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Preserving the environment through conservation tillage with animal traction

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Abstract

While tractorization programmes in the sub-Saharan Africa (SSA) region have hardly served the power supply needs of smallholders, animal traction has proved itself as a dependable and versatile source of agricultural power, including tillage and transport. The 1998 Namibia, ATNESA international workshop on conservation tillage concluded that meaningful conservation tillage (Contil) work at smallholder level needs a dependable animal power support and service. The reasons why Contil practice has not become common in this region are developmental, technical and socio-economic. Conservation tillage has been practised in large scale farms of the region for over a decade and is now slowly getting accepted as mandatory for sustainable agriculture in the interest of environmental preservation. Researchers have either not made tillage part of the soil and water conservation programme or research findings have not been passed on to end-users in any recognizable manner. Meanwhile 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%. Development and growth indicators show a region under agrarian stagnation and this does not help the situation.

Various fragmented research, extension and development works in the region have proved the gains of conservation tillage. Efforts in Zambia and Zimbabwe have persisted and have reached levels of developing appropriate Contil equipment useable by those with access to animal power. The gains are however yet to be accepted and techniques adopted en masse by the farming communities. At communal, national and regional level a culture of environmental 'consciousness' needs to be developed. Heavy networking will reduce duplication of efforts and help sensitize all parties, including planners who can eventually include tillage in environment policy. 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.

Among the recommendations made in this paper are, promotion of animal traction, farmer-centered, Contil farmer-trials applied multi-disciplinary and multi-sector, research methods, environmental education; marrying traditional knowledge with new practices, farmer and other party, exchange visits; identifying suitable equipment and promoting the same nationally and regionall,y among others. Only with real action at all levels will we face the new millenium with new hope, and progress.

Introduction

Tillage is about the mechanical manipulation of soil. Soil is the medium on which all life thrives. Its manipulation involves structural disturbance and this can have great deteriorative consequences if not carefully or adequately checked. Tillage modifies the soil surface where the complex and crucial partitioning of rainfall into runoff, infiltration and subsequent evaporation takes place. 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).

Conservation tillage (*Contil*) is a practice that is only recently gaining increased attention in sub-Saharan Africa, particularly so in smallholder agriculture. The practice gained prominence in the late 70's to early 80's in United States and parts of Europe. In the developing world and at smallholder level it well advanced in South American countries such as Brazil. Contil has been practised in South Africa, Zimbabwe and Kenya by large scale farmers, especially those who have stayed in direct touch with the developments of the Western World. Farmers like those growing wheat in Kenya have for the last decade used Contil implements with amazing results. Advances have even brought in implements such as the prickle harrow, which originated in Australia. In Kenyan large scale wheat farms, pneumatic seeders and tine based implements are now produced locally and hauled by giant tractors on the 5 000 to 10 000 hectare farms common in these areas.

The reasons why Contil practice has not become common in this region are developmental, technical and socio-economic. The hand hoe has remained the main tillage equipment and as agreed at a recent ATNESA workshop in Namibia, for Contil practice to prosper at smallholder level, animal traction is mandatory.

Even with the ongoing peasantry agriculture which bears high drudgery work in much of the region, there are some traditional conservation tillage methods which date back to time immemorial, like the Ngoro pits of Tanzania and the stalk strips of lower Embu in Kenya. Terraces have been constructed in many sloping areas of the region for many years, some dating back to the beginning of this century when coffee farming was introduced.

Many smallholder farmers in Sub-Saharan Africa are faced with problems of recurrent droughts, loss of rain water to runoff, erosion and degradation of soils. Conservation farming is now seen by many as one of the solutions to these devastating problems. For optimum tillage, planting and crop management systems to be developed, promoted and subsequently adopted, it is essential for researchers, extensionists and development agents to understand the constraints within which individual farmers operate.

Studies on the relationship between animal traction, environmental impact and the sustainability of production systems, are relatively recent. As a result, there is very little concrete information about the environmental impact of using draught animal power. Animal traction as a power source, cannot be considered in isolation. It must be examined in the context of the total farming system, in order to assess its positive and negative environmental implications. As it stands, used appropriately, with the right implements, environmental degradation by animal traction can be considered negligible. However the use of mouldboard ploughs in semi-arid and sloppy humid lands calls for great concern and cannot be considered environment friendly.

Soil conservation structures like "fanya juu/fanya chini" control the speed of run-off from the field and improves infiltration at the lower bunds but they do not solve the problems caused by ploughing. Deep ploughing is sometimes recommended in semi-arid areas for harvesting early rains in some clay soils as ploughing creates big clods under dry conditions. This can be true in theory but deep ploughing in hard soils is hardly practised in Africa. It is more a recommendation than an applied practice (Johnsson *et al.,* 1998).

Environmental preservation and poverty

"Soil erosion, widespread in all areas of Sub-Saharan Africa, is perhaps most serious in Ethiopia, where topsoil losses of up to 290 metric tons a hectare/yr have been reported for steep slopes. In West Africa, losses of 10 to 20 metric tons of soil per ha/yr have been reported even for very gentle slopes. Wind erosion is significant in drier areas. There are numerous reports of a decline in the fertility of cultivated land in many parts of the region. A common feature of degradation is the removal and weakening of vegetative cover by overgrazing, over-cultivation, or deforestation, which exposes the soil to rain and wind. With several notable exceptions government efforts to combat soil degradation have failed because soil conservation usually requires the farmer to provide extra labour – labour that is often unavailable. Moreover low prices for produce coupled with uncertain land tenure make conservation financially unattractive."
[IBRD (1989)]

"The grave erosion which occurs on plough land from time to time has often induced an "old-timer" to say ruefully that we should never have put a plough into Africa. However, the relatively unscarred Africa which carried a small population on the basis of shifting cultivation remained curiously unprogressive in a world which was advancing in scientific knowledge by leaps and bounds. Western interference caused the population to increase while accelerating the rate of deterioration of the soil. The biggest problem is not the soil directly but the people on the soil. Soil must be used by good farmers to remain productive. The emphasis must always be on the people who care for the land, not directly on the land. A poverty-ridden people pass their suffering to the soil"
(Maher, 1950)

Dry land farming (DLF) is a concept with the main aim of optimum utilisation of limited rain water and crop nutrients for increased and sustainable crop production in semi-arid agro-pastoralist areas. This had proved feasible especially in countries like Zimbabwe, Zambia and South Africa. Another concept that has become popular in recent days is rainwater harvesting (RWH). In Contil studies it is understood as harvesting of run-off water.

