Tropical Ecology
Support Program (TÖB)

Soil Fertility

Pilotprojekt
Ressourcenschonende
Landnutzungssysteme

Conserving Natural Resources and Enhancing Food Security by Adopting No-tillage

An Assessment of the Potential for Soil-conserving Production systems in Various Agro-ecological Zones of Africa

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An Assessment of the Potential for Soil-conserving Production systems in Various Agro-ecological Zones of Africa

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Foreword

Food security and the preservation of natural resources count among the prime objectives of German development cooperation. The link between them are soil resources, the basis for plant and animal production. Despite their vital importance for a sustainable agricultural and rural development, soil resources are degrading worldwide at an alarming pace.

There are many reasons why soils are overexploited and even destroyed; why farmers and other land users do not undertake adequate and appropriate measures to protect soil resources and maintain soil productivity. One of them is poverty. Land users are apprehensive about the high investment costs necessary, either in form of labour or capital, which show their benefit only in the long run.

Because of this, real success stories of sustainable soil management in development projects are rare. Land users often abandon protective measures after the expiration of development projects and the accompanying assistance and encouragement offered by them. But there are success stories, and the outstanding one is the development and dissemination of no-tillage systems in Latin America. The development of these production systems commenced in the early seventies and today, twenty five years later, millions of farmers in Brazil, Argentina, and Paraguay practice no-tillage, thus preserving more than 10 million hectares of land.

This success story forms the background for the present study on the potential for adopting of no-tillage systems in sub-saharan Africa. It is well known that technologies cannot be simply transferred from one place to another and that the conditions in Africa are quite different to those in Latin America. Against this background the study here presented defines ecological and socio-economic conditions that are conducive to the introduction of no-tillage practices into African farming systems.

Quite a number of persons contributed to the study: African farmers, development experts and researchers. Particular thanks are due to T. Frick, B. Gutberlett, Prof. Dr. Köller, S. Lüttke-Notarp and J.B. Ntahondi, University of Hohenheim; Dr. J. Lamers, Aachen; R. Lycklama à Nijeholt, ICRISAT, Niamey; and Dr. K. G. Steiner, GTZ for their contributions.

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Summary

To help achieve the core objectives of development cooperation - poverty reduction, food security and sustainable natural resource management - measures to stabilise and increase soil productivity need to be taken without delay. However, this cannot be achieved using conventional tillage methods which promote soil degradation and thus reduce soil productivity.

One promising alternative to conventional tillage is the technique of no-tillage (or direct planting), in which soil tillage is dispensed with entirely. At the same time, this practice helps prevent soil erosion by wind and water because it always entails a protective surface mulch layer. It is thus possible to sustainably increase soil fertility, improve the water balance and, ultimately, raise soil productivity.

In the first instance, however, the economic appeal of no-tillage to farmers consists in the reduction of production costs, above all as a result of considerably lower expenditure on energy and labour. In the medium and long term, no-tillage leads to appreciable increases in yield accompanied by reductions in the need for agricultural inputs (fertilisers, pesticides).

As a consequence of the enrichment of surface soil organic matter and of the reduced energy requirements, no-tillage techniques exhibit a positive CO_2 balance. The soil becomes a CO_2 sink instead of a CO_2 source. No-tillage has a similarly positive effect on biodiversity. The variety and number of soil organisms is significantly increased.

The convincing advantages of no-tillage have led to an impressively broad dissemination of this technology in Latin America: almost 6 million hectares in Brazil and over 3 million hectares in Argentina are now being farmed using no-tillage practices. In Paraguay alone, the area under no-tillage was expanded from 20,000 ha (1992) to 230,000 ha (1996) with the assistance of a German Technical Cooperation project.

The success stories of no-tillage in Latin America call for further studies, especially concerning the conditions under which these systems might be successfully applied in zones of Africa. This calls for a precise knowledge of the agro-ecological, socio-economic and institutional conditions prevailing in those zones. This study was initiated to gather and analyse such information, and subsequently assess the potential and limiting factors for no-tillage in Africa.

The study established the following:

- Experience has been gained with soil-conserving production methods in almost all of the investigated regions, mostly with various forms of minimum tillage, and less so with no-tillage techniques. Research institutes, development projects and individual agricultural

enterprises are working on the development and dissemination of soil-conserving production systems, but generally work independently of each other. Many large farms (in south-eastern Africa) are already using soil-conserving production techniques on a significant proportion of their land or are working on developing appropriate techniques. In south-eastern Africa, where ploughing was intensively propagated over a prolonged period and is now widely used, government agricultural services are displaying a more reserved attitude to these innovations than in West Africa.

- Agro-ecological prerequisites: The most favourable conditions for the application of no-tillage practices obtain in the subhumid and humid regions (mean annual precipitation > 1000 mm). These include the areas of rainforest, the moist savannas of West Africa and part of the East African highlands. The criteria are an extended growing season (= 6 months) and, linked to that, high levels of biomass production. The widespread cultivation of root and tuber crops (yams, cassava, sweet potato) may have a limiting effect, however, as more or less intensive tillage is carried out when these crops are harvested.

  In the semiarid and arid regions (mean annual precipitation < 800 mm) of West and south-eastern Africa the main constraining factors are the relatively short growing season, the lower levels of biomass production and the competition for crop residues from livestock husbandry. In these regions it is therefore necessary to use second-best methods, such as minimum tillage. Some experience has already been gained with such methods, especially on large farms in southern Africa.
- Socio-economic prerequisites: No-tillage, as well as minimum tillage, are relatively new production methods. They impose greater demands on rural infrastructure, in particular with regard to access to inputs such as implements and agrochemicals (mineral fertilisers, herbicides), credits, information and sales outlets. Moreover, these techniques require increased management inputs; this applies particularly to weed control and ground cover (mulch management, crop residue management).
- Incentives for farms: The great interest in no-tillage practices, as well as in other forms of minimum tillage, is founded on a number of key advantages:
  - ⇒ Cost savings through a reduction in the amount of labour and energy required for soil cultivation

- ⇒ Reduced time requirements for ploughing and seedbed preparation, allowing sowing to be carried out at the appropriate time, leading to improved yield potential and reducing the planting risk
- ⇒ Protection of the soil and the build-up of soil organic matter result in increased soil productivity while at the same time reducing the need for mineral fertilisers
- ⇒ Improved infiltration of rainfall, better water storage capacity and a reduction in evaporation losses boost the efficiency of water-use, increase yields and reduce the risk of drought

<u>Approaches to promotion</u>: In all of the regions covered by the study there is a strong demand for information, both from other African countries and from Latin America. There are numerous approaches and initiatives geared to the development and promotion of no-tillage or minimum tillage techniques, but these remain uncoordinated and unharmonised. One important line of action that can be taken is to improve the exchange of information through networks, newsletters and training courses. Targeted use should be made of the many years of experience gained by Latin American institutions and practitioners. The promotion of cooperation between the private sector, implement manufacturers and the chemical industry is another point of departure. Cooperation is also needed in order to ensure that the experience gained by large commercial estates is also made accessible to

1 Introduction

The conservation of natural resources, food security and poverty alleviation are among the fundamental components of Agenda 21, the declaration agreed on at the UNCED conference in Rio de Janeiro in 1992. Pursuant to the provisions of Agenda 21, special priority should be assigned to these areas in the shaping of national development policies (UNCED, 1992). The Federal Republic of Germany was one of the first countries to declare its assent to the content of Agenda 21 and to ratify it in parliament.

The sustainable management of land resources plays a central role in the implementation of the demands because the limited amount of land reserves means that the only way to achieve an increase in food production is to increase the productivity of areas already in use. A critical factor in this context is the alarming degradation seen in soils, especially in the particularly erosion-sensitive tropical and subtropical regions. Around the world, some 55% of the land under cultivation is affected by erosion by water and wind (GLASOD, 1990). Annual soil losses from this amount to 15-150 t/ha, as a result of which an area of 5-7 million ha is irrevocably lost by agriculture every year (UNEP, 1992). In developing countries in particular, where rates of population growth are high, the declines in yield associated with soil degradation are increasingly leading to ominous shortages in food supply.

