practices for increased agricultural production in Africa. In Ahenkoroha, E; Owusu Bennoah
and G.N.N. Dowuona (eds). Seminar Proceedings on Sustaining Soil Productivity in

Reij, C.; Scoones, I. and Toulinn, C., 1996. Sustaining the Soil-Indigenous Soil and Water
Conservation in Africa. International Institute for Environmental and Development.

UAC Progress Report 1988/89.

the Southern Highlands of Tanzania. A Consultancy Report for IFAD/SHERFS Project.

Proceedings of the First Workshop of the Animal Traction Network for Eastern and Southern

Starkey, P. 1995. Animal traction in South Africa: Empowering Rural Communities. SANAT.

The role of animal traction in soil and water conservation tillage practices among smallholder farmers in Malawi

by

Wells F. Kumwenda

Ministry of Agriculture and Irrigation, Farm Machinery Unit
Chitedze Research Station, P.O. Box 158
Lilongwe, Malawi

Abstract

Agricultural production in Malawi is carried out by smallholder farmers tilling fields of up to a hectare on customary land usually producing food crops like maize, sorghum, potatoes, cassava, bananas, pulses and others. Estate farmers have fields ranging from 35 hectares and over 500 hectares on leasehold land. While tractors are used on the estates, hand tools predominate on smallholder farms, placing an effective limit on the time and amount of land that can be tilled within a given time. Almost all crops except sugarcanes are dependent on rainfall as their source of moisture. Standing agricultural recommendations advocate the use of ridges across slope for soil and water conservation. Ridges, box ridges and small dams have been recommended in dry areas but few farmers have taken up these technologies, mainly due to labour intensity and lack of equipment. The total food production has to be increased quickly to satisfy the demands of rapidly growing populations in this region. This paper presents a review of draft animal based tillage and planting techniques as practised by smallholder farmers in Malawi.

1. Introduction

The low and unpredictable rainfall that defines dry land farming is found on about 40% of the world’s land surface, most of which is in the developing world. Lack of rainfall for Africa was probably less critical in the past than today because of increasing rates of population growth on this continent (Brady, 1988).

Africa’s rapidly expanding population is a major factor in changing the face of that continent’s agriculture. Agricultural production has not been able to keep pace with population increases and soil erosion has increased in severity.

Malawi is a semi-arid country. This means the country gets less rainfall than the humid tropical regions. Fortunately, however the country is blessed to have a vast mass of water in lakes which cover almost one third of the country and several perennial rivers. The problem that all this water is not used for irrigation to improve crop production except for a limited amount in sugarcane and rice production (Maida, 1986). Agricultural production in Malawi is solely dependent on rainfall. In good years the country has managed to produce enough for its population but of late the frequency of droughts has forced the Nation to import maize for supplementation.

There is standing recommendation that farmers should till their fields between April and June when there is still moisture in the soil. Most farmers do not till their fields during this period because they are pre-occupied with crop marketing, building repairs and the like. They later have to contend with tillage of dry soils, with hand tools. A small percentage of farmers attempt to make ridges during the dry season but these ridges are smaller and highly prone to be eroded by the heavy rains at the beginning of the season. The UN predicts that by the year 2000, soil erosion will have reduced land productivity by 25% from the 1975 level. Because of the dry weather condition, farmers have no choice other than wait for the rain to soak the ground before they can start tilling. This delays their planting time and greatly lowers their yields.

Human energy by itself is inadequate to make a significant impact on agricultural productivity. Acreages and yields are limited by the slow and heavy toil of hand cultivation especially in Malawi where a farmer is expected to split old ridges and move a lot of soil in the process of making new ridges. A man with a hand hoe can comfortably cultivate 0.4ha per year because he can rarely exceed using 1500 calories per day.
The National total food production has to be increased quickly to satisfy the demands of a rapidly growing population. Today, in order to feed a much larger and rapidly growing population farmers are forced to use their farms year after year with limited inputs and without allowing the land to fallow in order to renew itself. As a result vast areas are becoming totally unproductive. Soil erosion has increased in severity in many parts of the country and has caused soil degradation and siltation of rivers. Less electricity is generated on the Shire River.

2. Conservation practices

2.1 Animal traction

Animal traction refers to the use of animals for ploughing, harrowing, ridging, carting, logging, pumping, threshing, planting and pulling sledges. In areas where insect pests and diseases do not prohibit herding of livestock, the incorporation of animals into the agricultural systems can help farmers in many ways. Where motorised mechanised farm implements are unavailable or prohibitively expensive, animal traction is often the only alternative to back-breaking human labour. Beyond the energy they provide, farm animals can furnish organic fertiliser, milk, meat, skins and offspring. They can also become the source of additional income for many farmers through hiring of traction services, sale of milk, meat and other products.

Animal power plays a significant role in crop-livestock mixed farming systems in a number of agro-ecological zones of sub-Saharan Africa which include Malawi. Draft oxen are predominantly used in these regions. However their use is limited mainly to tillage and transport. Motorised mechanization is out of reach of many farmers in the region because of the size of their fields, technical know how and resources that are available to them.

Shortage of feed and water in some areas of the country before and during planting renders the animals generally weak at the time when they are needed most. Cultivation using animals typically allows a farmer a threefold increase in the amount of cropland that can be prepared by an average family using hand hoes.

2.2 Tillage practices

Tillage practices in Malawi have been heavily influenced by historical events in the country. During the late 1940’s agricultural planners made a number of recommendations that were designed to protect the soil, environment and water. This was good intention especially for a country that has no mineral resources but unfortunately no effort was made to extend civic education on these recommendations to the farmers. Farmers viewed the blanket recommendations as part of a punishment plan. Some of the recommendations were too general to be applicable. An example of some of the recommendations which resulted in a lot of resentment were:

- the compulsory digging of bunds in every farm which was introduced in 1948. Farmers who neglected or failed to dig the bunds were imprisoned.
- the making of ridges on every farm before planting. This is still a hot issue in many flat areas including the Lower Shire Valley.

These recommendations were made hoping that there would be adequate rains every year. It has been reported (Harsh, 1999) that conservation plans virtually ignored the involvement and knowledge of local communities both at planning and execution level of projects. No recommendation was made for farmers in dry and drought prone areas. The current persistent occurrence of droughts calls for a review of the recommendations on ridge making, to suit the prevailing weather conditions and specific areas with critical slopes.

2.3 Primary tillage

Primary tillage for many of the smallholder farmers at present involve splitting the old ridges and with the soil from the old ridge make a new ridge on the previous furrow. If this is done using a hand hoe like most farmers do, it is best done when the ground is moist, which is usually after the first rains.

Those farmers who have access to animal traction can till their fields at the end of the rainy season or depending on the soil type during the dry season. The implements frequently used by farmers using draft
animals is the plough for cutting the soil, the harrow for levelling or breaking the clods and the ridger.

2.4 Conservation tillage

Conservation tillage systems provide the most practical means of controlling soil erosion by wind and by water. This is achieved by reducing the number of tillage operations and maintaining crop residues as mulches on the soil surface which in turn reduce runoff, evaporation, energy use and mechanical disturbance of the soil (Anderson, 1992).

Conservation tillage systems also utilise cover crops to ensure effective water conservation practices which help to offset soil degrading processes, to maintain soil productivity. Conservation tillage can increase the available water during the growing season through increased infiltration and reduced evaporation. It enhances crop yields where water is in limited supply (Parr et al. 1990).

Small scale farmers in Malawi tend to leave trash that has been cut and removed from the top of the ridge either scattered or heaped in the furrows. This trash will reduce the flow of water so that more water can sink into the soil. At the same time it reduces evaporative loss of soil water from the furrow area. Small amounts of crop residues in these systems can effectively control both wind and water erosion.

2.5 Rationale for water conservation

Malawi practices dryland farming which is characterised by low and unpredictable rainfall. With increasing frequency of droughts in the country, lack of adequate rainfall for agricultural production is perhaps the most critical factor currently. Researchers are developing technologies that farmers can use to sustain productivity at a profitable level, while conserving renewable natural resources. However, these can only be useful if there is rainfall or irrigation facilities. Water is important in crop production, livestock farming, fish farming and for human use.

Conservation of water resources is an important element in productive agriculture and a major consideration in dryland areas. In areas where rainfall is barely adequate to support crop cultivation with less than 250mm annually, farmers must have technologies to conserve all available water.

3. Role of animal power in soil conservation

3.1 Small dams

There are many farmers in the upland areas of Malawi who would like to have a small dams of water for their own use. These farmers make dams using animal drawn dam scoops based on the BAIN design of Zimbabwe. The procedure for digging these dams is described in detail by Kumwenda (1988). The scoops which have a capacity of 0.2m³ were imported from Zimbabwe. The dam scoop is made from a 3mm steel plate. It is 80 cm long and 70cm wide with the back and sides 30cm high. The bottom is flat and is reinforced with 4cm thick flat bar runners every 16.5cm along its length. The digging front edge is a removable metal plate 16.5cm wide by 80cm long. It is attached to the scoop body with eight screws in such a way that 4.5 cm is left protruding, to do the digging. A drawbar is attached to lugs from the centre of the sides. The drawbar must be able to swing freely from the front to the back of the scoop to enable the operator to tip it over. Wooden handles are attached to the sides behind the drawbar attachment point. The length and angle of the handles should be made to suit the operator.

Before digging the pond, an area should be chosen with a fairly flat terrain. The area within the pond should be ploughed or dug by hand hoe to loosen the soil. When the scoop is attached behind the oxen, it should be pulled along the loose soil while tilted slightly by lifting up the handles. When the scoop is filled with loose soil the handles can be released and the scoop let to be dragged to the dumping point where the handles are then lifted up sharply with the oxen still moving forward. This tips the scoop over completely with little effort from the operator. The scooped soil is deposited to form the walls by turning it over on its side or by pulling back on the handles when the oxen have stopped. Usually the finishing touches such as the walls and sloping the banks are best done by hand.

3.2 Box and tied ridges

In dry areas farmers are advised that when they have made their ridges along the contour, they should also make short ridges across the original ridges at every four or five metres along the furrow. This exercise is known as tied ridging. If the ridges are closed with short ridges at the end only then they are
called boxed ridges. Box as well as tied ridging requires more time and labour to make therefore farmers are not keen to make them although they are quite useful in dry areas where rainfall is inadequate. If farmers use hand hoes these structures are really difficult to make but with animal drawn implements such as the ridger and tie-ridger, it becomes much easier to construct them.

3.3 Use of old ridges

Use of old ridges previously made by animal drawn implements has proved to be quite successful. Planting row crops on preformed (old) ridges has been gaining popularity as a time, energy and nutrient conservation practice especially for maize production in the tobacco growing areas. Maize is planted on the same planting station as previously occupied by tobacco. Advantages are decreased soil erosion since only the planting stations are disturbed and increased water conservation. The method enables the farmer to plant as soon as the rains come and it also allows the maize to use the residual fertiliser that is not utilised by the previous crop. The use of old ridges has been proved by farmers and researchers as being equally effective in production of maize. Kumwenda (1990), found no significant differences in yields of maize grown on new ridges and the yield of maize grown on old ridges. The critical factor that farmers prevent in this case is late planting which is caused by preparing the fields after the first rains, resulting in late planting of crops.

3.4 Modified ridges

There is a technique in Malawi which farmers use to capture maximum moisture from rain water. They use modified ridges. In case where farmers are late in making new ridges before the first rains they dig some soil from the old ridge into the furrow where there is more moisture and make a new planting station on top of this soil. After two or three weeks just when it is time for weeding, the farmer will come to make complete ridges along the furrow. This ridging operation combines with the first weeding operation. This type of tillage can only be practised if the farmer is using a hand hoe in the second year to dig new ridges that were previously made with animal drawn implements because they retain their big size after a rainy season.

3.5 Planting in the furrows

Almost all the farmers in Malawi plant their crops on the ridges. Ridges act as basins in the field because they concentrate rainwater into the furrows. The furrows therefore have more moisture than the ridge. The most suitable place to plant seed when inadequate moisture is expected in the season is in the furrows. Using this technique, farmers are able to plant as soon as the rains have arrived. The only disadvantage of planting in the furrows is if the field has been prepared by hand hoes over many years. Then, the furrows are part of the hard pan, which cannot be penetrated easily by root crops.

3.6 Planting techniques

It is always good to plant early whenever it is suspected that there will be less soil moisture available. It is also advisable to have the correct plant population so that plants can cover the ground as soon as possible. This reduces evaporation water from the soil but allows soil water to escape only through the plant. Plants also act as cover crops that effectively control certain weeds by blocking sunlight and suppressing their growth. Animal drawn planters are available but most of them cannot plant a constant number of seeds, cannot plant on the ridges and require seed that is graded.

3.7 Networking

Within the country and among countries there is need for networking if the results of traditional knowledge and modern research in the region are to be delivered in the most comprehensive and timely manner. Communication within the user community must be enhanced. To this end the results must be made available to decision makers research, extension agents and farmers who will use them. There is a growing worldwide recognition of the importance of sustainable agriculture as a means to ensure that agricultural productivity will be maintained for future generations. While increases in production are needed to meet increased food demands, these demands must be met by practices that will not deplete soil water and degrade the quality of the soils on which the crops are being grown. This is an area where animal traction can play a significant role in providing power to perform timely activities or reduced drudgery.

Some of the technologies researchers are developing are such as:
a. To maintain soil productivity by adding small amounts of organic manure from the animals and chemical fertiliser.
b. Using crop and other plants to biologically fix nitrogen.
c. Employing alternative tillage methods such as conservation tillage.
d. Conserving the available water resources by better timing of agricultural activities, use of crop residues on soil surface and various cultivation techniques such as terracing, tied ridges and furrowing.
e. Using biotechnology to develop plant varieties that are harder, faster growing and more resistant to pests and diseases, drought and soil conditions that constrain productivity.
f. Alternative farming systems such as alley cropping and mixed farming which can help farmers to conserve and improve the renewable natural resources upon which their productivity depends.

4. Discussion and conclusions

According to Harsch (1995), in order to banish the scourges of hunger and poverty, African farmers have to do two things together:

1. greatly boost their farm yields and
2. ensure the long term viability of the natural environment, upon which agriculture depends.

The fertility of Africa’s soils, the condition of its rivers and ground water and the abundance of its vegetation, trees and wildlife are all essential elements in Africa’s ability to produce enough food for its people. Farmers have to overcome many problems, for them to succeed. The main problems at the moment facing smallholder farmers with their tillage, soil and water conservation are:

1. Smallholders have for many years been using the hand hoe for tillage weeding and all other field cultivation. Due to the nature of this implement and the power required farmers are unable to plough deep enough therefore a hard pan has formed in almost all their fields. During the rainy season, especially at the beginning of the season the pan prevents the water from rapidly sinking into the ground. As a result there is excessive soil and nutrition erosion caused by the water. There is need to break the pan at least once in five years to enable rain water permeate into the soil easily. This is best done by smallholders through the use of animal traction.

2. The mechanisms and structures for soil conservation require that every farmer in a catchment area should have the right structures constructed in the proper manner and in a coordinated manner. Upper catchment farmers can destroy the farms of those downhill. Gullies also easily develop.

3. On most smallholder farms there is a severe shortage of soil nutrients because of the way farmers have historically been producing their crops. Farmers grow the crops, control the weeds and at the end the season remove all crop residues from the fields either to prevent livestock from coming to their fields and pulverise the soil or the residues are used as firewood. This practice does not allow some biomass to be left on the fields therefore the soil has very little nutrients and soil micro and macro organisms.

4. Smallholder farmers do not have adequate time to prepare their fields. Although it is recommended that farmers should start preparing their fields immediately after the rains, they can incorporate residues that would help improve their soils structure and fertility but most of the farmers are so busy at this time of the year harvesting and marketing their crops. By the time the farmers finish these operations the ground is normally too hard for effective ploughing.

5. The effects of soil and water conservation structures take a long time to be appreciated. There is need to teach farmers the benefits of conservation tillage and that they take a long time to be realized. The civic education should also cover the importance of regular maintenance of these structures for effective results.

6. Use of draft animals can greatly increase farmers crop yields by providing power to perform a number of farm operations on time without drudgery. These efforts have been frustrated by lack of draft animals, poor training, lack of trained personnel, poor animal management, availability of feeds and water, high animal mortality rates, financial problems, uncertain supply of equipment and spare parts, lack of suitable equipment, poor harnessing techniques, land shortage and poor terrain.

References

Rome, Italy.


A study was conducted in two smallholder areas in Zimbabwe to relate the occurrence of a plough pan to tillage depth, under draft animal power situations. Bulk density (BD) and penetration resistance (PR) measurement was taken to quantify tillage-induced compaction. Soil mechanical analysis was also conducted to determine the effect of different sized particles on soil compaction. Cylindrical sampling cores of 5 cm diameter and 5 cm height were used to collect undisturbed soil samples at 10 depths. A penetrometer with a 12.83 mm diameter cone was used to measure PR to a depth of 52.5cm. The GENSTAT Procedure was used to conduct the statistical analysis. Ploughing depth measurements were carried out at 23 and 12 sites in Chinyika and Mutoko, respectively. It was noted that 89% (N=45) of the farmers in the two areas did not achieve the 23 cm recommended ploughing depth. Soils in Chinyika were basically loamy, whereas those in Mutoko were sandy. Bulk density values in Chinyika decreased with depth, whereas those in Mutoko increased with depth. Surface BDs in Mutoko were however, higher than those in Chinyika. This was attributed to the different soil textures. A highly significant linear relationship between BD and clay (p<0.001; \( r^2 = 0.65 \)) and BD and sand (p<0.001; \( r^2 = 0.58 \)) was observed in the top 12 cm of the soil. However, below 12 cm, no relationship between BD and soil texture was evident. Factors other than texture, such as tillage, were thus thought to determine the BD. Sixty nine percent of farmers in Mutoko (N=16) and 67% in Chinyika (N=25) had the problem of surface crusting and subsurface high BD values (BD ≥ 1.6 Mgm\(^{-3}\)). The latter could be equated to plough pans. Forty-four of the farmers in Mutoko also had evidence of plough pan occurrence, approximately 8 cm below the average tillage depth. Penetration resistance measurements in Chinyika also indicated a high proportion of farmers with plough pan problems in the 17.5-35 cm region (83%; N=12). In general, high PR values in Chinyika were observed about 8 cm below tillage depth, and at almost the same level of average tillage depth in Mutoko.

1. Introduction

Tillage is normally performed on the onset or just after rains start. Due to limited feed resources at this time of the year, draft animals are usually weak, resulting in shallow ploughing where conventional tillage is practised. A considerable number of farmers meet the optimum planting dates by ploughing when the soils are still dry (before rains), thereby increasing the chances of shallow ploughing.

Plough pan development has been reported where ploughing was repeated at the same depth year after year (Waddington, 1991; Unger and Kasper, 1994). The shallower the tillage depth, the greater is the likelihood of a plough pan developing near the soil surface. When this happens, there is limited area for moisture and nutrient extraction for the crop since roots cannot penetrate the deeper soil layers. Runoff as well as erosion losses are also increased. All these factors result in decreased crop yields (Taylor and Burnet, 1964).

Draft requirement for tillage may also be drastically increased by soil compaction (Dannowski and Seidel, 1987). This could create problems during primary tillage since the animals are unlikely to handle the additional draft required.

Even though it is common knowledge that in Zimbabwe, subsoil compaction is caused by development of plough pans, little has been done towards quantification of this problem in the Communal areas (CAs) of Zimbabwe.
1.1 Objective

The objective of this paper is to determine the relationship between depth of tillage and soil physical and textural characteristics of soils farmed by smallholders in Chinyika and Mutoko areas.

2. Materials and methods

2.1 Examination of compaction in the field

To study the effect of tillage-induced compaction, bulk density (BD) and penetration resistance measurements were taken in Chinyika and Mutoko. Penetration resistance (PR) measurements were taken to complement bulk density measurements due to the numerous advantages that PR has over BD (Voorhees et al., 1983). A penetrometer is however, not appropriate for measuring surface crusting whereas bulk density measurements may detect it. There is need therefore to consider both PR and BD measurement.

2.2 Bulk density and solid moisture determination

Bulk density measurements were conducted in the two areas. Twenty and sixteen sites were chosen in Chinyika and Mutoko, respectively. Cylindrical sampling cores, of 5cm diameter and 5cm height with sharp cutting edges were used to collect undisturbed soil samples according to the method of Blake and Hartge (1986). Three replicate samples were collected at 10 depths at each site. The core samples were then oven dried for 24 hours at 105°C in the laboratory. Soil moisture was gravimetrically determined at the same time.

2.3 Penetration resistance

Penetration resistance was first measured in the farmers’ fields at the same time as the bulk density measurements (1996). The same was repeated during the following season, one year later. Only twelve sites were measured in Chinyika. In addition, soil moisture data was collected at the 0-15, 15-30 and 30-50 cm depths at the time. This is because soil moisture has a strong influence on PR (Logsdon et al., 1987). Five soil strength measurements were taken at each site with each position chosen randomly throughout the field. These were measured in 15 cm depth increments using a hand-held Bush Penetrometer, with a 12.83mm diameter cone (Anderson et al. 1980) up to a depth of 52.5 cm.

2.4 Particle size analysis

Particle size analysis was used to determine the proportion of different sized particles of soils from the study areas using the procedures described by Head (1980). Sedimentation was used to separate silt and clay size fractions, based on the Stoke’s Law relationship between the diameter of suspended particles and their rate of settlement in a liquid at constant temperature. Suspension densities were then measured using hydrometers. Dry sieving was used to measure the sand fractions.

2.5 Ploughing depth

Ploughing depths were measured at 23 and 12 sites in Chinyika and Mutoko, respectively; at ploughing time. Sites were randomly selected making sure that only one site was chosen per individual farmer. The ploughing depth was measured in six furrows which were randomly chosen during ploughing, with a minimum of three readings taken in each furrow.

2.6 Statistical analysis

The GENSTAT procedure was used to conduct statistical analysis. Analysis of variance was used to test for any significant differences in bulk density between different soil layers. The LSD test was used to separate the treatment means. Regression analysis was also carried out to test correlation between bulk density and soil texture.

3. Results and discussion

3.1 Ploughing depth in Chinyika and Mutoko
Ploughing depth values are shown in Table 1. Farmers who hired tractors are the ones who achieved greater ploughing depths of at least 20cm. These farmers have however been excluded from this study in order to concentrate on animal powered tillage. These farmers only constituted 17.4% in Chinyika whereas in Mutoko none of the farmers used a tractor at all.

Table 1: Ploughing depths for Chinyika and Mutoko farmers

<table>
<thead>
<tr>
<th>Area</th>
<th>N</th>
<th>Depth range (cm)</th>
<th>Mean ± se</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinyika</td>
<td>19</td>
<td>11.3-15.8</td>
<td>14.0± 0.27</td>
</tr>
<tr>
<td>Mutoko</td>
<td>12</td>
<td>12.7-15.7</td>
<td>14.9± 0.23</td>
</tr>
</tbody>
</table>

One observation made in the two areas was that almost all the mouldboard ploughs had the hitch assemblies removed. The hitch assembly is useful in maintaining a desired tillage depth. All the farmers believed that this attachment would make the plough heavier for their small and weak draft animals. This is one reason why ploughing depths were not only shallow but also similar across the different sites.

3.2 Bulk density

In Chinyika, bulk density values consistently increased with depth (Table 2). Normally, bulk density tends to increase with soil depth mostly as a result of low organic matter (OM), less aggregation and root penetration as well as pressure exerted by overlying layers. Conversely, this was the reverse in Mutoko where bulk density values decreased with depth. The greater development of structure in the loamy textured surface soils of Chinyika could account for their low densities compared to more sandy surface soils in Mutoko. This explained why bulk density values were generally lower in Mutoko than in Chinyika.

Table 2: Bulk density values at different soil depths for sites in Chinyika and Mutoko

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Chinyika</th>
<th>Mutoko</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 12</td>
<td>1.39a</td>
<td>1.60a</td>
</tr>
<tr>
<td>12 – 30</td>
<td>1.47b</td>
<td>1.51b</td>
</tr>
<tr>
<td>30 – 48</td>
<td>1.52c</td>
<td>1.49bc</td>
</tr>
<tr>
<td>48 – 60</td>
<td>1.54c</td>
<td>1.46c</td>
</tr>
</tbody>
</table>

Means with the same letter in a column are not significantly different (p<0.05) based on LSD test.

In Mutoko, surface bulk densities were quite high compared to those in Chinyika, possibly due to their sandy texture. Eleven sites out of 16 had surface (0-12 cm) bulk density values greater than 1.6Mgm⁻³. Of these, the values for layers just below (12-30 cm) were lower except at one site. This is an indication of surface bulk density greater than 1.6 Mgm⁻³. The bulk of the surface values were around or below 1.4Mgm⁻³.

In Mutoko, seven of the sites appeared to have high bulk density values between 20 and 25 cm depth. These dense layers were approximately 8 cm below average tillage depth. At some of the sites, more than one high-density peak was evident. Considering the farmers’ shallow ploughing depths, there is a considerable chance that these layers will develop into restrictive “hard pans” with time. The result is restriction to root growth, which ultimately decreases crop growth.

De Geus (1973) quote bulk density values greater than 1.75 Mgm⁻³ for sands, as causing hindrance to
3.3 Relationship between bulk density and soil texture.

To distinguish between textural and tillage effects on bulk density, regression analysis was conducted. At the 0-12 cm depth there was a highly significant relationship between bulk density values and clay \( (p<0.001; r^2 = 0.65) \) as well as sand \( (p<0.001; r^2 = 0.58) \). This means that the amount of clay and sand in a soil determines bulk density in the top 12 cm. Similar results have been reported elsewhere (Jones, 1983). However, at the 12-60 and 50-60 cm depths there were no significant relationships. This therefore means that bulk density values are due to some factors other than soil texture. Tillage is suspected to be playing an important role in determining bulk density just below the plough pan. Some management factors other than tillage and texture are however thought to be responsible for determining bulk density in the 50-60cm depth region. Generally, for the two sites, results of the regression analysis seem to exclude soil texture as the main determinant of the bulk density.

3.4 Penetration resistance (PR)

The first set of PR values taken in Chinyika showed very distinct layers of high resistance at 10 sites \( (N=12) \) between 17.5 and 35cm. These dense, hard layers are generally considered to be the same as "plough pans" as the hard layers restrict root growth. For the next season’s readings in Chinyika \( (N=11) \) the maximum surface PR at crop harvesting was 3000 kPa. Most PR values except at two sites were found to exceed 2000 kPa, which is considered to be the limiting value for root growth (Blanchard et al., 1978; Gill and Miller, 1956; Olsen, 1993; Taylor et al., 1966; Vogel, 1992). The soil water content at the time of these measurements was, however, very low. Values greater than 4000 kPa were at times recorded at depths as low as 21cm at about 5% moisture content. Considering high PR and the farmers’ shallow average ploughing depth, root penetration was restricted to 20cm only.

In Mutoko, out of the five sites measured, four had very distinct high PR values between 14 and 17.5 cm. PR thereafter decreased with depth in agreement with bulk density measurement. Only one field had a peak between 21 and 24.5cm with a sharp drop thereafter. This was contrary to results in Chinyika which showed evidence of plough pans between the 17.5 and 3.5cm depth, a situation commensurate with high bulk density values within the same region.

Average PR, readings did not differ much between the two seasons, there was a considerable drop around 14cm (close to average ploughing depth) relative to the underlying depths (Figure1). This meant that the topsoil layers were loosened by tillage during ploughing, leaving hard layers beneath plough depths. Generally, in Chinyika, plough pans due to tillage were quite evident, with some pans occurring as close as 3cm below the plough sole. Similar results have been reported elsewhere (Chuma, 1993; Grant et al., 1979; Vogel and Olsen, 1993). Table 3 shows the depth to the first maximum PR value, followed by a sudden drop in PR. It should however be noted that some peaks had further high PR value peaks beyond the first depth recorded.

Table 3: Depth to the first peak and maximum PR in relation to plough depth (1997)

<table>
<thead>
<tr>
<th>Area</th>
<th>No. of farmers</th>
<th>Mean of plough depth (cm)</th>
<th>Mean depth (cm)</th>
<th>Mean PR (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinyika</td>
<td>9</td>
<td>14.3 ± 0.27</td>
<td>22.2 ± 2.92</td>
<td>3362± 230.03</td>
</tr>
<tr>
<td>Mutoko</td>
<td>4</td>
<td>14.7 ± 0.68</td>
<td>14.88± 2.20</td>
<td>2853± 176.16</td>
</tr>
</tbody>
</table>

There is clear evidence that ploughing depth plays a very important role in determining peaks as indicated by the sudden rise in soil strength after 14cm in Chinyika. For both seasons, PR values beyond
35 cm were similar. The variation between 0 and 35 cm is therefore thought to be determined by tillage whilst beyond 35 cm soil structure is likely to be the main determinant. The occurrence of peaks and depressions at the same depths in both years inspite of the difference in magnitude is clear indication that plough pans exist at these depths.

The results in Table 3 illustrate contrasting behaviour between soils in Mutoko and Chinyika. Resistant compact layers occur in Chinyika at about 22 cm, an average of 8 cm below the plough depth (14 cm). This concurs with results reported by Grant et al. 1979 and Chuma, 1993. In contrast, in Mutoko, the high PR layers occur at the same depth (+ 15 cm) as the plough sole. This anomaly is probably due to the sandy nature of the soil. The structure in Mutoko could have a different packing arrangement resulting in a compact zone being formed immediately on impact of the plough.