Rainwater harvesting

Under the DLF concept a main concern is to avoid run-off and catch the raindrops where they hit the ground. The drops should infiltrate as soon as possible and be stored in the soil to be absorbed by the roots and to recharge the ground water. This technique has proved to be an appropriate rainwater

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harvesting method in the semi-arid areas for crop production (Hatibu *et al.*., 1996).

Working in Northern Tanzania with the Land Management Programme (LAMP), Jonsson *et al.* (1998) reported that the compilation of rainwater statistics showed that the LAMP area was not suffering from less rain. There were regular drier years but the trend showed increased precipitation. They wondered how people could complain of worsening droughts when statistics show increasing rain? Poor rainwater utilisation had to be the reason. A closer look at the statistics also showed long dry periods between heavy rains throughout the cropping season. The average precipitation looked good providing the surplus water after a heavy downpour could be harvested and stored in the soil for later use by the crop. A minimum requirement for an appropriate cropping system under semi-arid conditions is that it can cope with at least four weeks without rain and it is evident that this was not the case in the LAMP area (Jonsson *et al.*, 1998).

Tillage has a high impact on soil and water conservation and just might be the best means towards better utilizing the elusive rains which are common-experience in sub-Saharan Africa.

There should be no standard recommendation or package for conservation tillage promotion in semi-arid areas. Blanket approaches need to be avoided. Instead research and extension should promote a range of options that farmers can choose from depending on their biophysical and socio-economic circumstances (Ellis-Jones *et al.,* 1995).

Background

Conservation tillage, environmental protection and sustainable development

Conservation tillage though "ignored" by researchers in smallholder farming is a major contributor to the soil and water management efforts. As a practice Contil feeds directly into the concept of sustainable development. Sustainable development has received a lot of planning and other redress at policy level in recent years, but a lot remains to be done before concepts and plans can be translated into activities of immediate benefit to smallholder farmers or the environment. Where practice has gone beyond the research stations, to the smallholder farms, like in Zambia and Zimbabwe, farmers are yet to agree to the benefits of Contil in their own terms. Overall, the region seems to lack a sense of the environmental care and gains, without which sustainable development may remain far-fetched. Shortcomings arise from tendencies such as traditional practices Soil conservation is among the global environmental and resource issues. Sustainability in terms of soil which do not necessarily favour environmental protection but remain deeply engraved, among the many socio-economic priorities of the precarious survival game.

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).

Several international agencies have been keen to see sustainable development come to be in all sectors, including smallholder farming and other micro-enterprise development. The World Conservation Union, United Nations Environmental Programme (UNEP), and the World Wildlife Fund (WWF), the World Commission on Environment are some of these. Their main interest has been to 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 and legal principles for environmental protection and sustainable development were addressed. The gains of this endeavour are yet to be felt at ground level, where they are needed most (Kaumbutho *et al.,* 1998).

conservation implies utilisation without waste, so as to make possible the 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. Cultivated fields, over-grazed pastures, and cut over forestlands have always suffered from erosion. An eroded soil is degraded chemically, physically and biologically. Fertile top soil is washed away to rivers while the deposition of erosion is among the sources of air and water pollution, and therefore soil erosion is an environmental problem (Kaumbutho *et al.*. 1998).

The conservation tillage system

It is imperative to look at conservation tillage as a sub-system of the larger farm system. This way the larger picture of farm level needs and demands, which are inevitably much more than technological, and may be socio-economic or part of the prevailing political economy, are not left out. The larger picture (see Figure 1) can therefore be viewed as composed of natural factors and soil factors, operating in an environment of socio-economic and technological influences.

Natural factors affect the various capacities available to the farm manager, who may in turn have certain strengths or weakenesses in terms of training, experience, sensitization etc. The natural factors also affect the soil, determining what management practices are needed. For example a vertisol on a slopy farm land will bring about the extremities in soil and water management needs.

Researchers and development workers alike must therefore view the farm from the systems perspective. Tillage is a means to an end and not an end in itself and must be considered in relation to numerous concepts factors and methods (see the Chart below).

The chart clearly shows the large number of concepts, factors concepts and even approaches to soil and water management. It underlines the need for a holistic and multi-disciplinary approach. The number of concepts as much as parameters and factors can easily confuse the researcher and extensionist alike. It is these persons that are bound to create fears in the minds of the farmers who may find their constant fight to spread risks, compromised in ways that spell doom. The complexity of the system involved must in no way be taken forgranted. Researchers and scientists must understand it enough to be able to simplify it for the farmer, the prime client.

Biological or engineering methods

Some of the biological or agronomic approaches that stand out can be summarised as: mulch farming, high seed rate, deep sowing, cover crop, residue mulching, vegetative hedges, agroforestry, farmyard manure, supplemental dose of N and P rotations, organic ammendements, banding, vegetative hedges and strip tillage.

Physical or engineering methods include: Diggets and stone lines, no till, minimum till, sod seeding, ridges, contour ridges, tied ridges terracing, supplemental irrigation, potholes, pre- or post-planting ridges, kralling etc.

Problems, constraints and achievements

Carrying potential and the sub-Saharan Africa environment

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 semiarid, 23% is sub-humid, and another 13% is humid. Arid and semiarid 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. 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.

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 (Lal, 1993b and Kaumbutho *et al.,* 1998).

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The complex conservation tillage system chart

Concepts	Factors	Methods
▪ Dryland farming ▪ Timeliness of tillage operations ▪ Power source and tillage options ▪ Operational drudgery ▪ Soil and water conservation and tillage for soil and water conservation ▪ Soil compaction and formation of hardpans ▪ Crop and livestock interaction ▪ Tillage induced surface structure ▪ Correct implement setting ▪ Organic farming ▪ Organic and inorganic fertilizers, farm yard manure ▪ Technological and industrial advancement ▪ Equipment supply, maintenance and repair ▪ Access to affordable and appropriate education or information ▪ Sustainable agriculture ▪ Rural System Research (RSR) ▪ On-farm client oriented resaearch ▪ Agroforestry ▪ Socio-cultural deterrents ▪ Gender and environment issues ▪ Pollution and global warming ▪ Available natural resources ▪ Flora and fauna preservation and capacity ▪ Catchment and micro-catchment approach ▪ Environmental sensitivity, exposure and culture of preservation, protection and maintenance ▪ Exploitation of environment for short term gains	▪ Topography ▪ Agroclimatology ▪ Microtopography and surface roughness ▪ Soil type, texture and structure ▪ Total soil porosity, macro-porosity, pore continuity and pore size distribution ▪ Soil parent material ▪ Deep or shallow soil ▪ Rainfall re-distribution, water infiltration capacity, runoff and net runoff ▪ Waterholding capacity and drought stress ▪ Erosivity and erodibility relative to soil structure and slope ▪ Energy requiremnt per tonne of soil turned ▪ Tillage depth, penetration resistance and tillage energy and power requirment ▪ Operational speed, field capacity and efficiency ▪ Operational, time, farm and power management ▪ Draught power requirement versus available power capacity ▪ Capacity to communicate ▪ Nutrient depletion and imbalance ▪ Termite activity ▪ Costs and credit availability ▪ Alluvial flood plains	▪ Manual, animal powered or motorizd means of tillage ▪ Applied or adaptive research approach ▪ Research centre or farm-level, user-centred approach ▪ Participatory approaches to technology development and transfer ▪ Use of PRAs and RRAs menas of information gathering ▪ Training and other institutional support including government policy ▪ Universal soil loss equation ▪ Early sowing with onset of rains ▪ Soil inversion in dry season ▪ Rough ploughing at end of rains ▪ Water harvesting and drainage