The scale of erosion on areas under agricultural use is substantially determined by the type and intensity of soil cultivation, as well as the naturally occurring climatic and soil conditions. Conventional tillage involves loosening and turning the upper layers of soil, and almost all of the crop residues (organic material) are removed after harvesting to facilitate tillage. The destruction of the soil structure associated with this process and the loss of the protective mulch layer are highly conducive to erosion. The rapid rate of soil organic matter decomposition promoted by soil cultivation and by the widespread practice of the burning of crop residues, together with the accelerated nutrient release (mineralisation) that this entails lead quickly to impoverishment of soils, especially in tropical climatic zones, and to drastic declines in yield even during the first years of soil use. Other disadvantages of conventional production methods are their high requirements of labour, time and energy (fuel). The effect of these factors in reducing yields and income is particularly apparent in regions with a short growing season.

As long ago as the beginning of this century, the problems outlined above led to intensive debate concerning the need for soil to be tilled, and at the same time to the development of

cropping systems in which cultivation of the soil is largely dispensed with (minimum tillage) or even relinquished altogether (no-tillage). According to the present state of knowledge, no-tillage is the most promising measure to reduce wind and water erosion, and thus can make an important contribution to the maintenance of soil fertility and to sustainable food production.
To date, at least trials with no-tillage have been carried out in almost all countries of the world and in almost all arable farming regions. The main areas where no-tillage has been applied on a broad scale are in North, Central and South America (Fig. 1).

Especially in the countries of Latin America, the rates of increase in the areas farmed using no-tillage practices can be interpreted as a successful return to traditional agricultural methods

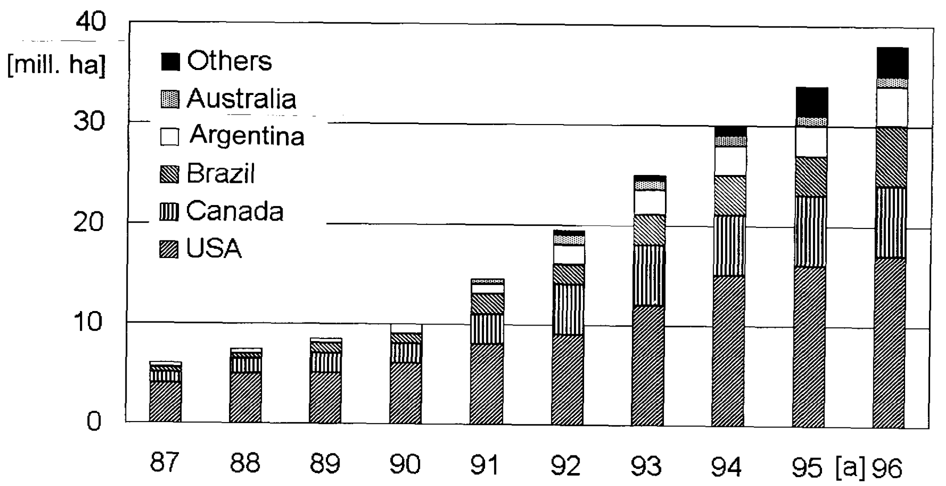

Figure 1: Increase in areas farmed using no-tillage practices around the world (HEBBLETHWAITE, 1997).

appropriate to the climatic and soil conditions of the tropics. This example also clearly illustrates the fact that technologies which make a significant contribution to minimising cost, effort and risk are often much more readily accepted than labour- and capital-intensive production methods geared to maximising yields.

2 Objectives and Procedure

The call to reverse the trend towards tillage practices which cause degradation in parts of Africa, on the basis of the experience gained in Latin America, seems an obvious one. However, a basic prerequisite for successful transfer of this experience to practical application in African agriculture is a knowledge of the prevailing agro-ecological, procedural, socio-economic and institutional conditions and of the effect these have on the technology, i.e. whether they are conducive or act as constraints. Only when this knowledge base has been established can practical approaches to the development of farm-specific and site-specific solutions be elaborated and decisions taken concerning possible promotional measures within the scope of development cooperation.

This was the rationale underpinning the objectives of this study:

The study aimed to appraise the potential for no-tillage techniques on the basis of the results from the available literature, from interviews with experts in various countries of Africa and from three field studies in selected countries of West and south-eastern Africa. Particular attention was to be paid to the identification of factors liable to have a constraining effect on the introduction of no-tillage practices.

The source of the information gathered can be pinpointed by referring to Fig. 2.

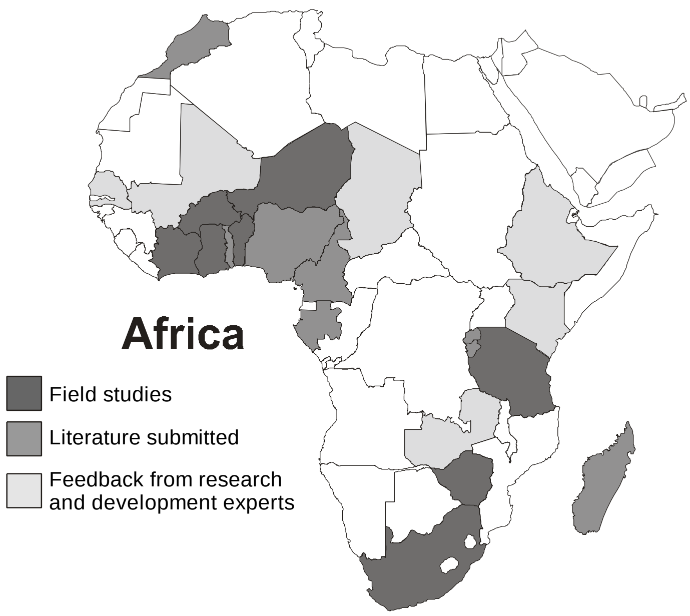

Figure 2: Areas examined within the study

The field studies focused mainly on two areas, West Africa and south-eastern Africa, where minimum tillage initiatives already exist which offer scope for further development. The countries visited belong either to semiarid, subhumid or humid climatic zones. This selection meant that it was possible to carry out a comparative evaluation of the potential for no-tillage under different agro-ecological and socio-economic conditions.

The map (see fig. 2) also pinpoints the countries from which publications relating to ongoing or completed research work are available. Countries are also marked from which experts in research and development cooperation supplied useful responses to the questions they had been sent.

Lists of the organisations and experts contacted are provided in Chapters 6 and 7.

3 Key Elements of No-tillage: Results from Evaluation of the Literature and Poll of Experts

The key elements of the no-tillage technique are explained in the following sections, taking into account the results of the survey of experts and of the evaluation of the literature. A full description of the technique would be beyond the scope of this study. For more detailed information the reader is therefore referred to the constantly growing body of general descriptions (LINKE, 1998; STEINER et al., 1997; KÖLLER, 1993; WIJEWARDENE et al., 1989; DERPSCH et al., 1988; YOUNG jr., 1982; ALLEN, 1981; KAHNT, 1976)

The charts and tables shown on the following pages make use where possible of the results of investigation from the regions covered by the study, wherever appropriate data was available. In several cases, however, it was necessary to fall back on findings from Latin America or the temperate climatic zones, the information content of which is greater on account of the longer experience in those regions.

Definition of terms

The absence of standardised, internationally accepted linguistic usage in the field of tillage and cultivation methods often leads to misunderstanding. Consequently, definitions of the terms to be used in the subsequent explanations are provided below.

- Conventional tillage:
  loosening and turning the soil with a hoe or plough (mould board or disc plough)

- Minimum tillage:
  superficial loosening of the soil (5 cm) or ripping of planting rows with a ripper tine (chisel plough)
- No-tillage or direct planting:
  no tillage of the soil at all, planting through a mulch layer with special planters
- Conservation Tillage.
  general term for any kind of reduced, ridge, minimum, or no-tillage techniques

Conservation tillage requires a certain degree of ground cover by crop residues. Consequently the Soil Conservation Service (USA) classifies tillage practices according to the degree (percentage) of ground cover (taken as cereal residues in units of mass) (CTIC, 1994).