4. Conclusion

Soils in Mutoko were very sandy throughout the 0-60 cm depth. Surface crusting was noted to be very common at most of the sites, with critical bulk densities of greater than 1.6 g cm\(^{-3}\) exceeded at most sites. Clay contents were extremely low throughout. In Chinyika, the soils were predominantly loamy, with clay content increasing with depth. Bulk density values were generally lower than those in Mutoko.

Pronounced plough pans were evident approximately 8 cm below plough depth, particularly in Chinyika. This means that unless ameriolated the problem is likely to build up which would restrict root growth. The shallower the depth of the pan, the worse the water and nutrient status for the crop, particularly in an environment that is limiting. It is, therefore, important that adequate feed is administered to draft animals during ploughing time, when feed is particularly scarce.

It is anticipated that when draft animals are strong, ploughing depth is deeper, resulting in a larger water and nutrient extraction zone for the plant. In Chinyika, tillage needs to concentrate on breaking or minimising plough pans whereas in Mutoko, emphasis should be put more on breaking surface crusting.

References


Indigenous conservation tillage system in East Africa with an example of their evaluation from South West Tanzania

by

R. Kayombo¹, J. Ellis-Jones² and H.L. Martin³

¹Botswana College of Agriculture, P/Bag 0027, Gaborone, Botswana
²Silsoe Research Institute, Bedfordshire, U.K. MK 45 4 HS
³Formerly at Dept. of Agric. Eng. & Land Planning, Sokoine Univ. of Agric., P.O. Box 3003, Morogoro, Tanzania

Abstract

Available literature in East Africa reveals that indigenous conservation techniques (ICT) are prevalent in areas of water-deficit conditions and in semi-arid zones. Due to changing natural and socio-economic environment, some of these ICT systems are beginning to show signs of decline. To reverse the declining trend, there is paramount need to understand these systems as a first step towards their improvement. The socio-economic evaluation of ICT techniques in Mbinga District of S.W. Tanzania has shown that Ngoro cultivation is efficient at controlling soil erosion, increasing soil moisture at critical times of the year and maintaining soil fertility. The problems associated with it, notably decreasing fallow periods and high labour requirement, indicate their declining use. The technical evaluation has shown that compared to ridges, when Ngoros are intact, they increase soil moisture and consequently yields. When badly degraded, soil moisture is decreased but despite this, maize growth and yields are better than on ridges, when no fertiliser is used. In Ngoro, the majority of eroded soil is re-deposited into the pit, whereas on ridges it is often transported elsewhere. The immediate future challenge is to build productivity enhancing improvements into the present system without destroying its unique advantages.

1. Introduction

A number of large-scale land development projects with mechanised agricultural production were carried out in East Africa during the 1950-60s. However, the conclusions drawn from a critical appraisal of implemented large-scale agricultural development schemes is far from encouraging. Failure of such schemes has been attributed to many factors, including:

- socio-economic conditions and infrastructure (Baldwin, 1957),
- insufficient baseline data to enable adequate planning for resource development and management (De Wild, 1967),
- failure of monsoons,
- ‘top down’ approach taken by the majority of the projects and

These barriers to agricultural development have received greater attention in recent years (Hudson, 1991; Baum et al., 1993) and have resulted in a paradigm shift. Previous top-down approach which attempted to impose ‘improved’ technology packages are being replaced by more facilitating and participative approaches to extension (FAO, 1995). In adopting such ‘bottom-up’ approaches, it is acknowledged that any new technology must accord with the experience of the user.

Accordingly, IFAD (1992) states that the first step in the design of a new soil and water conservation programme should be the identification of indigenous farming systems and their conservation techniques. Central to this approach is utilising traditional knowledge in the improvement of indigenous soil and water conservation techniques (Critchley, 1992). Indigenous Conservation Tillage (ICT) systems in this context mean all those traditional cultivation practices which conserve soil and water and increase soil fertility for increased crop production. In East Africa, the manual effort provides all the mechanical power in agricultural operations including seedbed preparation and weed control (i.e. hand hoeing, slash and burn).

1.1 Objectives
The purpose of this paper is two-fold:

i. to document existing indigenous conservation tillage (ICT) systems and

ii. to analyse the usefulness and shortcomings of ICT using a case study from South West Tanzania.

2. Conservation tillage systems

2.1 Natural and socio-economic environment

The seasonal rainfall patterns are governed by the seasonal shifts and intensity of the low pressure Inter Tropical Convergence Zone (ITCZ). Semi-arid areas receive average annual rainfall of 800-1000mm. Potential evaporation ranges from 1450 to 2200mm. The rainfall though low and erratic, occurs in high intensities of short duration and is highly erosive. High amounts of runoff are often generated from these storms owing to inherent low infiltration rates of the soils. Concentrated runoff flows are responsible for the severe erosion that occurs in these marginal rainfall areas.

The most dominant soils in marginal rainfall area of East Africa are Luvisols, Acrisols and Vertisols. Except for the vertisols, the other two soils are characterised by shallow soils with inherent low organic matter, water retention capacity, salt and sodium content and strong surface sealing and crusting properties. The dominant clays of Luvisols and Acrisols are usually of the 1:1 ratio (kaolinite). Water infiltration in the soils is rather low especially in the B-horizons where the textures are heavy. Luvisols and Acrisols are often cropped during the rainy season. Vertisols are characterised as deep soils having moderate to high salt and sodium content, montmorillonitic (2:1) clay mineralogy, and low infiltration rates. Vertisols are usually cropped after the rainy season.

The major crops grown in semi-arid areas of East Africa include maize, beans, sorghum, millet, cassava, pigeon peas, sweet potatoes, cowpeas, groundnuts and cotton. Crop performance and yields are significantly influenced by the amount of rainfall and distribution. As a result of inherent soil moisture deficits, the period of cropping is limited to the rainy season. Intercropping is a very common farming practice as it minimises the risks of crop failure owing to unexpected soil moisture deficits.

During the past two to three decades, human and livestock population in semi-arid areas of East Africa has significantly increased and consequently led to an over exploitation of the limited land and water resources. Soil and vegetative degradation have become widespread owing to overgrazing, deforestation, burning and over-cultivation. Accompanying this unprecedented population increase, is the fragmentation of landholdings and sedentarization of pastoralists which has destabilised the very fragile ecology of the areas (Biamah et al., 1993). This has adversely affected food and fodder production and left the entire population vulnerable to food and fibre shortages. Unpredictable weather conditions have exacerbated the problems and further eroded the production potential of the resource base.

2.2 Indigenous conservation tillage systems

ICT systems are prevalent in areas with water-deficit conditions and in semi-arid zones where the hand-hoe is the main tillage tool backed-up by measures which improve soil-water-fertility conservation for crop production.

2.2.1 Kenya

The ICT techniques described below are the most common among smallholder farmers in Mbeere District of Eastern Province in Kenya.

Trash lines are formed by placing crop residues in lines, across the field. They are intended to impede runoff and enhance infiltration, but as Critchley (1992) states, their effectiveness is dependent on the composition and care with which they are established. According to Altshul and Okoba (1996), the technique was present before (1907) and has been passed down orally from generation to generation. The trash lines are constructed mainly from sorghum and millet stovers which are slower to decompose and are of lower palatability to livestock than maize stovers. The position of most trash lines is not fixed but instead new trash is placed 3 to 5m up slope each season.

Trash lines are not a permanent ICT measure and they are destroyed by ants and termites. They can withstand deluges of water because, being permeable, they ‘leak’ water. Furthermore, the decomposition...
of trash line material improves soil fertility.

Stone-bunds are a popular technique in stony areas and are a practical method of clearing stones from cultivated land. Their permanent nature makes them more popular with farmers than trash lines but they are also more labour intensive. The bunds are semi-permeable; allowing water to pass through but retaining soil and the process of cultivation on the inter-bund areas leads to the formation of natural benches over time. Stone bunds are found on slopes of up to 45 percent. On older farms, the bunds can be very large, wall-like structures, built with large stones on the outside and the wall centre filled in with smaller stones. These large bunds may take several years to be completed, with a new course of stones being laid each season as time allows. Like trash lines, stone bunds have been traditionally used for several generations (Atshul and Okoba, 1996).

Log lines are only found on recently cleared land. The trunks left standing after the slash and burn cycle are felled and used to make the lines, which may be filled out using crop residues or weeds. Competition for log use exists between log lines and charcoal production and for this reason the lines are mostly constructed from softwood, which has low economic value. Some farmers compromise by constructing log lines from hardwoods and then burning the logs for charcoal after the terrace has formed. Like trash lines, log lines are destroyed by ants and termites. The technique is dying out as an ICT measure due to increasing population density, which has led to a decline in shifting cultivation (Atshul and Okoba, 1996).

Retention ditches are used in steep areas of Kenya, where runoff is captured and allowed to infiltrate for crop roots to tap (Thomas and Biamah, 1991).

2.2.2 Tanzania

Stone and earth terraces have been used by smallholder farmers for several generations in a number of areas in Tanzania. Stones were collected and built into terraces by inhabitants on densely populated Ukara Island in Lake Victoria to protect and increase cultivated land whose fertility has continuously been revamped by composting plant residues and addition of animal manure (Allan, 1965). The 'ladder terraces' of the Uluguru Mountains (in Morogoro) are shaped terraces which take the form of steps across the hillsides constructed when strips of plant waste are covered with soil dragged from above. The resultant high content of incorporated organic matter increases soil fertility as well as promoting rainfall infiltration (Temple, 1972).

Ridges (with-and-without incorporation of organic residues) are widely used in the Southern Highlands (of Iringa, Ruvuma and Rukwa) on slopes of 4-20% to grow maize, wheat, groundnuts, round and sweet potatoes. These ridges control soil erosion and retain some moisture as they are usually constructed on the contour (BACAS, 1993).

Tied ridges which are parallel ridges with earthen bunds constructed at right angles to them, at intervals of 1-4m), are used in growing maize and other grain crops in Mwanza and Shinyanga in the Lake Victoria zone although their popularity has considerably declined in recent years due to the amount of labour required under hand-hoe cultivation. The tied ridges, nevertheless, create a series of individual basins that increase the surface retention capacity, decreasing runoff, and increasing crop growth and yields (Prentice, 1946; Kayombo, 1993).

Ngoro or Matengo pit system of soil fertility and crop yield enhancement, found on steep slopes of Mbinga District of Southwest Tanzania, has been in use for at least 200 years and currently extend over some 18,000 ha (Allan, 1965; Kayombo and Dihenga, 1993). It consists of a series of regular pits, 1.5m square and 10-50cm deep, which from a distance resemble a honeycomb. The ridges are built on top of lines of cut grass which decomposes to release nutrients to the soil. Crops are only grown on the ridges, not in the pit itself.

Soil and water conservation as a result of water being trapped in the pits, reduces erosivity. The increased soil organic content encourages granulation hence aggregate stability. The Ngoro are also likely to create a sheltered microclimate. A combination of these factors allows beans, planted towards the end of the rains, in March/April, to be cropped on residual soil moisture.

Floodwater harvesting (FWH) is practised by smallholder farmers of Ukara Island in Lake Victoria to raise crops. The runoff provides water and fertile sediment for crop growth in gullies. Farmers use stone barriers to create small-scale silt traps. Alluvium is trapped and fertile gardens are created for the production of fruits and vegetables (Allan, 1965).
FWH is also being used to support paddy production on "mbuga" soils which are vertic, black-grey cracking clays around Dodoma, Singida, Tabora, Shinyanga and Mwanza. Farmers in these regions have developed an elaborate system of retaining the seasonal flood in bunded basins called majaruba. Records show that the development of this system started in the early 1940’s (Allnutt, 1942). It is estimated that 32% of rice in Tanzania is produced under the majaruba system [Kanyeka et al., 1994]. In Shinyanga and Tabora Regions for example, valley fields are subdivided by bunds of 25-100 cm height to form cultivated reservoirs or majaruba which are transplanted with rice crop (Mwakalila and Hatibu, 1992). The importance of this runoff farming is illustrated by the biggest increase in rice production in Tanzania over a 15 year period occurring in the semi-arid marginal areas (MoA, 1993). Yields are, however, still low compared to those of well-managed irrigation projects (6t/ha) (Hatibu et al., 1997).

Vinyungu, an ingenuous camber-bed type of cultivation, is practised by smallholder farmers in Makete, Ludewa, Mufindi and Njombe districts of Iringa administrative region to grow maize, beans, peas and vegetables during the dry (June-November) season. This practice is commonly used on heavy soils (clays) found in wet valley bottoms and other low-lying areas. The ridges are built up higher (up to 0.6m) and wider (up to 5-20m), with a cambered surface sloping down to the open drain on either side. They form a significant source of green produce for the urban centres of these districts in the dry season.

2.2.3 Uganda

Knowledge on existing ICT techniques comes from Kamwezi subcounty, Kabale District, in the highland area of South West Uganda. This area is renowned for its history of high population densities, land degradation and soil conservation programmes (Tukahirwa, 1995). Kamwezi lies at altitudes of 1400-2000m with a mean annual rainfall of 830mm. Farmers are, however, able to successfully grow bananas with about half the annual rainfall received by most banana growers in the world (Gowen, 1995). This has been possible due primarily to the persistent use of ICT techniques by local farmers under the water deficit conditions of Kamwezi. Among the well-known ICT techniques are the trashlines and banana mulching.

Trashlines are used on slopes of 20 to 30%, in a range of annual crops including maize, sorghum, beans, peas, cassava, round and sweet potatoes. The indigenous practice is to leave the land fallow after harvest, during the non-cropping season, allowing weed cover to develop thus protecting the soil surface from erosion. Land preparation includes seedbed preparation and heaping of trash and previous crop residues in lines along the contour. Some farmers favour annual movement of trashlines so that fertility around them is spread across the field. The major improvements to crop yields and the soil in the vicinity of the trashline, however, occur after the trashline has been in a single position for two seasons (Briggs et al., 1996).

Banana mulching on the plantation floor is used to conserve soil and water, to maintain soil fertility and to reduce weed growth. Harvested rainwater is also led into banana plantations via interception ditches. Banana mulching is a century old tradition. The indigenous banana mulching practice uses a mix of four different mulch components, namely, bean and sorghum stover, banana pseudo stem, and grass.

The two above and other ICT techniques, including their purposes and where they are used, are shown in Table 1.

Existing ICT techniques in East Africa are summarised in Table 2. The following factors (acting singly or in combination), as reported by Critchley et al., (1994), have allowed these ICT techniques to thrive to the present time:

1. A historical obligation to produce crops on hillsides and mountain slopes where the need to preserve the thin topsoil layer as a growing medium is paramount;
2. Population pressure and
3. Influence of land tenure.

These conditions favouring the persistence of ICT techniques provide us with guidelines on how to improve them as need arises. The first step in this direction is to analyse the usefulness and shortcomings of ICT techniques. Socio-economic and technical evaluation of ICT techniques are currently being carried out in Kenya (Altshul et al., 1996; Okoba et al., 1996) and Uganda (Briggs et al., 1996).
The socio-economic and technical evaluation of ICT techniques in Mbinga District of South West Tanzania aimed at:

i. examining the socio-economic (productivity) aspects of the Ngoro compared to the use of ridges

ii. examining the technical (physical) aspects of the Ngoro compared to ridge cultivation on 15, 40 and 45% slopes.

### 2.3.1 Socio-economic evaluation

This involved a Participatory Rural Appraisal (PRA) in late 1994 followed by monitoring of nine farmers from two villages over a 12 month period selected as being representative of farmers with different socio-economic backgrounds and access to resources. Interviews were also held with each farmer on two separate occasions. A workshop was conducted in each village with the farmers and other community leaders in January 1996.

### 2.3.2 Locations and agro-ecological environment

The main focus for the project are the Matengo Highlands and surrounding areas of the Mbinga district in South West Tanzania. Mbinga District is 11935km$^2$ and can be divided into five agro-ecological zones: high and low altitude mountains, a high plateau, rolling hills and a lakeside zone. These are shown in Table 3 as well as Map 1.
The climate can be described as temperate tropical with a unimodal rainfall pattern. The rain season extends for at least six months with a colder dry season for the remainder of the year. Average minimum and maximum temperatures are 19-23°C and 29-31°C respectively. The average annual rainfall for the district is 1224 mm. Unfortunately no long-term rainfall records exist except for Mbinga town which averages 1064 mm per annum. Monthly distribution is shown in Figure 1. The onset of the rains at the end of November is fairly reliable. The growing season extends from 6-7 months in the low altitude mountains to 9 months in the high altitude areas and plateau. Evapotranspiration data is not available but between May and October evapotranspiration exceeds precipitation. Adequate soil moisture is, therefore, critical in achieving economic yields in beans, wheat and other dry season crops.

The soils are Haplic or Humic acrisols depending on their position in the toposequence (ICRA, 1991). At higher elevations the most common soils used for crop production are deeply weathered highly leached yellow red soils which are well drained with good permeability. Textures are largely sandy clay loams. On the plateau, soils tend to be shallower with impeded drainage in places. At lower elevations soils are less leached brown red in colour sandy clay loams and sandy clays. Shortages of nitrogen, phosphorus and micro nutrients particularly zinc and copper are common. The relatively low incidence of soil erosion can be largely attributed to high inflation rates combined with the ngoro land preparation practice.

The natural vegetation of the area is largely Miombo woodland, dominated by Julbernardia and Brachystegia, which has almost totally disappeared in the Mountains and Plateau areas. At lower elevation secondary wooded grassland is common. Deforestation for the establishment of new lands is an ongoing process, especially in the lowland areas where Miombo woodland still exists, with most of the wood consumed in Mbinga coming from this area. In the Highlands and Rolling Hills North, there is a shortage of wood and therefore increasing pressure on the remaining woodlands.

2.3.3 Socio-economic environment

The population is estimated to be 320,000 people with a growth rate of 3.4%. There are four main ethnic groups in the district; the Matengo in the Highlands, Ngoni in the North-east, the Manda in the East, the Nyasa along the lakeside. The district is one of the wealthiest regions in Tanzania largely as a result of the introduction of coffee in the 1930s. As a result of the high agricultural potential, the district has the highest population density (32 people per km²). The resulting high land pressure gives rise to intensive agricultural practices and recent deforestation as well as considerable out migration especially of young men and families in an attempt to acquire land in other areas. Almost all income in the area is derived from agriculture, coffee being the main cash source. At lower altitudes although coffee is still important maize and beans are more important as cash crops. Transport infrastructure is in very poor condition and is a major constraint to increased production particularly in the mountainous areas. In most villages these are problems of accessibility during the rainy season. This leads to problems of supplying inputs and marketing produce. The official marketing of agricultural commodities, mostly coffee but also maize and beans, has been through the Mbinga Cooperative Union (MBICU) with crop procurement undertaken through primary grassroots cooperatives. Since 1990 the declared intention was to make the Cooperative Union the property of primary village cooperatives. However, since market deregulation in 1994 private operators have played an increasingly important role in both buying coffee and supplying fertilisers and chemicals.

Table 1. Existing ICT techniques in Kamwezi subcounty, Kabale District, SW Uganda

<table>
<thead>
<tr>
<th>No.</th>
<th>Practice</th>
<th>Where Used</th>
<th>Soil Conserv.</th>
<th>Main Purpose Water Conserv.</th>
<th>Fertility Improv.</th>
<th>Other Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>STRUCTURAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>Trash lines (TL)</td>
<td>Slopes, Annual Crops</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
### Table 2. Summary of Indigenous Conservation Tillage (ICT) systems in East Africa

<table>
<thead>
<tr>
<th>Country</th>
<th>Region</th>
<th>Rainfall</th>
<th>Indigenous</th>
<th>Major</th>
<th>Reference</th>
</tr>
</thead>
</table>

**S = Structural/Physical Measures**  
Source: Miiro et al. (1996)  
**A = Agronomic/Cultural Practices**  
**TL = Trashline**

### 2.4 Farming systems

Agriculture is entirely based on smallholder production with farm size varying from a minimum of 1 ha to over 12 ha. Crops are grown alone or mixed nearly always using ngoro except on the flat where intricate drainage systems are seen. The season starts with the onset of the rains in November or December when maize and cassava are planted, with a second planting in April or May for crops such as beans, wheat, potatoes and peas which grow on residual moisture. The most common crop rotation on ngoro is beans with some planting of cassava followed by maize. Some farmers keep the ngoro and ridge systems completely separate. Others convert from ridges to ngoro when fertility declines.

Most manure is used close to the homestead on coffee, fruit trees and occasionally maize. Due to the low numbers of livestock in the area manure is always in short supply. Most farmers apply nitrogenous fertilisers (CAN-27%N, SA-21%N or urea-46%N) to their coffee crops, occasionally to maize but never to other crops. Mulching of coffee is recommended and commonly carried out with material from nearby fields or from the leaves of *Grevellia robusta* which is common as a shade tree for coffee.

### 2.4.1 ICT Systems

All soil preparation is undertaken by hand using either the ngoro system or one of two types of ridges: with or without plant residue incorporated. Flat cultivation occurs only in the valley bottoms.

The most conspicuous and original feature of agriculture in the area is the ngoro system. Ngoro are used almost exclusively for food crops within a slope range of 10% to 60%. However, it is dependent on fallow period the minimum of which is 6-8 months. The length of fallow in the rotation varies according to population and cropping intensity. As population intensity increases, fallow decreases in terms of both duration and percentage of total land use. In the highest population areas fallow is rarely found. Table 4 indicates the periods of cultivation and fallow in each zone.

### Table 2. Summary of Indigenous Conservation Tillage (ICT) systems in East Africa

<table>
<thead>
<tr>
<th>S2</th>
<th>Ridges (R)</th>
<th>Ridges and flat</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>AGRONOMIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>Mulching</td>
<td>Bananas,</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tomatoes,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coffee,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pineapples</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>Crop Rotation</td>
<td>All Annual</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(CR)</td>
<td>Crops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>Burying Weeds</td>
<td>All crops</td>
<td>-</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>and Trash</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4</td>
<td>Trash Heaping</td>
<td>On flat</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>land and between</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TL. on slopes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Increases soil volume for tubers

Weed control

Pests/Disease control

Weed Control

Clean fields
Indigenous conservation tillage system in East Africa with an example...

Table 3. Description of Agro-ecological zones

<table>
<thead>
<tr>
<th>AGRO-ECOLOGICAL ZONE</th>
<th>ALTITUDE (Metres ASL)</th>
<th>INDICATIVE RAINFALL (mm)</th>
<th>DESCRIPTION</th>
<th>% OF AREA CULTIVATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uganda</td>
<td>800-1000</td>
<td>Bananas, round and sweet potatoes, sorghum</td>
<td>Miro et al. (1996)</td>
<td></td>
</tr>
</tbody>
</table>
Indigenous conservation tillage system in East Africa with an example...

<table>
<thead>
<tr>
<th>Mountainous areas</th>
<th>High Altitude</th>
<th>1600-1900</th>
<th>1400-1600</th>
<th>Strongly dissected mountains with steep slopes and narrow valleys</th>
<th>80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low altitude</td>
<td>1400-1600</td>
<td>1000-1400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High plateau (Hagati plateau)</td>
<td>1500</td>
<td>1400-1600</td>
<td>Gently rolling plateau at the top of the mountains</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>Rolling Hills</td>
<td>North</td>
<td>1300</td>
<td>1000-1200</td>
<td>Flat to undulating plains intermixed with mountains up to peaks of 1600m</td>
<td>66%</td>
</tr>
<tr>
<td>South</td>
<td>1200</td>
<td>1000-1200</td>
<td></td>
<td></td>
<td>33%</td>
</tr>
<tr>
<td>Lakeside</td>
<td>500-600</td>
<td>900-1400</td>
<td></td>
<td>Mainly flat with undulating hilly slopes rising to steep escarpment adjoining the highlands</td>
<td>20%</td>
</tr>
</tbody>
</table>

Source – PRA report (Ellis-Jones et al. 1994).

Figure 1: Average monthly rainfall

The ngoro are formed in March/April and are constructed as follows: Grass is slashed with a nyengo (sickle) and lain in a matrix of discrete squares or rectangles with side dimensions ranging from 2-2.5 metres. After dying for a week, soil is dug by jembe (hoe) from the centre of these squares and thrown over the grass to form bunds on all sides and consequently a pit (ngoro) in the centre. The bund walls thus consist of a layer of grass sandwiched between a layer of top soil and the original soil surface beneath it. Throughout the year weeds and crop debris are thrown into the pits to form compost. Unless an extended fallow period is used, pits are reformed every 2 years after a 6-8 month short fallow.

They are reformed in the same way, but this time laying the grass lines across the centre of the existing pits and bunds. Soil is dug from the existing bunds and placed over the grass to form new bunds. Thus, what was previously a pit becomes a bund and vice versa. Burning on ngoro was rare but is now increasing to reduce crop residue and labour requirements. The greatest concentration of ngoro is with
the Matengo people in the mountainous zone of Mbinga. However, ngoro has spread to the lowlands as a result of mixed marriages and migration of Matengo people. Estimates provided by DALDO staff on the relative use of ngoro and ridges on food crops are shown on Table 5.

Table 4. Average duration of cultivation and fallow in the Highlands (years)

<table>
<thead>
<tr>
<th>AGRO ECOLOGICAL ZONE</th>
<th>CONTINUOUS CULTIVATION</th>
<th>FALLOW PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountains</td>
<td>6.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Plateau</td>
<td>6.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Rolling Hills North</td>
<td>3.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Rolling Hills South</td>
<td>4.0</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Source: Derived from ICRA (1991)

Table 5. The extent of ngoro and ridges (% of land under cultivation)

<table>
<thead>
<tr>
<th>LAND PREPN SYSTEM</th>
<th>HIGHLANDS</th>
<th>LOWLANDS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Mountains and Plateau) North</td>
<td>South</td>
</tr>
<tr>
<td>Ngoro</td>
<td>95</td>
<td>70</td>
</tr>
<tr>
<td>Ridges</td>
<td>5</td>
<td>30</td>
</tr>
</tbody>
</table>

There are basically two types of ridging, one with organic matter incorporated and one where organic matter is burnt off first. When the ridges are reformed the following year, grass is cut and laid in the furrows before being covered with soil dug from the old ridges. This method eliminates the need for burning and has many of the advantages of increased fertility, organic matter content and associated soil improvements described for ngoro. Ridges with no incorporation of plant residue are formed in a similar way to the ones described above.

There is a fairly clear division of labour between men and women. The husband is the decision-maker controlling the allocation of resources. Most of the work on food crops is undertaken by women as are most household tasks. Making of ridges is jointly undertaken but the construction of ngoro is traditionally female work, except for initial land clearing and laying out the grass matrix. Men are mainly involved with coffee production and view the ngoro as being too laborious, even if payment is offered. Money from sale of coffee is almost always kept by men. Women retain income from sale of maize and beans unless there is no coffee, when men retain this as well.

2.4.2 Farmers’ perceptions and evaluation criteria

Two separate workshops were held with the participating farmers and local leaders to establish within a group forum farmers views and their evaluation criteria on the comparative advantages of ngoro and ridges. The main conclusions emerging are shown in Table 6.

All groups regarded Ngoro as the best ICT practice. Farmers’ views confirmed that the most important benefits of ngoro are erosion control, moisture retention and fertility maintenance. Important also is the fact that higher yields are achieved in comparison to ridges when no fertiliser is applied, April planted bean yields are higher and land preparation is only undertaken once every two years.

About the ridges, the view was that they can be as effective as ngoro when properly constructed and organic matter is incorporated. They require less labour and give higher yields when fertiliser is used.
Table 6. Benefits of *ngoro* and ridges

<table>
<thead>
<tr>
<th><strong>NGORO RIDGES</strong></th>
<th><strong>Benefits</strong></th>
<th><strong>Ranking</strong></th>
<th><strong>Benefits</strong></th>
<th><strong>Ranking</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion control 1</td>
<td>Can be as effective as <em>ngoro</em> in controlling soil erosion when organic matter is incorporated</td>
<td>1</td>
<td>Requires less labour than <em>ngoro</em> 2</td>
<td>2</td>
</tr>
<tr>
<td>Provides better moisture in soil 2</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retains fertility better when no Fertiliser is applied 3</td>
<td>Give higher yields than <em>ngoro</em> when fertiliser is Applied 3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gives higher yields than ridges When no fertiliser is applied 4</td>
<td>Men and women share the work 4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best on steep slopes 5</td>
<td>Best for intercropping maize and beans 5</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best for beans planted in March 6</td>
<td>Easier to plant than <em>ngoro</em> (using proper spacing) 6</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Made every two years 7</td>
<td>Best for beans planted in December 7</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava can be grown on <em>ngoro</em> 8</td>
<td>Easier to fertilise than <em>ngoro</em> uses less fertiliser 8</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional system 9</td>
<td>Easier to employ people to construct 9</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helps people not to migrate 10</td>
<td>Easier to mechanise 10</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other important benefits were that men and women shared the work and that ridges were better for inter-cropping. As for the criteria on choice of either *ngoro* or ridges, control of soil erosion, labour availability and having the finance available to buy fertiliser ranked highest in deciding the ICT measure to use.

