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 (Scotney & 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 some 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 alkalinasation, 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

This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. A publication supported by French Cooperation, Namibia. For details of ATNESA and its resource publications, see **http://www.atnesa.org**

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 seedbed, 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 trush. 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 shallowly 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 1933 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.

This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. A publication supported by French Cooperation, Namibia. For details of ATNESA and its resource publications, see **http://www.atnesa.org**

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 (Mallett, 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. Mallett & 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 continuos 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 practises which maintain higher levels of surface residues retained more water.

This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. Publication supported by French Cooperation, Namibia.
For details of ATNESA and its resource publications, see **http://www.atnesa.org**

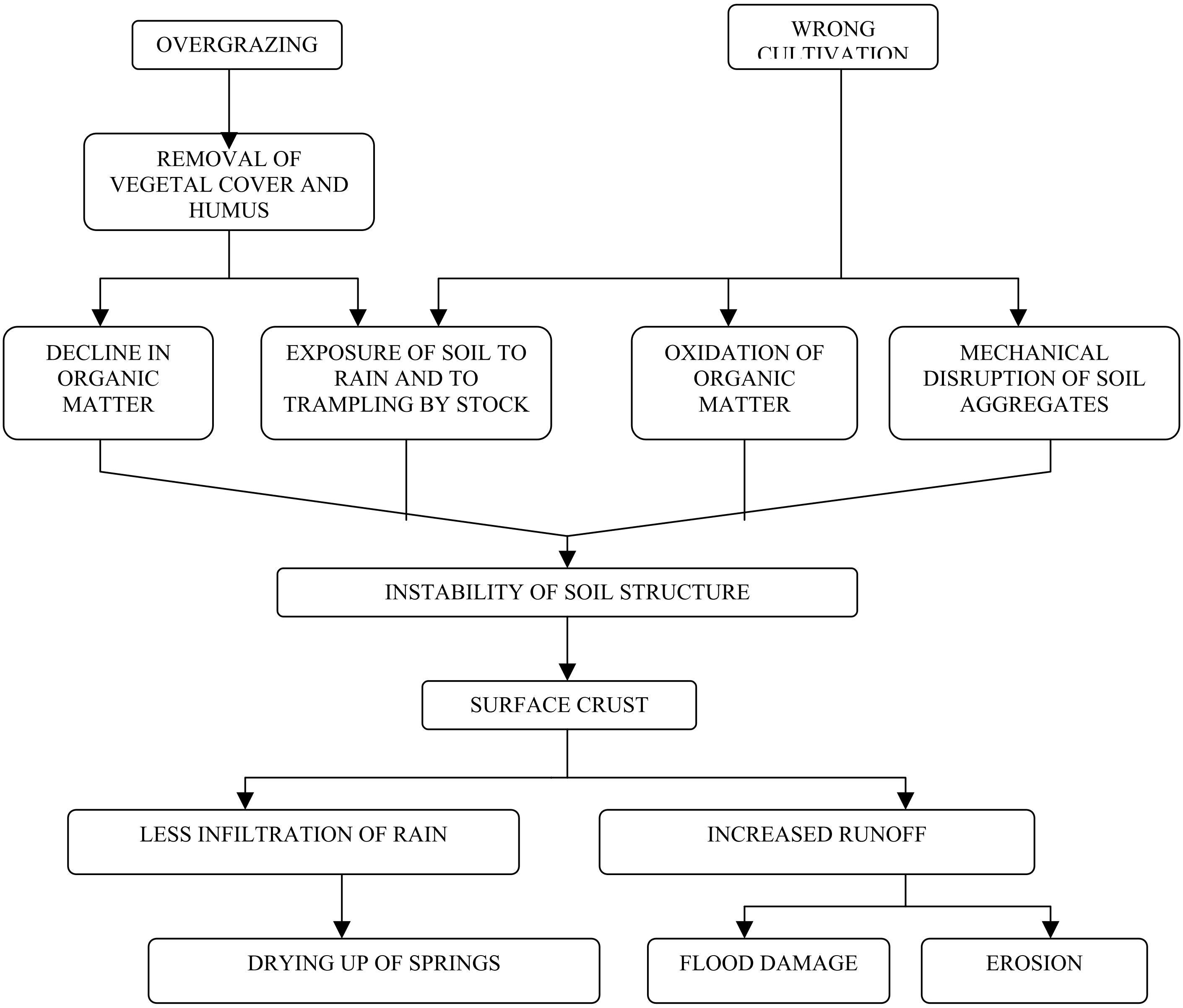

Figure 1: The consequences of inappropriate land use (Klintworth, 1957).

This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. A publication supported by French Cooperation, Namibia. For details of ATNESA and its resource publications, see **http://www.atnesa.org**

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.

This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. A publication supported by French Cooperation, Namibia. For details of ATNESA and its resource publications, see **http://www.atnesa.org**

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).

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

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.

This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. A publication supported by French Cooperation, Namibia. For details of ATNESA and its resource publications, see **http://www.atnesa.org**

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

	Maize grain yields (Kg/ha)				
Tillage	**Control**	**Lime**	**Paraplough**	**Lime & P/Plough**	**Mean**
No-Till	5129	7246	5868	7670	6478
Chisel	7455	8141	7967	7974	7884