	Groundcover		Crop residues
• **Conventional Tillage**			
Residues on the soil surface:	<15%	or	<560 kg/ha
• **Reduced Tillage**			
Residues on the soil surface:	15-30%	or	560-1120 kg/ha
• **Conservation Tillage**			
Residues on the soil surface:	>30%	or	>1120 kg/ha

This form of classification takes account of the two key features of the no-tillage technique:

- Complete renunciation of soil cultivation
- All-year-round soil cover with organic material (crop residues, intermediate crops, green manures)

Effects of no-tillage on the soil, water balance and climate

Erosion protection

The erosion-abating effects of no-tillage practices are described in numerous publications (for bibliographical references the reader is referred to the section on soil cover). By way of example, Table 1 shows the losses of soil and water as measured at the IITA in Ibadan in 1973.

Table 1: Soil loss and water loss in maize growing (precipitation 780 mm; first cropping period, 1973) (GREENLAND, 1975).

Gradient [%]	**Soil loss** [t/ha]		**Water loss (runoff)** [mm]	
	No-tillage	Conv. tillage	No-tillage	Conv. tillage
1	0.08	1.2	11.4	55.0
10	0.08	4.4	20.3	52.4
15	0.04	23.6	21.0	89.9

<u>Water balance</u>

Another important aspect of no-tillage, especially in the semiarid regions, is the improvement of the water-use efficiency. On the large farms of south-eastern Africa visited as part of the study, a higher priority is attributed to this factor than to the economic advantages of no-tillage.

Figs. 3 and 4 provide an indication of how different methods of soil cultivation affect the infiltration rate and the availability of water.

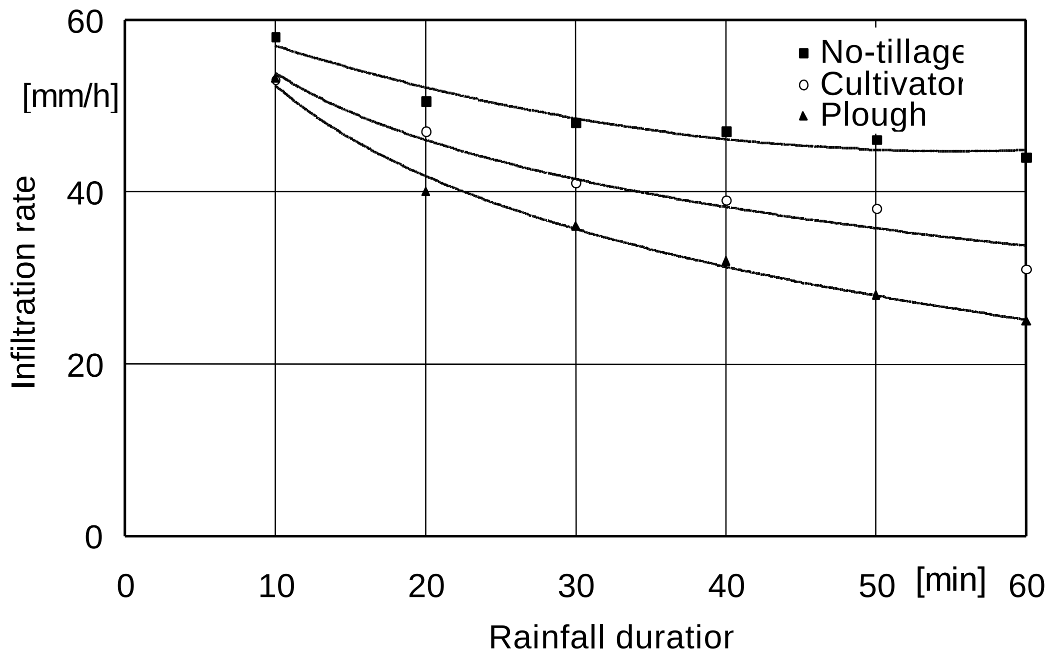

Figure 3: Infiltration rates in various tillage systems (DERPSCH et al., 1988)

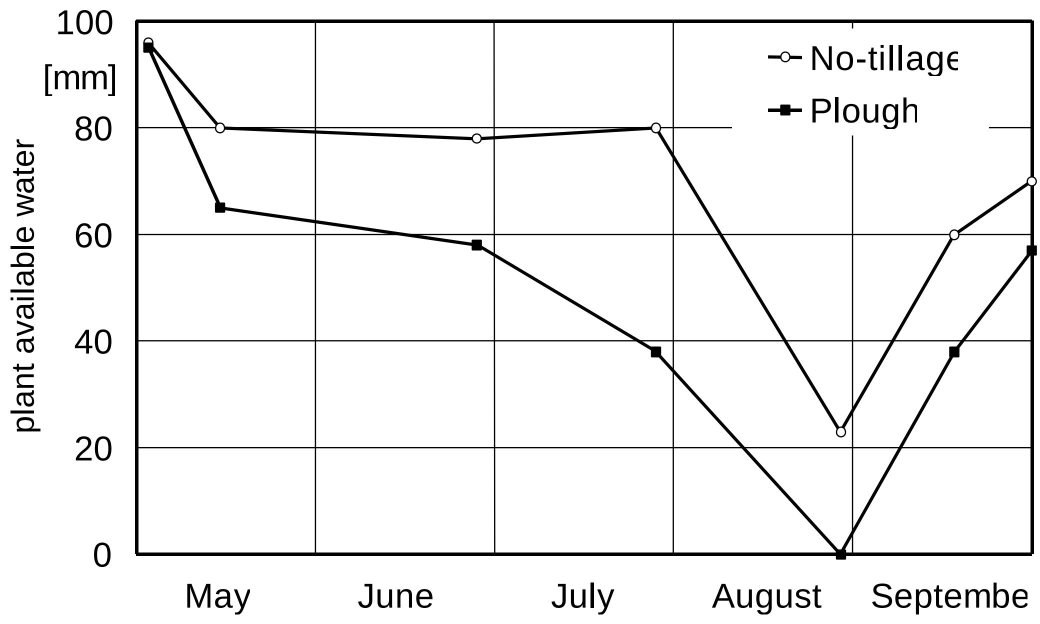

Figure 4: Comparison of plant-available water in no-tillage as opposed to ploughing (PHILIPS et al., 1984).

In addition to increasing the infiltration rates and the water storage capacity of the soil, no-tillage reduces soil water evaporation, something that occurs particularly when the soil is ploughed and harrowed. The fact that the ground is covered also protects against further evaporation losses. As a result, efficient use can be made of low and sporadic precipitation. Sowing can be carried out immediately once adequate precipitation has fallen and thus the growing season can be fully exploited (BERRY et al., 1989; BERRY et al., 1985).

Soil organic matter

In areas where no-tillage is practised, soil organic matter is built up as a result of changed cropping sequences and the fact that the crop residues are left on the field (Table 2). The results of a 6-year comparison of no-tillage and conventional tillage (plough and harrow) revealed that with no-tillage it was possible to increase the amount of organic matter in the soil by 7%, while the pH value fell by 0.3. In contrast, the effect of the ploughing option was a reduction in soil organic matter of 72% and in the pH value of 1.7 (LAL, 1984).

Table 2: Effects of tillage and nitrogen application rates on soil organic matter (THOMAS, 1993).

Fertiliser nitrogen/year	No-tillage	Conventional tillage
	% organic matter	
0	4.10	2.40
84	4.93	2.53
168	4.28	2.45
336	5.40	2.73

Soil organisms

In no-tillage systems, loosening of the soil and the creation of a large-pore system is taken care of by soil organisms. In conjunction with the mull effect of the organic residues, the soil life prevents the soil from becoming too heavily compacted, which would impede plant growth. The development of varied and rich soil fauna is favoured by the discontinuance of tillage, the increased supply of biomass and by the presence of a ground cover (**Tables 3** and **4**). The use of environmentally compatible herbicides such as glyphosate under no-tillage has less of a detrimental effect on soil organisms than does tillage when the seed bed is prepared in the conventional manner.

Table 3: Qualitative representation of the abundance and variety of soil organism groups at two locations used for arable farming and forestry in Paraguay (RÖMBKE et al., 1998).