In considering whether *ngoro* would increase or decrease in the future, farmers were split almost 50:50 in the views.

### 2.4.3 Economic analysis

As a result of discussion with farmers on an individual and group basis as well as measurements being recorded in the field, the comparative labour requirements of *ngoro* and ridges have been determined. Field measurements and information based on individual discussions were similar and indicated nearly 20% less labour for ridges. Burning allowed labour to be reduced by nearly 50%. This is shown in Table.7. This confirmed that *ngoro* is most labour intensive conservation technology followed closely by ridges with organic matter incorporated. It is for this reason that farmers seek methods to reduce the labour input associated with *ngoro*. Examples include: reducing the organic matter within the *ngoro* through burning excess grass and laying the grass in parallel lines. All costs, except those associated with the purchase of hoes and sickles comprised labour which was in most cases provided by the family. When people hired labour it was for ridge construction as hired labour is regarded as untrained for *ngoro* construction.
Table 7. Labour requirements for ngoro and ridge cropping systems (days per ha)\(^3\)

<table>
<thead>
<tr>
<th></th>
<th>NGORO With organic matter</th>
<th>NGORO Without organic matter</th>
<th>RIDGES With organic matter</th>
<th>RIDGES Without organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planting date</strong></td>
<td>Maize Dec</td>
<td>Beans Apr</td>
<td>Maize Dec</td>
<td>Beans Apr</td>
</tr>
<tr>
<td>Burning</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Slashing</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Arranging grass</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Pitting or ridging</td>
<td>13</td>
<td>30</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Planting</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Fertilising</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Weeding</td>
<td>13</td>
<td>0</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Pest Control</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Harvest</td>
<td>13</td>
<td>8</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>60</td>
<td>70</td>
<td>58</td>
<td>50</td>
</tr>
<tr>
<td><strong>% labour for April ngoro</strong></td>
<td>85%</td>
<td>100%</td>
<td>82%</td>
<td>71%</td>
</tr>
<tr>
<td><strong>% labour for two crop system</strong></td>
<td></td>
<td></td>
<td>83%</td>
<td></td>
</tr>
</tbody>
</table>

Considerable variation in crop yields occurs depending on altitude, rainfall, fertiliser use and other management factors. Typical yields have been obtained through discussion with DALDO extension staff and local farmers as well as from measurements. These are shown in Table 8.

Table 8. Typical yields and ranges for the main crops (kg per ha)

| MAIZE LAND PREPARATION FERTILIZER YIELD SYSTEM APPLICATION (kg/ha) | BEANS FERTILIZER APPLICATION April December (kg/ha) (kg/ha) |
Trials in the 1940s (Berry and Townsend, 1972) confirmed that ngoro maize yields were higher compared to tied ridging or flat cultivation. Trials in the 1950s (Allan, 1965) confirmed this indicating however that the difference was not great except in exceptionally wet years. Yields on ngoro are said by most farmers to be considerably greater than those on ridges when fertiliser is not used. When fertiliser is used at recommended rates, little difference in yield results. Gross-margins detailing returns to land, capital and labour have been calculated in order to compare the relative productivity of ngoro and ridges. These have been based on two levels of production:

**Table 9. Gross margin analysis based on high input practices (DALDO recommendations)**

<table>
<thead>
<tr>
<th>CROP</th>
<th>ICT METHOD</th>
<th>YIELD</th>
<th>INPUTS</th>
<th>RETURNS</th>
<th>RANK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(kg/ha)</td>
<td>Labour (day/ha)</td>
<td>Cash (Tsh)</td>
<td>Land (Tsh/ha)</td>
</tr>
<tr>
<td>Maize</td>
<td>Ngoro Basal and topdressing 4000</td>
<td>4000</td>
<td>60</td>
<td>112750</td>
<td>107250</td>
</tr>
<tr>
<td></td>
<td>Ngoro Topdressing only 1500</td>
<td>4000</td>
<td>58</td>
<td>112750</td>
<td>109750</td>
</tr>
<tr>
<td></td>
<td>Ridges with organic matter</td>
<td>3500</td>
<td>50</td>
<td>112750</td>
<td>84750</td>
</tr>
<tr>
<td></td>
<td>Ridges without organic matter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans (planted April)</td>
<td>Ngoro Basal and topdressing 500</td>
<td>500</td>
<td>70</td>
<td>32500</td>
<td>72500</td>
</tr>
<tr>
<td></td>
<td>Ridges with organic matter</td>
<td>500</td>
<td>50</td>
<td>32500</td>
<td>92500</td>
</tr>
<tr>
<td></td>
<td>Ridges without organic matter</td>
<td>200</td>
<td>25</td>
<td>31000</td>
<td>14000</td>
</tr>
<tr>
<td>Beans (planted December)</td>
<td>Ngoro Basal and topdressing 500</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Ridges with organic matter</td>
<td>500</td>
<td>65</td>
<td>32500</td>
<td>77500</td>
</tr>
<tr>
<td></td>
<td>Ridges without organic matter</td>
<td>400</td>
<td>43</td>
<td>32500</td>
<td>65500</td>
</tr>
</tbody>
</table>
Indigenous conservation tillage system in East Africa with an example... http://www.fao.org/ag/ags/agse/agse_s/3ero/namibia1/c12.htm

Table 10. Gross margin analysis based on lower input practices

<table>
<thead>
<tr>
<th>CROP</th>
<th>ICT METHOD</th>
<th>YIELD (kg/ha)</th>
<th>INPUTS</th>
<th>RETURNS</th>
<th>RANK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Labour (day/ha)</td>
<td>Cash (Tsh)</td>
<td>Land (Tsh/ha)</td>
</tr>
<tr>
<td>Maize</td>
<td>Ngoro</td>
<td>1500</td>
<td>60</td>
<td>28600</td>
<td>21400</td>
</tr>
<tr>
<td></td>
<td>Ridges with organic matter</td>
<td>1000</td>
<td>58</td>
<td>27000</td>
<td>-9500</td>
</tr>
<tr>
<td></td>
<td>Ridges without organic matter</td>
<td>500</td>
<td>50</td>
<td>23600</td>
<td>-36100</td>
</tr>
<tr>
<td></td>
<td>Ngoro</td>
<td>300</td>
<td>70</td>
<td>12000</td>
<td>28000</td>
</tr>
<tr>
<td></td>
<td>Ridges with organic matter</td>
<td>200</td>
<td>50</td>
<td>11500</td>
<td>13500</td>
</tr>
<tr>
<td></td>
<td>Ridges without organic matter</td>
<td>150</td>
<td>25</td>
<td>11250</td>
<td>18750</td>
</tr>
<tr>
<td></td>
<td>Ngoro</td>
<td>400</td>
<td>65</td>
<td>12500</td>
<td>70000</td>
</tr>
<tr>
<td></td>
<td>Ridges with organic matter</td>
<td>300</td>
<td>43</td>
<td>12500</td>
<td>55500</td>
</tr>
<tr>
<td></td>
<td>Ridges without organic matter</td>
<td>300</td>
<td>43</td>
<td>12500</td>
<td>55500</td>
</tr>
<tr>
<td>Maize and beans</td>
<td>Ngoro</td>
<td>130</td>
<td>38500</td>
<td>49400</td>
<td>621%</td>
</tr>
<tr>
<td></td>
<td>Ridges with organic matter</td>
<td>108</td>
<td>40600</td>
<td>49400</td>
<td>621%</td>
</tr>
</tbody>
</table>
A high input level based on the use of hybrid seeds, fertiliser and pesticides as recommended by DALDO (Table 9).

A lower input level where local seed varieties, small amounts of fertiliser (topdressing only) and minimum pesticides (Table 10) are used.

All participating farmers used the lower input system.

The resulting gross margins present two conclusions:

- In high input systems, ridges incorporating organic matter and requiring lower labour input provide best returns to land and labour for both maize and April beans. Burning crop residues, although saving labour, results in lower yields and lower returns to land for all crops. However, December beans show greater returns to labour indicating the attractiveness of burying and as labour prices rise burning becomes increasingly attractive from a short term economic standpoint.
- In low input systems, however, the traditional ngoro outperforms ridges despite the increased labour requirement. Returns to land, cash and labour are higher when comparing the system over both a maize and a bean crop. However, the results show burning, again, to be attractive, especially for both April and December beans. Despite achieving lower yields, the reduced labour requirement makes returns to labour attractive in the short term.

In comparing the two sets of results returns to land and labour attractive in the short term. In comparing the two sets of results returns to land and labour are significantly less for low input systems, but returns to cash (capital) are significantly greater.

While capital is scarce and labour is plentiful it is rational to use the lower input systems based on ngoro which provides the greatest returns.

A major concern must be the attractiveness of burning and the long-term degradation that will result. The challenge is therefore to identify methods of reducing the labour requirements for ngoro and ridges as well as low cost yield increasing technologies that maintain the conservation advantages of both ngoro and ridges.

2.4.4 Technical evaluation

Three sites were selected in March 1995. The following ICT methods were investigated:

1. Ngoro (N)
2. Ridges with incorporated organic residues (R+OR)
3. Ridges with no incorporated organic residues (R-OR)

All three methods were investigated at the three sites described in Table 11. At each site the three ICT treatments, each measuring 22x60m, lay side by side, separated by tied ridges and with a cut off drain at the top and bottom. Each field had previously been under fallow and was formed and planted with beans in April 1995, harvested in June 1995, and then weeded and planted with maize after the first rains in December 1995 which was harvested in July 1996.

Table 11. Field descriptions

<table>
<thead>
<tr>
<th>Area</th>
<th>Slope (%)</th>
<th>Average <em>Ngoro</em> dimensions (m)</th>
<th>Average ridge spacing (m)</th>
<th>Previous fallow period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipumba</td>
<td>15</td>
<td>2.30x2.37</td>
<td>1.12</td>
<td>1</td>
</tr>
<tr>
<td>Lipumba</td>
<td>45</td>
<td>2.60x2.25</td>
<td>1.00</td>
<td>4</td>
</tr>
<tr>
<td>Mhekela</td>
<td>40</td>
<td>2.33x2.06</td>
<td>1.41</td>
<td>1</td>
</tr>
</tbody>
</table>

2.4.5 Technical investigations

Climatic monitoring was carried out through a manual raingauge installed at each site in November 1994. Organic Carbon percent (%C) and total N (%N) content were determined in all fields using core samples taken at 0-5 cm increments down to 20cm depth. Samples were also collected every two weeks from newly formed *ngoro* and analysed for % C and %N to investigate the extent and duration of nitrate depression. *Ngoro* length, width, depth, and growing area on each bund, was recorded on 15 newly formed *ngoros* in each of three fields in each of three slope classes (2-10%, 15-25% and >40%) at each of Mhekela and Limpumba sites. Length and width of 10 *ngoros* in each of a further 11 fields was also noted and 50 holes augured to investigate the extent of buried residues.

Figure 2a: Mean seasonal soils moisture content (December 1995-April 1996) at Lipumba -45%
In May 1995, exploratory soil moisture measurements were taken with a Speedy Moisture (calcium carbide) Meter in all trial fields under beans at Mhekela, 22 days after the last rainfall. In November 1995, 54 neutron probe tubes were installed. The probe was calibrated for each site and weekly measurements taken since. On ngoro, one tube was installed in the centre of the bottom bund, the centre of the side bund and in each bottom corner, of 3 ngoros. Three tubes were installed in all ridged fields and one calibration tube per site. Monthly soil surface profiles were recorded down the slope during the rainy season using a locally manufactured Soil Surface Profile Gauge. Profiles were also taken across the slope through several ngoro. To investigate the volume of soil moved in ridges compared to ngoro, profiles were taken before and after formation of each.

Plants were counted in three areas of each field to estimate plant populations. Plant height and number of leaves were measured weekly. The growing area per hectare in each field was calculated and all yields recorded. Maize yield from the side bund of ngoro's was compared to that from the bottom bund.

3. Results and discussions

Rainfall at Lipumba during 1994/95 season was 958 mm compared to 1030 mm at Mhekela village, increasing to 1080 and 1218 mm respectively during 1995/96.

Ngoro's are generally larger than the historically quoted (1.5m$^2$). Average dimensions, measured in April 1996 at Mhekela, where ngoro has a long history, were 2.36 x 2.08m (aligned downslope) varying from 1 to over 3 m. At lipumba, where ngoro is relatively new, the pits were slightly smaller and more rectangular (2.31 x 1.95m). On gentle slopes ngoro's tend to be more square with the actual pit often being round, but as slope increases, they become longer and thinner, usually aligned downslope. These findings confirm that farmers are beginning to abandon tradition in favour of easier options, especially at Lipumba.

Within recent years, many farmers have also stopped laying the grass into a matrix, in preparation for ngoro construction. Instead they only lay it into parallel lines running downslope. This means that the fertility of the top/bottom bunds, in the absence of buried residues, will decrease. Soil erodibility may also increase as it is these smaller bunds which are subjected to the strongest erosional forces and whose continued existence dictates the effectiveness of the pits, in terms of both soil and water conservation.

Table 12. Variation in pit depth with slope

<table>
<thead>
<tr>
<th>Slope Class (%)</th>
<th>Depth Range (cm)</th>
<th>Average Depth cm</th>
</tr>
</thead>
</table>
Table 12 shows the average depth to decrease from 30 cm on gentle slopes, through 21 cm on average slopes, to 14 cm on steep slopes. Depth also decreases throughout the season as the pit becomes filled with plant residue thrown into it and with soil eroded from the surrounding ridges.

Soil moisture measurements using the neutron probe (Rs/Rw values) taken from December 1995 to April 1996 showed that ridges retained more moisture than ngoro. R+OR (ridges plus organic residues) and R-OR (ridges less organic residues) retained the most moisture at Lipumba-45% and Lipumba-15% respectively (Figure 2a). In both cases ngoro retained the least. The ngoro bottom bund (BB) retained more moisture than the side bund (SB) from 0-40 cm at Lipumba-45% and at all depths at Lipumba-15% (Figure 2b), presumably as a result of water pooling above the BB. At all sites, the corners generally retained the least moisture.

Results obtained from the calcium carbide meter taken in May 1995 showed different trends. The ngoro at Mhekela, had more moisture than the ridges, especially below 15 cm. These were the most important results as beans are grown at this time on residual soil moisture. Neutron probe values were taken whilst maize was growing, from December to July, when there was little water stress. Moisture reached a maximum at 15 cm which corresponded with the centre of the organic layer and this was presumably due to the organic residues causing an increase in the soils water holding capacity.

Figure 3a: Soils moisture measured on Ngoros under beans: large (3x2.5m), medium (2.5x2m) and small (2x1.5m) ngoros
Figure 3b: Soils moisture measured on Ngoros under beans: on various bunds of small (2x1.5m) ngoros

Table 13. Plant populations per hectare

<table>
<thead>
<tr>
<th></th>
<th>Ngoro</th>
<th>R+OR</th>
<th>R-OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipumba-45%</td>
<td>34,200</td>
<td>24,200</td>
<td>21,900</td>
</tr>
<tr>
<td>Lipumba-15%</td>
<td>30,900</td>
<td>16,000</td>
<td>23,200</td>
</tr>
<tr>
<td>Mhekela</td>
<td>23,500</td>
<td>20,700</td>
<td>20,800</td>
</tr>
</tbody>
</table>

Figure 4. Soil distribution in Ngoro at Mhekela from May 1995 to March 1996

Soil moisture content in the side bunds clearly increased with pit size (Figure 3a). The effect was less clear on the bottom bunds and corners. Overall the corners retained the most water and side bunds the least. This was especially clear in the smallest pits (Figure 3b).
Soil surface profiles taken in the period May 1995 to March 1996 showed that the majority of ngoro’s and ridges had degraded into flat or gently sloping terraces (Figure 4). The amount of deposited sediment in pits of a ngoro field is large (Figure 4). In the ridged fields, however, the degree of decomposition in the furrows was small, suggesting that some soil is transported elsewhere.

At Lipumba all fields had similar initial maize growth rates (Figure 5), but by end of January 1996, the ngoro had taken a clear lead. The two ridged fields had similar values with R+OR being slightly better. Similar plant growth trends were observed at Mhekela although this site suffered the most past erosion.

Table 13. Shows the ngoro to have more plants per ha at all sites. The differences are most apparent at Lipumba-45% where 3 rows were planted on the SB’s, and Lipumba-15%, with two rows, compared to just one row at Mhekela.

The rains finished early in May 1995, so bean yields were very low, with no harvest from Lipumba-15%.
Table 14 shows that ngoro produced superior yields. It appears therefore, that when under severe stress, ngoro may make the difference between something and nothing. The higher yields on R-OR at Mhekela are presumably due to this field having higher initial nitrogen levels.

Figure 6 shows quite clearly that the ngoro produced the highest maize yields in all three fields harvested in July 1996. The yield per plant was lower on ngoro, due to an increased competition for resources between higher number of plants (Table 13) but this is an acceptable sacrifice.

Table 14. Bean yields (kg/ha)-June 1995

<table>
<thead>
<tr>
<th></th>
<th>Lipumba-45%</th>
<th>Mhekela-40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ngoro</td>
<td>82</td>
<td>133</td>
</tr>
<tr>
<td>R+OR</td>
<td>44</td>
<td>89</td>
</tr>
<tr>
<td>R-OR</td>
<td>44</td>
<td>133</td>
</tr>
</tbody>
</table>

4. Conclusions

ICT techniques in East Africa are prevalent in areas of water-deficit conditions and in semi-arid zones. These techniques have survived through several generations as a result of a combination of factors, among them:

- the realisation of moisture conservation to overcome moisture scarcity as a crop production constraint,
- the historical obligation to produce crops on hillsides and steep mountain slopes with thin topsoil layers,
- population pressure and
- the influence of land tenure.

Due to changing natural and socio-economic environment, some of these ICT systems are beginning to show signs of decline. The need to understand these systems is a first step towards their improvement.

The socio-economic evaluation of ICT techniques in Mbinga District of SW Tanzania has shown that ngoro cultivation is efficient at controlling soil erosion, increasing soil moisture at critical times of the year and maintaining soil fertility. The problems associated with it, notably decreasing fallow periods and high labour requirement, indicate declining use, except at the traditional centre of the ngoro.

The technical evaluation has shown that compared to ridges, when ngoros are intact, they increase soil moisture and consequently bean yields. When badly degraded, soil moisture is decreased but despite this, maize growth and yields are better than on ridges, when no fertiliser is used. In ngoro, the majority of eroded soil is redeposited into the pit, whereas on ridges it is often transported elsewhere.

The immediate future challenge is to build productivity enhancing improvements into the present system without destroying its unique advantages.

Acknowledgements

The work described in this paper formed part of the Collaborative Environment Research Project funded by British Overseas Development Administration (ODA) and managed by Silsoe Research Institute (SRI). This collaborative effort resulted in an East African Workshop held in May 1996 at Nyeri, Kenya, of which Proceedings are available.

References


Kanyeka, Z.L., Msomba, S.W., Kihupi, A.N. and Penza, M.S., 1994. Rice ecosystems in
Indigenous conservation tillage system in East Africa with an example...


Conservation tillage for sustainable crop production systems:
Experiences from on-station and on-farm research in Zimbabwe
(1988-1997)

by

Isaiah Nyagumbo

Soil and water conservation branch, Institute of Agricultural Engineering
P.O. Box BW 330. Borrowdale, Harare.

1. Introduction

Conservation Tillage is generally defined as any tillage sequence the object of which is to minimise or reduce the loss of soil and water. Operationally it is a tillage or tillage and planting combination which leaves at least 30% or more mulch or crop residue cover on the surface (SSSA, 1987). In Zimbabwe this term has been loosely used to refer to any tillage system whose objective is to conserve or reduce soil, water and nutrient loss or which reduces draft power input requirements for crop production. It is in this context that the term is used in this paper.

The Conservation Tillage project entitled "Conservation Tillage for Sustainable Crop Production Systems" (CONTILL) was a collaborative project between the department of Agricultural, Technical and Extension Services (AGRITEX) and the Germany Agency for Technical Cooperation (GTZ). The project was initiated in response to extensive problems of soil loss and run-off which were being experienced by smallholder farmers in Zimbabwe which were considered unsustainable (Elwell and Stocking, 1988; Whitlow, 1998). The primary objective of the project was to assess the soil and water conservation and yield merits of several tillage systems with a view to the development of sustainable crop production systems suitable for smallholder farmers in different agro-ecological regions.

In 1988, two experimental sites were established on sandy soils under natural rainfall at Domboshawa Training Centre and Makoholi Experiment Station. The first site, Domboshawa (17° 35' S, 31° 10'E) lies about 35 km North of Harare at an altitude of 1560m above sea level (asl) in a relatively high potential region receiving 750-1000mm rainfall while the second at Makoholi Experiment Station (20° 10’ S, 30° 45'E, 1210 m asl) lies about 40km near Masvingo in a semi-arid region receiving 450-650mm rainfall per annum.

Both sides were under rain-fed maize production. Soils on both sites were shallow granite-derived sands with clay content lower than 5 percent, bulk densities were in the order of 1.6 Mg/m3 while organic levels were low (0.2-0.5 percent).

Five tillage systems were put in place on two sites and research activities were identical and focused on the effects of hand or animal powered conservation tillage systems on surface run-off, sheet erosion and crop performance.

To ensure the technologies generated from these experimental sites would be acceptable within the farmers’ socio-economic environment, adaptive on-farm trials were established in 1990. These trials were composed of 32 farmers (8 farmers per cluster) drawn from 8 communal areas with 4 of the clusters in Natural Region IIa and the other 4 in Natural Region IV. Up to 1995 a total of seven clusters each composed of 8 farmers per cluster participated in the trials with Communal Areas of Musana, Chiweshe and Chinamhora in the sub-humid north and four clusters in the South: Zaka, Chivi, Gutu and Chikwanda.

Objectives

The objectives of the trials was to test the performance and assess the acceptability of one of the conservation tillage techniques, no-till tied ridging (nttr) by communal farmers though a farmer participatory approach. A two pronged approach inter-linking both on-station and on-farm research was
established.

This paper highlights some of the major results and experiences from this work since 1998. Results from the project’s work have been published in various forms and a total of 15 research reports have so far been produced.

2. Methodology

Five tillage systems were investigated on-station since 1988. These are:

1. No till tied ridging:

A system of semi-permanent ridges with cross-ties along the furrows to trap run-off. The ridges were laid across the main slope at a grade of 0.4-1%. Normally once constructed the ridges were not destroyed for a period of six seasons depending on the crop rotations practised by the farmer. Planting is done on top of the ridges. In subsequent seasons land preparation simply involves planting on top of the ridges. For good emergence, planting is recommended only when the ridges are fully moist. In drier areas planting may also be carried out in the furrows where most of the run-off water collects.

2. Mulch ripping:

A conservation tillage system involving the retention of stover on the surface and use of a ripper to open up planting lines. Crop rows alternate between seasons. Planting was carried out along the rip-lines. No ploughing took place.

3. Clean ripping:

This system was the same as mulch ripping except that no stover was retained after harvesting to mimic livestock grazing situations. An ox-drawn ripper was used to open up rip lines into which planting was done.

4. Hand hoeing:

Involved the use of hoes to open up planting holes to mimic situations where draft power is not available. Weed control was achieved by hand weeding.

These treatments were being tested relative to control, the conventional farmer practice: the annual mouldboard ploughing. Mouldboard ploughing involved ploughing to a depth of about 23 cm and planting into a clean seed-bed. These tillage plots were set in a completely randomized block design replicated 3 times.

3. Highlights of findings

3.1 Soil loss, runoff and maize yields

Soil loss measurements on-station (slope 4.5%) at Domboshawa Training Centre and at Makoholi Experiment Station gave the results presented in Figure 1. The results generally showed effectiveness of the tested conservation tillage techniques against sheet erosion, particularly no-till tied ridging and mulch ripping. On both stations a dramatic increase in soil loss levels was observed under the conventional tillage system after 4 cropping seasons probably indicating declining soil organic carbon below some threshold value below which soil erodibility abruptly increased.

Since the season 1993/4 (fifth cropping season) conventional tillage systems consistently gave the lowest maize yields at Domboshawa compared to other tillage systems (Figure 1c) but with a somewhat erratic performance at Makoholi (Figure1d). From these and other results mulch ripping and tied ridging were considered as the most sustainable tillage techniques (see Chuma and Hagman, 1995; Munyati, 1997; Vogel 1993; and Vogel et al. 1994) for detailed descriptions of some of the work on these sites.

3.2 Organic carbon

Conventional tillage since 1989 consistently showed the lowest organic carbon levels compared to the other conservation tillage systems (Figure 2). It is noteworthy here that hand-hoeing was introduced a
year later than the other treatments and therefore seemed to portray the highest organic carbon levels. The general trend showed a gradual decline in organic carbon for all treatments but a rather steeper gradient with conventional tillage. This has also been matched by increases in annual soil loss and run-off from this treatment. No statistical analysis has been carried out yet to confirm how statistically significant the differences are. Similar results were observed at Makoholi (Chuma and Hagmann, 1995) where percent organic carbon levels declined by 41% for conventional tillage compared to 9% for mulch ripping after five years of cropping.

It appeared therefore that continuous cropping with conventional tillage generally led to a decline in soil organic carbon and an increase in soil erodibility leading over long periods to unsustainable levels of annual soil loss.

3.3 Weeds

A major criticism of conservation tillage systems lies in the problems associated with weed control. Heavy weed infestations were generally observed at Domboshawa on all tillage systems and on conservation tillage systems particularly clean ripping and mulch ripping where perennials such as couch grass (Cynodon dactylon) and Mexican clover (Richardia scabra) posed serious problems. Conventional tillage tended to suffer more from heavy infestations of annual weeds soon after crop emergence. An in-depth study of weeds under the different tillage systems is given by Vogel (1994a). A statistically significant treatment effect on weed biomass was observed for the seasons 1992/93 and 1993/94.

Effects of 4 conservation tillage systems on cumulative seasonal soil loss (t/ha) and maize grain yields (t/ha) at Domboshawa Contil site (sub-humic North) and Makholi Experiment Station (semi arid South). The results of this study also showed that application of Round-up Dry (glyphosate) at the rate of 2.2 kg active ingredient per hectare resulted in an effective perennial weed suppression while hand-hoe weeding proved inefficient and highly labour intensive for conservation tillage systems (Vogel, 1994a; Vogel, 1994b). The traditional farmer’s practice of inter-cropping maize with cow-peas or pumpkins also showed a significant weed suppression effect and could be a potential weed management alternative.

Post-planting weed biomass patterns at Domboshawa for the last four seasons since 1994/95 show that tied ridging in most seasons experienced the lowest weed biomass levels particularly where weeding was carried out after re-ridging with an ox-drawn ridger or plough (Figure 3). This result was also confirmed by farmers participating in the on-farm trial programme who considered suppression of weeds and hence
lower weeding labour demands as being one of the major advantages of tied ridging over the conventional mouldboard ploughing systems. Field assessments also ratified this point (Nyagumbo, 1993). Furthermore the prevalence of mexican clover has declined appreciably in the last 3 seasons resulting in lower total weed biomass levels under tied ridging.

In a separate study at Makoholi Experiment Station Riches et al., 1997 found that the weeding effort which accounted for more than 60% of the labour used for maize production in semi-arid Zimbabwe, was greatly eased while grain yields and return to weeding labour significantly improved where animal drawn implements such as cultivators and ploughs were used to control weeds. The efficiency of weed control was also found to greatly improve where farmers used re-ridging with the plough as a weed control measure under no-till tied ridging in the sub-humid north of Zimbabwe (Nyagumbo, 1993).

Complimentary work by Shumba et al. (1992) showed that the use of the ripper tine for primary land preparation allowed for timely planting but resulted in earlier and heavier weed infestations. Thus, unless effective weed control can be achieved the benefits of timely planting accrued using the ripper tine in conservation tillage systems are lost. The relatively higher adoption of conservation tillage in the large scale commercial farming sector could therefore be attributed to the availability of suitable machinery and the use of herbicides which have tended to be unaffordable to smallholder farmers in Zimbabwe. Weed control in conservation tillage systems therefore remains a major bottleneck to smallholder farmers in Zimbabwe.

3.4 On-farm research

On-farm research on no-till tied ridging was carried out extensively from 1990. Despite its high effectiveness in reducing run-off and soil loss levels measured on-station, no-till tied ridging did not give the desired crop yield increases over the conventional tillage system. Instead maize yields from no-till tied ridging compared to conventional tillage tended to be erratic and site-specific, depending on season quality, soil types and farmer’s management skills. Table 1 shows typical yields from the sub-humid north obtained from these farmer managed adaptive trials. Across-site ANOVA (analysis of variance) on the 1992/93 yield results (Nyagumbo, 1993) showed a significant correlation between treatment and farmer input leading to the conclusion that the performance of the tied ridging system was strongly dependent on farmer circumstances like management, rainfall, soil type and other resources.

Weekly monitoring of soil profile water contents also revealed that on sands the tied ridging system did not overly increase soil profile moisture due to excessive dessication in the ridge caused by a higher exposed surface area. Measurements at Domboshawa estimated 14% over conventional tillage and low water holding capacity of sands. It is however noteworthy that these profile measurements were being taken from the ridge top. In the furrows water content tended to be higher, a situation attributed to water flow concentration in the furrows.