Technology development adoption and impact

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 deserves the attention of sociologists, anthropologists, policy makers, and extension specialists. One of the principal reasons for the low rate of adoption is the top-down 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 develop a hyphothesis, 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 matchbox. The absence of poor adoption of improved and apparently high-yielding technologies 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.

The role of donors

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 were transferred from developed countries to Africa. It seems, however, that most of this aid was rather ineffective in stimulating growth, breaking the vicious cycle, and alleviating poverty and human suffering (Lal 1996).

Tillage method and effects on the soil

Reporting on Zimbabwe Elwell (1993) observed that although a comparatively large amount of research and development work has gone into various conservation tillage systems, farmers in both large and small scale sectors have been slow to adopt them. 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. 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 to be 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 It appears that the argument that tillage reduces evaporation losses through the "soil mulch" theory needs further assessment.

Crop yields and potential

Potential yield of most crops 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 2). 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 in 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).

Vogel, (1993) reported that maize (*Zea mays*) yields from granitic soils, cultivated by different tillage techniques, and measured over a period of three rain seasons in the sub-humid and semi-arid regions of Zimbabwe, revealed that besides tillage, seasonal rainfall pattern and the Year X site interaction had highly significant effects on maize production.

In addition, topographical and soil profile characteristics were highly related to maize yields. Of five tillage systems, the no-till tied-ridging technique resulted in highest grain yield in the sub-humid region (4.6 to 5.0 t ha^{-1}). This was mainly due to lower topsoil water contents in the elevated ridges which prevented water-logging in the sub-humid region but caused emergence and establishment problems in the semi-arid region.

In the semi-arid region, the mulch ripping technique was superior to the other treatments (2.3 to 5.9 t ha-1). Holing-out (hand hoeing), practised by subsistence farmers short of draught power, performed consistently well in the sub-humid region (3.4 to 3.7 t ha^{-1}), but yielded inconsistently and rather poorly compared to the other treatments in the semi-arid region (1.0 to 3.9 t ha^{-1}). These results imply that animal traction will continue to be mandatory, especially for smallholder farmers in semi-arid regions.

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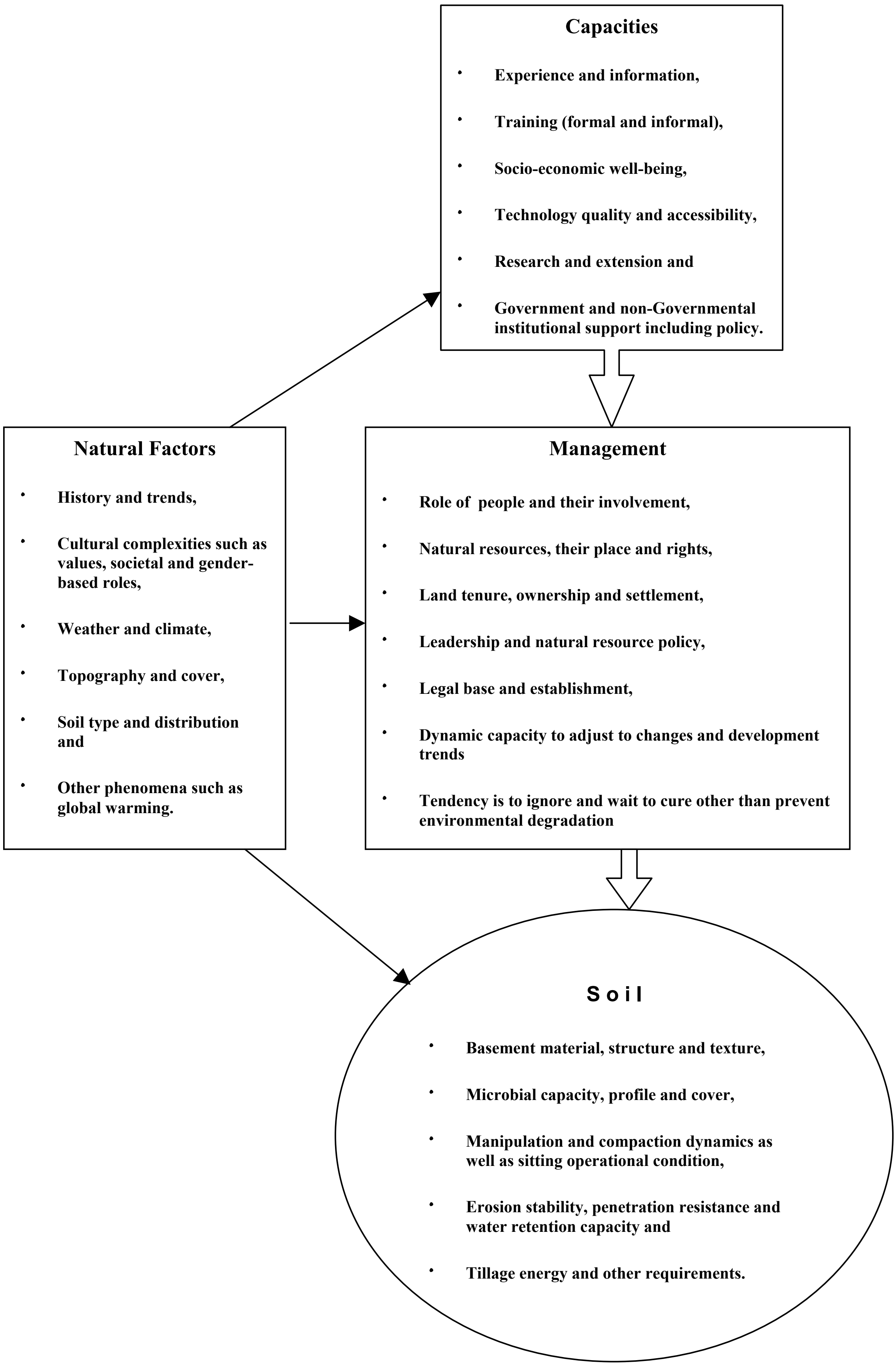