	Conventional*		**No-tillage***		**Forest**	
	Abundance	**Diversity**	**Abundance**	**Diversity**	**Abundance**	**Diversity**
FRIESLAND						
Oligochaeta	++	**1**	+++	**2**	+++	**3**
Mesoarthropoda	+	**2**	+++	**2**	++	**2**
Araneida	+	**2**	++	**1**	++	**1**
Chilopoda	--	-	+	**1**	+++	**2**
Diplopoda	--	-	+	**1**	+++	**2**
Blattoeda	--	-	+	**1**	+	**1**
Coleoptera	+	**1**	+++	**2**	+	**1**
Diptera	+	**1**	++	**2**	++	**2**
Hemiptera	++	**1**	+++	**2**	+	**2**
Hymenoptera	++	**1**	++	**1**	+++	**3**
Isoptera	+	**1**	-	-	+++	**3**
OBLIGADO						
Oligochaeta	++	**1**	+++	**1**	+++	**3**
Mesoarthropoda	+	**1**	++	**1**	+++	**1**
Araneida	+	**1**	++	**2**	+++	**3**
Chilopoda	+	**1**	+++	**1**	+++	**2**
Diplopoda	+	**1**	+++	**2**	++	**3**
Blattoeda	-	-	-	-	-	-
Coleoptera	++	**1**	+++	**2**	++	**3**
Diptera	+	**1**	-	-	+	**1**
Hemiptera	+++	**2**	+	**1**	+	**1**
Hymenoptera	+	**1**	+	**2**	+++	**3**
Isoptera	+	**1**	+++	**1**	++	**1**

Abundance +: low ++: average +: high -: not present
Variety 1: low 2: average 3: high

Table 4: Soil fauna under no-tillage as compared with conventional and conservation tillage (DERPSCH et al., 1986).

	Conventional tillage	**Conservation tillage**	**No-tillage**
Earthworms/m² March 1979	**5.8**	**7.5**	**13.0**
Earthworms/m² November 1981	**3.2**	**5.2**	**27.6**
Anthropods/300 cm³			
Soya bean/wheat	**7.0**	**-**	**33.0**
Soya bean/cover crop	**23.0**	**-**	**192.0**

Climatic change - CO_2 balance

Areas under no-tillage exhibit a positive CO_2 balance overall. This is the result on the one hand of the reduced consumption of fossil fuels for soil cultivation, but much more so from the accumulation of soil organic matter. In no-tillage systems the soils are transformed from a CO_2 source to a CO_2 sink (Fig. 5).

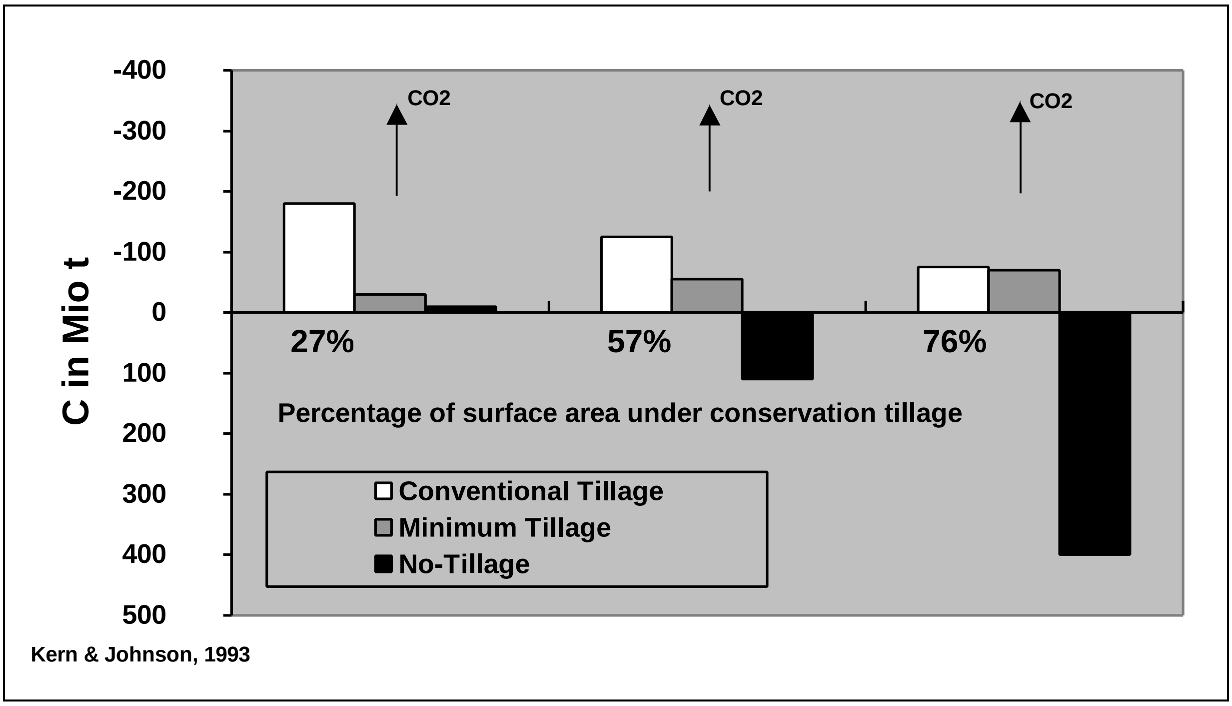

Figure. 5: Release of carbon as a function of surface area under different tillage systems for the total arable area of the USA up to the year 2020 (KERN et al., 1993).

According to estimates from the CTIC (1996), the global potential for reducing CO_2 emissions if conservation tillage techniques were to be adopted amounts to 16%.

Soil and climate requirements

In terms of their suitability for the application of no-tillage, the various climatic and vegetation zones can be characterised as follows (MANSHARD, 1968):

- Rainforest and moist savanna (> 1,000 mm, > 7 month growing season)

This zone is the one best suited to no-tillage practices. Production systems with cereals and legumes do best. The soils considered typical for the humid and subhumid zones are oxisols (ferralsols) and alfisols. The very high levels of precipitation in this climatic zone and the erosive effect of the precipitation are the specific factors which make no-till cultivation appropriate. Before the no-tillage method is introduced, however, appropriate solutions must be found to the problem of weeds and the question of mulch management (BOLFREY-ARKU, 1995; KOMBIOK et al., 1995; OSEI-BONSU, 1995; OSEI-BONSU et al., 1995).

- Dry savanna (750 - 1,000 mm, 3 ½ - 6 months growing season)

At least in those areas where the growing season is 5 - 6 months, it is possible to grow undersown crops or catchcrops to improve ground cover. Crop rotation sequences with enough cereal components, maize and sorghum, also produce sufficient biomass to provide soil cover. In order to ensure adequate soil protection, however, it is necessary to abandon the practice of burning plant residues including fallow vegetation (as well as to protect against uncontrolled fire), and to control the grazing of fields after harvesting. Where compacted horizons are to be found (plough soles, compaction of sandy soils), deep loosening (sub-soiling) must be carried out before no-tillage practices are introduced (BOLI et al., 1996; VALLÉE et al., 1996).

- Thorn-bush savanna (> 300 mm, 2 - 3 ½ months growing season)

Precipitation varies greatly from one year to the next. On the few occasions that rain falls, the rainfall is of high intensity. Only small amounts of biomass are produced, insufficient to protect the soil adequately, resulting in heavy soil loss caused by the intensive rainfall as well as by wind erosion during the dry periods. Uncontrolled grazing of crop residues leads to the soil being completely uncovered and therefore unprotected by the time the next rainy season begins. It is particularly this uneven distribution of the small amounts of precipitation that makes methods of cultivation geared to conservation necessary in order to efficiently use soil moisture. There are limiting factors, however: the sandy soils (compaction) and the lack of availability of mulching material (ALEM, 1993; LAL, 1993; ABIYO, 1987).

Cropping methods

No-tillage is a different cropping system and not merely a different seeding technique. No-tillage imposes considerably higher requirements in terms of the management of all agricultural activities. This applies in particular to selection of the appropriate crop rotation, to the approach used for weed control and fertilisation and to ways of dealing with crop residues and catch crops. The scheduling of the various activities also differs from that required by conventional methods. Some of the most important system components are therefore described in this section.