Formal and informal surveys during implementation of the trials revealed that farmers faced a multi-sectoral range of problems which were classified into four main categories namely financial, technical, environmental and social. All these led to the core problem of hunger and starvation (Nyagumbo, 1993). Results also indicated that farmers were seriously resource constrained in terms of draft power, land, implements and labour.

Socio-cultural factors were also observed during the studies which included attitude problems like the receiver mentality, beliefs in withcraft, suspicion and jealousy among peers, abuse of customary laws and high death rates (Nyagumbo, 1997). These constraints generally contributed to instability within the communities and thus tended to hamper development.

3.4.1 Realizations

Following statistical analysis of results of 1992/3, from subsequent seasons and from complimentary work in Masvingo (Chuma and Hagman, 1993), conclusions were reached that there was no scope for giving blanket recommendations to farmers on no-till tied ridging. Instead there was need to offer farmers a basket of technology options from which they could select the ones most suited to their resource endowments. It was also realised from this work that tied ridging alone could not address the wide range of farmers’ problems. There was a need to consider these issues from a farming systems perspective in order to comprehensively address farmers’ problems. For instance, it was not much benefit to address conservation alone without the fertility component incorporated. Tied ridges could not work without the support of structures such as contour ridges, infiltration pits, fanya juus and other preventive structures.
Transfer Strategies

The above realisations led to new thinking and development of alternative approaches to the problems at stake. Years of on-farm research work with smallholder farmers had yielded no appreciable adoption of the technologies by farmers.

From the conclusions drawn, transfer strategies particularly the traditional top-down approach extensively used by the local extension service AGRITEX, was identified as one of the key factors hampering adoption. Cook-book recommendations and solutions were being resented by farmers with only certain aspects of recommended technologies being taken up. This realisation led to the development of various farmer participatory technology developments and extension strategies as the best approaches for technology transfer through farmer experimentation (Hagmann et al., 1996a; Hagmann et al., 1996b; Nyagumbo, 1997).

4.1 Way forward

A farmer participatory research and extension approach known as Kuturaya (lets try) was initiated and developed in Masvingo in Chivi district (Hagmann et al., 1996a). This approach involved the development of a research and extension approach which recognized farmer’s views and aspirations. Farmers were taken as partners and equals in research and farmers indigenous technical knowledge was taken as the basis for innovation development.
Figure 2: a) Average tillage treatment % organic carbon trends at Domboshawa since 1988 and b) Reduction in average tillage treatment % organic carbon after five years of cropping at Makholi.

Figure 2: a) Average tillage treatment % organic carbon trends at Domboshawa since 1988 and b) Reduction in average tillage treatment % organic carbon after five years of cropping at Makholi.

Farmers were exposed to various technological options which they could experiment on and implement according to their own resource endowments and preferences. Annual evaluations were carried out together with farmers where farmers played a leading role.

Due to the success of this approach farmers embarked on various innovations which they tried to test on their own.

Currently other tillage techniques such as mulch and clean ripping and strip cropping have been introduced in Musana, Chiweshe and Chinamhora communal lands where conservation farming competitions were initiated in 1996 through a farmer participatory research and extension approach.

The use of this approach, ratified by a technical workshop in Masvingo in 1995 (Twomlow et al., 1995),
has resulted in the identification and recognition of farmer innovations. For example the widespread use of infiltration pits originates from a farmer in Zvishavane (Maseko, 1995). Most local institutions including NGOs have now adopted the participatory approach as a tool for implementation in various smallholder projects.

4.2 Other initiatives

4.2.1 Reference material

Another constraint identified and recommendation made during the Masvingo (1995) workshop (Twomlow et al., 1995) was the unavailability of technical information on the promising technologies and the need to develop reference material for extensionists, technocrats and farmers. The development of these materials is now being facilitated by the integrated Rural Development Programme (IRDEP) in Masvingo as "material for technocrats and extensionists" and DFID (the United Kingdom Department for International Development as "material for farmers", together with other local and international stakeholders. Final draft copies of these materials were due to be ready by September 1998.

4.2.2 Farmer participatory development project

Farmer participatory development of sustainable soil and water management techniques in the smallholder farmer sector of Zimbabwe is a follow-up project based on it will implement the recommendations of the work done by the CONTILL project.

It is a joint effort by the Department of Agricultural Technical and Extension Services (AGRITEX) and the Department of Research and Specialist Services (DR&SS) and is to be funded by the Agricultural Services Management Programme (ASMP).

Table 1: Typical maize yields over five seasons comparing no-till tied ridging to the farmer practice annual mouldboard ploughing obtained on four on-farm sites in Chinamhora, Musana and Chiweshe communal lands, sub-humid north, Zimbabwe.

<table>
<thead>
<tr>
<th>Farmer</th>
<th>Season</th>
<th>Tied Ridging</th>
<th>Conventional Till</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(t/ha)</td>
<td>(t/ha)</td>
</tr>
<tr>
<td>Kapita</td>
<td>1991/92</td>
<td>1.02</td>
<td>0.41</td>
</tr>
<tr>
<td>(chinamhora)</td>
<td></td>
<td>9.57</td>
<td>9.24</td>
</tr>
<tr>
<td></td>
<td>1993/94</td>
<td>7.41</td>
<td>8.17</td>
</tr>
<tr>
<td></td>
<td>1994/95</td>
<td>4.10</td>
<td>3.47</td>
</tr>
<tr>
<td></td>
<td>1995/96</td>
<td>8.08</td>
<td>7.96</td>
</tr>
<tr>
<td>Mean (t/ha)</td>
<td></td>
<td>6.04</td>
<td>5.85</td>
</tr>
<tr>
<td>Basikoro N</td>
<td>1991/92</td>
<td>1.19</td>
<td>0.79</td>
</tr>
<tr>
<td>(Musana)</td>
<td>1992/93</td>
<td>9.15</td>
<td>8.26</td>
</tr>
<tr>
<td></td>
<td>1993/94</td>
<td>7.79</td>
<td>8.27</td>
</tr>
<tr>
<td></td>
<td>1994/95</td>
<td>1.34</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>1995/96</td>
<td>5.74</td>
<td>6.18</td>
</tr>
<tr>
<td>Mean (t/ha)</td>
<td></td>
<td>5.04</td>
<td>5.10</td>
</tr>
</tbody>
</table>
Conservation tillage for sustainable crop production systems

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Marewo J. (Chiweshe)</td>
<td>0.98</td>
<td>5.17</td>
<td>9.90</td>
<td>2.96</td>
<td>6.52</td>
<td>5.10</td>
</tr>
<tr>
<td>Bulawayo P. (Chiweshe)</td>
<td>1.11</td>
<td>5.91</td>
<td>5.84</td>
<td>4.86</td>
<td>5.73</td>
<td>4.69</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.22</td>
</tr>
</tbody>
</table>

Figure 3: Postplanting dry weed biomass production over four growing seasons at Domboshawa under five tillage systems: Conv (conventional mouldboard); MR (mulch ripping); HH (hand hoeing); CR (clean ripping) and TR (tied ridging).

The project aims at focussing on conservation technologies from a catchment perspective and intends to engage in participatory experimentation with soil and water management technologies.
1. The indigenous Soil and Water Conservation Project (Phase 2) dubbed (ISWC2) co-ordinated by the Institute of Environmental Studies, University of Zimbabwe is aimed at further strengthening and developing indigenous local farmer knowledge and innovations through joint experimentation with farmers. This project comes as a result of another phase (ISWC1) in which current and indigenous soil and water conservation practices in Africa were identified and documented as reported by (Reij et al., 1996).

5. Summary

Some of the major findings and conclusions reached from the project include:

- That no-till tied ridging and mulch ripping are the most sustainable crop production techniques of the treatments tested from a run-off and soil loss point of view. They maintained soil loss levels to below the tolerable limit of 5 tonnes per hectare per year using data from the first 6 years. When compared to conventional tillage and averaged over the first six years, the nttr system reduced soil loss by 84% (from 4.4 to 0.7 t/ha/yr.) and by 90% (from 10.1 to 1.0 t/ha/yr.) at Domboshawa and Makoholi respectively.
- Mulch ripping on the other hand reduced soil loss by 72% (from 4.4 to 1.2 t/ha/yr) and by 89.5% (from 10.1 to 1.1 t/ha/yr.) at Domboshawa and Makaholi respectively. With regard to ecological sustainability the research has confirmed that conventional mouldboard ploughing is not a sustainable tillage system.
- That the advantages of tied ridging over conventional mouldboard ploughing are most pronounced under waterlogged conditions.
- Despite its outstanding water harvesting benefits through run-off reduction, tied ridging on sandy soils, does not overally increase soil water content within the rooting zone due to the low water holding capacity of sands. However no till tied ridging increases the effective rooting depth of crops though the elevated ridges which also increases the rooting volume for nutrient up-take when growing conditions are optimum. It has been confirmed that sandy soils under conventional tillage tend to develop a hard pan which limits the rooting volume.
- That there is not much scope for giving blanket recommendations as yield results from on-farm trails have tended to be site-specific depending on seasonal rainfall, soil type and management capabilities of the farmer.
- That socio-economic and socio-cultural constraints play a very important role in the adoption or rejection of innovations. These problems can sometimes override the technical constraints associated with an innovation. Experience has shown that some of these problems can be alleviated through the use of various development tools which encourage farmer participation.
- Farmers’ problems are multi-sectoral. Conservation tillage technologies alone will not address farmers’ problems. There is need to combine tillage strategies with other erosion control structures such as infiltration pits, *fanya juus* as well as fertility improvement measures.

References


Hagmann, J., Chuma, E., and Murwira, K., (1996a). Kutoraya (let’s try): Reviving farmers knowledge and confidence through Experimentation. In "Farmer’s research in Practice" (ILLEIA, ed.).


Table of Contents
Soil fertility and minimum tillage equipment trials in the North Central, Namibia

by

C. Rigourd, T. Sappe and P. Talavera

Northern Namibia Rural Development Project,
P.O BOX 498 OSHAKATI, NAMIBIA

Abstract

The paper highlights investigations conducted to identify soil types and their fertility status in the North Central Division of Namibia. The survey was necessary to describe the soil status before introducing minimum tillage and soil conservation tillage practices in the area. Several animal drawn implements were tested on the farmers' fields. These included cultivators from Senegal, Zimbabwe and Zambia. Preliminary results of the survey have been reported and discussed.

1. Introduction

The Northern Namibia Rural Development Project (NNRDP) started its activities in 1994. The project adopted an Action Oriented Research approach, working with farmers as equal partners in pilot communities of the North Central Division (NCD). Project staff and farmers identified weeding as a major constraint in the area. Consequently, in 1994/95 and 1995/96, tests on three animal drawn cultivators, the Senegalese cultivator, French cultivator and BS 41 were conducted. By 1996, the use of the cultivator for weeding had become an extension message.

During the 1996/97 and 1997/98 seasons, tests on minimum tillage and dry sowing with animal traction in the North Central were initiated. It was realized that the selection of appropriate equipment and the definition of comprehensive extension messages would be incomplete without a fair knowledge of the soil types in the area.

In 1996 a soil survey was therefore initiated and carried out in 1997 and 1998.

1.1 Objectives

The main objectives of the survey were:

- to assess farmers' knowledge of the different types of soil
- to assess soil characteristics
- to identify and investigate some of the fertility problems in the NCD
- to gather information on farmers practices and
- to analyze the rational of the use of implements for minimum tillage in the North central regions.

2. Materials and methods

The following activities were carried out:

- 22 interviews, specifically on soil fertility, with farmers from 4 NNRDP pilot communities namely: Eefa (Central Oshana area, Oshana Region), Eunda, Onesi (Western area, Omusati Region), and Onamutanda (Central and Eastern Oshana area Ohangwena Region).
- Collection of 42 soil samples which were analysed by the agricultural laboratory in Windhoek. Soil profiles were drawn from 15 sites.
- Other interviews with farmers, related to soils, minimum tillage and weeding.
- Literature review.

3. Results

3.1 General problems related to fertility
During the survey, some common features which were observed included:

- Soils are sandy and poor in some nutrients (nitrogen, phosphorus).
- Soils are very poor in organic matter and have very low structural stability.
- Soils have a poor water retention capacity and tend to form a hard pan naturally or after repeated ploughing at the same depth.
- Although farmers are well aware of the benefits of applying manure on their field, they do not always have the means to do so.
- Water-logging is common although rainfall is limited and water content of some soils may change drastically over short periods (from water-logging to surface crusting).
- Rainfall is low, erratic and often occurs as big storms.
- Direct sun light is extremely high and temperatures are high.
- Farmers practice continuous cereal cropping.
- Land is completely bare during the dry season.
- Most of the current practices to manage fertility are labour intensive although labour is a major limiting factor in the farming system.

### 3.2 Identification of soil types

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Farmers’ assessment</th>
<th>Technician assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft and deep sandy soils</td>
<td>These soils are deep and sandy, very soft, forming neither hard crust nor hard pan. Water percolates very easily but water retention is poor.</td>
<td>These soils are characterised by a poor potassium, phosphorus and calcium content and a low pH. They often have low magnesium content.</td>
</tr>
<tr>
<td></td>
<td>These soils are found mainly in the highest Part of the field. They occupy large Portions of the field in the cuvelai basin and western areas.</td>
<td>These soils can be classified as arenosols. They have the lowest chemical fertility (but not the lowest fertility, since they do not tend to water log).</td>
</tr>
<tr>
<td></td>
<td>Local names of these soils are &quot;ehenge&quot;, &quot;omuthitu&quot; and &quot;efulu&quot;.</td>
<td></td>
</tr>
<tr>
<td>Low ground and swamps, loamy sandy soils</td>
<td>These soils contain more clay than other types. Have low percolation and are found in lowest parts of the field. These soils constitute the oshana system. They cover large areas in the cuvelai basin, smaller areas in the eastern and western parts of the NCD.</td>
<td>These soils, well described by farmers, are also characterised by a fair amount of silt and a rather high fraction of clay (20%) in the deeper horizons (deeper horizons are sandy clay loam soils)</td>
</tr>
<tr>
<td></td>
<td>Local names of these soils are: &quot;okashana&quot;, &quot;oshana&quot;, &quot;edhiya&quot; and &quot;okatenhegue&quot;.</td>
<td></td>
</tr>
<tr>
<td>Water logged/ Hard dry soils</td>
<td>These soils are characterised by a hard pan, between 20 to 30 cm depth. Have low percolation and after a rain shower, the soil they turn to mud. When rain evaporates, a hard crust is formed on the surface.</td>
<td>These soils are characterised by: a thin layer (10 to 30cm deep), high concentration of calcium, which may hamper the absorption of other nutrients. The thin layer is very hard, prevents water percolation. pH neutral on the surface, alkaline deeper (8.5 to 10.5)</td>
</tr>
<tr>
<td></td>
<td>These soils have the poorest fertility, are often found in the lowest and the middle part of the field. They are common in the cuvelai basin and the western areas.</td>
<td>Deeper horizons are saline, which limit the ability of the plant to absorb water. Furthermore, the high Na concentration induces a low structural stability (the soil turn to mud very easily).</td>
</tr>
<tr>
<td></td>
<td>Local names of these soils are: &quot;ehenene&quot; and &quot;olundanda&quot;</td>
<td></td>
</tr>
</tbody>
</table>
Good deep
And dark soils

These deep soils are relatively soft. The water penetrates easily and those soils have a good water retention capacity.

These soils are found in the highest parts of the field, in both the cuvelai basin, the western and the eastern areas.

Local names of these soils are: "omutunda" and "elunda"

These soils, have the following characteristics:
- pH neutral,
- poor phosphorus content,
- normal Ca content,
- relatively good concentration of the various other nutrients,
- gentle transition between the horizons and
- a good water retention capacity.

Very hard
Soils/ new fields

These soils are very hard, with a very poor water penetration and a very poor fertility. These soils are mainly found in the western areas.

Local names for these soils are: "etunda" and "oshikalanga"

It has not been possible to take samples from this type.

Other soils

Termite hills ("oshiwanda"), old termite hills ("oshitunu") and riverine type of soils ("omulonga") have been described by farmers but have not been investigated properly.

3.3 Farmers’ conclusion

At the field level soils are extremely heterogeneous. Basically, all the types described previously can be found within the same field. Therefore, a transect representing the location of the soil types has been established.

Consequences have been as follows:

- Farmers consider water in the soil and not only rainfalls, to be the first determinant of the yield. Water penetration and water retention are indeed the key issues.
- Farmers consider that the hardness of the soil is an important criteria. Soft soils are preferred in the NCD.

3.4 Technician’s conclusion

In the NCD soils vary from sandy to sandy loam. On average, the sand content is 87%, the clay content is 9.5% and the silt is 3.5%.

In the NCD, soils have a rather poor water holding capacity and soils are poor in nutrients.

4. Discussion

4.1 Farmers’ management of fertility

Cattle and goat manure are well known by farmers to improve the fertility of their field. Donkey manure is hardly use in the NCD.

Manure is always applied in big quantities, when available, spread all over the field, under the form of a "dry kraal powder" (and not "fresh manure"). It is usually used pure, only few farmers mixing it with straw or grass.

Manure is usually applied in November/ December, to allow the crops to take benefit from it. However, to apply manure is labour intensive and manure is not always available in adequate quantities, especially if cattle are sent to cattle posts and do not stay around the homestead, in kraals.
4.2 Ridges and soil preparation

Reasons for erecting ridges, in the NCD, are to eliminate the excess of water in water logging soils. Crops are cultivated on top of the ridges. The ridges evacuate the excess of water toward an Oshana or a water reserve area. It has to be noticed that excess water in the furrow can constitute a reserve of soil moisture.

In sandy soils (eastern areas) farmers sometimes cultivate their crops in the furrow left by the plough and water may settle in it.

4.3 Use of fertilisers

Fertilisers are hardly used by farmers because they are expensive (poor cost/benefit ratio) and not always balanced. In the NCD, fertilisers should have phosphorus predominant.

Some well-balanced fertilisers could be useful to upgrade the phosphorus and magnesium content of the soft and deep sandy soils.

4.4 Other management practices

In the NCD, farmers do not practice fallow and do use crop rotation.

It is the traditional to use the hand hoe for land preparation. However, it is time consuming and this technique does not allow farmers to prepare their whole field on time.

Furthermore, farmers can erect ridges using the hand hoe, but it is time consuming and labour intensive.

4.5 Utilizing animal drawn implements

Such implements allow farmers to prepare the field on time, to erect ridges easily and to control the plough depth.

However, in water-logged or hard dry soils, continuous ploughing at the same depth must be avoided, as it will enhance the formation of the hard pan. Animals must be ready, trained and healthy at this time of land preparation yet this is usually the time of great fodder shortage.

4.6 Use of tractors

Tractors allow farmers to prepare large fields quickly. However they are not always available when needed or on time. Like with animal traction, on waterlogged and hard dry soils continuous diskng at the same depth must be avoided due to the formation of the hard pans. According to farmers diskng can create hard pans in "hard-pan-free" sites and diskng does not allow farmers to control tillage depth.

5. Experimenting with weeders

From preliminary findings were clear that it was worth trying implements for minimum tillage using animal traction. The implements tested in the NCD were for minimum tillage and dry sowing

5.1 The Senegalese cultivator

This implement was tested in 1996/97. The tool was 1 cm thick, 24 cm long and was characterised by a working depth of 8 to 10 cm. This tool was attached to the body of the cultivator. The implement was light and could be pulled by a single donkey. It made small line and on sandy soils, sand fell back into the furrows. The positioning of the chisel tine at the middle of the frame of the cultivator made the implement unstable.

It was therefore, decided together with farmers, to test an improved tine with a larger angle bar and an attachment at the rear side of the cultivator.

5.2 The improved chisel tine
This implement was tested in 1997/98. The angle bar was welded on the chisel tine and was about 5 cm wide. The chisel tine was 24 cm long and it was positioned at the rear side of the body at the beginning of the handle.

The prototype was produced by a local welding company (Oshakati Best welding) at a cost of N$ 20.00. A single donkey could still pull the implement.

With the improved manipulated chisel tine the furrow was still not deep or wide enough. It didn’t prove suitable for hard soils (water logged or hard dry soils), sandy soils (soft and deep) or low ground and swamp, loamy soils). It was suitable only for soft soils (good deep and dark soils).

The improved chisel tine and improved manipulated chisel tine were not adapted to the NCD conditions, except in very special soil conditions which were good, deep and dark.

5.3 The Zimbabwean curved ripper

This unit was adapted from the Senegalese cultivator. This implement had been tested in 1997/98. The Zimbabwean curved ripper was bigger than the improved manipulated chisel tine and made larger furrows. But since it was adapted from the Senegalese cultivator it remained lighter than the Magoye ripper which was held on the traditional plough beam.

The Zimbabwean curved ripper was 28 cm in length, 6.5 cm in width and it was attached on the rear side of the body of the Senegalese cultivator.

Adapting the Zimbabwean curved ripper on the Senegalese cultivator required a special attachment system. This one was produced by the same local welding company at a cost of N$ 20.00.

With wings adapted to it two donkeys were needed to pull the equipment.

On performance, depth and width of the lines were correct. On soft and deep sandy soils, wings were compulsory. However, the implement was not tested on farms as farmers were reluctant to try it.

The Zimbabwean curved ripper penetrated hard soils which were water logged and hard and easily so. Draft requirements were low on soft soils.

The Zimbabwean curved ripper was therefore the most versatile and required minimal draft.

5.4 The Magoye ripper

This implement which utilized the traditional plough beam was tested in 1996/97 and 1997/98. This implement was 24 cm in length, 9 cm wide and 0.9 cm thick. The unit required two donkeys to pull it.

When wings were added at least two donkeys were needed. A pair of oxen was even better. The depth and the width of the furrows was correct and even better than the ones obtained with the Zimbabwean curved ripper. In soft and deep sandy soils, wings were needed to keep the soil from falling back into the furrow.

The Magoye ripper penetrated very easily, opened the soil nicely but was heavy to pull in water logged and hard dry soils. The Magoye ripper with wings was very well adapted to soft and deep sandy soils.

Occasional problems of the Magoye not fitting on the plough beam were encountered. The mouldboard was also occasionally difficult to remove since farmers did not always have the tools needed to take it off when installing the ripper. Unlike the Zimbabwean curved ripper, the Magoye ripper was applicable in most soil types.

The wings on both the Zimbabwe curved ripper and the Magoye Ripper were well suited for deep sandy soils, which tended to flow back into the furrows. The wings were 19 cm wide and 22 cm high. With the wings, at least two donkeys were needed.

6. Conclusion
Soils in the NCD are sandy and very poor in nutrient and organic matter content. They are highly heterogeneous.

It is recommendable that conservation tillage, animal drawn implements have wings and be capable of deep and wide furrows. Two implements appeared appropriate for the NCD conditions These are the Zimbabwean curved and the Magoye rippers.

It was noted that animal drawn implements allow farmers to prepare larger fields. Animal drawn minimum tillage implements encouraged farmers to plant in lines which was conducive to the use of cultivators for weeding.

Two questions remained unanswered:

- What would be the effect of minimum tillage on the hard pan in the long run? and
- How could minimum tillage affect the weed prevalence and weed species under the NCD conditions in the long term?

References


Rigourd C. and Sappet (1998). "Investigation into soil fertility in the North Central Regions". NNRDP, Namibia, 41 pp

Rigourd C; (1998). Results of the tests run in the 97/98 rainy season in the North Central Division on Minimum tillage/ Dry sowing.
IMAG-DLO and conservation tillage: Activities and experiences

by

C. Kaoma-Sprenkels, P.A. Stevens and A.A. Wanders

IMAG-DLO, P.O. Box 43, 6700 AA Wageningen, The Netherlands.
SAMEP, P.O. Box 31905, Lusaka, Zambia

Abstract

The Institute of Agricultural and Environmental Engineering (IMAG-DLO) belongs to the Agricultural Research Department of The Netherlands Government. The Department of Development Cooperation within IMAG-DLO works in Africa and Asia and concentrates on animal traction and crop processing technologies. Applied tillage research conducted by IMAG-DLO in partnership with the Ministry of Agriculture in Zambia clearly showed the need for alternative tillage systems in order to improve conservation of rainwater and soil, to improve timeliness of planting, and to cope with reduced availability of draft power. The research resulted in the development of the animal drawn conservation tillage equipment: a ripper, ripper-planter and sub-soiler. All implements are low-cost, durable attachments which can be simply interchanged with the plough body of any commonly available plough beam. It was realized that, when introducing these conservation tillage tools on smallholder farms, weeding would become an even more critical aspect than it already was in the conventional ploughing system. Herbicides are beyond the reach of most farmers and the availability of an effective mulch cover is not guaranteed. Mechanical weeding with draft animals is a practical option to keep the weed problem under control. For weeding a new animal drawn cultivator was specifically designed to suit harsher soil conditions while ripper-ridge, could also be used. All equipment was designed to enable local manufacture in the region. The animal traction based conservation tillage techniques as developed and promoted by IMAG-DLO and its partners, can be seen as an intermediate step towards a fully fledged system of Conservation Tillage. This paper highlights the experiences regarding user support, as well as the "dos and don'ts" of equipment development, promotion maintenance and marketing. Design, manufacture and distribution of implements, applied technical and socio-economic research and training issues are also discussed.

1. Introduction

1.1 IMAG-DLO

The Institute of Agricultural and Environmental Engineering works under the Agricultural Research Department (DLO) of the Ministry of Agriculture, Nature Management and Fisheries of The Netherlands. The mandate of IMAG-DLO is to research and develop agricultural and environmental mechanisation technologies which are socially, economically and environmentally accepted. The institute has approximately 200 staff. IMAG-DLO’s Department of Development Co-operation works in Africa and Asia. The mission of the department is to contribute to increased agricultural income and food security in a sustainable manner.

Within this context the prime task is to work on mechanisation technologies which increase labour productivity. Most activities relate to animal traction and post-harvest technologies. The major target groups are smallholder farmers and rural entrepreneurs (IMAG-DLO, 1998).

Typical characteristics of activities carried out by the department are:

- multi-disciplinay
- building partnerships with local organisations
- advancing links between the public and private sector, in particular between research, training, extension, manufacture and marketing.

Most activities are funded on a project basis, The Netherlands Government being the larger financier. Other funding comes from international organisations and private firms.

1.2 IMAG-DLO in Southern Africa
IMAG-DLO long-term assignments in Southern Africa started in Zambia (1987-1999) and were in 1997 extended to South Africa (Box 1). In addition, short-term advisory services are provided to governments, NGO's and rural development programmes in an increasing number of other countries.

In Zambia IMAG-DLO has been involved in five programmes. The two partners are the Ministry of Agriculture, Food and Fisheries and Africare.

Till 1995 the focus was on animal traction. This followed the policy decision by the Government of Zambia, in the mid-eighties, to move away from tractor based mechanisation for the small scale sector and to boost animal traction instead (Mwenya et al, 1992). IMAG-DLO's work on animal traction centers around two principles:

- Increased use of animal traction, especially in areas were the technology is new and
- Diversified use of animal traction, to operations other than ploughing and transport and particularly for ripping, planting, weeding and harvesting.

In 1995 post-harvest technologies were added to the activities in Zambia. Emphasis was on manual or engine operated machinery for threshing, shelling, dehulling, milling and oil expelling.

In South Africa IMAG-DLO has a formal link with the Institute for Agricultural Engineering of the Agricultural Research Council with regard to the initiation of a wide-spread, smallholder oriented, conservation tillage on-farm trial and demonstration programme. This programme includes adaptation and local manufacture of equipment developed in Zambia.

1.3 Conservation tillage: Research & development

Since 1988 IMAG-DLO is involved in on-farm research and implement development focussing on soil & water conservation tillage and related planting and weeding techniques.

It was found that many farmers who use animal traction for land preparation do not manage to plant their crops in a well prepared seedbed during the optimum planting period, yield reduction being the result. The delays and other inadequacies in planting are caused by the following interrelated factors, which are further compounded by a worsening environmental and economic situation:

- The optimum planting period, especially in the southern part of the country, is very short: 1 to 2 weeks. Compared to this critically short period ploughing with draft animals is a slow method.
- The percentage of households owning draught animals is 50% at most (Dibbets & Mwenya, 1993). In most areas the percentage is much lower. Many farmers depend on draught animals which are hired or borrowed well after the rains have started.
- Crops are planted at uneven depths in furrows made by the plough causing uneven germination.
- In fields where ploughing with animals is done year after year, often a hard layer is formed hindering rain water infiltration and deep rooting.
- During the dry season the condition of draught animals deteriorates affecting their capacity to plough when rains start.

Supply and maintenance of animal traction equipment is inadequate. Several farmers apply a reduced tillage system. These farmers do not plough but work the field in lines, holding the plough on its point whereafter seeds are sown in the furrows. This reduced tillage system solves some of the immediate problems farmers have when ploughing: lack of time, labour and draught power.

Opportunities for practical improvements of the reduced tillage system applied by farmers formed the basis for directing the on-farm trials towards conservation tillage.