Figure 1. The conservation tillage system

Table 1: Projected population of sub-Saharan Africa+

Region	1986	1990	2000	2025	2050
	Millions				
Western Africa	189.7	215.2	294.9	648.1	1357.0
Eastern Africa	133.5	151.4	207.5	456.0	954.8
Central Africa	48.1	54.6	74.8	164.4	344.2
Southern Africa	61.3	69.5	95.2	209.2	438.0
Sub-Saharan Africa	432.6	490.7	672.4	1477.7	3094.2

+ Rate of increase : (i) 1986 to 2000, 3.2% yr (ii) 2000 to 2025, 3.2% yr; and (iii) 2025 to 2050, 3.0 % yr.

Table 2: Yield potential of crops

Land capability	Input	Millet	Sorghum	Maize	Soybean	Bean	Sweet potato	Cassava
		Mg ha^{-1}						
Very suitable	Low	0.9	1.1	1.6	0.7	0.7	2.2	2.0
	High	3.5	4.6	6.4	3.0	3.0	9.1	12.2
Suitable	Low	0.6	0.8	1.0	0.4	0.4	1.5	1.0
	High	1.8	3.0	4.2	2.0	2.0	6.0	8.1
Marginal	Low	0.3	0.4	0.5	0.2	0.2	0.7	0.3
	High	1.2	1.5	2.1	1.0	1.0	3.0	4.0

Source FAO, 1997

Table 3: Comparison of the extent of utilization of hand, DAP and tractors in SSA and Asia (1985)

	Sub-Saharan Africa	India	China
Total cultivated land (ha-million)	146	169	101
Active population in agriculture (million)	129.1	199.8	438.5
Draught oxen in use (millions)	11.3	80.5	53.0
Tractors in use ('000s)	133.6	607.8	873
Cultivated land per worker	1.13	0.86	0.23
Hectares of cultivated land per draught oxen	12.9	2.1	1.9
Hectares of cultivated land per tractor	1094	278	116
Irrigated land (as of cultivated land)	2.3%	26%	49%
Fertiliser use (kg/ha)	8.9	68.7	261.9

Source: Kayombo and Mrema (1994)

Table 4: Comparative costs of ploughing using oxen and tractor (Z$)

	Oxen (4 oxen and plough)	Tractor (50kW and plough)
Capital Costs	6450	266000
Annual operating costs	2000	163000
Cost per ha	170	1060
Cost per ha (£)	12	76

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Table 5: Comparative costs of using cattle and donkeys

	4 small oxen	2 large ox	4 cows	6 small donkeys	4 large donkeys
Direct costs per ha	200	229	232	141	137
Net cost (after discounting indirect benefits)	129	166	149	139	134

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

Country	% of cultivated land		
	Human muscle power	Draught animal power	Mechanical power
Botswana	20	40	40
Kenya	84	12	4
South Africa	10	20	70
Tanzania	80	14	6
Zimbabwe	15	30	55

Source: Ellis-Jones, 1997

Animal power role and contribution for labour efficiency

Animal traction remains the most economic form of draught for many farmers with the cost of ploughing by tractor some 600% greater than with oxen. This shows that the cost of donkeys can be substantially less than that of cattle. Draught animal power as a technology is appropriate and cheap to most small scale farmers.

However, research and extension needs a new approach to ensure that all farmer needs are met. Most field operations particularly by smallholder 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.

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 smallholder farming sector is estimated to be below 1% (Nyagumbo, 1998).

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 Africa centre around the traditional 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 (Kaumbutho *et al.*., 1998)

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 others had certain benefits.

- 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 smallholder 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.

Gender issues in conservation tillage and technology transfer

After several years of applied research in Northern Tanzania Jonsson *et al.* (1998) noted that planting was a commonly used practice in the study area. It was a quick operation but it was done with uneven germination and uneven row spacing, which eliminated the possibility for ox-mechanised weeding. While ploughing, a male responsibility was mechanized, the women dominated hand-weeding was not. Tractor and ox ploughing in combination with hand weeding was an inferior cropping system. Why not mechanise both ploughing and weeding? (Jonsson *et al.*, 1998)

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-headed 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 actors
- Communication in the families
- Problems of a male-dominated extension service
- Decision making

The study concluded that: Training for Transformation (TFT) was a method to use. They described it as one that 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. It breeds self-reliance.

A study in Uganda (Jonsson, Soroti 1992-93) showed poor design and workmanship of depth and width adjustment on common ploughs, which became disfunctional after a few seasons. Simple improvements changed the picture completely and farmers started to appreciate the depth and width adjustment. With adjustments possible even young girls could use the ploughs. This proved that ox-ploughing is not a tough job beyond the capacity of women if it was properly applied.

Solutions and achievements

Some applied research achievements

Many research achievements have been reported in the region. From lessons learnt from 12 years of conservation tillage research by cotton research institute under semi-arid smallholder conditions, Mashavira *et al.* (1995) recorded results of farmer managed trials which indicated that effective, low cost, conservation tillage practices can be achieved using existing implements to enhance water conservation, which will allow:

i) earlier and more even crop establishment;
ii) reduce effect of mid-season droughts and
iii) extend the growing season where there is an early cut off to the rains.