Crop rotation

No-tillage techniques require a pattern of crop rotation which produces sufficiently slowly decomposing biomass for the ground cover. Changing the crop rotation with due attention to the climatic and soil conditions on the one hand and to the market situation on the other is one of the biggest difficulties associated with the introduction of no-tillage. Only in exceptional cases can recommendations on crop rotation from Latin America be applied to African agriculture.

The crop rotations must contain a relatively large cereal component which allows a higher amount of biomass production and therefore produces additional mulch. Crop rotations should include green manure if at all possible after 3 to 4 cropping periods. This causes difficulties, especially in the dry savannas, where the short growing season in conjunction with well-defined consumption preferences allow only very limited diversification of the crop rotation pattern. On the Highveld in South Africa, for example, sorghum, millet or wheat is grown every year, occasionally also in mixed cropping with legumes such as pigeonpea, groundnut or cowpea. Under these conditions, however, no-tillage practices can easily become conducive to more frequent occurrence of plant diseases.

Soil cover

One problem associated with no-tillage is the achievement of all-year-round soil cover, especially in semiarid regions. Often the amount of biomass produced is not sufficient or the crop residues are taken away for alternative purposes (animal fodder, fuel, building material). In regions where traditional land rights conflict with controlled grazing of the fields it is virtually impossible to introduce the no-tillage system with any degree of success.

This has long been a topic of intensive research, as verified by the numerous bibliographical references:

(ASOEGWU, 1998; LAMERS et al., 1996; LAMERS et al., 1996; LEIHNER et al., 1996; ANANE-SAKYI, 1995; ASAFU-AGYEI, 1995; BOLFREY-ARKU, 1995; JUMAH et al., 1995; KOMBIOK et al., 1995; LAL, (1993); LAMERS et al., 1993; OLDREIVE, 1993; BERRY et al., 1989; BARYEH, 1988; BERRY et al., 1988; DERPSCH et al., 1988; ABIYO, 1987; DERPSCH et al., 1987; DERPSCH et al., 1986; LANG et al., 1984; MALLET, 1983; LAL, 1978; LAL, 1976; LAL, 1976; LAL, 1975).

Commensurate with the variety of site-specific conditions, work is being carried out on various different approaches. The investigations are not restricted merely to the identification of suitable in-situ ground cover production such as undersowing, green manuring or catchcroppin, but are also concerned with practices of external mulch production and mulch management (alley cropping, fence-rows, cut-and-carry).

It is particularly worth highlighting the positive experience that has been gained with ground cover plants such as *Mucuna ssp.*, *Pueraria phaseoloides* or *Callopogonium* which function at the same time as a biological weed control (see section on weed control and plant protection). Over and above this, leguminous ground cover plants can also be used to improve the nitrogen balance of the soil.

Weed control and plant protection

The primary purpose of soil cultivation - ploughing, harrowing, hoeing - is weed control. Consequently, where no such cultivation is carried out in no-tillage systems, other measures of direct and indirect weed control are required.

The use of herbicides is often the subject of controversial discussion and is wrongly seen in a negative light. It is usually overlooked that herbicides are also used in conventionally cultivated fields, often even at higher dosages and in less environmentally acceptable formulations. From an ecological point of view, the agents frequently used in no-tillage systems, glyphosate and sulphonyl carbamide, are comparatively safe. The agents are quickly decomposed in the soil. As this decomposition is brought about inter alia by biological activity in the soil, a quicker decline in the concentration of the active ingredients is usually observed in areas under no-tillage than in intensively cultivated soils with considerably sparser soil fauna (LINKE, 1998). After expiry of the proprietary rights, the prices for glyphosate have in many places fallen so far that it also makes economic sense to use it.

As indicated by the data given for the development of soil life in Tables 3 and 4, the use of glyphosate has less of a detrimental effect on soil fauna than tillage has.

With a varied crop rotation pattern and the use of *Mucuna* green fallow it is also possible to control problem weeds such as *Striga*, which are very difficult to control using conventional methods (Table 5).

Table 5: Biological control of Striga with mulching by various ground cover plants and no-tillage (CHARPENTIER, 1996).

Ground cover plants	**Maize plants affected by *Striga* [%]**		**Maize yields [t/ha]**	
	FO	**FV**	**FO**	**FV**
Puearia phaseoloides	2.8	1.4	2.54	3.42
Calopogonium mucunoides	3.6	1.9	2.26	3.05
Cassia rotundifolia	18.4	7.3	2.31	3.00
Macroptilium atropurpureum	98.0	93.0	1.25	1.45
Centrosema pubescens	100	98.0	1.12	1.41
Tephrosia pedicellata	100	100	0.91	1.17
Control (uncovered soil, untilled)	100	100	0.73	0.84

FO: 200 kg/ha NPK(10-18-18)
FV: 200 kg/ha NPK (10-18-18) at time of sowing + 100 kg/ha urea 40 days after sowing

No-tillage results in fewer weed seeds being stimulated to germinate. In conjunction with efficient weed control, and above all when seed formation is prevented, the weed population is therefore drastically reduced under no-tillage even after just a few years, as investigations in Brazil have shown (Fig. 6). (*insert Excel file fig6 or fig61*)

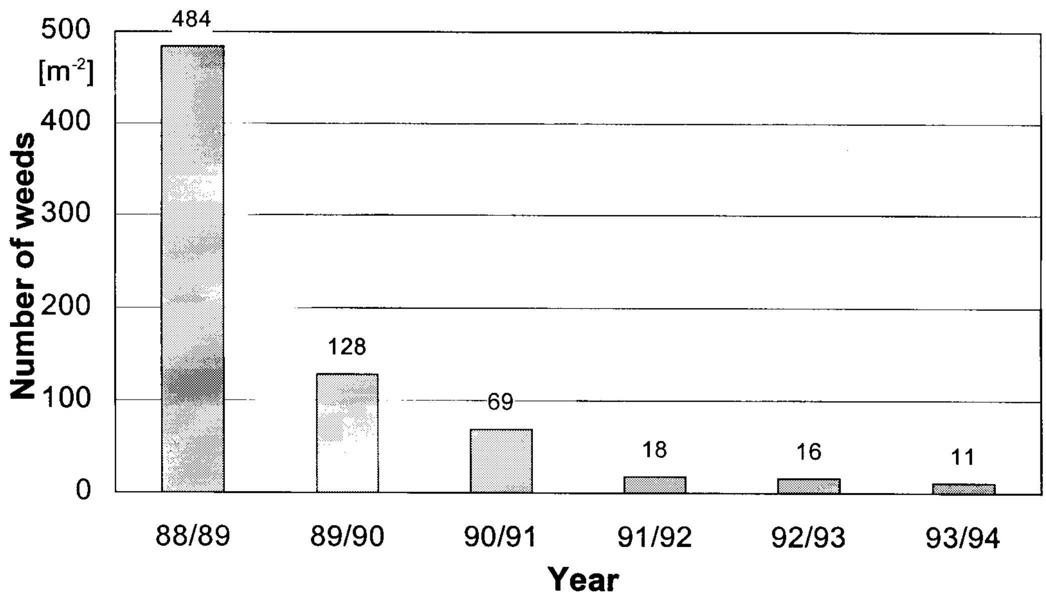

Figure 6: Decline in weeds under no-tillage as a result of reduced seed formation (SKORA NETO et al., 1996).

Crop rotations and permanent ground cover increase biodiversity, consequently also encouraging predators and thus reducing pest infestation. On well managed farms it is thus possible to dispense entirely with the use of pesticides.

Implements for no-tillage and minimum tillage

No-tillage can essentially be practised at all levels of mechanisation. Implements for seeding and weed control are available both for manual labour and for use with draught animals and tractors.

No-tillage implements must be suitable for use in unworked soil. At the same time, they must also enable the seeds to be planted through a mulch layer of greater or lesser density. Conventional sowing implements do not normally satisfy these requirements and are therefore not suitable for use in a no-tillage system.