There are many definitions for 'Conservation Tillage'. Generally, soil disturbance is prescribed to be kept to a minimum. Ideally, the soil is only worked to such an extent that it allows the placement of seeds at the required depth. Usually, it is also understood that the soil surface is protected by a cover of mulch or stover whereby a 30% soil cover is often being stated as the criterion. Many conservationists further assume that (spot) weed control has to be based on the use of herbicides.
Long term IMAG-DLO Technical Assistance in Southern Africa

**Name programme & Period Partner organisation & Main activities**

**Z A M B I A**

<table>
<thead>
<tr>
<th>Programme</th>
<th>Period</th>
<th>Partner organisation</th>
<th>Main activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Animal Draft Power Coordination Project</td>
<td>1987-1996</td>
<td>Ministry of Agriculture, Food and Fisheries (MAFF; HQ Lusaka)</td>
<td>Policy support; National animal traction survey; Lobbying &amp; networking</td>
</tr>
<tr>
<td>Magoye Animal Draft Power Research &amp; Development Project</td>
<td>1987-1993</td>
<td>Magoye Regional Research Station of Ministry of Agriculture</td>
<td>Applied research on technical and agricultural suitability of various animal traction technologies; Developing protocols for on-station and on-farm comparative tests</td>
</tr>
<tr>
<td>Palabana Animal Draft Power Training Project</td>
<td>1989-1993</td>
<td>Palabana institute of Ministry of Agriculture</td>
<td>Curriculum development for ADP in-service training; Physical establishment of ADP training center</td>
</tr>
<tr>
<td>Palabana Animal Draft Power Development Programme</td>
<td>1993-1996</td>
<td>Palabana institute of Ministry of Agriculture</td>
<td>In-service staff and farmer training; On-farm demonstrations; Production of extension materials; Prototype development and on-farm research, including post harvest technologies</td>
</tr>
<tr>
<td>Smallholder Agricultural Mechanisation Promotions</td>
<td>1996-1999</td>
<td>Africare &amp; Ministry of Agriculture</td>
<td>Support to local manufacturers, rural workshops, and private equipment wholesale and retail; On-site testing of post-harvest and animal traction equipment; Support to improved draft animal supply and management; Liaison between public, NGO and private sector</td>
</tr>
</tbody>
</table>

**S O U T H A F R I C A**

<table>
<thead>
<tr>
<th>Programme</th>
<th>Period</th>
<th>Partner organisation</th>
<th>Main activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smallholder On-farm Trial &amp; Demonstration Programme</td>
<td>1997-1999</td>
<td>ARC-IAE Institute for Agricultural Engineering, Pretoria</td>
<td>On-farm trial &amp; demonstration of animal traction and post-harvest technologies; Support to private local manufacturers; Smallholder farming policy support</td>
</tr>
</tbody>
</table>

Planting in lines using an animal drawn ripper tine without prior ploughing is a step in the right direction: much less soil is disturbed than by ploughing. The soil is only worked in narrow bands, while the surface between these lines is left undisturbed. However, weed infestation problems are likely to arise.

A good mulch cover would suppress weed growth very well, and enable farmers to control the weeds by hand (either with a hand hoe or a herbicide), if timely and consequently done almost throughout the year. But the availability of enough mulch is a major bottleneck. Many farmers clean their fields by burning old weeds and the residues of the previous crop usually after first having taken away the bulk of stover for use as building material and animal feed or by allowing their animals to graze on it. Even without burning, the quantities of stover remaining on the fields are normally too small to form a protective mulch cover. Weeds will quickly overgrow the field and get out of control, particularly on fields that are too large to allow complete eradication of weeds by hand hoe.
Chemical weed control increases labour productivity tremendously, and would therefore be an attractive option. However, herbicides and spraying equipment are not a reality for most farmers; they are either not available or too expensive.

Considering the above, the following elements were included in IMAG-DLO’s approach towards conservation tillage research and development.

1.3.1 Equipment development

A plough is not the best implement for breaking up soil in lines. This practice requires equipment which can work in narrow bands but deep enough, especially in dry soils and without turning over the soil, as is done by the mouldboard of a plough. Modified animal drawn planting and weeding equipment is also needed.

1.3.2 Early land preparation and early dry planting

To spread labour and to fully utilise the first rains, land preparation starts as early as possible in the dry season. In this way, and when appropriate, dry planting can be practised. It also enables planting of crops at a much earlier stage than in the conventional system.

1.3.3 Weeding

Because a thick enough mulch cover or herbicides are not guaranteed inputs on most smallholder farms as yet, another option that must be availed. For draught animal users who see the benefits of conservation tillage and who work large areas, a sturdy cultivator or ridger, in addition to ripping equipment, is indispensible. Weeding with draught animals is a technology which is already known and accepted by many farmers. It will enable farmers to make a safe and practical start with conservation tillage by reducing the risk of weeds getting out of hand.

1.3.4 Supplementary feeding of draught animals

Supplementary feeding is necessary to ensure good condition of draught animals which in conservation tillage are put to work in the field before the rains start.

2. Equipment development

IMAG-DLO contributed to the development of the following animal traction equipment suitable for conservation tillage (Stevens, 1998):

2.1 Magoye ripper attachment

This is used for making planting furrows, followed by planting by hand in unploughed or ploughed fields. The attachment works well in dry soils. With additional extensions the attachment can also be used for other field operations.

2.2 Ripper-planter attachment

This is a ripper attachment to which an additional planter module is fitted. The planter can be used much earlier in the season than a conventional planter. Different crops can be planted by using different seed rolls.

2.3 Sub-soiler attachment

This is for deep furrowing in compacted soils. The attachment needs a beam extension.

2.4 The adjustable cultivator

For weeding, this implement resembles the popular adjustable cultivator produced by Zimplow of Zimbabwe. The features are the same but its design is meant to be more durable in harsh soil conditions. A donkey version of this new adjustable cultivator, with 3 in stead of 5 tines, is currently being developed.
2.5 Ripper-ridger attachment

This is a Magoye ripper attachment to which a pair of adjustable wing extension blades and an optional rudder are added. Just as any ridger, it can be used for weeding and making and re-building ridges (Jonsson, 1996).

Other than the cultivator which is a complete implement, all other equipment are attachments which fit on the plough and ridger beams. Plough beams are commonly available in areas of Southern Africa where animal traction is used. They can be modified to make them fit on other types of beams such as beams of donkey ploughs.

The fact that most implements are attachments, renders the investment for farmers who change to conservation tillage relatively low (see Chart 1).

For the above listed attachments to work well, the farmer needs to carefully set them using a hitch point. Removing the hitch-point and setting the implement with the wheel, which is common farmer-practice when a plough is used, cannot work. A sturdy hitch assembly was developed. For good setting, a longer chain than used for ploughing (up to 3.5 hitch assembly metres) is also needed.

Chart 1

<table>
<thead>
<tr>
<th>Indicative offactory prices (excl. VAT) in US $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magoye ripper attachment</td>
</tr>
<tr>
<td>Ripper-planter attachment</td>
</tr>
<tr>
<td>Planter attachment (without ripper tine)</td>
</tr>
<tr>
<td>Subsoiler attachment</td>
</tr>
<tr>
<td>Adjustable cultivator</td>
</tr>
<tr>
<td>Ripper-ridger attachment</td>
</tr>
<tr>
<td>Set of ripper wing extension blades</td>
</tr>
<tr>
<td>Rudder assembly for ripper-ridger</td>
</tr>
<tr>
<td>Hitch assembly</td>
</tr>
</tbody>
</table>

The development of the mentioned equipment took several seasons and involved a cycle of prototype development, on-farm testing and cooperation with manufacturers to prepare commercial production.

At this stage all equipment was being manufactured in Zambia. In 1997 local manufacture of the attachments was initiated in South Africa. Manufacturing guidelines are available.

3. Observations and experiences

3.1 Farmers responses

Farmers using the new implements prefer to use them for direct ripping systems. They make furrows in unploughed or winter-ploughed fields followed by dry planting or planting during the very first rains. Mechanical weeding is done as early as possible after planting with one or two repeats. The direct ripping system can be considered a practical step towards the development and introduction of a fully fledged, animal traction based, conservation tillage system among smallholder farmers. The equipment development activities of IMAG-DLO have attracted interest from programmes and organisations promoting conservation tillage (ZNFU/CFU, 1987). Besides Zambia, where approximately 1500 ripper attachments are in use, the equipment has been introduced in Tanzania, South Africa, Zimbabwe, Namibia and Lesotho. Organisations in Mozambique and Kenya have expressed interest in acquiring the implements.

3.2 Importance of equipment development

Although the development and introduction of new equipment is not an end in itself, it marks the removal of a potential bottleneck in the process of popularising conservation tillage among small scale farmers.
As Benites and Friedrich (1998) state: "... there are constraints to the adoption of conservation tillage or no-tillage concepts on animal draught or motorized mechanization levels. There is an urgent need for further local development and commercial supply of suitable equipment to the farmers in order to assist in the adoption of conservation farming practices..." 

3.3 Equipment manufacture

In its equipment development work, IMAG-DLO emphasizes cooperation with and support to local manufacturers at the earliest possible stage. When feasible this includes small and medium sized rural enterprises. The early link with manufacturers is necessary to ensure sustainable commercial production once the technology has been fully developed.

Work on conservation tillage equipment in Zambia was done with 5 medium size companies of which one continued to show sufficient interest in commercial manufacture. Cooperating with several manufacturers in stead, of with one or two minimises the risk of having no reliable manufacturer once the equipment is ready for the market. While developing the conservation tillage equipment several companies lost interest or capacity to produce an acceptable standard. Similar experiences were recorded for other types of equipment (OSPP, 1997).

Important elements in raising and maintaining interest of manufacturers are:

- supply of information on test results and potential demand from farmers
- finances for jigs, technical drawings and first series production.

3.4 Marketing and repair services

Capable and interested manufacturers are few and mostly located in towns. Obviously, hardly any farmers buy directly from the manufacturer. For proven equipment to be adopted on a significant scale, mass marketing through private channels is necessary. Manufacturers are seldom good distributors. In most of Southern Africa countries a widespread network of private agricultural outlets is not yet available. It is therefore important that this gap between farmers and manufacturers is closed.

In Zambia IMAG-DLO, in cooperation with Africare under the SAMeP programme, obtained positive experience in setting up a network of private, rural based, and small scale, equipment outlets. The marketed equipment includes commonly known and new implements, as well as spare parts. All outlets are existing businesses, such as general dealers. Some of them are already involved in agricultural input supply and crop marketing. An important next step in this programme is to facilitate private commercial wholesale and distribution to these outlets, which is until now being done by SAMeP as a pilot scheme (SAMeP, 1998).

Equipment repair and maintenance is another essential service needed by farmers. Rural workshops are therefore included in the network of outlets. Especially the supply of spare parts, in addition to steel and tools, is vital for these workshops. Training and financing are usually required as well.

3.5 Gender

Compared to the conventional system a major benefit of conservation tillage for female farmers is labour spreading during land preparation and planting. Female farmers who use animal traction, usually depend on draught power borrowed from the husband or other relatives or hired from elsewhere. In situations where draught animals are scarce, traction is available only after the owner has finished ploughing. This causes serious delays in planting by the borrower or hirer, especially in areas with a short rain season. With ripping equipment, land preparation can be done much earlier and faster (2 to 2.5 ha per day per pair of animals). Because ripping can start much earlier than ploughing, land preparation can be spread over a longer period. In this way the owner of draught power can make the animals available for non-owners more timely. If female farmers, whose major responsibility is to grow food crops, can plant earlier, and possibly larger acreages, food production will increase and household food security will improve.

When conservation tillage is applied the weeding job may be a threat for female farmers. On many farms where animal traction is used, a large part if not all of the weeding, is still done by hand, mainly by women and children. The reasons for emphasizing weeding with draught animals when conservation tillage is introduced, include gender considerations. Female farmers benefit in two ways from weeding with animal
traction:

- considerable savings in labour requirement and
- the share of male labour in doing the job increases when draught animals are used.

The introduction of conservation tillage means a far reaching change in farming practices. Female farmers need to be deliberately involved in work to develop and promote conservation farming to ensure that they have enough information to practice the system and to ensure that they can play their role as decision makers and disseminators of technology. In its equipment testing and demonstration activities, IMAG-DLO experienced that it is not very hard to involve a fair representation of female farmers, provided an extra effort is made, especially by fieldstaff and community leaders, to approach them.

In Zambia many female farmers belong to women clubs. Although many clubs are dormant do not undertake communal productive activities, usually the major reason for starting them up) the club structure can be effective for extension purposes.

### 3.6 Draught animals

Compared to handhoe systems, the use of draught animals for conservation tillage increases labour productivity and therefore agricultural production and income. This potential is undermined by the prevailing, and growing, shortage of draught animals. In many areas cattle and donkeys are traditionally not reared. In other areas the number of cattle is diminishing at an alarming rate. This is caused by drought (Mashavira, 1997), poor animal feeding, inadequate control of diseases, and overworking of draught animals. The revival or introduction of effective veterinary and animal husbandry services is necessary for widespread adoption of animal traction based conservation tillage.

In this regard the use of crop residues for mulch, as promoted in conservation tillage, is an issue since the same crop residues can also be fed to livestock (or left for grazing by livestock which is the common practice in communal areas). This need not be a contradiction. The feeding value of crop residues strongly varies and depends on the type of crop and the stage at which it is harvested. In Zambia good experiences exist with feeding of groundnut and cowpea stover to draught animals (Palabana ADPDP, 1995). The stover is harvested and dried at the same time as harvesting the pods and stored away in special structures for feeding during the dry season. Poorer quality stover can be used as mulch provided no livestock is allowed in the field.

### 3.7 Dissemination

In the experience of IMAG-DLO and its partners in Zambia radio broadcasts, on a very regular basis and in different languages, are a powerful means in raising awareness on the existence of new, in this case conservation tillage, equipment. Increased awareness strongly supports the interest of farmers in attending, and requesting for field demonstrations to see what the equipment looks like and how it is used. Awareness raising can be further enhanced with posters and leaflets.

An intensive programme of field demonstrations and farmer training, in combination with reliable and widespread supply of affordable equipment, is needed to ensure that farmers start practising conservation tillage. A field demonstration programme is a must, but is expensive in terms of time, human resources and transport. In many rural areas there are clear opportunities for sharing and reducing these costs by establishing co-operation among public, NGO and private organisations. If these opportunities are fully exploited, the rate of adoption should improve.

An important lesson which has been learnt from programmes promoting profitable, new equipment for treadle pump irrigation and manual oil expelling is that the costly exercise of wide-spread and continuous field demonstrations will finally payoff once a critical mass of adopters is reached. The intensity of field demonstrations and other forms of promotion can then be relaxed as the equipment seems to start selling itself (Egan, 1997; OSPP, 1997)

### 4. Conclusion

IMAG-DLO will continue its work towards the advancement of conservation tillage. The institute is committed to provide advise and support to public, NGO and private sector agencies with regard to:

- design, manufacture and distribution of implements.
applied technical and socio-economic research.
promotion and training.

References


Jonsson, L.O. Rain water management to avoid drought. Local Management of Natural Resources Programme, Tanzania. 1996.


Efforts and initiatives for supply of conservation tillage equipment in Zambia

by

Isaac Sakala
Africare SAMeP, Box 31095, Lusaka, Zambia.

Abstract

Before liberalization of Zambia’s agricultural industry in 1991, animal traction equipment supply to the smallholder farmers was through a highly centralized co-operative movement; the Zambia Cooperative Federation (ZCF). After the agro-industry was liberalised, the co-operative movement in Zambia started to collapse. This was due to the removal of government subsidies which had sustained its operations. Many rural retail outlets for animal traction equipment also collapsed and a vacuum was created in the process.

To fill the vacuum was created, the Africare Smallholder Agricultural Mechanization Promotions, (SAMeP) programme has greatly helped the smallholder farmers. The programme aims to increase agricultural productivity and profitability in rural areas. Activities are primarily geared towards making relevant technologies including the necessary spares available and accessible to end users, who are the farmers and rural entrepreneurs. Additional technology development work through applied research and development supports activities and helps to broaden the equipment supply base. This paper focuses mainly on SAMeP’s efforts and initiatives in the supply of animal traction, soil conservation and water retention technologies for more sustainable crop production. These efforts include promoting locally proven animal traction technologies for soil and water conservation and problem analysis and identification testing and adapting promising technologies. The limitations and achievements in the efforts to carry out the objectives are highlighted.

1. Introduction

Prior to the liberalization of the agricultural industry in Zambia, equipment supply and distribution to the remote areas was done through a centralised parastatal system. This system had its own effects on the demand and supply of equipment in the remote areas.

From the farmers point of view, constraints such as poor profitability of food crop farming, low farm prices and poor marketing systems, absence of credit and the delayed payment for farmers’ produce contributed to the poor demand for agricultural implements and spares.

Poor awareness by farmers of new or existing equipment options and techniques for tillage had its own effects. Overall, the weak position of farmers due to poor representation within supplying co-operative societies led to top-down and arbitrary decisions relating to the type, origin, quality and price of equipment supplied to farmers. These factors contributed negatively to the marketing arrangement for agricultural implements.

On the supply side, within the centralized government and parastatal sectors, there existed a financial crisis and an inefficient top-down distribution system to, and within rural areas. For local development programmes in areas introducing animal traction, there were major problems of costs, risks logistics and infrastructure. The private sector did not have efficient retailer, dealer or agent networks within rural areas and there were problems of costs, risks and logistics of setting up a new system of agents. Assembly workshops did not exist in rural areas and the transport costs of supplying such workshops would have been exhorbitant.

There was lack of sustainable credit at realistic rates, therefore, existing small rural workshops faced constraints with capital and supply of raw materials.

Soon after the multiparty elections in 1991, the Government of the Republic of Zambia decided to liberalise the agricultural industry. The centralized and subsidized system of marketing arrangement that was in operation for many years through the Zambia Co-operative Federation (ZCF) began to collapse. This was due to the removal of Government subsidies which had sustained the system’s operations. The
collapse brought about a vacuum in the supply and distribution of agricultural equipment especially to the remote areas of Zambia.

Smallholder Agricultural Mechanization Promotions (SAMeP) is a project being implemented by an American non-governmental organization called Africare. Africare is widely involved in rural development work in Zambia and 26 other African countries. In East Africa, Africare works in Tanzania, Uganda, Rwanda and Burundi. In the Southern African region, Africare works in Angola, Malawi, Mozambique, Zimbabwe, Namibia, Republic of South Africa and Zambia. In Zambia, Africare has been involved in Agricultural Programmes targeting the rural population since 1980. These projects include seed multiplication, small-scale cooking oil production, post harvest processing technology, livestock production, re-training of extension workers on production of high value crops and smallholder agricultural mechanization.

1.1 The SAMeP project

SAMeP evolved from the current Palabana Farm Power and Mechanisation Centre, formerly the Palabana Animal Draft Power Development Programme. It is an initiative under the Agricultural Sector Investment Programme of the Government of Zambia. SAMeP is oriented towards strengthening the private sector. This complements efforts by the public sector, in particular within the Farm Power and Mechanisation Sub-programme under the Ministry of Agricultural Food and Fisheries. The project operates nationwide and has Field Offices in Lusaka, Southern, Central, Northwestern, Northern and Eastern Provinces of Zambia. In Western Province, SAMeP tasks are being undertaken by a partner NGO called Keepers Zambia Foundation (KZF). All the mentioned field offices including KZF are currently engaged in the wholesale tasks in the distribution of agricultural implements.

SAMeP plays its role in close collaboration with NGOs, the private sector and various other organisations, at field level. At national level it collaborates with the Department of Field Services, Technical Services Branch of the Ministry of Agricultural Food and Fisheries, NGOs and the private sector.

1.2 Conservation tillage implements promoted by SAMeP

SAMeP focuses on Conservation Tillage Animal traction technologies with the aim of increasing farm labour productivity and food security, through water and soil conservation for more sustainable crop production. These technologies include conservation tillage based on subsoiling, ripping, planting and weeding. The implements promoted are:

- **Palabana Subsoiler attachment:** This implement is used to break the hard plough pan, improving water infiltration and conservation. It can be used both in the dry season on lighter soils and during the rainy season between crop rows. At the moment, this implement is still under intensive promotion. Sales through the established network have been low.

- **Magoye Ripper Attachment:** After on-farm testing, this implement has been widely accepted by farmers. It is used for making planting furrows, either on ploughed or unploughed land. Manual planting follows. The Magoye Ripper Attachment works fairly well on dry soils and dry, early planting is possible. Currently, there are more than 1500 Ripper attachments operational in Zambia. Promotional work for the equipment is ongoing.

- **Ripper-planter attachment:** This is an attachment to the ripper. The planter attachment eliminates planting manually behind the ripper furrows. It saves on time because ripping and planting become a single pass operation. Dry planting is made fairly easy. The implement eliminates the labour burden on women, whose task it is to plant even after ripping. Different seeds can be planted by fitting different sizes of seed cells depending on the size of seeds. Compared to the conventional planter, the planter attachment is less costly.

- **Ripper-Ridger attachment:** This is a ripper attachment with extended wings and a rudder. It can be used for making ridges prior to planting, either after ploughing or directly, on flat land or by splitting old ridges. It can also be used for weeding. The rudder gives it more sideways stability and is very useful especially for splitting old ridges. Test results have been positive and the implement is available for sale.

- **SAMeP adjustable cultivator:** This is an entire implement on its own. It is an implement with two front tines to break up the soil before the two tiller blades push the soil into the row. The space in between is weeded with the sweep in the rear. The implement is adjustable whilst working in the field. This implement, among all the above listed is more popular because Zambian farmers have been using a similar Zimbabwe-made unit for a longer time.
2. Efforts and initiatives

Since its inception in 1996, SAMeP has been focusing on the following activities:

2.1 Implementation of pilot activities

SAMeP has been involved in a pilot activity to test the feasibility and create awareness for marketing of broader range of equipment and spares by local traders. Through establishing an equipment fund, SAMeP field offices have acted as the wholesalers in the distribution of equipment and spares. The equipment range is wide and includes other animal traction equipment and spares other than conservation tillage equipment only. Currently SAMeP works with more than seventy (70) sales agents throughout Zambia. Some of these retail outlets are already established retail shops selling agricultural implements. Others are small rural shops selling a wider range of groceries but have decided to take up the initiative to sell agricultural equipment and spares as well.

SAMeP, through its field offices supplies equipment and spares on consignment basis to these rural retail agents. The initiative to take up this challenge of selling agricultural equipment is extended to potential retailers during village demonstrations. Entrepreneurs wishing to take up this challenge sign a legally binding sales agreement.

2.2 Support to rural workshops

The support from SAMeP to rural workshops is mainly in the area of equipment repair, retail and rehabilitation. Mobile workshops, repairing and rehabilitating old equipment were conducted in 1997 and in early 1998, 10 rural workshop owners in Kapiriimoshi District attended a course. This course was planned and conducted together with the District Agricultural Coordinator and a private entrepreneur.

Additional support with training materials and technical advice was provided by Smallholder Mechanization Services (SAMS) one of the Manufacturers of Agricultural equipment based in Lusaka. After this training, a follow up on further advice, logistical and financial support will take place, depending on the initiative of the workshop owners themselves.

2.3 Public awareness

SAMeP has been carrying out massive demonstrations of conservation tillage implements through all its field offices and Keepers Zambia Foundation in Western Province. These demonstrations are carried out in conjunction with Ministry of Agricultural Food and Fisheries extension staff and others in collaboration with NGO’s.

Every month SAMeP produces radio scripts on different topics, including conservation tillage. These are aired on the Rural Note Book programme or Radio Farm Forum in all the eight major languages of Zambia.

Other promotional activities involve production of leaflets and other extension materials on conservation tillage implements.

2.4 Problem analysis, identification, testing and adapting promising technologies

SAMeP’s approach includes client-based needs assessment and evaluation, identification of proven technologies, on-site testing and development of appropriate equipment involving manufactures and working in close co-operation with research institutions and programmes with local extension staff.

Some recent or current activities include:

- the final design of the ripper-planter attachment for local manufacture in conjunction with SAMS. The possibility of using the small Magoye ripper wings as opposed to side plates is envisaged. This would simplify the use of the ripper-planter and reduce costs.
- improvements to the ox-drawn cultivator were made and a final prototype has been manufactured by SAMS.
- development of a three-tine Donkey weeder has been developed.
3. Progress made

3.1 Achievements

- SAMeP has proved that it is possible to carry out wholesale tasks in the distribution of conservation tillage implements targeting private entrepreneurs. This could be proved through the more than seventy agents currently carrying out retail tasks in six provinces.
- SAMeP has distributed equipment worth US $75800 to date and has received US $56750 as repayments or reimbursments from the sales agents. This represents 75% recovery rate.
- Formation of Smallholder Agricultural Implement Suppliers and Workshops Association of Zambia SASWAZ which will look into the interests of rural workshops and Retailers with one common goal. Eventually, it is hoped that SASWAZ will assume most of the tasks currently being undertaken by SAMeP.
- Through networking with the Ministry of Agricultural other NGOs and the private sector, promotion of the Magoye ripper has been very successful. The Co-operative League of the United States of America in Zambia (CLUSA) has ordered five hundred Magoye Rippers from SAMS for onward lending to smallholder farmers in their catchment areas of Southern and Lusaka Provinces.
- Other achievements include successful on-farm tests of the Magoye ripper-planter, ripper-ridger and the new prototype adjustable cultivator-weeder.

3.1 Setbacks

- Lack of a reliable private sector driven agricultural marketing system has led to poor marketing of agricultural produce and poor farm prices, thereby reducing farmers' income. This has led to poor demand for minimum tillage implements such as cultivators, whose price is relatively high for smallholder farmers.
- Lack of an extensive sales and distribution network in the rural areas has negatively impacted the adoption of minimum tillage implements.
- Absence of rural credit has contributed to the poor demand for minimum tillage implements. As a result of the demise of credit institutions such as the Co-operative Movement, ZCF in particular, and agricultural lending institutions, such as LIMA Bank, smallholder farmers cannot meet the borrowing criteria used by commercial institutions who require collateral.
- Limited awareness by farmers of existing or new implements for minimum tillage has also contributed to the poor response. This could be attributed to weak and under resourced extension services. This has led to few demonstrations being undertaken annually.
- On the supply side, an extensive wholesale and distribution system is lacking. At the moment, only SAMeP is involved in the wholesale tasks. It is hoped that through the formation of Smallholder Agricultural Implement Suppliers and Workshops Association of Zambia (SASWAZ) these tasks will be undertaken by the private sector through the privatized SAMeP Field offices in coordination with SASWAZ.

3.2 Way Forward

Wholesale tasks carried out by the SAMeP Field Office in the Central province of Zambia are in the process of being privatized. A former Africare employee and SAMeP Field Manager in Central province has formed a limited company called Climbers. It is expected that Climbers Limited will carry out all the wholesale tasks which were carried out by SAMeP covering Lusaka and part of the Copperbelt province. Climbers Limited will get financial and material support from SAMeP.

Other SAMeP Field offices to be privatized include Eastern Province which is expected to benefit from the African Development Bank credit programme implemented by Africare and the Zambia National Commercial Bank and Southern Province which will be privatized, including Farm Implements Repair Organization (FIRO).

On 1st June, 1998, Rural Metal Workshops and Smallholder Agricultural equipment Suppliers joined forces and formed an association called Smallholder Agricultural Implement Suppliers and Workshops Association of Zambia (SASWAZ). This association aims to promote on a national scale, the interests of its members within the agricultural equipment repair industry. This will provide the members with a channel for market information and a platform for creating business opportunities.

SASWAZ will also promote and demonstrate conservation tillage implements within their smallholder
farming communities. The founding meeting at Palabana Farm Power and Mechanization Centre had 11 rural workshops and equipment traders from Eastern, Central, Western, Lusaka and Southern Provinces. SAMeP’s support to SASWAZ included financing the costs for their initial meeting at Palabana Centre on 1st June, 1998. SAMeP has initially provided services of a coordinator who is currently SAMeP’s Field Manager in Eastern Province to run the secretariat. This includes financial support in the running of the secretariat for the initial year amounting to US $5000.

Through publicity and effective support to members, SASWAZ plans to increase its membership significantly.

References:


Chitalu GM The perceived Role of Africare in the Zambian Agricultural Sector Investment Programme (ASIP) (December 1997).

Temba J, Lupupa N. Africare Zambia Household Food Security Programme: Seed Multiplication Component.

Conservation farming with animal traction in smallholder farming systems: Palabana experiences

by

Martin Bwalya

Palabana Farm Power and Mechanisation Centre
Private Bag 173, woodlands, Lusaka, Zambia

Abstract

Minimum tillage, conservation farming among other words being used have, in recent times become attractive and popular concepts in sustainable farming. Concerns about sustainable use of the land resource base have been noted and expressed by many, including farmers. Through a participatory on-farm trial process, the Palabana Farm Power and Mechanisation centre has taken up the challenge to develop and provide mechanisation inputs in the application of minimum tillage and conservation farming particularly in animal power based farming systems. The Centre has successfully adapted a ripper, a sub-soiler and ripper-planter. These technologies are getting popular in Zambia and are facilitating farmers’ efforts into conservation farming. This paper shares Palabana’s experiences in the process of developing and promoting the conservation tillage technologies.

1. Introduction

Minimum tillage, conservation tillage, zero tillage, conservation farming, are terms which are gaining popularity in natural resource management and farming. The meaning and interpretation for these terms vary from one situation to another. It is, therefore, important to begin the discussion by presenting the definitions of the above terms as has been used by Palabana.