Looking at several approaches they characterised them by practicality, advantages and disadvantages. Some of these were as follows:

i) Farmer flat or open plough furrow plant had a practicality of quick and efficient implementation and took the full and rapid advantage of available rainfall. It required the least labour for crop establishment, a minimum of DAP equipment and was rapid, allowing timely operations over large areas. Its advantages were excellent initial water conservation ability if roughness from winter ploughing was maintained. Harrowing had to be excluded. Disadvantages were that water losses due to run-off became unacceptable once the initial roughness from winter ploughing was lost.

ii) Ridge and cross-tie had a practicality of how to construct, how to fertilise, how to plant and how to weed. The advantages were the system offered the maximum water conservation throughout the wet season. Its disadvantages were significant rain was needed to wet the entire ridge profile, and emerged seedlings on the ridge top had a chance of failing to establish. The ridges dried rapidly. Extra labour was required. Seeds in the ridge top washed away if first rains were heavy. There was difficulty of maintenance in sandy to sandy clay loam soils.

iii) The Mid-season Ridge and cross tie had the advantage of being extremely flexible in terms of the timing of water conservation tillage, weeding

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iv) and equipment usage. The disadvantage was, unacceptable water loss which occurred for a short period after the break down of clods and tilth created at winter ploughing.

v) Pot holes were very labour intensive, not practical when there was access to animal power. If animal power was not available, pot holing was a viable option especially on areas of high fertility such as anthills or small intensively cropped areas.

vi) Minimum tillage as a means, relied heavily upon the use of crop residues, which were not generally available in communal areas. Therefore, more advantages from soil surface protection by stover did not apply e.g. protection of soil surface from heat energy of insolation and pounding of rainfall. Infiltration did not improve.

Ellis-Jones and Mudhara, (1997) collected socio-economic data from two groups of twelve households in two contrasting communal farming areas in semi-arid Zimbabwe over a two year period. Cropping systems, resource utilization, and adoption patterns of conservation technologies were closely monitored.

During the first year, households were introduced to alternative conservation tillage systems. During the second season farmers were encouraged to adopt those they considered suitable for their conditions. This allowed evaluation of the alternative soil and water conservation tillage technologies under farmer management conditions.

Table 7 summarises the labour requirement and timing of the different implement systems for conventional tillage practices.

Ellis-Jones and Mudhara, (1997) concluded that existing recommendations on conservation tillage practices increase the demand for both labour and DAP, accentuating peak requirements. If these peaks could be reduced or spread through the year, the likelihood of new practices being adopted was increased. They cautioned that there should be no standard recommendation or package for conservation tillage promotion in semi-arid areas. Blanket approaches needed to be avoided. Instead research and extension should promote a range of options that farmers can choose from depending on their biophysical and socio-economic circumstances.

In agroecological and ecological aspects of soil tillage (Pulawy 1997) hand-made ridges treatment was significantly ($P<0.01$) greater, at 362 h ha^{-1} than the flat control or the two mechanically ridged systems. This reduced productivity, in terms of grain yield per hour worked, by as much as 50% when compared with mechanically constructed ridges or the flat control.

Applied research efforts in the region

There have been several concentrated efforts towards eventual introduction of conservation tillage at farm level in the SSA region. The efforts have seen various degrees of success. In turn the efforts have taken various forms of localized and national ventures with minimal regional dissemination. Duplication of efforts has not been totally absent.

Table 7: Labour requirements for alternative implement systems

Operation	Weeks into season	No DAP		Partial DAP		Full DAP	
		(hours per ha and % of total)					
Land preparation	0-4	300	46%	22	6%	20	8%
Planting	0-4	32	5%	32	1%	8	3%
1st weeding	2-6	74	11%	74	21%	33	12%
Crop protection and fertilising	6-8	16	2%	16	5%	16	6%
2nd weeding	6-12	52	8%	52	15%	8	3%
Harvesting	12-18	180	28%	180	52%	180	68%
Total		654	100%	352	100%	265	100%

Source: Ellis-Jones and Mudhara, 1997

Work carried out in introducing conservation tillage research and management at both stations and farms include 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 Silsoe Research Institute; works of Kenya Agricultural Institute (KARI) and Regional Land Mangement Unit (RELMA), formerly Regional Soil Conservation Unit (RSCU) in Kenya, GTZ funded work in the region, the Palabana, Zambia work on CONTIL equipment, the Improved Maresha prototype produced by University of Nairobi and Swedish University of Agricultural Sciences (Gebresenbet and Kaumbutho, 1997) among others.

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.

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.

Briefs on other research input

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. 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.

Mbanje (1997) analyzed implement and selection factors with an aim of achieving practical opportunities to reduce draught 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 is cultivated and the nutrients that were added to it. For example, addition of manure and organic matter helped reduce draught demand.

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 treatments 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 upto 2.5m tonnes/annum) organic carbon leading to increased erodibility.

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Table 8: Economic analysis of method of ridging trial at Makoholi Experimental Station (1992/93)

Tillage system	Flat control	Ridged by hand	Ridged by plough	Ridged by ridger
Grain yield, kg ha^{-1}	2772	2976	2682	2662
Stover yield, kg ha^{-1}	1424	1582	1539	1500
1. Gross income* Z$^	2953	3172	2862	2840
2. Purchased inputs Z$	1985	2028	1966	1962
3. DAP cost Z$	301	301	410	447
4. Labour cost Z$	252	340	252	252
5. Total costs Z$ (2+3+4)	2538	2669	2682	2661
6. Gross Margin Z$ (1-5)	415	503	234	179
7. Total labour, hours	275	362	282	284
8. Returns to labour Z$h^{-1} ((6+4)/7)	2.43	2.33	1.72	1.52
9. Return to cash expenditure Z$ Z$$^{-1}$ (1/2)	1.49	1.56	1.46	1.45

(Mudhara and Ellis-Jones, 1996)
*Maize grain – 1050Z$t^{-1} ; Maize stover – 30Z$$^{-1}$
^ Zimbabwe dollars 13 to 1£sterling – 1996 exchange rates

Weeding
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 upto 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

Networking to face current and future challenges of conservation tillage

Emanating from ATNESA Contil workshop in Namibia

The October 1998 Namibia meeting considered a wide range of aspects regarding appropriate Contil initiative for Namibia. The broad outputs of the Namibia workshop were also programme outputs for a Namibian Contil initiative. These were as follows:

1. Promotion of conservation tillage with animal traction
2. Improving soil fertility, crop and weed management.
3. Crop and livestock integration and environmental management
4. Entrepreneurship, credit and marketing support.

The government was considered to have the role of coordinating the implementation of the projects, working closely with farming communities. ATNESA was recognized as the body to provide the necessary backstopping.

Regional collaborative activities
The Namibia workshop saw the following as regional activities towards the promotion of Contil:

i. Development of guidelines on conservation tillage with animal traction in semi-arid areas of East and Southern Africa.. It was noted that FAO was currently preparing general international guidelines on conservation tillage. What was required for the region was specific guidelines for Eastern and Southern Africa on Conservation Tillage with Animal Traction (for more details see Kaumbutho and Simalenga, 1999).

ii. Development of a database on conservation tillage systems.

FARMESA, a regional program had initiated collecting information on Conservation tillage systems. Participants felt there was need for ATNESA to collaborate with FARMESA and produce a comprehensive database and inventory of existing technologies.

iii. Establishment of regional network on conservation tillage.