Probably the best-known and best-proven direct-planting implement is the tool known as the Matraca (Fig. 7), which has now been in use for decades in South America for the manual seeding of large areas. The Matraca is available as a plain sowing device but also as a more sophisticated version with a fertilising option. The device has already been used in trials in various African countries, including for sowing cotton in Cameroon and in Côte d'Ivoire. The implement is simple to handle and can also be manufactured locally. In addition, various semi-automatic and fully automatic further developments of the device are available, which can also be operated with one hand. In the course of a comparative test at the IITA, one of the factors that made these implements impressive was their particularly good ergonomic features (LADEINDE et al., 1994).

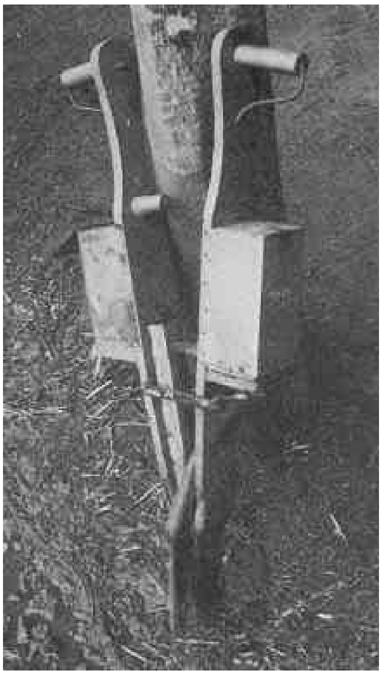

Figure 7: Matraca.

There are also a great variety of animal-drawn and tractor-drawn direct-planting implements produced in South America, and a small number of these are being exported to Africa. So far, however, little is known about the suitability of these implements for use under African conditions.

Although a tractor-drawn direct-planting device is already being manufactured in Zimbabwe, there is as yet no significant market for manually operated or animal-traction implements. The Rolling Injection Planter (RIP) (Fig. 8) developed at the IITA has achieved a certain dissemination in West Africa. It is available both in animal traction form and as a manually operated version. So far, however, the only experience of using the RIP has been gained on tilled and uncovered areas. Other implements of supraregional significance, such as the *'SuperEco'* in West Africa or the *'Pitman-drive planter'* produced by ZIMPLOW (Zimbabwe), are not suitable for use under no-tillage conditions.

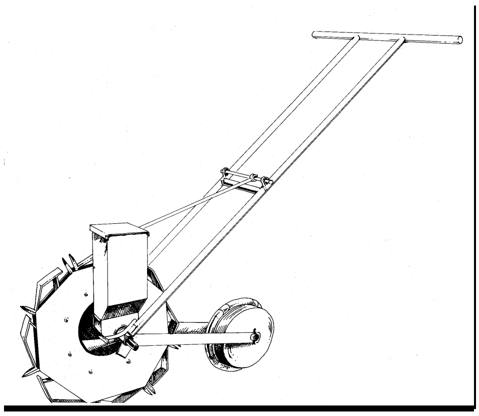

Figure 8: Rolling Injection Planter.

One particular device, the animal traction version of the *Bonner spade planting device*, has been successfully tested in Tanzania for maize growing. At its current stage of development, however, the high purchase costs are a constraint to widespread dissemination of the implement (SCHEIDTWEILER, 1996; SCHEIDTWEILER et al., 1996).

In Zambia and Zimbabwe a range of animal-traction implements have been developed for creating seed furrows in unworked soils. The developed implements are single-row chisel ploughs, known as rippers. The Palabana Animal Draft Power company (Lusaka) brought the Magoye ripper onto the market a few years ago. When an optional seed unit is attached, it can also be used for sowing (Fig. 9). In addition to the version for oxen traction, there are also lighter implements for use with donkeys. In contrast with the devices for conventional tillage, however, the demand for rippers is still very low.

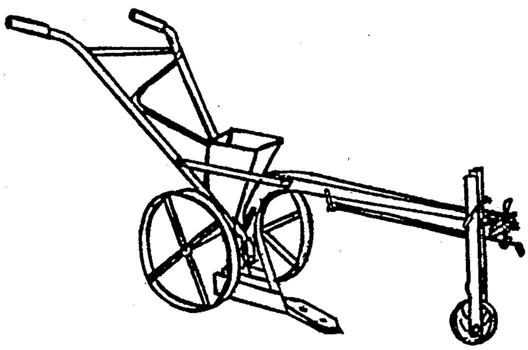

Figure 9: Magoye ripper with seed unit.

Economic efficiency

The attraction of the no-tillage technique lies not merely in conservation of the soil and the stabilisation of yields, which are long-term benefits, but also in the reduction of the amount of labour, time and energy expended on soil cultivation, which is immediately perceptible. A great number of cost calculations have been carried out, under various framework conditions. Both on motorised farms (Table 6) and on manually run farms (Table 7), no-tillage is characterised by considerably lower production costs compared with conventional methods while the level of yield remains the same or is actually higher (MATLON et al., 1984).

Table 6: Comparison of costs for conventional tillage and no-tillage in motorised operations in Zimbabwe (WINKFIELD, 1997).

	Consumed units/ha		Cost Z$/ha	
	Conventional tillage	No-tillage	Conventional tillage	No-tillage
Fuel [l/ha]				
Plough	36.0	0	396	0
Disk harrow	6.0	0	66	0
Roller	2.0	0	22	0
Plant protection (herbicide)	1.4	1.4	15	15
Subtotal	45.4	1.4	499	15
Weed control				
Gramoxon, presowing [l/ha]	4.0	4.0	380	380
Manual work [d/ha]	1.0	6.0	17	104
Dual [l/ha]	3.0	3.0	345	345
Atrazine [l/ha]	5.0	5.0	242	242
Gramoxon [l/ha], postemergence	4.0	4.0	380	380
Bladex [l/ha]	2.0	2.0	210	210
Subtotal			1574	1661
		TOTAL	**2073**	**1676**

Table 7: Comparison of working time for conventional tillage and no-tillage in manual work during two consecutive cropping periods in Fashola, Nigeria (WIJEWARDENE et al., 1989).

	First cropping period [man-hours/ha]		**Second cropping period [man-hours/ha]**	
	Conventional	**No-tillage**	**Conventional**	**No-tillage**
Field preparation				
Burning off	4	4		
Clearing	132		76	
Tillage	127		85	
Plant protection (herbicide)		8		6
Planting				
Planting (manual)	35		35	
Planting with Rolling Injection Planter (53,000 plants/ha)		13		9
Plant protection				
Weed control, manual	190	4	150	3
Weed control, pre-emergence herbicide		9		5
Insecticide		2		2
Fertilisation				
Fertiliser application, manual	25		25	
Fertiliser application with IITA band applicator	3	8		8
TOTAL	**516**	**48**	**371**	**33**

Apart from the reduction in production costs, the reduced time requirements for ploughing and seedbed preparation are crucially important. This applies in particular to the semiarid regions, where planting is possible only during very short periods, referred to as the planting window. Working without tillage means that it is possible to sow early and thus avoid yield losses caused by late sowing. As shown in Fig. 10, when a no-tillage system is used the peak labour loads for soil cultivation and weed hoeing are effectively evened out.