1.1 Minimum tillage

This refers to those tillage practices where by minimum or no disturbance is effected on the soil for purposes of crop production. It involves the making of furrows or holes where seed is planted. The rest of the field remains undisturbed and crop residue is left on the surface. This practice reduces soil erosion, causes build up of organic matter in the soil, hence better chemical and physical soil fertility. Minimum tillage also implies reduced labour, energy, and reduced time demand in land preparation. Hence, cropping can be done in time at less cost. In most commercial farming, the weeding in minimum tillage systems would be done using herbicides.

1.2 Conservation tillage

This moves further on the definition of minimum tillage to bring in aspects related to sustained environmental care for the natural resource – SOIL. While minimum tillage focuses on the level of soil disturbance and energy level required, conservation tillage includes the WHEN and HOW this tillage is done. The “when” basically refers to the moisture-state of the soil. Conservation tillage takes into account both environmental and tillage factors.

- Environmental factors: slope, vegetation, soil type, rain pattern and intended crops.
- Tillage factors: type of implement/s, timing of operations, depth of the tillage and soil condition.

1.3 Conservation Farming

This concept embraces everything as practised in minimum and conservation tillage. It goes further to include all socio-cultural and traditional practices and decisions relating to sustained chemical and physical fertility of the soil. This is about all those land use practices, which go to allow nature, regenerate and sustain soil fertility as the soil is being used. These include practices such as crop rotation, inter-cropping, tillage patterns (gathering and casting) use of organic and inorganic fertilisers, fallowing, etc.

As both large and small farmers pursue farming practices which are not only cheaper, but guarantee
sustained fertility of the land resource, several questions arise such as:

- Why is conservation farming a major concern now?
- What are previous and current farming practices and what is their impact on the environment?
- What is the way forward if we have to increase agricultural output and at the same time sustain the soil resource base?

2. Background

Zambia has an area of 75 million hectares with about 9 million noted as suitable for arable farming with good potential for crop production. 25 million hectares are reported as suitable for agricultural production. Much of the agricultural land, about 80%, (MAFF-World Bank report, 1995) is actually held in traditional smallholder-subsistence farming systems. A typical farming household would have in excess of 20 hectares under its direct control. However, only about 10 – 20% of this land is cropped in any one season. The farming practices in these communities reflect this fact and the following can be noted:

"... soil and water, the primary natural resource inputs in crop production have a way to regenerate themselves (naturally) with TIME being one of the main critical factors."

This fact and also that land was vast and readily available, influenced farming practices. In Zambia’s smallholder traditional systems, most common practices include:

- **Chitemene System** involves the cutting of tree branches in a field to be used for crop production. The cut branches are collected and heaped around the same field. Once dry, the branches are burnt; the remaining ash providing fertile portions of the field. Such a field will be used for a few seasons (3-4). Once its fertility is exhausted, yields reduced critically and the field is abandoned and the tree tracks which had been left standing in the field are allowed to re-grow. This field can be used again after 5-10 years.
- **In Fallowing System**: completely cleared and destamped fields are left unused for a few seasons. This allows natural regeneration of the soil fertility.

As from the mid 1960s, Zambia started to experience increased pressures for higher agricultural output. The government, then, came in to facilitate and support those interventions aimed at increasing agricultural output in the country. Some of such interventions with environmental implications was the use of inorganic fertilisers. Just after the country attained political independence, the government aggressively and extensively promoted use of inorganic fertilisers even in smallholder-subsistence systems. In 1980 the Nitrogen Chemicals of Zambia was opened to manufacture and supply of fertilisers. This situation continued into the 1990s with farmers forgetting the use of inorganic fertilisers (like inorganic manure), with which they could use same fields for longer.

Other factors have been such as the LIMA recommendations, which effectively discouraged inter-cropping, promoted the maize based mono-culture and, hence, limited possibilities for crop rotations. This led to continuous degeneration of the country’s land resource.
In the advent of the new political and economic era coming with the introduction of multi-party politics in 1991, smallholder farmers have been having increasing difficulty in obtaining fertilisers. The price has gone up and there are no more government fertiliser loans and the many subsidies. As a result farmers have noted progressive decline in yields.

The need to facilitate soil regeneration is now paramount. With this realization the Palabana Farm Power and Mechanisation Centre has taken up to develop and promote animal power based technologies which offer farmers opportunities for improved, but cheaper soil conservation practices.

3. Palabana interventions and experiences on conservation farming

3.1 Objectives of the interventions

To fully appreciate Palabana’s experiences with conservation farming it is in order to highlight the initial aims and objectives of the Palabana interventions.

Three factors in the circumstance at the turn of the 1990s provided the motivation and hence a basis for the aims and objectives of Palabana’s conservation tillage work. These were:

- Three out of every five years in the last 15 years have essentially been drought years. This has had obvious implications for crop production. Among the ideas and practices to mitigate against this problem were planting early, "harvesting" the little rain within the field and tillage practices which prevented excessive water losses from the soil.
- A study of Zambia’s agricultural performance noted an apparent surplus in farm land in the country. In smallholder farming systems, an average household was reported to using about 10-20% of the agricultural land under their control.
- A multiple regression analysis of crop production and productivity in smallholder farming systems conducted in the same study identified shortage of active labour and the number of draft animals as the two most important determinants of area cultivated.

Labour saving technologies were noted as the way forward (de Graaf, 1993) in enabling farmers cultivate larger areas. This was to be attained by minimum tillage technology.

The three factors formed the basis of Palabana’s initial work in development of minimum tillage technologies. The main objectives of this work were to develop and make available technologies that would enable farmers to:

- Prepare their fields and plant in time for optimal benefits from the now shorter rain period.
  - "harvest" the little rain into within the crop field by ripping through the plough pan to allow for more water infiltration.
  - prepare and plant larger areas within the available time and farm power.

The focus of this work was, hence, development of the ripper and sub-soiler. The ripper was worked on the basis of the ard plough commonly used for centuries in mostly temperate parts of the world.

3.2 Development methodology

This is the process that developed over the years. It is based on in-situ on-farm trial concept, where selected farmers apply the trial technology in their own natural, socio-economic circumstances. The farmers involved were provided with only the prototype and information which empowered them to make objective observations on the technical and socio-economic performance of the prototype. The methodology was interactive and essentially driven by farmer needs and input.

In the ripper and sub-soiler trails, the main parameters under investigation were:

- draft power requirement,
- technical performance of the prototypes, their effectiveness in opening up planting lines (ripper) and ripping through the hard pan (sub-soiler),
- ease of operation (handling, adjusting, etc.),
- level for repair and maintenance within rural circumstances.
Conservation farming with animal traction in smallholder farming sy...

other factors related to socio-cultural, gender, financial factors in rural farming communities.

The development of both the ripper and sub-soiler was pre-conceived as an attachment on the conventional beam-handler. This attachment concept was justified by the fact that:

- It was going to make use of the largely abandoned and widely available plough and ridger beam-handle units.
- Manufacturing requirements are simpler and scrap steel could be used for some parts, and
- It was going to be cheaper and hence financially within the reach of the targeted farmers.

![Figure 2: The Magoye Ripper](http://www.fao.org/ag/ags/...)

### Figure 2: The Magoye Ripper

#### 3.3 The ripper and sub-soiler attachments

##### 3.3.1 Design aspects to meet draft requirement

Both ripping and sub-soiling were carried out in relatively dry soil. This allowed early planting. Sub-soiling allowed the desired breaking up of the soil. Draft requirements would increase.

The design challenge was therefore to manipulate a combination of tine shape, tine size and angle of attack so that the draft required was within the draft ability of a pair or two of oxen.

Through the on-farm trials with back-up on-station trials, a $35^0$ attacking angle was determined and shape and size of the tine was decided. With this angle of attack, working in dry average sandy-loam soils a draft force of 100 Newton (N) was required. This was within the pulling capacity for a pair of oxen.

The tine was made from hardened steel and was reversible when worn. The subsoiler was most popular in Southern Province during the drought years. Palabana noted a lot of farmer innovations in the use of this implement. The implement was used in land preparations. Often before ploughing or ripping the sub-soiler was passed through the field. This was to break the plough pan. However, the most common use was to rip through a field between rows of crops. This was done when rain was expected. It increased infiltration and, harvesting of water within the field.

On-station trials were conducted at Magoye Technology Assessment Site (Simuyemba, 1998) and they indicated insignificant difference in yield between a field ploughed and later sub-soiled and one ploughed normally. However, the effect of the sub-soiling was significant and encouraging in critical drought seasons.

One major remarkable issue brought out in the use of the sub-soiler was the amount of draft power required. This operation to be meaningful, had to be done in dry soil, and had to be deeper than ripping. This meant higher draft demand. In normal operation two pairs of cattle were required. However, this could not go on well as the province was at the same time suffering from epidemic level, cattle deaths.

To meet the power demand required, one farmer group in Kalomo area developed the idea of a three-unit yoke (see Figure 3).
Farmer interest in the sub-soiler has lately regained interest due to the effects of hard pans which farmers are increasing noting in their fields.

3.3.2 Weeding

The weed problem was the immediate outcome of using a ripper for minimum tillage – making planting lines and leaving the rest of the field undisturbed. Even with the advantage of ease of preparing the land for planting and possibilities for expanding area and planting early, the weeding issue was more of a deciding factor for farmers. It is noteworthy that in most cases the mulch left on the surface was minimal. Also compounding this problem was that with ripping, the household would increase the area planted, but still it depended on hand based weeding systems.

So, with limitations in the use of chemical weed killers, a feasible option for large-scale commercial farmers, some mechanical weeding technology had to be integrated into the system. This compelled the incorporation of an animal drawn weeder in the use of a ripper in minimum tillage. A cultivator was promoted with two weeding sessions recommended; one just after germination and the other when the crop is about knee-high.

3.3.3 Planting

In ripped fields planting was by, manually placing the seed in the furrow and covering it with the foot. This planting system, which was the most common way of planting, regardless of how the field was prepared had problems, especially in relation to its extensive labour demand.

With the ripper gaining popularity, the idea of a combined ripping-planting operation developed.

A ripper planter was put under trial from 1992 to 1997.

3.3.4 Yields and ripping

Ripping was viewed as an integral part of a cropping system. Therefore, its application has to ultimately affect cost of production and indeed the profits from cropping. This was in three ways:

- Reduced production cost (land preparation costs per unit area),
- Increased area cultivated and
- Increased crop yields.

Trials done at Magoye TSA (Simuyemba, 1998) during the 1995/96 and 1996/96 seasons indicated insignificant yield difference between ploughed and ripped fields (Table 1). The yield difference between 1995/96 and 1996/97 could be due to the fact that 1996/97 was a better season with a good rainfall.

Table 1: Yield comparisons in ploughed and ripped fields
<table>
<thead>
<tr>
<th></th>
<th>1995/96</th>
<th>1996/96</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(tonnes/ha)</td>
<td>(tonnes/ha)</td>
</tr>
<tr>
<td>Ploughed</td>
<td>3.695</td>
<td>4.067</td>
</tr>
<tr>
<td>Ripped</td>
<td>3.618</td>
<td>4.333</td>
</tr>
</tbody>
</table>

The effect of ripping on physical soil fertility normally takes a few years to manifest. It is therefore difficult to see yield improvement within the first few years.

### 3.3.5 Soil degeneration – refocusing of trial objectives

During the years of the ripper, sub-soiler trails, other critical developments with implication for agricultural productivity were taking place. With the withdrawal of subsidies among other agricultural input and the collapse of the smallholder farming credit schemes, use of inorganic fertilisers drastically dropped, with more than expected effect on the yields. This brought the awareness that most fields could not produce anything unless fertiliser was used.

It became apparent that these soils had been damaged. The land use patterns for these lands allowed very little replacement of organic matter into the soil. Crop residue was either feed to cattle or burnt. An urgent need to reclaim such lands and develop land use patterns, which will ensure no or little damage to the soil structure, was identified. At this point, focus started to shift from timely planting technologies to soil conservation technologies.

### 4. Discussion and conclusions

#### 4.1 The minimum tillage technologies

The ripper technology, has steadily gained in popularity and adoption rates in Centre, Southern and Western provinces and to an extent in Eastern Province. These are areas, which are relatively dry with shorter rain seasons. The soils are generally light sandy to sandy-loam, getting more sandy to the South. The areas are intense farming (crop and livestock) locations. Due to less rainfall and other natural factors these areas have little plant matter especially, for feeding the livestock. Little organic matter gets back into the soil.

Ripping has obvious and almost immediate effects on timeliness in planting, labour and energy demand, however, its effect on yield may not be significant in the initial years. Effect of ripping on yield is affected by various factors including the soil type. Ripping works well on sandy soils with concerns for conservation of soil and water. On dense clay and self-compacting soils, ripping could easily have negative effects on yield, unless combined with other practices, such as deeper sub-soiling and mulching.

Ripping can also not be taken in isolation, especially in the longer term. Alternative combination of ripping and conventional ploughing after a few years would be ideal in maintaining the soil fertility.

#### 4.2 The ripper-planter technology

The ripper-planter, because of its considerable time and labour saving possibilities has made it a widely accepted technology among Zambian farmers. Also “difficulties” on conventional planters (expensive and complicated; require a relative smooth and fine seedbed) goes to make the ripper-planter popular.

This technology may provide the desire break through in easing planting problem for smallholder farmers. The ripper planter can effectively be used in both ploughed fields or fields not ploughed (direct dry planting), become desirable.

#### 4.3 Conservation farming

Considering current and future agricultural demand on land, need for integration of conservation farming techniques cannot be over-emphasised. Whatever, conservation farming technologies are developed, the cardinal factor is their adoptability. It is, therefore, important to realise that mechanisation inputs do not
easily and immediately translate in higher yields, as would be the case with fertiliser. Therefore important factors to influence farmers’ adoption of the technologies will mostly relate to:

- Increase in area cropped,
- Reduction in drudgery, energy and time.

Adoption will also be influenced by:

- Cost of new technologies and practices.
- Compatibility of new technologies and practices with existing socio-cultural practices.
- Information support services in addition to farmer training.

Conservation farming will affect the entire cropping and farming practices in a community. Therefore, any attempts at such should consider a broad based and multi-disciplinary approach.

References


Minimum tillage for soil and water management with animal traction in the West-African region

by

Alioune Fall¹ and Adama Faye²

¹Agricultural Mechanisation, ISRA/CRA Djibélor, ²Animal Scientist, Coopération Suisse)

Abstract

The paper reviews the utilization levels of animal traction for better soil and water management, through conservation tillage in the West Africa region. Various tools and techniques used by farmers are reported. Recommendations in order to improve farmers’ environmental conditions for better agricultural productivity and sustainability have been proposed.

1. Introduction

Farmers in the West-African region are mainly smallholders who must contend with increasing population pressure on available land, low level of mechanisation, short fallow, permanent cropping and risky rainy seasons. The existing farming systems seem to be vulnerable with regard to continuous degradation of the farmers’ environmental conditions. Current practices have led to advanced soil erosion which has compromised productivity on both land and crops.

Farmers depend greatly on animal traction for energy supply to meet their agricultural production objectives. The energy provided represents more than 90% of the mechanical energy used in agriculture in the area of study. The use of animal traction is viewed by Jaeger (1984) as an important step in creating more production opportunities and increasing returns through better land preparation and improved timeliness of field operations. However, the intensity of animal traction utilisation in relation to the level of farmers’ experience is highly variable from country to country.

Animal traction was introduced in Senegal, Guinea and Mali in the late 1920s and early 1930s. The most significant impact of animal traction in today’s farming systems has been the increase in cultivated area per active household member rising from 30 to 40% in Senegal and 40 to 70% in Mali.

For the last two decades, agricultural production throughout the Sahel has been mainly bound by the shortage of rainfall along with its uneven distribution during the rainy season. The amount of rainfall has decreased by an average of 33 to 45%, inducing new farmers’ production strategies towards meeting food security requirements (Posner et al., 1988). The coping strategies translate the farmer’s concern to reach sustainable cropping systems through decisions to be made on when and how to conduct field activities in relation to available resources (Jouve, 1986). However, there is a number of limiting factors on farmers’ performance which can help explain their response to the situation.

A number of research studies, conducted both on-station and on-farm throughout the region, have shown that sustainability of cropping systems is better achieved when agricultural practices are aimed at improving plant-soil-water relations.

1.1 Objective

The objectives of this paper are:

• to review the use of animal traction in the region towards better soil-water management through conservation tillage,
• to identify the most suitable tools and techniques available to farmers and
• to formulate recommendations in order to improve farm environmental conditions for enhanced sustainability.

To do so, major research findings in relation to major constraints to soil-water management, tillage and crop growth are discussed. Most of the researches on animal traction have been conducted in Senegal, Mali, Guinea, Togo, Sierra Leone, Burkina Faso, Niger, Nigeria and Tchad. However, there is emphasis
on research activities conducted in Senegal.

2. Climate and soils description

2.1 Climates

The climatic transition in West Africa takes place across a short distance between humid and dry weather. In this short distance away from the equator, the occurrence of two rainy seasons is observed. The dry spell between the two rain seasons is short and can vary in length in relation to the duration of the sun cycles. Vegetation in the area corresponds to the humid forest. The high amount of rainfall has the tendency to create more soil nutrients and leaching problems leading to fragile and infertile soils. Soil protection is a must.

As pointed out by Beets (1990), the weather around the 15° latitude is divided into two distinct seasons in relation to occurrence of rains: dry season and rainy season. The area where this climate prevails is becoming narrower with the global pejoration of the weather. The rainfall is still significant and relatively reliable. It stretches from moist to forest Savannah with an average annual rainfall of 1000 mm. Water runoff is a serious problem as are forest fires during the dry season. Fires are frequent and can burn completely the grass covering and protecting the soil, leaving bare soil surfaces to receive the first tropical rain events at the beginning of the rainy season.

Northward, the semi-arid to arid types of climate prevail in the central and northern part of Sahel countries from Senegal to Chad. The weather is dry and hot with one short rainy season. Rainfall is unreliable as drought situations are always reported from year to year in terms of mid-season droughts or dry spells during the rainy season. Many studies have showed difficulties encountered in finding solution to the drought situations.

Dupont (1986) and Sivakumur (1988) developed techniques to predict the level of probability of dry spells from the onset of rains to the end of the final development stage of the crops grown at the farm.

2.2 Soils of West Africa

The soils in the West-African region have been surveyed for more than twenty years by teams of African and European soil scientists. Charreau (1974) published the first most exhaustive soil classification for the Sub-Saharan Africa. This was made possible by a team of IRAT and ORSTOM (France) soil scientists. The West-African soil map was made of 12 classes subdivided into sub-classes, groups and sub-groups, families, series and types of soil. The family was composed of soils originating from the same kind of parent material. The series related to the position of the soil on the toposequence and the types to the texture of the surface horizon. Sub-Saharan Africa was divided into five large zones (Charreau, 1974):

- In the northern part of Senegal, Mali and Niger and Chad: sand and dunes.
- In the Niger River’s arc and in a great part of the Chad basin: alluvial deposits ranging from pure sand to fine clay.
- West, South-West, and East of the Niger River’s arc in Burkina Faso, in two-thirds of Senegal, and in Southern Chad were found the Terminal Continental formations. The materials generally went through a strong ferrallitic alteration.
- In the Southern part of Niger River’s arc, in the central part of Mali, and in the Western part of Burkina Faso is a vast area of Cambrian-Ordovician sandstones overlanded by an ancient “lateritic” iron pan.
- In the southern part of Mali, in Burkina Faso, in the central part of Chad: crystalline shield made up of plutonic rocks, metamorphic rocks and volcanic rock*

The soil map showed that large areas of the West-African region are occupied by grey and yellow-to-beige ferragenous soils (Allisols), and by red ferrallitic soils (Oxisols). These soils are mainly characterised by a field capacity of 15 to 20% v/v and a wilting point of 7 to 9% v/v. The oxic horizon of the ferragenous and ferrallitic soils are mainly made of a mixture of three elements: kaolin, amorphous hydrated oxides (iron and aluminium), and quartz. They are desaturated and characterised by a low cation exchange capacities (CEC) due to the presence of kaolinite, and by having almost reached the end of weathering in their evolution.

The ferragenous soils (“sol beige”) present a sandy to course loamy texture in the upper horizon with a
sub-angular blocky structure and a fine loam to fine clayey texture in the deeper horizon with angular blocky structure. The ferrallitic soils ("sol rouge" or red soils) present some alfif characteristics with sub-surface horizons made of clay accumulation. Their texture and structure are similar to the grey type. Other important types of soils are those located in dryer areas, mainly made of sandy texture and these soils represent a transition between ferragenous and vertisol types (Ducreux, 1984).

The characteristics of these soils are important for two main reasons:

- the wetting and drying cycles in relation to the aggregates and structure stability, and
- the hardening process ("prise en masse") taking place during the dry season and after intermittent rainfalls followed by dry spells during the rainy season.

For these reasons, the management of soil moisture regime appears to be a critical issue for plant growth in this part of Africa, especially at the beginning of the rainy season.

Nicou (1975) had studied these two combined characteristics which tend to confer to the soils specific physical and mechanical behaviour. A major finding, confirmed by Ducreux (1984) was the fact that the low clay content in the upper horizon (8 to 12%) and the presence of kaolinite are responsible for the tendency of the aggregates to harden through cementation during the drying phase of the cycle.

A textural index called "Hardening Index", defined as the ratio of the clay content over the coarse fraction of the soil (coarse silt + coarse sand), was introduced to describe the physical behaviour of the tropical soils. They found that there was a linear relationship between the hardening of the soil upper horizons and the HI index for soils studied in Senegal and Niger. The higher the HI index, the higher the tendency of the soils to harden during the drying phase of the cycle.

The phenomenon just discussed was found to be important in relation to crop production, in tillage and in root penetration. If the hardening process took place during land preparation, the draft required (averaging 250 kN) on these ferrogenous and ferrallitic soils was too high for draft animals found in West-Africa. For better utilisation of existing animal-drawn farm implements and optimisation of available animal energy, more studies need to be oriented towards determining the soil specific resistance to traction at different soil moisture level.

After the occurrence of the first useful rain, farmers in their majority do not carry out field operations at optimal soil water content as the window in terms of working days is usually too short to allow the completion of the task on time (Fall, 1985; Lee et al., 1993). In relation to other limiting factors, farmers need to be aware of the different techniques used in conservation tillage in order to take full advantage of the available soil water content.

The key success to environmental and farming system sustainability is to train smallholders to become soil moisture managers by giving them more insight on subjects like:

- Animal-drawn implements selection with suitable working components.
- Physical and mechanical characteristics of their soil types.
- Soil moisture regime (infiltration, holding capacity).
- Consumption rate and vegetative development of grown crops.

3. Conservation tillage with animal traction

Research activities on no-till, minimum tillage, and later on conservation tillage with animal traction started in the early 1960s in many West African countries. These activities were mainly conducted on station until 1979 when the shortage of rainfall and the drought situation induced significant changes in farmers’ production systems. However, conservation tillage could not be isolated from the broader practices of soil conservation. The baseline was to develop techniques that:

i. reduced the number of mechanised field operations,
ii. improved timeliness of field operations,
iii. reduced energy requirements,
iv. reduced wind and water erosion,
v. improved soil-water availability to plants,
vi. maintained soil fertility,
vii. reduced capital investment for farm implements.
The combination of two or more conservation practices must contribute to the implementation of a sustainable farming system to preserve the environment. Sustainability is complex concept as shown by the many definitions encountered in literature. Jodha (1990) cited by the FAO (1994) gave a comprehensive and sufficient definition:

"the ability of the agricultural system to maintain a certain well-defined output level of performance over time, and if required, to enhance that output without damaging the essential ecological integrity of the system".

The dynamic characteristic of sustainability, as time is involved, required farmers to adapt their practices according to the changing environment (meteorological, economical, etc.). In these conditions the use of animal traction has a significant role to play towards helping farmers achieve more durable reproductive farming systems. Seedbed preparation represents the most critical field operation for which to find adequate solutions in relation to better soil-water management, soil protection and energy savings.

The energy savings aspects are viewed by many policy makers as a real dilemma as many experiences around the world have showed the positive correlation between energy input and crop yields per ha. It must be emphasised at this point that the energy involved in this study is more mechanical than commercial.

3.1 Energy savings and soil protection

Conservation tillage aims to maintain and enhance soil productivity by preventing land degradation. The reduction of the number of field operations is achieved with animal traction in comparison if compared with conventional tillage. The level of investment on farm implements is lower with minimum tillage compared to conventional.

An important and undesirable side effect of tillage is soil compaction as energy from farm equipment traffic is directly transmitted to the soil. Ducreux (1984) and Fall (1992) tried to evaluate the effects of this energy by using the Proctor method which compared the variation of soil bulk density at different soil water contents under simulated charges. The results were as follow:

- Animal traction 65 J/dm$^3$ of soil
- Small to medium tractors 104 J/dm$^3$ of soil
- Heavy machinery 350 J/dm$^3$ of soil

These levels show that the use of animal traction can improve soil aeration and water infiltration as levels of compaction are less. For the tropical soils, especially for ferrallitic and ferrigenous, the water retention is higher in non-compacted soil, with an exception of silty soils. The beneficial effects provided by animal traction can be further improved by adding organic matter to the soil, such as manure and crop residues. These help increase water holding capacity. Experiences conducted in Ghana showed that the decrease of organic matter in sandy soils from 5 to 3% reduced soil water retention from 57% to 37% (Beets, 1990).

In the same study, Beets (1990) mentioned the other beneficial effects of soil organic matter towards protection of soil from degradation including:

- supply of CEC to weathered soils,
- contribution to soil aggregation,
- reduction of the soil susceptibility to erosion
- decrease of the concentration of Aluminium and Manganese
- increase in flora and fauna activities by creating channels for better soil aeration.

The question that remains now has to do with what is the current status on the techniques available to farmers or tested by research, especially for seedbed preparation and cultivation, to optimise these benefits.

3.2 Seedbed preparation in wet soil at the beginning of the rainy season

These seedbed preparation techniques concern mainly farming systems located in areas with rainfall more than 800 mm. The advanced soil degradation observed today in many farming systems in the Humid Tropical West-African region is mainly due to ploughing in relation to the precipitation profile
during the rainy season and to soil erosion. Deep ploughing in these conditions can result in disastrous effects on soil resources as the energy from tropical raindrops will literally explode soil aggregates and destroy their structure. Experiences conducted in sandy clay soils showed that, if the soil surface is not protected enough, soil erosion (in t/ha) and nutrient loss (in kg/ha) increased respectively by 27 and 15 times as runoff (in % of rainfall) increased by more than 1000 times (Khatibu et al., 1984).

For the crop development aspects, Nicou et al. (1970) had showed that on average, roots development in ferrigenous type of soil (Beige soil) was far better under tillage executed with a mouldboard plough than under soil surface scarification.

The responses given by animal traction users to these environmental conditions were mainly oriented towards better choice of implements and types of soil protection practices to be applied as animals got more and more integrated in the cropping system. Nevertheless, farmers are generally confronted with three major problems:

- the unpredictable onset of the rainy season,
- the narrow range of soil moisture for seedbed preparation and
- the rapid growth of weed after the onset of rains

In the dry and semi-humid West-Africa, the onset of the rainy season has been investigated by Sivakumar (1988) who stipulated that it corresponds to:

"the date after May 1st when rainfall accumulated over 3 consecutive days is at least 20 mm and when no dry spell within the next 30 days exceeds 7 days".

Because of the hardening process phenomenon discussed earlier ("prise en masse"), most of the tropical soils can be worked only if the soil is wet enough to allow the working component of the implement to penetrate the soil surface. When dry, the amount of draft required is just too high for the species of draft animals used by farmers. The moisture of status of these soils (ferralitic and ferragenous) is such that the plastic phase is non-existent as the soil goes from solid (11 to 13% v/v) to liquid (14 to 17% v/v) state (Ducreux, 1984; Fall, 1992). Seedbed preparation with animal traction is only possible in the friable state of the soil.

Field operations monitoring and experiences have showed that a 20 cm mouldboard plough working at an average depth of 10 cm gave the best results in terms of draft requirements and weed control. Two techniques are applicable: ploughing and ridging. To prevent soil erosion, the field must not be ploughed to the edge, a narrow band of grassed unploughed land needed to be left to prevent lose soil particles to follow waterways (Fall, 1985). From the onset of rains, the number of working days is the most limiting factor for farmers to achieve their production objectives in terms of amount of land to seed on time and energy requirements. Le Moigne (1981) found that on one hand, ploughing and ridging were not advisable for rainfall between 30 mm/day and 50 mm/day. On the other hand, the operation was difficult to perform after a 10-day dry spell. If performed correctly, these seedbed preparation techniques gave the best results with regard to yield, plant roots development and soil protection.

### 3.3 Post-crop development cycle tillage in wet soil

This technique has shown its merits in many experiences conducted on-station. The target farmers are the same as the above, in areas with annual rainfall greater than 800 mm. The best results were obtained in rice growing areas where soils stayed wet longer than in upland areas after the rains had stopped. The main objectives of this end-of-season-tillage was to take full advantage of the level of current status of soil moisture and to bury the crop residues, after harvest, in order to protect the soil from wind erosion and to increase soil organic matter. The techniques are yet to be accepted by farmers who are still using crop residues for animal feed or as input for other off-season activities.