A regional network for conservation tillage was in the process of formation, an initiative spear-headed by various organization led by GTZ.

Follow-up expert's Namibia visit

Following the Namibia workshop, Brazilian Contil experts visited Namibia at the beginning of the rain season. Carlos Brigard and a colleague, Ademir Calegari visited December 5 to 18, 1998 and made the following observations in so far as farmer capacity for Contil development in Namibia was concerned:

- Farmers were concerned about saving moisture but they were not into any practice that would help them to maintain it. On the contrary they were turning the soil with ploughs.

- Farmers and extension agents had great concern about weeding at a very early stage when population of weeds was still low. They used hands as well as animal drawn implements.

- They observed that the way planting was done needed to improve urgently so as to use less seed and achieve better plant distribution. Farmers were planting six to ten seeds per hole arguing that they were allowing for the fact that many of the seeds would be lost to pests.

- Probably by tradition farmers liked to see the soil without no vegetal residue on top of the ground. The animals were also very important to the farmers.

- Both areas visited had soils with low fertility due to the low organic matter content. There was talk of soil compaction though this was not evident. Plant roots were straight and the apparent density was not at a level that would limit good plant growth. Heavy duty disc harrows were in use and they were not good for the soils of such low organic matter content.

- They noted that the draught animal power program was very important and it would need little effort to get farmers to change the implements they were using, which was bound to increase crop production while protecting soil and its fertility.

- Several readings of soil temperature were taken and in bare soils with no cover at a depth of 5 cm a reading of 55°C was recorded. An adjacent location with mulch cover gave a reading of 26°C at the same depth.

Based on the experiences of common practice in South America, the following recommendations were made:

- As demonstrated during the visit, with a ripper planter brought from Brazil, an implement that can prepare the seedbed, plant and fertilise in one pass is ideal for early planting. Better seed distribution would help as fertiliser is then available to the plants from the beginning. Two models of manual planters "matracas" were also brought to Namibia. The animal drawn planter is capable of 3 ha per day when used by trained operators and animals. It has a light pull. The "matracas" plant and fertilise around 1 ha per day with trained operators. A sample of a harness was also was also left in Namibia for production trial by the artisans.

- Technicians and farmers need to understand that they can use soil all year round and not only during the rain season. Keeping soil covered during the dry season is important and can maintain enough soil moisture to allow for early planting, hence good crop production.

- It was noted that rain season extends for almost six months and with appropriate varieties it may be possible to plant two short period crops as practised successfully in Brazil. Expertise for crop variety selection is needed here.

- Use of herbicide was strongly recommended as a way of converting green manure into dead cover, hence increased organic matter content, biological activity and water harvesting.

- Cover crops were also recommended and several species such as the jackbean (*Canavalia ensiformis*), cajan pea (*Cajanus cajan*), crotalaria (*Crotalaria juncea*) were named as possibilities. On farm trials would be the way to experiment with these, which would also enhance cattle feed supply.

- For cattle grazing it was recommended that farmers improve their management by dedicating a section of the land to generate good grass to feed the cattle and make hay to feed them during the dry season. This way they can save the cover crops and crop residues to be used as organic matter and have strong animals at the beginning of the season.

- It was strongly recommended that a number of ripper planters and "matrasas" be imported from Brazil and tried in Namibia and elsewhere. Also a number of people could visit Brazil to see the advances of extensive Contil practice by farmers who originally had similar problems of low crop production and lack of soil moisture.

Networking for the Contil initiative in East and Southern Africa

Following an FAO, GTZ and FARMESA sponsored Conservation Tillage for Sustainable Agriculture

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international meeting, held in Harare, Zimbabwe in June 1998, ATNESA conducted a Namibian, Ministry of Agriculture Water and Rural Development (MAWRD) sponsored Conservation Tillage with Animal Traction international workshop.

As an example of how efforts from these gatherings propelled themselves, in Kenya, RELMA (SIDA sponsored, Regional Land Management Unit) sponsored a Kenyan Technical training course on Conservation Tillage practices for small scale farmers in November 1998. This course took the form of an exchange of experiences between Contil practitioners from Kenya, Tanzania, Zambia, Zimbabwe and Ethiopia. Practical field demonstrations were conducted by KENDAT of Kenya, Agritex of Zimbabwe, SAMeP of Zambia and the LAMP/SCAPA project of Northern Tanzania.

At the end of the course it was agreed that a Contil initiative for Kenya be initiated. The initiative would be spear-headed by groups from different parts of the country and supported by RELMA. Four groups representing different agro-ecological zones and regions of the country emerged. Pilot projects have now started and will make a real start on farmer-centred participatory methodologies towards Contil development and practice in Kenya. A steering committee made up of Ministry of Agriculture, RELMA, University of Nairobi, KARI and KENDAT was appointed and will see to the coordination of the initiative. Experiences from SAMeP of Zambia have been brought on board the Kenya initiative with great gain in speed. The initiative will merge efforts with the Kenya Agricultural Research Institute (KARI) Tillage in Vertisols project among others.

Regional Initiative for Contil

Within this same effort RELMA, last July (1999) sponsored Laikipia farmers to visit their counterparts in Northern Tanzania where conservation tillage work is quickly becoming common practice, thanks to the LAMP/SCAPA project. From the visit, Kenyan farmers came back convinced that Contil is a way forward. Similar initiatives are underway in at least Tanzania, Zimbabwe and South Africa. At smallholder farm level Zambia and Zimbabwe may comfortably claim leadership in promoting Contil practices in the region.

With the continued and determined efforts of individuals from GTZ, Agricultural Research Council of South Africa, FARMESA, RELMA, ATNESA, AGRITEX and others, an Africa Network for Conservation Tillage was launched in Zimbabwe last April (1999). An internet list-serve for information and experience exchange is one of the planned activities.

At the workshop that led to the initiation of the network, an expert-facilitated project planning workshop found that although networking for conservation tillage was mandatory, it would not alone, do the service of promoting Contil practices. The structured problem analysis that took place came up with 6 prime outputs (what the major achievements of the initiative should be) namely:

1) Information and Support on Contil technologies and approaches made available and exchange of knowledge facilitated among all stakeholders
2) Users access to information and knowledge on Contil and their ability to apply the knowledge is effectively enhanced
3) Information on farmer-oriented research methods exchanged and effectively applied by the main research organisations
4) An African Network for the promotion of Contil is formed and functional
5) National capacity for Contil training and dissemination enhanced and supportive policy encouraged and
6) Linkage between farmers and support services and equipment manufacturers strengthened.