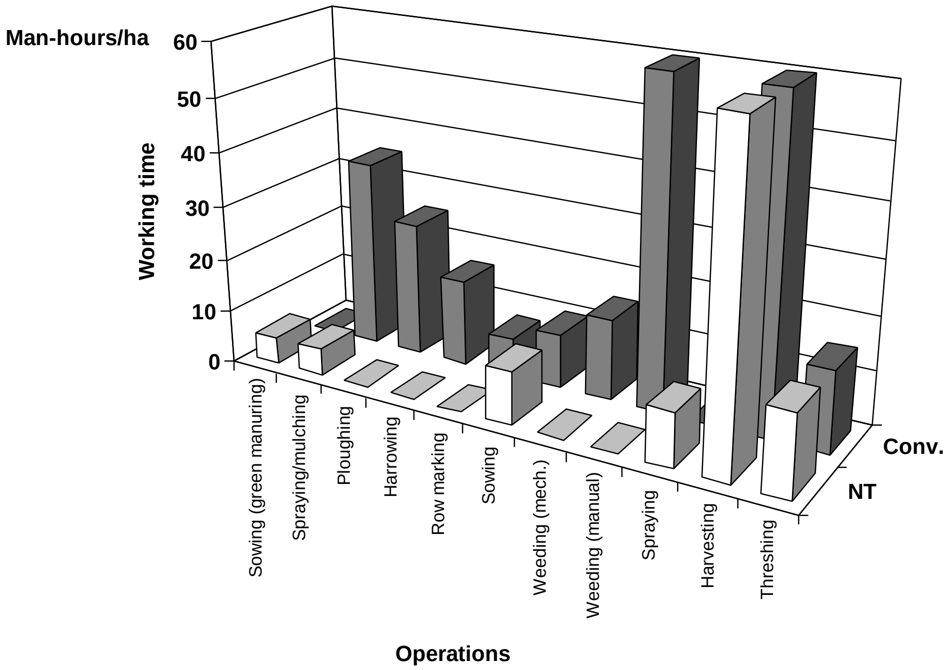

Figure 10: Reduction of peak labour loads through introduction of no-tillage techniques (SAMAHA et al., 1996).

The only peak labour load remaining is during the harvest period. As labour is not only in short supply at the times of the traditional peak labour loads but also expensive, this aspect is another economic advantage of no-tillage.

4 Field Studies

Neither the evaluation of the literature nor the interviews with experts gave sufficient information to allow full appraisal of the potential for no-tillage practices in Africa. The technical literature contains only little on the development work that has been carried out in recent years in many parts of Africa. It was therefore essential to obtain on-the-spot information from the various research institutions and development organisations.

4.1 Field Study in West Africa

A variety of climatic and vegetation zones are to be found within a limited area in West Africa, ranging from rainforest to thorn-bush savanna. The region is therefore eminently suitable for a field study. The countries visited were Benin, Burkina Faso, Côte d'Ivoire, Ghana and Niger.

4.1.1 Agro-ecological Framework Conditions

Annual precipitation in the area covered by the study ranges from less than 350 mm (dry boundary of the rain-fed farming zone) to over 2000 mm in the southern coastal regions. In the dry regions there is a high risk of drought due to the wide deviations from the long-term mean precipitation (+/- 30%), while the deviations in the humid tropics are less extreme (+/- 15%) and of less consequence on account of the high mean level. In the arid and semiarid northern regions the distribution of precipitation is unimodal with a short rainy season (4 - 4.5 months). In the humid and subhumid south, on the other hand, there are two rainy seasons (with different amounts of rainfall).

The high intensity of rainfall means that the soils are subject to a high risk of erosion throughout the investigated area.

A great variety of soil types are found in the region. Generally speaking it can be said that apart from their usually low humus and nutrient content the soils are characterised by poor water infiltration (even in sandy soils), soil crusting and hardening during dry periods (making cultivation difficult), low water-holding capacity and a high degree of chemical degradation. In subhumid and humid regions there is a risk of nutrient leaching.

A large number of different production systems have evolved in the region, commensurate with the broad variation in agro-ecological environmental conditions.

4.1.2 Socio-economic Framework Conditions

In the short time available it was not possible to obtain detailed information on agricultural and economic policy in each country. As a consequence of structural adjustment measures and deregulation, government agencies are in a constant state of change; a snapshot of the situation at any given time would therefore be of little informative value.

In the coastal states (Benin, Ghana, Côte d'Ivoire), infrastructures are relatively well developed. Access to agricultural supplies (fertilisers, pesticides), manufacturing facilities, semi-finished products (steel sections) and finished products is made easier by the presence of the seaports. Thanks to the existence of marketing companies, large commercial plantations and food-processing plants there is an infrastructure in place from which even small farms far from the economic centres are able to benefit.

In the inland states (Burkina Faso, Niger) such facilities are available only to a limited extent. Nevertheless, in these countries too, there are numerous examples of how the distribution of agricultural inputs (above all fertilisers and pesticides) operates efficiently in the private sector. However, the greater expenditure on transport and distribution together with additional administrative hurdles result in considerably higher prices for imported goods. In both countries agricultural implements are produced in manufacturing plants organised on a cooperative basis, but also in relatively small, well-equipped metalworking shops. On the whole, though, current demand for farming implements is low.

One precondition for the introduction of no-tillage is that land rights and rights of use should be secure for at least the medium term. In the region of this study, however, there are no standardised regulations in this regard. Often, traditional forms of land rights are applied, pursuant to which the land is assigned to farmers by the village headman ('chef de terre') for use over a certain period. The assigned periods of use and the level of fees to be paid can vary greatly from region to region. One factor constraining the introduction of no-tillage is the fact that the right of land use is often limited to the growing season. After the harvest the land is accessible to everyone for grazing or for the removal of crop residues. It is only after the emergence of the crop in the following year that access to the fields is restricted again and grazing is forbidden by the chef de terre under threat of punishment. In extreme cases apportioned land can also be withdrawn at short notice, for example if the user inserts a fallow period and does not produce any yields (subject to a levy) during that time.

Having said that, there also exists privately- or family-owned land to which, in principle, the owners have unrestricted access. These fields would, however, need to be protected with fences against uncontrolled grazing.

An increase in the number of smaller plots generated by true partition of inheritance (as a means of reducing risk) does not act as a constraint to no-tillage; it is more a problem for conventional cultivation where there are several operations required for tillage and planting.

The relationship between labour supply and demand during the seasonal peak periods (tillage, planting, weed control) is one of the factors determining the mode of agricultural production.

Generally speaking the demand for labour-saving production methods in West African agriculture is very high. There are various causes behind the shortage of labour encountered in all of the investigated regions, especially at the start of the season: for most of the year male family members look for work in the urban centres, particularly near to the coast ('exode rural'). The increasing school enrolment rate for children has also led to a reduction in the labour force in some regions of Ghana. At the same time the intensive production of commercial crops (tomatoes, onions) has also been introduced there, leading to a further deterioration in the situation. Farmers who can no longer afford to hire expensive wage labour are often faced with a labour shortage which threatens their livelihood.

In this connection, too, no-tillage offers a promising alternative to conventional labour-intensive practices. It must, however, be ensured that no new peak labour loads are created for weed control. This requires either access to herbicides or the provision of suitable mechanical aids. Merely redistributing the peak labour loads (dispensing with tillage and shifting the burden onto weed control) is highly unlikely to meet with farmers' acceptance.

4.1.3 Technical Framework Conditions

Soil preparation

Traditional forest fallow management methods are still encountered very frequently in the subhumid regions of West Africa. However, there is a marked tendency towards ever shorter fallow cycles (bush and grass fallow), as predominate in the north of the studied region. The widely familiar consequences are a rapid decline in soil fertility and the appearance of difficult-to-control root-stock weeds and grasses.

There is generally little tillage undertaken in the forest fallow systems. One reason is that the soil has a loose structure after clearing, and another that weed pressure is minimal after forest fallow. Furthermore, de-stumping of the fields, a prerequisite for mechanised tillage, would not be economically worthwhile.

When the fields are cleared after the harvest the degradation processes described above set in and weed infestation increases. After only a short time it is barely possible to farm the soil without prior cultivation.

The intensity of soil cultivation is dependent on the soil type, rainfall conditions and the requirements of the crops grown. Heavy soils in high-rainfall areas are in some cases very intensively cultivated. The farmers' main motives are to improve water infiltration and reduce weed pressure. In poorly drained soils ridging systems are created. In contrast, sandy soils as found in the semiarid regions are only tilled when cash crops are grown. The subsistence crops predominating in these regions (millet and sorghum) do not require particularly high-quality seed-beds.

Ground cover

In the northern part of the study region the amount of biomass produced is usually insufficient to build up the mulch layer needed to make a no-tillage system operable. The crop residues, already small in quantity, are either fed to livestock or used or sold as construction material or fuel. Significant reduction of erosion and/or increases in yield from the use of crop residues can only be expected from application rates of at least 1 - 1.5 t/ha (millet growing in southwest Niger) (MÜHLIG-VERSEN et al., 1996).