Chisel & disc	7772	8318	7693	8239	8006
M/brd & disc	8918	9044	8854	8345	8790
Mean	7319	8187	7596	8057	

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:

i) the introduction, proliferation and protection of earthworms;
ii) the allelopathic and other effects of crops and weeds, growing or residues;
iii) crop rotations;
iv) cover crops;
v) surface acidification prevention and redemption;
vi) the identification and development of appropriate implements, both tractor and animal powered;
vii) the draft requirements for implement; soil type: moisture content permutations;
viii) 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?

This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. A publication supported by French Cooperation, Namibia. For details of ATNESA and its resource publications, see **http://www.atnesa.org**

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).

	Number of seasons		
Clay content Top 150 mm	**Grain crops**		**Silage crops**
	Dryland	**Irrigated**	
1 - 8%	1	1	1
9 - 16%	2	2	2
17 – 24%	4	3	2
25 – 32%	8	5	3
33 – 40%	16	8	5
>40%	32	11	7

This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. A publication supported by French Cooperation, Namibia. For details of ATNESA and its resource publications, see **http://www.atnesa.org**

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 Kwa Zulu-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

Agenbach, G.A. & Maree , P.C.J., 1989. The effect of tillage on soil carbon, nitrogen and oil strength of simulated surface crusts in two cropping systems for wheat (Triticum aestivum). Soil & Till Res.14:53-65.

Berry, W.A.J., 1998. Soils and crops towards 2000. No till field day. Soil Sci. Soc.S.Afr.Congress, Bergville.

Berry, W.A.J., Mallett, J.B. & Greenfield, P.L.. 1987. Water storage, soil temperatures and maize (Zea mays L.) growth for various tillage practices, S,Afr.,J. Plant Soil 4:26-30.

Berry, W.A.J., Mallett, J.B. & Johnston, M.A., 1985. Soil-Water conservation as affected by primary tillage practices, S.Afr.J.Plant Soil 2:21-26.

Critchley, W. & Netshikovehla, E., 1997. Perceptions of erosion and traditions of soil and water conservation amongst the Venda: A case study from Thohoyandou District. Unpublished paper.

Fowler, R.M., 1996. Conservation tillage techniques for small scale farmers in South Africa. Unpublished paper.

Goodland, R.J.A., 1995. South Africa: Environmental sustainability and the empowerment of women. In South African Issues. Int. Assoc. Impact Assessment. World Bank. 59pp.

Joubert, P.W.B., 1979. Wind erosion in lands. Pamphlet Maize F.1.2. In Farming in South Africa. Govt. Printer, Pretoria.