From a participants ranking session the number one priority was identified as number 2) above. Especially at national level it was therefore most important that the benefits of conservation tillage be shown on the ground, to farmers. Conservation tillage information needed to be exchanged and support availed.

Some of the activities defined as contributors to Output 2 were:

- Setting up of pilot projects and carrying out capacity building among farmers
- Development of farmer-focused materials
- Initiation of farm demonstrations, competitions and organising farmer exchange visits, as well as visits between equipment manufacturers, farmers and researchers.
- Training of trainers, including implement manufacturers

The least (though important) priority output was the formation of Contil policies at country and inter-country levels. The formation of the network ranked number five though it was agreed to be of very high priority at regional level.

The overall goal of the initiative was agreed as:

An increase in the effective and efficient utilization of agricultural and natural resources and a consequent improvement in the quality of life of rural communities.

The purpose was agreed as:

Enhanced knowledge on conservation tillage technologies and approaches and a conducive environment enabling farmers to adopt and adapt ecologically sound and economically viable soil and water management practices.

Some of the critical considerations for the initiative were such as: the farming systems approach i.e. conservation tillage or conservation farming? Managerial issues were such as whether the network would facilitate or implement activities on the ground, who to involve and when, where to locate the network core, its ownership, where to set pilots, time frames and more.

Conclusions and recommendations

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.

As conservation tillage is given due concern other issues like management need emphasis. Technology needs to be defined broadly, beyond equipment and handled to include sustainable soil and crop management options available to farmers in the region. Dry-planting and pre-season hard pan breaking are some of the practices which are mandatory, likely to show quick results and of great significance in the prevailing areas of limited rainfall amounts. These areas form about 80% of sub-Saharan Africa.

It is more than apparent that many commendable efforts towards conservation tillage practice have 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. The benefits of conservation tillage and environmental preservation need to be proved to farmers and others, in their own localities.

Following form the wide range of problems or constraints, efforts and achievements, the following are considered and appropriate recommendations:

i. 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.

ii. Marrying traditional knowledge, ideas and practice, while matching fears and limited experiences with technological, socio-economic and other concerns of end-users. Farmer exchange visits, equipment dealers and other parties will be most important in this regard.

iii. Identifying suitable equipment and promoting the same nationally and regionally while merging resources and eliminating duplication of efforts within and between nations.

iv. Applied field testing with farmers as more research findings are made, especially to quantify and prove the real and sustainable gains of the use of various technologies and practices while accommodating the natural and other development trends and narrowing the gap between research and end-users

v. 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 including micro-enterprise, industrial and other support for entrepreneurial creativity at all levels.

vi. Shortcomings in technology and equipment development is not unique to conservation tillage and for this reason, networking, collaboration and co-ordination backed by training, support for equipment supply, including simplification for local manufacture and other support is mandatory.

vii. 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 and promising growth in the agricultural sector.

viii. Conservation tillage practice needs to start with opening plough pans in already heavily cropped lands. Practices like ridging are engraved in African tradition as a means to improve rainwater infiltration and aeration while maintaining soil fertility and erosion control. Such practices must however be on farms whose pans have been eliminated.

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Generally and in conclusion, 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 hand hoeing has shown soil strengths that could inhibit root penetration. Hand-hoeing however persists.

Recent international workshops have brought much initial work and have been of much benefit to the endeavour. Initiatives in Zambia, Zimbabwe, South Africa and Kenya will back the regional Contil initiative and lead the way to real benefits for end-users into the new millenium.

References

Aagaard, and Gibson, D., (1986). "ZNFU Conservation Farming Unit Mission to Zimbabwe: Recommendation for the establishment of a Zimbabwe Conservation Farming Unit. "Rep. No. Draught report. World Bank, Harare.

Anazodo U.G.N., A.P. Onwualu and K.C. Watts 1991. Evaluation of alternative tillage systems in the absence of herbicides for maize production in a savanah loamy soil. Journal of Agricultural engineering Research 49:259-272.

Chuma, E.1993. Effects of Tillage on erosion-related soil properties of a sandy soil in semi-arid Zimbabwe. In: AGRITEX 1998. Documented output of the AGRITEX/GTZ Project 1988-1996, P.O. Box 790 Masvingo, Zimbabwe.

Dagg, M., and J.C. McCartney. 1968. The agronomic efficiency of the N.I.A.E. mechanised tied ridge system of cultivation. Exp. Agric. 4:279-294.

Ellis-Jones, J. & Mudhara, M. (1995). Factors affecting the adoption of soil and water conservation technologies in semi-arid Zimbabwe. In Soil and Water Conservation Tillage for Smallholder Farmers in Semi-Arid Zimbabwe: Transfers between Research and Extension, 106-117 (S. Twomlow, J.Ellis-Jones, J. Hagmann & H. Loos (eds), Silsoe Research Institute Bedford, U.K.

Ellis-Jones, J. & Riches, C. 1992. Zimbabwe: A rapid rural appraisal for conservation tillage; development of sustainable tillage and weed control systems for soil and water conservation management. AFRC Silsoe Research Institute, Overseas Division Report OD/92/5. Silsoe, Bedford, UK: Silsoe Research Institute.

Ellis-Jones, J. (1997). A farming system approach to increasing the productivity of draught animals . In " Improving the productivity of Draught Animals in Sub-Saharan Africa" (J. Ellis-Jones, A. Pearson, D. O'Neill and L. Ndlovu, eds.) 25-27 February 1997, UZ, AGRITEX, DRASS, CVTM, SR I,nstitute of Agricultural Engineering, Hatcliffe, Harare, Zimbabwe.

Ellis-Jones, J Draught Animal Power: lessons from sub-Saharan Africa. Silsoe Research Institute

Ellis-Jones J. and M. Mudhara 1997 Conservation tillage for resource poor farmers: the critical importance of farm power. Aagroecological and ecological aspects of soil tillage. Pulawy 1997 PL ISSN 0860-4088

Elwell, H.A., 1993. Development and adoption of conservation tillage practices in Zimbabwe. Chapter 10. In: Soil Tillage in Africa: Needs and Challenges. FAO Soils Bulletin 69. Soil Resources, Management and Conservation Service Land and Water Development Division. FAO, Rome 1993, 129-165.

Food and Agriculture Organisation. 1984. Land food and people. FAO, Rome.

Food and Agriculture Organization. 1978. Report on the agro-ecological zones project. Vol.1. Methodology and results for Africa. FAO, Rome.