More investigations and research are needed to design adequate implements and working components to carry out this type of tillage with animal traction. The main constraints are: efficiency of crops residues burial, level of draft required, and alternatives for animal feed.

### 3.4 Seedbed preparation in dry soil

Farmers located in areas with rainfall less than 600 mm are subject to drastic year-to-year weather variation as drought is more frequent and severe. It is crucial for farmers to take advantage of all the soil...
moisture provided by unpredictable rain events. For this reason, the soil water management techniques must go beyond tillage to include landscape improvement (live fences, windbreaks). There is no need to wait for the onset of the rain season to start field activities. The seedbed preparation in dry soil gives more timeliness in terms of weeding performed as early as possible to allow adequate crop germination and development as the rain season is short. Three techniques with specific implements are available to farmers:

- tillage in dry soil conditions,
- scarification with tines and different sizes of sweeps, and
- direct seeding with no-till.

### 3.4.1 Ploughing in dry soil

Ploughing in light soil is hard to perform. The difficulties reside in the lack of stability of the implement as the furrow is cut but not overturned. This technique of ploughing leaves an heterogeneous soil surface (Ducreux, 1984) to be subjected to wind and first rain event erosion. The practice is not sustainable over time and should not be advocated to farmers. In heavier soil, it is not only the quality of the tillage which is a problem but the draft requirements are just too high. Implements are subject to damages and to rapid wear. Field tests have reported the wear of 1 share per day in ferrigenous soils.

### 3.5 Scarification of soil surface

The seedbed preparation with implements (generally toolbars) equipped with a set of sweeps (3 or 5) of different shapes (full, half and sizes (200 mm to 350 mm). The technique consists of allowing the sweeps to till the soil subsurface and to undercut any standing stubble and weeds. The main advantage of this practice resides in the fact that crop residues are left mixed in the soil surface for effective protection against erosion and water runoff. This is the most widely used technique today in the dry semi-arid Sahel, from Senegal to Tchad). The purpose of this scarification is to allow the first rains to infiltrate and water to be stored in the sub-surface horizon for better seed germination. The draft requirements are moderate as the depth range of cultivation is around 6 to 9 cm. It must be noted that the positive effects of this technique on yield have not been demonstrated.

### 3.6 Shallow sub-soiling

Special $60^\circ$ angle-chisels, named Gouvy have been tested lately on farmers’ fields of the Groundnut Basin of Senegal aiming to improve soil water status in dry soil after the first rains (Pirot and Paris, 1980; Garin and Sene, 1988). Le Thiec and Bordet (1988) had also tested a similar steel-made chisel built by CEEMAT/CIRAD and called RS in Botswana and in Burkina Faso. It consisted of a single rigid standard frame toolbar equipped with an adjustable $60^\circ$ angle-chisel. At an average depth of 8-10 cm, the chisel shatters and loosens the soil especially in dry conditions. It requires less draft compared to mouldboard plough and also has the advantage of leaving crop residues on the surface. The chisel is ineffective when the soil is already wet, depending on the importance of water stress and the types of crops (groundnut, millet, maize). The distance between two single subsoil rows can vary from 30 to 100 cm. Water from rain will enter rapidly in the shattered rows to improve water lateral redistribution in the soil profile.

In general on one hand, the chisels had improved the soil surface rugosity by 20 to 60% to cut down significantly the water runoff during the first rains of the season. Groundnut yield was increased by 20% the first year. From the present status of research on animal traction towards water control, the seedbed preparation in dry soils needs further studies and investigations towards the development of better tools to enhance the soil moisture regime.

### 3.7 Direct seeding in dry soil

This is widely used in the Senegalese groundnut basin in the Gambia. The technique consists of using a one-row-weeder (Super Eco seeder from SISMAR) pulled by a donkey or a horse. It produces minimum of soil disturbance (Metcalfe and Elkins, 1980). After the seed is placed in dry soil, farmers pray for the rain to be at the rendez-vous. In this situation, timeliness is not a problem. However, it is important to mention that the way this practice is carried out by farmers is more oriented towards meeting their production objectives rather than protecting the soil from hazards.

One main reason is the fact that none of the seeders used at present time by farmers is really designed to plant crops in sod or stubble, meaning that more investigations are needed to improve farmers’ practices.
Globally, the advantages of this technique are the following aspects:

- reduction of production costs,
- improvement of soil retention and less runoff,
- decrease in level of soil compaction,
- better timeliness in seeding,
- reduction in some weather related risks.

4. Implements selection discussion and recommendations

The same types of implements are encountered in all the West-African countries except for Guinea where a significant part of the implements were introduced from China in 1968 at the earlier stage of animal traction implementation. Even if the implements are more less the same across the countries, most of them have been adapted to fit the local situation, with regard to draft animals, soil types, farmers height etc. The Ciwara and Houe Asine (Mali) were adapted from the Sine 9 cultivator and the Occidental Hoe respectively. The main local manufacturers are SISMAR and URPATA in Guinea.

Implants are still imported from developed countries (EMCOT, BAJAC. EBRA, etc.) and parts of the implements used today are built by local blacksmiths.

The most used implement types are mouldboard ploughs, ridger ploughs, spring and rigid tine cultivators, harrows, seeders and groundnut diggers. These implements have not changed since the 1960s except for some minor adaptations. In the selection and utilisation process, farmers are generally confronted with the challenge of fitting the energy requirements for different field activities to the draft animal without degrading the environment. Each implement has its own utilization requirements in terms of when and how to use it.

To slow down the process of soil degradation currently observed in farmers conditions, it is crucial that animal drawn implements be operated by skilled operators. Training farmers to new techniques is one way to limit the unwanted effects of the technology on the direct environment. It is also important to keep in mind that the learning process of farmers can be very slow and can take years (Fall, 1997).

The best practice towards environmental sustainability with animal traction starts first of all with increasing the range of implement selection with new types to take into account the changing environmental conditions. Mechanised farming must be conducted from a holistic perspective within agroforestry-based farming systems in order to improve land use. Beets (1989) defined agroforestry as a land-use in which trees are grown in such spatial arrangement to foster both ecological and economic interactions between the tree and the other component of the farming system: soil conservation by the rooting systems, dune fixation, fertility improvement, fodder trees for animals, windbreaks, etc.

5. Conclusion

The sustainability of the environment is a major concern to policy makers and to farmers willing to adopt new practices without jeopardising agricultural productivity. The introduction of animal traction in smallholders farming systems in West Africa has brought about significant positive changes in the production systems but on the other hand, has induced advanced soil degradation processes. It is possible to reverse the situation by introducing new farming practices that go beyond simple animal traction utilisation.

At this stage of development, animal traction has proven its positive impact in raising cropping systems productivity. However, the technology needs to be adjusted to the rapid changes taking place in the environment. Efforts must be oriented towards designing tools and introducing new practices to take full advantage of the scarce amount of rains falling in different parts of West Africa today. This will help mitigate the effects of droughts on crop production. The techniques will vary from one agro-ecosystem to another mainly characterised by the level of wetness. To this perspective, agroforestry practices need to be investigated to complement any activity around the use of animal traction.

Emphasis will be placed on a good ex ante farmers’ understanding of the potential contribution of the new techniques towards solving the sustainability and soil protection constraints. For these reasons, animal traction projects in the future must be apprehended from a multidisciplinary perspective. A number of questions need to be addressed when implementing future animal traction projects:
- Is it possible to explain to farmers what environmental sustainability is about?
- How can farmers manage the knowledge generated so far under the conceptual framework of sustainability as interpreted by WCED (1987).

Because the level of animal traction utilization is still low in most parts of West Africa, the room left for improvement can cover different aspects:

- design of better implements to include post-tillage operations like weeding and harvesting,
- optimization of draft animal utilisation to take full advantage of the available energy by planning field operations during the most suitable hours of the day,
- meeting the feeding requirements of the working animals from better integration of different farming system components,
- emphasising farmers' training sessions as part of any animal-traction-based projects to reduce the learning period.

References


Fall, A. 1985. Situation actuelle de l’environnement et de l’utilisation du pard ce matérials de culture attelée en Basse Casaamance. Mémoire de titularisation. DRSPTT en milieu rural. ISRA.


Fall, A. 1997. Methodology for evaluating the impact of animal traction at the farm level in a small scale multicropping system (Basse Casamance, senegal). Submitted to MSU in partial fullfiment of the requirements for the degree of Doctor of philosophy. Ag Engineering, E. Lansing, USA.


Soil-water and conservation tillage practices in Lesotho:

Experiences of SWACAP.

by

Letla Mosenene

Abstract

The paper highlights the experiences of the Soil and Water Conservation and Agroforestry Programme (SWACAP) between the period 1989 and 1998. Several sources of information have been used to compile this paper including: special studies, reports, discussions as well as evaluation papers. SWACAP was a government intervention programme to encourage conservation in agricultural production in the northern districts of Lesotho. The programme also initiated Agro-forestry research and policy co-ordination in the rest of the country. The programme was jointly funded by the Lesotho government and the International Fund for Agricultural Development (IFAD).

1. Introduction

Lesotho like all countries has experienced various axes of economic growth since independence. By 1994, Lesotho was still classified as the least developed country by the World Bank, with an average Gross National Product of USD 700. In the same year, the industrial sector, including the contribution from construction and building of the Lesotho Highlands Project, made up for the 42% of the GNP. Of this, 15% came from manufacturing, while the tertiary sector accounted for 46%.

Soon after independence, the GNP grew at the rate of 8% and this allowed for a significant growth of the public sector. However the 1980's saw a growth decline due to reduced domestic production, especially in agriculture, alarming public expenditure and high inflation which ended the decade in a budget deficit of 20%. The structural adjustment programme embarked upon between 1990 - 1993 stabilised the situation and yielded a surplus equivalent to 3.6% of GNP in 1994.

This growth however does not seem to have reached the social sector because poverty still threatens 55% of the farming households who are below the poverty line. Miners' retrenchment, rising unemployment, drought of the 1990's, were the biggest contributors to the declining socio-economic situation. Political instability exaggerated the context by delaying any measures to mitigate this dull scenario.

Since 1991, Lesotho has articulated policies on poverty alleviation, employment generation, income distribution, planned population growth and durable economic development. From 1996, there has been strong effort at various sectoral levels to develop strategies and programme actions that would implement these policy goals. One can still conclude that, all is not well in Lesotho regarding the economic and social conditions. Perhaps a strengthened agricultural sector could contribute towards alleviating or mitigating the two most threatening consequences of unemployment and poverty.

1.1 Agriculture in Lesotho

The contribution of the agriculture sector towards the GNP stood at 12% in 1994, following a drop from 50% in the seventies. Livestock (wool and mohair) dominated the sector with 50% share and the crops accounted for 40%. The majority (60%) of the population relies on agriculture for employment and it directly supports a little over half of the country's people. Exports have dropped from 25% in the mid-1980s to 16% in 1994. In normal years, Lesotho imports 25% of its foodstuff.

More than 80% of the country is rangeland, 67% of which, is highland at more than 1, 800 meters above sea level. In general there is biomass dis-equilibrium on both rangeland and in cropping areas due to the heavy burden from increasing numbers of humans and livestock, both of which are exacerbated by natural phenomenon. Arable land has decreased from 14% in the '70s to 9% in the 1990s and is still falling. Crop production is dominated by mono-cropped maize (80% of planted hectares), followed by sorghum, wheat, peas and beans. Yields are declining despite the increasing use of fertilizers. Yields are at half the level in l970s. Lesotho’s production is at 1/3, compared to the neighbouring Republic of South Africa (Ministry of Agriculture, 1994).
Average land holdings are 1.3 ha. Landlessness on the other hand has increased from 13% in 1976 to 25% in 1986. Land allocated is inheritable and has become a means of security. Although there are some large scale farms, small-scale farming dominates with maize, the staple food, being grown on 80% of the area under cultivation (Bureau of Statistics, 1994). The yields have been declining despite the increased use of fertilizer, with long term averages of 400 kg/ha for maize. Several factors are responsible, but it is interesting to note that crop populations are usually lower than the optimum. Draft animals are a limiting factor as well as implements with a result that many fields are planted late in November, December and sometimes in January.

Table 1: Effect of tillage systems on on-farm maize yield (kg / ha) during the 1992 / 93 summer season.

<table>
<thead>
<tr>
<th>Tillage Systems</th>
<th>Poka</th>
<th>Qoqolosing</th>
<th>Mopeli</th>
<th>Sheeshe</th>
<th>Hlalele</th>
<th>All the 25 trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard control</td>
<td>1453.4</td>
<td>1024.6</td>
<td>1183.9</td>
<td>1610.3</td>
<td>550.8</td>
<td>1123.6</td>
</tr>
<tr>
<td>Rip line planting system (treatment)</td>
<td>2239.0</td>
<td>1619.1</td>
<td>2159.8</td>
<td>2220.8</td>
<td>994.0</td>
<td>1834.2</td>
</tr>
<tr>
<td>F- value</td>
<td>43.89**</td>
<td>14.88**</td>
<td>254.16**</td>
<td>43.89**</td>
<td>22.6**</td>
<td>159.91**</td>
</tr>
<tr>
<td>LSD at 5% level (kg /ha)</td>
<td>517.1</td>
<td>549.7</td>
<td>215.3</td>
<td>355.6</td>
<td>391.0</td>
<td>192.7</td>
</tr>
</tbody>
</table>

Because of the social structure that has developed over the years; that of the absence of men in 63% households; agricultural activities especially those relating to ox-drawn implements are undertaken by boys. Relatives, volunteers in the village; or in the worst case a hired male may also assist.

Historically, agriculture enjoyed a large share of the public resources (30%); but now it has been reduced to 8%. Consequently, the sector relies on foreign donor aid accounting for 45% of the budget, but that is also decreasing. (IFAD, 1997).

In 1997, ASIP (Agricultural Sector Investment Programme) was introduced. The planning process for this initiative was started around 1995, coming to fruition in 1998. The overall strategy of ASIP was to commercialise agriculture into a competitive sector, responsive to market signals. Related sub-strategies are:

1. Further development of market reforms;
2. Privatization and deregulation to curtail state involvement in agriculture;
3. Land reform and improvement of the natural resource base;
4. Diversification of agricultural base embracing a switch into higher value of horticultural crops, intensive livestock production and promotion of rural non-farm activities;
5. Reorientation of agricultural support services towards sub sectors where Lesotho has competitive advantage.

1.2 Climate and soils

Lesotho has sub-tropical to temperate climate of warm, wet summers and cold dry winters. During the months of December and January, sometimes including February, there is a dry hot spell. This is usually fatal since it may happen when crop flowering occurs or fruit setting is being initiated. Rainfall has become erratic since 1990 and also un-seasonal. On the whole the drought phenomenon seems to have become a constant rather than an occasional incident. Rainfall ranges from 500 mm in the southern lowlands to 1,000 mm per year in the north-eastern highlands. The most typical rainfall character is that of short duration but high intensity. Frosts are common and are as indeterminate as hail storms; but generally occur between May and September. It is tempting to classify Lesotho as semi-arid. In relation to
Soil climate it has been said that crop farming is an especially risky business in Lesotho.

The two commonest soils are derived from the basalt and sand stones or shale in areas above and below 1,750 m respectively. The mollisols (basalt derived) are fairly deep with loamy texture and are moderately fertile. The alfisols (sand stone derived) on the other hand are typified by a coarse top layer with fine clay underneath. They are highly erodible due to the hard pan that reduces rainfall infiltration. These encourage piping and are therefore responsible for the gully formation that forms the southern lowlands landscape (Robinson, 1995).

**Table 2: Effect of Tillage Practices and Low-input (250 kg/ha) During the 1994/94 Summer Season**

<table>
<thead>
<tr>
<th>Name of Cluster</th>
<th>Farmer's Control</th>
<th>Rip-line System</th>
<th>Rip-line System + Liming at Planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Khabos</td>
<td>773.5</td>
<td>2484.0</td>
<td>3583.0</td>
</tr>
<tr>
<td>(2) Peka</td>
<td>971.0</td>
<td>1155.0</td>
<td>1873.5</td>
</tr>
<tr>
<td>(3) Ha Mphele</td>
<td>1871.5</td>
<td>3283.0</td>
<td>3823.5</td>
</tr>
<tr>
<td>(4) Linotsing</td>
<td>1388.8</td>
<td>2803.2</td>
<td>4016.9</td>
</tr>
<tr>
<td>(5) Ramapepe</td>
<td>1469.0</td>
<td>3548.8</td>
<td>3832.6</td>
</tr>
<tr>
<td>(6) Pitseng</td>
<td>1007.1</td>
<td>2459.6</td>
<td>2997.6</td>
</tr>
<tr>
<td>Mean</td>
<td>1246.8</td>
<td>2622.3</td>
<td>3354.5</td>
</tr>
<tr>
<td>% increase over control</td>
<td>-</td>
<td>110.3</td>
<td>169.0</td>
</tr>
</tbody>
</table>

Topography varies from gentle, to moderately steep in the lowlands. The combination of the topography, the soil types and rainfall intensifies as do poor management which is responsible for the observed accelerated erosion.

Seven of the ten Benchmark soils are acidic with pH of 5 or less and have very little organic matter (Conservation Division, 1979). Current recommendations on liming range between 2 and 20 tons/ha (Badaamchian, 1991). Sheet erosion has devastated soil fertility, and in many cases the top soil is no longer there.

**1.3 The SWaCAP project**

SWaCAP’s main goal was to promote conservation based agricultural production systems within a framework of client demand and extension approach. The specific objectives were to:

- Promote soil and water conservation measures as the normal part of agricultural activities in a way that it increased farm productivity, food production and family income;
- Establish agro-forestry research capability to contribute to the development of ecologically sound agricultural production systems.
- Create an effective agricultural extension service based on the client demand principles.
- Monitor and co-ordinate the soil and water conservation policies, programmes and projects of the Ministry of Agriculture (IFAD, 1988)

SWaCAP’s clients and beneficiaries were to be the poorest of the poor as defined by IFAD, the co-sponsor of the programme. These were defined to be households that satisfy a number of criteria mentioned below:
Households with land but lacking labour for cultivation;
Households with smaller than average land holdings;
De jure and de facto female headed households and
Landless households.

This definition encompassed 85% of the rural population and did not clearly leave out households with external or even off-farm income generation activities, with or without land. Consequently the programme attempted to develop a working definition and after a series of interviews with rural people and workshops, three categories were set to define the poor (Ministry of Agriculture, 1991).

Table 3: Responses to Fertilizer Treatments in Maize (kg/ha) in 1992/93. Village based farmer’s group

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Peka</th>
<th>Qqolosing</th>
<th>Mopeli</th>
<th>Sheesba</th>
<th>Hialele</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1798</td>
<td>889</td>
<td>1010</td>
<td>1470</td>
<td>518</td>
<td>1011</td>
</tr>
<tr>
<td>NPK + LAN</td>
<td>2357</td>
<td>1696</td>
<td>1899</td>
<td>2047</td>
<td>883</td>
<td>1706</td>
</tr>
<tr>
<td>NPK + Manure</td>
<td>2304</td>
<td>1381</td>
<td>2108</td>
<td>2230</td>
<td>841</td>
<td>1719</td>
</tr>
<tr>
<td>Average</td>
<td>2153</td>
<td>1322</td>
<td>1672</td>
<td>1916</td>
<td>747</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Maize Yields (kg/ha) Comparing Fertilizer and Tillage Treatments (1992/93)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>Rip-line</th>
<th>Rip-line + Lime C/</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>513</td>
<td>857</td>
<td>892</td>
<td>754</td>
</tr>
<tr>
<td>T2 A/</td>
<td>955</td>
<td>1460</td>
<td>2118</td>
<td>1511</td>
</tr>
<tr>
<td>T3 B</td>
<td>975</td>
<td>1660</td>
<td>2280</td>
<td>1638</td>
</tr>
<tr>
<td>Average</td>
<td>814</td>
<td>1325</td>
<td>1763</td>
<td>1916</td>
</tr>
</tbody>
</table>

A/ V NPK (100 kg/ha 3.2.1.(25)
B/ NPK (100 kg/ha 3.2.1.(25) + 1 t/ha manure
C/ Dolomite (250 kg/ha)

Category 1: Household with the following three features:
- one field or less
- 2 cattle or less
- no external salaried income

Category 2: Female managed household with no external or salaried income, including the following:
- widows
- unmarried mothers
- divorced mothers who did not live at home and did not provide any financial support.

Category 3: Household managed by a disabled person or an elderly person with no external or salaried income.

The discriminatory nature of this definition of beneficiaries within the framework of client demand extension service rendered this targeting impractical. Consequently the Programme worked with farmers that showed interest. However to avoid putting the poor into further disadvantage, the programme developed and promoted technologies which by design were not attractive to the well-to-do farmers.

2. The development of conservation farming concepts

It has been mentioned in other parts of this paper that poor soils combined with unpredictable weather conditions cause frequent and more failure of agricultural production than any other factor. Biomass dis-equilibrium occurs on both range and crop lands. This is partly due to the heavy populations of both
animals and humans on a limited area. The rampant use of stover as wood fuel implies that there is no organic matter recycling. During farmer interviews, it was also established that other key constraints were, inadequate moisture for crops during the growing season; high cost of inputs (inorganic fertilizers and hybrid seeds), and late planting due to inadequate (few & poor in health) draft animals or tractors.

Although several other soil and water conservation measures were implemented within the programme this paper discusses the tillage technology in the form of “rip-line system” as it was later to be known.

The rip line system was developed to conserve water in-situ and make it available over a longer time. Alongside the rip-line system development, tied ridges and no-till or minimum tillage were experimented with the farmers. The experiments were conducted on-farm, with a participative farmer approach. The tied ridges and minimum tillage techniques were soon rejected although the farmers acknowledged their usefulness. Reasons were that they interfered with crop cultural management operation like weeding and weed infestation was too much to eradicate. It will be noted that herbicides were not incorporated in trials due to the low investment potential of the technology users.

Table 5: Maize yields (kg/ha) comparing fertilizer and tillage treatments (1993/194)

<table>
<thead>
<tr>
<th>Set of on-farm trials</th>
<th>Control</th>
<th>Rip-line</th>
<th>Rip-line + Lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1</td>
<td>1022</td>
<td>NA7</td>
<td>2218</td>
</tr>
<tr>
<td>Set 2</td>
<td>NA</td>
<td>2636</td>
<td>2736</td>
</tr>
<tr>
<td>Set 3</td>
<td>1274</td>
<td>2735</td>
<td>3499</td>
</tr>
</tbody>
</table>

Note: 100 kg/ha NPK 3.2.1.(25) given as basal treatment.
c/ Dolomite (250 kg/ ha)

Table 6: Sunflower seed yields (kg/ha) under two tillage systems and five fertilizer treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Normal Tillage</th>
<th>Rip-line Tillage</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>648</td>
<td>904</td>
<td>256</td>
</tr>
<tr>
<td>Manure A/</td>
<td>612</td>
<td>1209</td>
<td>597</td>
</tr>
<tr>
<td>NPK B/</td>
<td>743</td>
<td>1322</td>
<td>579</td>
</tr>
<tr>
<td>NPK + manure</td>
<td>903</td>
<td>1729</td>
<td>826</td>
</tr>
<tr>
<td>NPK + LAN c/</td>
<td>942</td>
<td>1439</td>
<td>491</td>
</tr>
<tr>
<td>Average</td>
<td>770</td>
<td>1321</td>
<td>551</td>
</tr>
</tbody>
</table>

A/ 2t /ha
B/ 100 kg/ha 3.2.1.(32)
c/ lime Ammonium Nitrate 100 kg/ha

A number of trials and demonstrations were undertaken between 1989 and 1994 (IFAD 1997). Between 1990 and 1994 more that 200 trials were conducted in rip line planting and crop nutrition management. The intention was to conserve water by breaking the plough pans which were forming or had formed at about 15 cm depth. At the same time, it was important to develop a low cost package that would achieve soil amelioration at the same time. Farm yard manure was applied to the rip-line before or during planting. The results of these trials are shown in Tables 1 through 6.

Farmers further improved the technology by double ripping. After the last cultivation operation a ripper was run between the rows to harvest the important rain in December through February.

By 1993 it was clear that the benefits of the rip-line system was indisputable and that the technology was vastly superior to that which the farmers were using; the conventional mouldboard plough. The technology was extended to test sunflower, beans, sorghum and groundnuts which gave positive performance. The plant nutrition management that was running concurrently and whose results are in the Tables, also included application of agricultural lime. All in all, the farmers who assisted in the development of this ripping tine (attached to the plough beam) acknowledged the reduced amounts of lime use & manure when applied on the rip-line rather than when broadcasted, as was the practice.
3. Discussion and lessons learnt

3.1 Soil type

It is important to determine which pan is in existence on the farm. A soft plough pan situation can be corrected by using the ripper. However the hardpan such as found on the duplex soils would be hard and thick and would need a tractor hauled subsoiler. Three distinct situations were identified in the utilization of the ripper:

- a relatively infrequent situation of light soils with modest plough pan where farmers had sufficient draft power,
- the more common situation of suitable soils but insufficient animal draft power; and
- a common situation where soils were heavier and the plough pan was well developed. Here, draft animals were simply not feasible.

3.2 Animal power

It was found that it is actually easier to hire animals for ploughing, planting and cultivating than for ripping. The reason as advanced by the women especially, was that ripping seemed to stress animals more than the other operations. Secondly ripping was done in the spring as part of the land preparation operation. Due to the dry hard ground after the moisture-free winter, the fields had to be ploughed, followed by ripping and application or no application of manure. The condition of animals was usually too poor to handle the ripper, even in a ploughed field.

3.3 Gender sensitivity

Culturally the use of ox-drawn farm implements is not a domain for women. However they could hoe, weed, harvest, thresh and store the grains. In Lesotho where female managed households make 63%, women will consider redefining their role under these circumstances since producing food remains a pressing challenge. An experience that was recorded with the female participating group of Ha Rakoloi was an interesting one. After learning the use of the ripper and control over the animals for the operation, they recommended the following:

- oxen move fast and so may not be good for women who will have to run after them;
- horses move fast, especially because they are used as singles;
- mules when used single, are as fast as the horses but slower when used in pairs;
- donkeys are slow and appropriate, however they require a lot more training.

The development of the use of the donkey was however "hampered" by a MoA policy which restricted the keeping of these animals on range.

3.4 Labour requirement

Four distinct operations had to happen in order to establish a crop under the rip-line system:

a) Ploughing had to be done.
   - Rip lines were then drawn and manure was not applied in the rip-line.
   - Planting was done with or without application of manure.
   - Manure was applied as a distinct operation.

3.5 Availability of manure

The coupling of farmyard manure to the technique discouraged adoption, especially by those who could not access the manure or have a transportation problem to the fields. However although it was labour intensive it may not have been advantageous to ignore manure application which helped restore the structure and infiltration potential of the soil. There was need to carefully understand the farmer's position.

3.6 Institutional support

The programme was perceived as an external activity which was even contradicting the long standing
"beliefs", practices and policies of the Ministry. The issue of the use of farm yard manure and donkeys was foreign, which were believed to be taking the farmers into the dark ages. The institutional resistance was very high. Secondly the curriculum for training of extension workers did not include this technology and even in the refresher training programmes it was not included. The dissemination vehicle was unprepared to promote this system which they were not fully acquainted with. The linkage between the programme and the manufacture entrepreneurs was totally lacking. Consequently the supply of the implement became a major problem and contributed tremendously to its reduced adoption.

3.7 The type of farmer

The rural disadvantage usually did not have time to experiment. This resulted in reduced participation especially as many of them had to borrow animals for the operations. They also preferred to try technologies that produced quick results. Experimenting or even demonstrations with farmers could also develop fatigue and could unconsciously block their innovativeness.

3.8 Packaging the technology

Like all products the messages, packages, practices, techniques and technologies need to be disseminated, paying full cognizance that farmers are not uniform. A standard message may not reach the desired effect. It is important to know the farmers involved and to build on tradition. The future is based on the present and it is important to know the technologies and techniques in existence already. It is important for the promoter to be a step ahead of the users.

Finally, from SWaCAP experiences it is hoped that others are encouraged to consider the environment around us and how it can influence our well being and conservation tillage in order that interventions are meaningful for those they are intended for.

References


Rainwater harvesting technologies for agricultural production: A case for Dodoma, Tanzania

by

N. Hatibu and H. Mahoo

Sokoine University of Agriculture
Department of Agricultural Engineering and Land Planning
PO Box 3003, Morogoro, Tanzania

Abstract

Rainwater harvesting (RWH) is a method of inducing, collecting, storing and conserving local surface runoff for agricultural production. This paper presents a brief treatise, of rainwater harvesting, and its historical perspectives. The paper reviews major techniques of RWH for crop production being practised. These fall into three broad categories namely: In-situ, Internal (Micro) and External (Macro) catchment RWH. The paper finally gives specific examples of RWH techniques being practised in Dodoma Region and their extent of usage in the region. The paper concludes by looking at the past, current approaches and the role of RWH in Dodoma region and the appropriate techniques and their relative viability.

1. Introduction

1.1 The basis of water harvesting

Water is essential to all life – human, animal and vegetation. It is therefore important that adequate supplies of water be developed to sustain such life. Development of water supplies should, however, be undertaken in such a way as to preserve the hydrological balance and the biological functions of all ecosystems. This is crucial for marginal lands.