Klintworth, H., 1957. Consequences of wrong systems of land-use. Pp14-17. In Farming in South Africa. Govt. Printer, Pretoria.

Lang, P.M. & Mallett, J.B., 1982. The effects of various methods of primary tillage and seedbed preparation upon the maintenance of surface residues in a maize monoculture system. Crop Prod. 11:55-58.

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

Lang, P.M., Mallette, J.B. & Berry, W.A.J., 1986. The effect of tillage system on lodging in maize resulting from a severe rainstorm. S.Afr.J.Plant Soil 3:165-170.

Lawrance, K.F., Du Toit, W. & Berry, W.A.J., 1998. Tillage system effects on crop growth and production costs for continuous maize. (In the press).

Leppan, H.D. & Bosman, G.J., 1923. Field crops in South Africa. C.N.A. South Africa. 358pp.

Mallett, J.B. & De Jager, J.M., 1974. A mathematical model for determining maize yield probabilities on a Doveton Soil:I. Theory. Agroplantae 6:1-6).

Mallett, J.B. & Johnston M.A. 1983. The effect upon grain yield and soil physical characteristics of continuous direct maize on a Doveton soil. Crop Prod. 12:38-40.

 This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. A publication supported by French Cooperation, Namibia. For details of ATNESA and its resource publications, see **http://www.atnesa.org**

Mallett, J.B., Koch, C.D., Visser, P.A. & Botha A.J., 1985. Tillage-related soil compaction and its effect upon maize grain yields on a Viljoenskroon fine sand. S.Afr.J.Plant Soil 2-52-56.

Mallett, J.B., Lang, P.M. & Arathoon, A.J., 1987. Changes in a Doveton clay loam after 12 years of direct-drill maize production. S.Afr.J.Plant Soil 4:188-191.

Mundy, H.G., 1923. Sub-tropical agriculture in South Africa. Argus Printing & Publishing Rhodesia, 3220 pp.

Oettle, N., Fakir, S., Wentzel, W., Giddings, S. & Whiteside, M., 1998. Encouraging sustainable smallholder agriculture in South Africa. Env. & Dev. Consultancy Ltd., Stroud, U.K. 80pp.

Owens, H.I., 1984., Conservation tillage in maize production. Phamphlet Maize F.1.4. In Farming in South Africa. Govt. Printer, Pretoria.

Ross, J.C. 1957. Soil conservation and planned farming. Pp 73-93. In Farming in South Africa. Govt. Printer, Pretoria.

Russell, W.B. & Gibbs, M.D., 1995. Ten years of soil and water loss monitoring on the Cedara runoff plots. Cedara Report N/A/95/. KwaZulu-Natal Dept. of Agriculture.

Saunders, A.R., 1930. Maize in South Africa. C.N.A., South Africa. 284pp.

Scotney, D.M. & Van der Merwe, A.J., 1992. Irrigation: long-term viability of soil and water resources in South Africa. Proc.Sth.Afr.Irrig.Symp.50-60.

Thompson, G.D., 1965. The effect of trash conservation on soil moisture and the sugarcane crop in Natal. Proc.S.Afr.Sug.Technol.Assoc.39;143-156.

Thompson, W.R., 1936. Moisture and farming in South Africa. C.N.A. South Africa. 260pp.

Van Der Merwe, A.J. & De villiers, M.C. 1998. The agrobiological management of soil fertility: a challenge. S.A. country paper, Agrobiological Management of Soils and Cropping Systems International Workshop, Antsirable, Madagascar.

Van Reenen, R.J., 1935. Resisting drought. Govt. Printer, Pretoria.

 This paper is published in: Kaumbutho P G and Simalenga T E (eds), 1999. *Conservation tillage with animal traction.* A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Harare. Zimbabwe. 173p. A publication supported by French Cooperation, Namibia. For details of ATNESA and its resource publications, see **http://www.atnesa.org**