Gebresenbet, G, 1991, Analysis of Forces Acting on Mouldboard Ploughs and Seed Drill Counters in Relation to Speed, Depth and Soil Conditions: Static and Dynamic Studies. Doctoral dissertation defended at Swedish University of Agricultural Sciences, Department of Agricultural Engineering, Uppsala, Sweden.

Gebresenbet G. and P.G. Kaumbutho. 1997. Comparative analysis of the field performances of a reversible animal-drawn prototype and conventional mouldboard ploughs. Journal of Soil and Tillage Research 40(1997) 169-183.

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

Hagmann, J. 1997. Farmer-driven Development of a Single Donkey pulled Toolframe for Weeding, Ridge-tying and Opening Planting Furrows. In: Starkey, P. (ed.) Animal Power for Weed Control. (Proceedings of a Workshop of the Animal Traction Network for Eastern and Southern Africa (ATNESA) held 1-5 November 1993, Tanga, Tanzania). (in print)

Harris D., G.J. Fry, S.T. Miller and A. Pain 1992. Crop Production, Rainfall, Runoff and Availability of Soil Moisture in Semi-Arid Botswana.

IBRD, (1989). "Sub Saharan Africa: From Crisis to Sustainable Development: A Long Term Perspective". The World Bank Washington D.C. 300pgs.

Kaumbutho P.G, E. Waithanji, J.M. Mutua and A. Karimi. 1997. Animal power development in Kenya: A report of findings from KENDAT field experiences. KENDAT, P.O. Box 30197, Nairobi. Kenya.

Klute, A. 1982. Tillage effects on the hydraulic properties of soil: A review. In: Unger P.W., D.M. Van Doren Jr., F.D. Whilsler and E.L. Skidmore (eds). Predicting tillage effects on soil physical properties and processes. ASA special Publication 44. Madison pp 29-43.

Krause R. (undated). Mechanization contribution to high level sustainable production: From tillage to mechanical weed control. University of Kassel. Dept of Agric Engineering. Nordbahnhofstr. 1 a, 37213. Witzenhausen.

Lal, R. 1988. Soil degradation and the future of agriculture in sub-saharan Africa. J. Soil Water Conserv. 43:444-451.

Lal, R. 1990. Low resource agriculture alternatives in sub-saharan Africa. J. Soil Water Conserv.45:437-445.

Lal, R. 1992. Institutional and manpower constraints on soil research in Africa. P.45-48. In K. Tato and H. Hurni (ed.) Soil Conservation for survival. Soc., Ankeny, IA.

Lal R., 1993a. Technological base for agricultural sustainability in Sub-Saharan Africa. In: Technologies for sustainable agriculture in the tropics: Proceedings of an international symposia. American Society of Agronomy. San Antonio Texas.

Lal R., 1993b. Technological options towards sustainable agriculture for different ecological regions in Sub-Saharan Africa. In: Technologies for sustainable agriculture in the tropics: proceedings of an international symposia. American Society of Agronomy. San Antonio Texas.

Lele, U. 1991. Aid to African agriculture; Lessons from two decades of donor experience. World Bank Report, The John Hopkins Univ. Press, Baltimore, MD.

Ley G.T. 1990. Tiallage and water management in Southern Highlands of Tanzania. In: Proceedings of the 1st annual Scientific Conference, SADCC Land and Water Management Research Programme. Saccar, Gaborone. Botswana. M. Kronen (ed) pp. 225-232

Maher, C. (1950). Soil Conservation in Kenya Colony: Part I. Factors Affecting Erosion, Soil Characteristics and Methods of Conservation: Part II: Soil Conservation Practice: Organisation and Legislation: Present Position and Outlook. In the Empire J. of Experimental Agriculture: Vol.XVIII (1950): No.71: 137-149; No.72: 233-248.

Mashavira ,TT, P. Hynes, S. Twomlow and T. Willocks. 1995. Soil and water conservation for smallholder farmers in semi-arid Zimbabwe. Transfers between research and extension. Proceedings of a Technical Workshop 3-7 April 1995 in Masvingo In: Lessons learned from 12 years of conservation tillage research by cotton research institute under semi-arid smallholder conditions.

Mashavira T.T., H.H. Dhliwayo, P.S. Mazike and S.J. Twomlow. 1997. Agronomic consequences of reduced tillage. Cotton Research Institute, P. Bag 765, Kadoma, Harare

Mbanje E. 1997. Analysis of factors to reduce draught requirement on animal-drawn tillage implements. Agritex, Institute of Agricultural Engineering, Zimbabwe.

MLAAR 1992. The Second Annual Report for Communal Area Farm Units, 1989/90 Crop Season. Harare, Zimbabwe: Economics and Markets Branch, Ministry of Lands, Agriculture and Rural Resettlement.

Mrema G.C. 1996. Agricultural development and the environment in sub-Saharan Africa: An engineer's perspective. Keynote paper presented at the First International Conference on Agricultural Engineering, the Environmental and Development organised by the Southern and Eastern Africa Society of Agricultural Engineers (SEASAE), Arusha, Tanzania, October 2-4, 1996.

Mwendera E.J. 1992. Analysis of the effect of tillage on soil water Conservation. Dissertations de Agricultura. Katholieke Universiteit te Laiven. Doctarvaatsproefschrift Nr.221 de Faculteit der Landbouwwetenschappen van de K.U. Leuven.

Nyagumbo, I, 1998. Experiences with conservation tillage practices in Southern and Eastern Africa: A Regional Perspective. Paper presented at Conservation Tillage for Sustainable Agriculture International Workshop, Harare, Zimbabwe 22-26 June 1998

Nyagumbo, I. 1997. Socio-cultural constraints to small-holder farming development projects in Zimbabwe: A review of experiences from farmer participatory research in conservation tillage. The Zimbabwe Science News 31, 2, 42-48, April/June 1997.

Riches C.R., S.J. Twomlow and H. Dhliwayo. 1997. Low-input weed management and conservation tillage in semi-arid Zimbabwe. Expl Agric. (1997), volume 33, pp. 173-187

Starkey P.H. A world-wide view of animal traction highlighting some key issues in eastern and southern Africa. In: Starkey P.H., E. Mwenya and Stares (Eds). 1994. Improving Animal Traction Technology. Proceedings of 1st Workshop of the Animal Traction Network for Eastern and Southern Africa (pp 66-81). Lusaka Zambia. February, 1992.

Vogel, H. 1993 Tillage effects on maize yield, rooting depth and soil water content on sandy soils in Zimbabwe. Field Crops Research, 33 (1993) 367-384 Elsevier Science Publishers B.V.,Amsterdam