Consequently, the human endeavour in the development of water sources must be within the capacity of nature to replenish and to sustain. If this is not done, costly mistakes can occur with serious consequences. The application of innovative technologies and the improvement of indigenous ones should therefore include management of the water sources to ensure sustainability and to safeguard the sources against pollution.

As land pressure rises, more and more marginal areas in the world are being used for agriculture. Much of this land is located in the arid or semi-arid belts where rainfall is irregular and much of the precious water is soon lost as surface runoff. Recent droughts have highlighted the risks to human beings and livestock, which occur when rains falter or fail. While irrigation may be the most obvious response to drought, it has proved costly and can only benefit a fortunate few. There is now increasing interest in the low cost alternative—generally referred to as ‘water harvesting’.

1.2 Definition of rain water harvesting

Rainwater harvesting is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions (Boers and Ben-Asher, 1982).

Rainfall has four facets. Rainfall induces surface flow on the runoff area. At the lower end of the slope, runoff collects in the basin area, where a major portion infiltrates and is stored in the root zone. After infiltration has ceased, then follows the conservation of the stored soil water.

1.3 Historical perspectives

Various forms of rain water harvesting (RWH) have been used traditionally throughout the centuries. Some of the earliest agriculture, in the Middle East, was based on techniques such as diversion of “Wadi” flow (spate flow from normally dry water courses) onto agricultural fields. Other examples include the Negev desert (Evenari et al., 1971), the desert areas of Arizona and Northwest Mexico (Zaunderer and Hutchinson, 1988) and Southern Tunisia (Pacey and Cullis, 1986).
The importance of traditional, small scale systems of rainwater harvesting in sub-Saharan Africa has recently been recognised (Critchley and Reij, 1989). Simple stone lines are used, e.g. Burkina Faso and Mali; earth bunding systems in eastern Sudan, Kenya and the central rangelands of Somalia.

1.4 Recent developments

The potential of water harvesting for improved crop production received great attention in the 1970s and 1980s. This was due to the widespread droughts in Africa which left a trail of crop failures and a serious threat to human and livestock life. Consequently a number of water harvesting projects were set up in sub-Sahara Africa. The main objectives were to combat the effects of drought by improving plant production and in some areas rehabilitating abandoned and degraded land (Critchley and Reij, 1989). However, few of the projects have succeeded in combining technical efficiency with low cost and acceptability to the local farmers or agro-pastoralists. This was partly due to the lack of technical "know how" but also often due to the selection of an inappropriate approach with regard to the prevailing socio-economic conditions.

1.5 Major techniques of RWH for crop production

1.5.1 Site and technique selection

Setting priorities; the people's choice:

Before selecting a specific technique, due consideration must be given to the social and cultural aspects prevailing in the area of concern as they are paramount and will affect the success or failure of the technique implemented. This is particularly important in the arid and semi-arid regions of Africa and may help to explain the failure of so many projects that did not take into account the people's priorities. In arid and semi-arid Africa, most of the population has experienced basic subsistence regimes which resulted over the centuries in setting priorities for survival. Until all higher priorities have been satisfied, no lower priority activities can be effectively undertaken.

Technical know-how and criteria:

In addition to the socio-economic considerations, a water harvesting scheme will be sustainable if it also fulfils a number of basic technical criteria AS SHOWN IN Figure 1. The chart shows the basic technical selection criteria for the different water harvesting techniques.

1.6 Major categories of RWH

In crop production systems, RWH is composed of a runoff producing area normally called the catchment area (CA) and a runoff utilisation area normally called cropped basin (CB) Therefore RWH systems for crop production are divided into different categories basically determined by the distance between CA and CB as follows:

1.6.1 In-situ rain water harvesting

The first step in any RWH system involves methods to increase the amount of water stored in the soil profile by trapping or holding the rain where it falls. This may involve small movements of rainwater as surface runoff in order to concentrate the water where it is wanted most. In-situ RWH is sometimes called water conservation and is basically a prevention of net runoff from a given cropped area by holding rain water and prolonging the time for infiltration. This system works better where the soil water holding capacity is large enough and the rainfall is equal or more than the crop water requirement, but moisture amount in the soil is restricted by the amount of infiltration and or deep percolation. The in-situ RWH is achieved mainly by the following means:

Deep tillage: Tillage normally assists in increasing the soil moisture holding capacity through increased porosity, increasing the infiltration rates and reducing the surface runoff by providing surface micro-relief or roughness which helps in temporary storage of rain water, thus providing more time for infiltration.

Previous research results have shown that the depth of tillage is the most important factor controlling or affecting soil moisture characteristics. Deep tillage helps to increase porosity, reduce surface sealing of the soil and permits roots proliferation to exploit soil water and nutrients at deep horizons (Hudson, 1987).
Significant reduction of surface runoff and increase in crop yields have been shown to occur with increased depth of tillage in Hombolo, Central Dodoma.

**Figure 1: System selection**

- **Contour farming and ridging:** This is important where cultivation is done on slopes ranging from 3% and above. All farm husbandry practices such as tilling and weeding are done along the contours so as to form cross-slope barrier to the flow of water. Where this is not enough, it is complemented with ridges which are sometimes tied to create a high degree of surface roughness to enhance the infiltration of water into the soil.

- **Agronomic practices:** Practices such as use of FYM, timely weeding and mulching are used to enhance water availability in the soil by improving the water holding capacity and reducing soil water evaporation.

**1.6.2 Internal (Micro) catchment RWH**

This is a system where there is a distinct division of CA and CB but the areas are adjacent to each other.

This system is mainly used for growing medium water demanding crops such as maize, sorghum, groundnuts and millet. The major characteristics of the system include:

- **Pitting:** These are small semi-circular pits dug to break the crusted soil surface (Figure 2). In West Africa where they are called ‘Zay’, the pits are about 30 cm in diameter and 20 cm deep. FYM is added in the pits thus permitting the concentration of water and nutrients. Seeds are planted in the middle of the pits. The same system is called Katumani pitting in Kenya. They are used in areas with rainfall of between
350-600 mm.

**Figure 2: Layout of pitting RWH**

**Strip catchment tillage:** This involves tilling strips of land along crop rows and leaving appropriate sections of the inter-row space uncultivated so as to release runoff. It is normally used where the slopes are gentle and the runoff from the uncultivated parts add water to the cropped strips (Figure 3).

The Catchment: Basin Area Ratios (CBAR) used are normally less than or equal to 2:1. The system can be used for nearly all types of crops and is easy to mechanize.

**Figure 3: RWH with strip catchment tillage**

**Contour bunds:** This system consists of small trash, earth or stone embankments, constructed along the contour lines. The embankments trap the water flow behind the bunds allowing deeper infiltration into the soil (Figure 4). The height of the bund determines the net storage of the structure.

**Figure 4: RWH with Contour bunding**

The water is stored in the soil profile and above ground to the elevation of the bund or overflow structure. This is a versatile system for crop production in a variety of situations. They can be easily constructed but they are limited to availability of power (for earth moving), stones and trash. They are useful where ground slope is not more than 5%, soil depth is at least 1 m and rainfall intensity is less than 20 mm/h for 1-hour duration storms with P = 20%. They are designed with CBAR of less than 3:1.

**Semi-circular bunds:** These are constructed in series in staggered formation as shown in Figure 5. Runoff water is collected within the hoop from the area above it and impounded by the depth decided by the height of the bund and the position of the tips. Excess water is discharged around the tips and is intercepted by the second row and so on. Normally the semi-circles are of 4-12 m radius with height of 30 cm, base width of 80 cm, side slopes 1:1.5 and crest width of 20 cm. The percentage of enclosed area which is cultivated depends on the rainfall regime of the area. Basic requirements of the semi-circular bunds are:

- ground slope must be less than 3%,
- soil depth, at least 1 m,
- average annual rainfall of at least 100 mm,
- CBAR of at least 3:1 and
- rainfall intensities of I60 equal to 50 mm/h for rainfall of P = 20%.

**Meskat-type system:** In this system instead of having CA and CB alternating like the previous methods, here the field is divided into two distinct parts, the CA and CB, whereby the CB is immediately below the CA. (Figure 6).

![Figure 5: RWH with semi-circular bunding](image)

![Figure 6: RWH with Meskat-type bunding](image)

In this system, the CA is treated either by removal of vegetation and compaction in order to increase the generation of runoff. The cropped basin (CB) is enclosed by a U-shaped bund to pond the harvested water. The CBAR is 2:1. It can be used for almost all cereal crops such as maize, sorghum and millet. Experimental results from semi-arid areas of Tanzania showed that optimum yields were obtained with the recommended CBAR of 2:1 (SWMRG, 1995b).

**Land conservation aspects:** Micro-catchment approaches have a high potential for combining water harvesting with soil conservation. The main problem is that, in most projects there has been a bias towards promoting conservation rather than soil and water conservation with production. Conservation of both moisture and soil has two major advantages:

- Due to increased crop yields, farmers will be more willing to implement and maintain the system;
- The rapid vegetation development made possible by improved soil-moisture status, provides early protection to the soil against erosion.

Micro-catchment rain-water harvesting, provides a good means for changing from soil conservation based on just runoff control to a focus on land husbandry integrating conservation and production.

### 1.6.3 External (Macro) catchment RWH

This is a system that involves the collection of runoff from large areas which are at an appreciable distance from where it is being used. This is sometimes used with intermediate storage of water outside the CB for later use as supplementary irrigation.

It is difficult to differentiate this system from conventional irrigation systems but in this paper the system is called RWH as long as the water for harvesting is not available beyond the rainy season.

This system involves harvesting of water from catchments of areas ranging from 0.1 ha to thousands of
hectares either located near the cropped basin or long distances away. The catchment areas usually have slopes ranging from 5-50%, while the harvested water is used on cropped areas which are either terraced or on flat lands.

When the catchment is large and located at a significant distance from the cropped area the runoff water is conveyed through structures of diversion and distribution networks. The most important systems include the following:

**Hillside sheet/rill runoff utilisation:** In this system, runoff which occurs on hill-tops (with stone outcrops), sloping grounds, grazing lands or other compacted areas flow and naturally collect on low lying flat areas. In many areas farmers grow their crops on the wetted part of the landscape and use the runoff without any further manipulation or management.

However, where the runoff is not high, bunds are constructed on the cropped area in order to form earth basins which assist in holding the water and increasing infiltration into the soil. These bunds are important when the cropped area is not at the bottom of the landscape. However earth basins are used to facilitate the distribution of the water even if the cultivated area is on flat land. Several designs of these earth basins are used and sometimes are mentioned as types of RWH systems by themselves. These include, for example trapezoidal basins banded on three sides, rectangular basins banded on three sides e.g. Teras (Figure 7), and cultivated basins banded on all the four sides with only small inlets and overflow spillway, e.g. ‘majaruba’.

![Figure 7: Examples of hill sheet flow RWH](image)

**Floodwater harvesting within the stream bed:** This is a system that uses barriers such as permeable stone dams to block the water flow and spread it on the adjacent plain and enhance infiltration. The wetted area is then used for crop production (Figure 8).

**Ephemeral Stream Diversion:** This system involves means for diverting water from its natural ephemeral stream and conveying it to arable cropping areas. There are two main methods of diverting and distributing the water.

In the first system, the cultivated field close to the ephemeral stream is first divided into open basins using either trapezoidal, semi-circular bunds or rectangular (Figure 9).

By means of a weir, water is diverted from the stream into the top most basin. The water fills the basin and the surplus spills to the next basin and so on until the whole farm is fully wetted.
In this system, one intake point can only be used by a single farm which must be relatively close to the source.

In the second system, the field is divided into a closed rectangular basin such as "majaruba" and the water is diverted using a weir and a series of channels to deliver the water to the basins (Figure 10). The system works using the same principles of surface flood irrigation and it can therefore serve several farms which may be located far away from the intake.

**Figure 10: Ephemeral stream diversion with distribution canals**

**RWH with storage:** Sometimes macro-catchment RWH, produces high volumes of runoff that cannot be stored in the soil profile. In such circumstances, the harvested water is stored in dams or water holes. Small dams are normally constructed in rolling topography where creeks can be found and the dams are constructed across them.

Water holes are storage ponds dug in a flat terrain and they are normally referred to in their Spanish name "Charco dams". In India they are called 'tanks'. They are normally used to store runoff generated from hillside catchments with sheet or rill flow. The system requires methods for controlling siltation especially if the area is prone to soil erosion, evaporation, and seepage losses especially if the subsoil is sandy.

**Land conservation aspects:** Land conservation role of macro-catchment RWH is much difficult to visualise. In reality macro-catchment RWH system condemn one part of the land (the catchment) for the benefit of another (the cropped basin). This is occurring naturally on the catena, where fine particles, nutrients and organic matter are disproportionately lost in the eroded fraction from catchment areas. This is referred to as the "enrichment factor", and is the amount by which the eroded material is richer in nutrients than is the soil from which it is taken.

For this reason careful planning of macro-catchment systems is necessary so as to avoid the degradation of land from which runoff is occurring.

**2. Experiences from Dodoma region**

**2.1 Extent of use of in-situ RWH techniques in Dodoma**

**2.1.1 Deep tillage**
Deep tillage requires high draft power which is normally in short supply in many parts of Dodoma region. There are three main areas where deep tillage is practised extensively. These are: parts of Kongwa District, Kondoa District and the Bahi rice growing area.

In Zoisa division of Kongwa district, tractors are the main source of power and there are farmers who farm and cultivate more than 50 ha of land. This has led to the area becoming a leading producer of maize with substantial marketed surplus. During the visit by the study team, there was clear evidence, for example in Songambele village, that maize production through improved tillage has had a positive impact in reducing poverty and bringing sustainable development.

In Kondoa district, the main source of power is draft animals which are used by nearly 90% of the farmers in some areas to achieve deep primary tillage. The use of draft animal power (DAP) is such an important aspect of the farming system to the extent that even HADO had to allow oxen into the KEA during land preparations.

Bahi is another area where tractors are widely used to cultivate the paddy basins before flooding. The majority of farmers till their fields using tractors hired from contractors operating services from Dodoma town.

In the remaining parts of the region, with the exception of small pockets e.g. Berege village in Mpwapwa, deep tillage is rarely achieved since the hand hoe is the main method of cultivation. In many areas, farmers do not implement primary tillage before the planting of sorghum and millet.

Despite the large herd of cattle in Dodoma, DAP is not widely used because of the following reasons:

- Traditional cattle owners are reluctant to use their animals for work,
- Only ploughs are available,
- Animals are poorly fed during the dry season prior to the main work period, and
- Lack of knowledge in using other animals such as donkeys.

2.1.2 Contour farming and ridging

Contour farming or ridging is not widely practised in the region. However, some ridging is used for crops such as groundnuts and sweet potatoes in some parts of the region. Some of the reasons advanced by the farmers for not using ridging include:

Lack of power and equipment to till and ridge the land, and poor implementation of ridging which leads to low crop population density. This was raised by farmers in Mpwapwa district especially in relation to groundnuts production.

2.1.3 Agronomic practices

Weed control is one of the most widely used methods of conserving soil moisture. This is sometimes done twice or thrice in order to reduce water loss through evapotranspiration. Research carried out in the region has shown significant increase in crop yields when FYM is used.

The potential for farm yard manure (FYM) is not fully exploited. Villagers keep large number of livestock in kraals where enough easily accessible manure accumulates.

Observations during the study revealed that the use of FYM is restricted to the fields near the homesteads and no farmer takes manure to the distant fields. Most soils in Dodoma would respond to use of FYM since they have a low organic matter content due to sparse vegetation cover and high temperatures that cause fast microbial activities.

In recent years, bylaws on the use of FYM have been instituted in certain parts of the region such as Mpwapwa district. Specifically, the by-laws require kraals not to be left to fill with manure, thus encouraging the availability of the manure for use on cropped fields even by those farmers who not own cattle (Box 1).

**Box 1 Commercial transportation of manure**

During the visit to Vikonje village, the team met two
entrepreneurs who have invested in ox-cart and were being paid by rich cattle owners to remove FYM from the Kraals as required by the by law. They were also being paid by farmers with no livestock, to transport the manure to their fields. They were being paid TShs. 600/= by the Kraal owner and another TShs. 600/= by the farm owner.

2.2 Extent of use of internal (micro) catchment RWH in Dodoma

2.2.1 Pitting

There is no use of systematically designed pits in the region. However, in the traditional system of sowing, large pits are made which collect runoff during the early growing stages of the crop. They thus act as RWH pits.

2.2.2 Strip catchment tillage

No evidence of the use of this system was found during the study in the region.

2.2.3 Semi-circular bunds

No evidence of the use of this system was found in the region during the study period.

2.2.4 Meskat-type System

There is no use of systematically designed Meskat system in the region. However, due to microtopography water may be redistributed within the field from elevated portions into low lying ones and therefore increasing soil moisture availability to plants in these areas, which sometimes may also be of high fertility. This is evidenced even in rangelands whereby high elevation areas remain dry for a long period after the beginning of the rain season while low lying areas become covered with green vegetation soon after the beginning of the rainy season.

Similarly due to high moisture content, low lying areas remain green for a longer period after the rainy season has ended.

2.2.5 Contour bunds

These are used in many parts by few farmers due to the fact that it is the means of soil and water conservation system being extended by extension offices. In HADO areas of intervention, for example, HADO’s main strategy for promoting soil and water conservation has been the construction of earth bunds along the contours as a runoff control measure within the cropped areas. This was started in 1984, and 10 years later a total of 775 km of contour bunds had been constructed.

The major failures of both the District extension services and HADO project, is that there was very little technology transfer to the farmers. Therefore, technical staff are still laying the contours and there is no spontaneous adoption of the techniques by the farmers.

2.3 Extent of use of external (macro) catchment RWH in Dodoma

2.3.1 Hillside sheet and runoff utilisation

This system is the most widely used. It exploits the valley bottoms and plains where the runoff collects, by growing high water demanding crops. Farms in these areas are called "Mashamba ya Mbugani" and are common in many parts of the region. These are mainly used to grow maize. Flooded valley bottoms are used for sugar cane and vegetable production. This method of exploiting naturally generated runoff is widely used in the drier areas of central and southern Dodoma. The majority of the farmers have at least one "Shamba la Mbugani" which indicates that most of the maize is produced by this method of water supply.

These areas are also attractive to many farmers due to their high fertility levels which is a result of fertility enrichment from the up-slope areas where nutrients are transported and deposited in these plains during seasonal flooding. One of the most important characteristics of this system is the lack of flood control.
measures. Thus this system does not use large investment of labour to manage the water. If anything is done at all, it is to leave the catchment area uncultivated in order to generate more runoff. However, few farmers collect the runoff and lead it into bunded fields or majaruba for growing paddy rice.

In some villages there is high demand of the low lying areas which receive runoff to an extent that there is land marketing and renting of these valuable pieces of land.

2.3.2 Floodwater harvesting within the stream bed

This system is not being used at all in Dodoma region although the potential exists.

2.3.3 Ephemeral stream diversion

The most commonly used stream diversion system is the one with closed bunded basins (majaruba), elaborate diversion and conveyance channels. This is the system supporting the rapid expansion of paddy production in the western part of Dodoma region using ephemeral streams (Box 2).

Box 2: Project assistance to RWH for rice production

The Bahi paddy rice production RWH project comprises of two main components. The first component of the project was initially started with a pilot project of 20 ha in 1982 under funding from FAO/USAID. It has been expanded by farmers on their own and now covers an area of about 550 ha. The second component is a 150 ha area which was funded by IFAD in 1990. These two components are adjacent to one another and the beneficiaries are the villagers at Bahi although some non-residents from as far as Dar es Salaam, have farms in the village.

IFAD is assisting to develop similar projects.

In Bahi village, there is evidence that the majority of the farmers are quite well off and to some extent have escaped poverty. The Bahi scheme clearly indicates the role that RWH can play in poverty reduction. The main problem with this system is the initial capital investment because diversion of flood water from the river requires structures such as weirs and distribution canals to divert the water into the fields. Apart from the initial costs, flood diversion schemes are also faced with problems such as damage to the diversion works during flash floods, siltation of weirs and canals resulting from deposition of sediment carried with flood water and problems of control and distribution of the flood water.

2.3.4 RWH with storage

This is also a widely used system is Dodoma especially in Dodoma district. In the 1950’s many earth dams were constructed for livestock and domestic water supply. Some of them are substantially large such as the Hombolo dam across the Kinyasungwe river. The waters of this dam are currently being used for full scale irrigation of maize and vegetables. In other parts of the region, dug out ponds collect water and villagers exploit this for domestic, livestock and vegetable production. These are mainly found along roads where contractors dig out soil materials for road construction. Due to the apparent widening use of ponds, during the UNDP pilot project (URT/94/001) it was felt necessary to undertake a fresh assessment of construction and utilisation of such ponds. This activity was subcontracted to the SWMRG and was implemented at Hombolo. The main findings are summarised in Box 3.

Box 3: Main findings from Pilot CRAS at Hombolo

The pilot experiment took place in a year of serious dry spells and no grains were harvested from plots without stored water for supplementary irrigation. At the same time in those plots where some supplementary irrigation was provided yields of about 1.5 t/ha were realised. Economic analysis showed that paddy production using RWH with storage reservoir will break even at about 1 t/ha and make much
more money at 2.2 t/ha. This indicates that RWH with reservoir storage for supplementary irrigation would be good for the production of rice.

The major problem facing storage schemes has been the lack of maintenance. Most of them are silted up and their cost of rehabilitation is prohibiting. Silting is caused by poor utilisation of catchment areas and lack of protection of the reservoirs. Further to these, livestock walks directly, into the reservoir to drink, which increases the damage to the reservoir by puddling.

The villagers have been using water collected in natural depressions or man-made reservoirs but have shown very little interest in adopting the technology. This observation is made from the fact that although the benefits of the technology have been very well demonstrated in Dodoma, very few individuals or villages has adopted the construction of their own reservoirs. Where one has been built, people just use the water until it dries without considering the possibility of increasing water availability by constructing more reservoirs or expanding existing ones.

3. Observations and conclusions

3.1 Current, past approaches and the role of RWH

The following observations and conclusions are based on studies carried out by the authors in the semi-arid areas of Tanzania, particularly Dodoma. Other areas include Kilimanjaro, Shinyanga and Mwanza regions.

- Majority of farmers in Dodoma were found to know the importance of water conservation and harvesting and they have been practising it in different ways at different scales.
- There is already an informal land use plan along the catena, existing in many villages, for exploiting runoff. In this plan, low water requiring crops (e.g. millet) are grown on elevated ground and high water demanding crops (e.g. maize) are grown at the bottom of the landscape where runoff collects.
- It was found that there is a significant use of water conservation and harvesting for crop production by farmers in Dodoma region.
- Where water harvesting has been adopted for crop production, there is a clear evidence of increased farmers' income and poverty reduction.
- However, the water harvesting systems preferred and practised by the farmers have not received enough technical support mainly because they operate outside formal projects.
- This may be due to lack of regional policy and strategy geared towards the development of different rain water harvesting systems for crop production.
- There is a need to formulate a coherent policy or strategy towards strengthening extension and technical support of rain water harvesting for crop production.

3.2 Appropriate techniques and their relative viability

Individually based water conservation/harvesting systems to a large extent have been more successful than collective based systems. Communally owned systems such as rain water harvesting and storage reservoirs were found to suffer from lack of protection, care and maintenance.

Water harvesting initiatives and interventions need projects aimed at improving existing individual farmer practices on water harvesting in Dodoma and beyond.

Potential for increasing cash income is a big factor affecting the adoption of rain water harvesting in Dodoma. It was noted for example that where it has been adopted, RWH is used for the production of maize, paddy rice and vegetables – crops that can be sold for cash.

Promotion of water harvesting should be done in conjunction with crops, which can be sold for cash. In some places this can be achieved by improving marketing channels for existing crops.

From the socio-economic stand point the potential is high because where clear benefits have been demonstrated, farmers have been ready to undertake, at their own initiative, huge capital investment in rain water harvesting. Examples include purchasing tractors to attain deep tillage and construction of bunds for
paddy rice production.

Micro-catchment approach to RWH has a high potential for improving land conservation. Macro-catchment may, to some extent, increase the risk of erosion on the area used for yielding runoff.

References


ANNEX FOUR

ATNES A AND NETWORK CONTACTS

ATNESA Steering Committee

Dr. T.E. Simalenga (ATNESA Chair)
Faculty of Agriculture, University of Fort Hare
Private Bag X1314, Alice 5700, SOUTH AFRICA
Tel.+27-404-22232; Fax:+27-404-31730
Email:TIM.S@ufhcc.ufh.ac.za

Dr. Alemu Gebre Wold
Institute of Agricultural Research (IAR)
P.O. Box 2003, Addis Ababa, ETHIOPIA
Tel.+251-1-511802; Fax:+251-1-611222
Email:c/o A.Astatke@cgnet.com

Dr. Pascal Kaumbutho
Kenya Network for Draught Animal Technology
Rainwater harvesting technologies for agricultural production

P.O. Box 61441, Nairobi, KENYA
TEL.+254-2-766939: Fax:+254-2-766939
Email: KENDAT@Africaonline.co.ke

Bertha Mudamburi
Agritex Institute of Agricultural Engineering
P.O. Box 330, Borrowdale, Harare, ZIMBABWE
Tel:+263-4-860019/55:Fax:+263-4-860136
Email:Atnesa@harare.iafrica.com

Emmanuel Mwenya
Mashare Agricultural Development Institute
P/Bag 2096, Rundu, NAMIBIA
Tel:264-67-255917: Fax:+264-67-255846

Nick Seobi
Director, Central Region
Department of Agric. and Environmental Affairs
Private Bag X2039, Mmabatho 2735
North West Province, SOUTH AFRICA

Mr. Goolam Oodally
Agricultural Engineering Service (AGSE)
Food and Agriculture Organization (FAO)
Via delle Terme di Caracalla
00100 Rome, ITALY
Tel:+39-6-52254614: Fax:+39-6-52256798
Email: Goolam.Oodally@fao.org

Lotta Sylwander
Embassy of Sweden
P.O. Box 1664, Pretoria 0001, SOUTH AFRICA
Tel:+27-12-211050:Fax:+27-12-3232776
Email: Lotta.Sylwander@sida.se

Professor Paul Starkey
(ATNESAA Technical Adviser)
Animal Traction Development

Oxgate, 64 Northcourt Avenue

Reading RG2 7HQ, UNITED KINGDOM

Tel:+44-118-9872152 Fax:+44-118-9314525

Email: P.H.Starkey@reading.ac.uk

Main National Network Contacts

<table>
<thead>
<tr>
<th>Animal Power Network for Zimbabwe (APNEZ), Attn.Bertha Mudamburi; Agritex Institute of Agricultural Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.O. Box 330, Borrowdale, Harare, ZIMBABWE</td>
</tr>
<tr>
<td>Tel:+263-4-860019/55;Fax:+263-4-860136 Email:<a href="mailto:Atnesa@harare.iatrica.com">Atnesa@harare.iatrica.com</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ethiopian Network for Animal Traction (ENAT), Attn.Kebede Desta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Technology Promotion Division, Ministry of Agriculture, P.O. Box 7838, Addis Ababa, ETHIOPIA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kenya Network for Draught Animal Technology (KENDAT) Attn: Dr. P.G. Kaumbutho</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.O. Box 61441, Nairobi, KENYA TEL.+254-2-766939: Fax:+254-2-766939 Email:<a href="mailto:KENDAT@Africaonline.co.ke">KENDAT@Africaonline.co.ke</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>South African Network of Animal Traction (SANAT) Attn. Bruce Joubert</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Fort Hare, Faculty of Agriculture, Private Bag X1314, Alice 5700, SOUTH AFRICA. Tel: +27-404-22125: Fax:+27-404-31730; Email:<a href="mailto:SANAT@ufhcc.ufh.ac.za">SANAT@ufhcc.ufh.ac.za</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tanzania Association of Draught Animal Power (TADAP), c/o Department of Agricultural Engineering, Sokoine University of Agriculture, P.O. Box 3003, Morogoro, TANZANIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tel:255-56-4562 or 4617: Fax:+255-56-4562: Email:c/oredent@twiga.com</td>
</tr>
</tbody>
</table>

**Animal Traction Network for Eastern And Southern Africa (ATNESAA)**
Animal Traction is an appropriate, affordable and sustainable technology that is increasingly being used in the countries of eastern and southern Africa. Cattle and donkeys are the main draft animals. They provide smallholder farmers with vital power for cultivation and transport.

ATNESA (Animal Traction Network for Eastern and Southern Africa) was formed in 1990 to improve information exchange and regional co-operation relating to animal draft power. The network aims to unite researchers, manufacturers, development workers, institutions and the users of animal traction in the region. Membership of the network is open to all individuals and organisations interested in its objectives. ATNESA is co-ordinated by a regional steering committee.

ATNESA has arranged several important workshops on improving animal traction, meeting the challenges of animal traction technology, gender issues in animal traction, animal-drawn carts and weeding using animal power. More than 400 people from 40 countries have participated in ATNESA workshops and several resource publications have been produced. ATNESA encourages the formation of national animal traction networks. Contacts for ATNESA and some national networks are given above.