In the southern subhumid areas, on the other hand, so many plant remains (crop residues plus weeds) are produced as to impede soil preparation and sowing. As there is only little pastoral farming here, the plant residues are usually burnt at the start of the season. The reasons given to explain this action were: alleviation of the workload, destruction of weed seeds, prevention of the transmission of plant diseases, and facilitation of the hunting of small animals.

If plant remains are turned under instead of being burnt, farmers often complain of the lack of suitable seeding technology. This is also the case for direct planting though a layer of plant residues. Correct seed placement becomes difficult, resulting in poor emergence rates aggravated by losses through insect and rodent damage. Nevertheless, better yields were obtained in Ghana in fully covered experimental plots despite poorer field emergence.

Crop rotation

A range of different crop sequences are used in the investigated regions, in some cases with highly complex intercropping and mixed sequences. The type and intensity of intercropping is often determined by the current state of the main crop, and decisions are often taken spontaneously. The prime goals are always to secure yields and minimise risks.

In the semiarid regions usually only one harvest per year is possible, whereas in the humid and subhumid areas two harvests can be achieved. Often, however, the fields lie fallow during the short rainy season. Major crops are cereals. Maize, sorghum or millet.

The growing of is very important In the humid regions of West Africa root crops (yams, cocoyams, cassava) are commonly grown. This is an obstacle to no-tillage systems. An alternative could be strip cropping, where roots crops alternate with grain crops.

Fertilisation

The most important instrument in maintaining or regenerating soil fertility is fallow management. However, growing population pressure and increasing land shortages are forcing farmers to use ever shorter and therefore inefficient fallow cycles.

By way of compensation, the fields are fertilised with organic domestic wastes, animal manure or ash. In regions with much livestock farming, pasture contracts are concluded with the nomadic livestock breeders who for payment allow their herds to graze on the farmers' fields for specified times, and in return leave behind the manure. One particularly effective form that this takes is penning up animals overnight on particularly low-yield ground. The use of animal manure is only of significance in the semiarid regions, however, because animal husbandry plays only a subordinate role in the humid and subhumid regions of the south.

The use of mineral fertilisers is usually restricted to cash cropping (especially cotton and rice), and is far less widespread in subsistence crops. There is often a lack of knowledge as to how such fertilisers should be correctly applied. It is assumed, for example, that in Benin only some 15% of farmers use mineral fertilisers correctly and efficiently. Access to mineral fertilisers is by no means uniform throughout the West African region, nor is their acceptance or the degree of correct application, as the factors are largely dependent on the locally applicable economic and agricultural policy regulations. In Niger, for example, mineral fertiliser is very expensive. A large proportion of traded fertiliser therefore consists of illegal imports from subsidised batches from neighbouring Nigeria. In Côte d'Ivoire, on the other hand, a programme lasting several years was launched in which fertilisers were distributed free in order to familiarise farmers with the techniques of handling them and with their mode of action.

Weed control and plant protection

Weed control is causing the greatest labour peak in the West African region. Incomplete or untimely weeding causes great yield losses and in extreme cases total crop failure.

Weed pressure is particularly high in regions with short fallow periods. Although tillage before seeding gives the cultivated plants a head start in growth, usually one or two hoeings are necessary. In bush fallow systems weed infestation is far less of a problem than in areas with short grass fallow cycles.

Weeding is carried out manually or with animal traction implements. In a few cases trials have been carried out with herbicides, for example in Senegal and Ghana. In Ghana the use of herbicides became widespread in maize farming after an advertising campaign on television. In Niger and Benin, on the other hand, herbicides are very difficult to obtain. In the other countries they are available in principle but are too expensive for widespread application.

Indirect methods of weed control such as legume fallow are still at the development stage. In Benin, notable success has been achieved with the undersowing of maize with *Mucuna*. In the following season the maize was sown directly in the *Mucuna* mulch. Trials with *Callopogonium* and *Pueraria phaseoloides* also proceeded highly satisfactorily even though the plants produce only small amounts of mulch and the mulch matter dries out very quickly.

Planting devices

The use of implements and machines in agriculture also varies greatly throughout the region of the study. The use of tractors is limited almost entirely to large commercial farms. Occasionally marketing companies provide small farms with the necessary credits to procure small tractors (SOFITEX in Burkina Faso, CIDT in Côte d’Ivoire). The use of draught animals has become established to a limited extent in trypanosomiasis-free regions where livestock farming traditionally plays an important role, expecially in the semiarid area.

Planting devices developed specifically for no-tillage have been tested by the CIDT (Côte d’Ivoire) in collaboration with IDESSA. The devices were imported from Brazil:

- The planting stick with seed and/or fertiliser metering as widely used in Latin America (Matraca).
- A planting device for animal traction. Some of the drawbacks reported include its high total weight and the difficulty of manipulating the multi-row version. The device also requires two oxen to pull it.

4.1.4 Research and Development

Only a small number of national and international institutions and projects in West Africa are involved in matters relating to no-tillage (CIMMYT and the Crop Research Institute, Ghana; CIRAD, Côte d'Ivoire and Cameroon; International Program for Arid Land Crops (IPALAC); GTZ project: Promotion of Sustainable Farming Systems, Sunyani, Ghana). However, there are still no practically applicable concepts or strategies for the introduction of no-tillage.

In the humid zones of West Africa and in particular on sandy soils the soil is not tilled before sowing. Nevertheless, this practice is not considered no-tillage as defined above, because fallow vegetation and crop residues are burnt and the soil remains uncovered.

In the semiarid areas the quantity of biomass production is very low. Crop residues are mainly used as fodder, fuel and construction material. Because the amount of residual plant matter remaining on the field is too low, it is impossible to set up a mulch management system with controlled grazing, and therefore the most important prerequisite for the establishment of a sustainable no-tillage system is missing. Weed control is usually carried out with a hand hoe, and to a lesser extent with animal traction implements. Opportunities to use herbicides are currently extremely limited on account of the shortage or complete absence of extension services, poor availability, and most importantly because herbicides are usually very expensive.

4.1.5 Appraisal of the potential for no-tillage techniques in West Africa

- <u>Humid and subhumid regions</u>

In the humid and subhumid zones, on the other hand, conditions are conducive to no-tillage practices. In fact, in the forest fallow systems conditions are even ideal. The promotion of no-tillage could be launched immediately here by providing appropriate technical aids to assist with planting in covered soils and with weed control.

In the forest zone the potential is limited solely by the cultivation of yams and cassava, because earth mounds are created for this purpose. On sandy soils, however, cassava is also planted in flat ground. This is also compatible with no-tillage, as experience in Latin America has shown.

The potential for no-tillage diminishes as both precipitation and livestock breeding increase. In the moist savanna (Guinea savanna) conditions remain favourable, whereas in the dry savanna (Sudan savanna) they are considerably less so. An additional factor is that ridges are used for planting on savanna soils which are either shallow or display a tendency towards waterlogging, i.e. the soil is intensively prepared.

- Semiarid regions:

In the semiarid climatic regions (Sudan Savanna, Sahel) the potential for no-tillage practices is very limited, mainly because of the shortage of mulching material. The most important prerequisite would firstly be to enhance the scope for increasing biomass production, together with controlled grazing. In view of the close traditional interrelationships between arable farmers and pastoralists, however, the latter will be difficult to achieve. In these areas it is necessary to fall back on other second-best techniques of conserving the soil, such as minimum tillage. Traditional techniques such as *tassa* or *zai* provide a good basis for such an approach.

The soil type and crop rotation are important determinants, followed by a multitude of socio-economic factors which influence the extent to which no-tillage is accepted. In this context it is particularly worthy of mention that there is already a widespread acute shortage of labour for important field work (sowing, weed control) which could be conducive to the dissemination of no-tillage. By contrast, one constraining factor is the lack of infrastructure in many regions, such as access to markets for agricultural inputs and to products, credit and information.

In order to promote the dissemination of no-tillage practices in West Africa, existing activities should be coordinated and harmonised, experience exchanged and joint concepts and strategies devised, while paying due attention to distinctive region-specific features. This could be achieved through a regional network. A desire for greater exchange of information and experience was expressed by all those interviewed.

4.2 Field Study in South-Eastern Africa

The countries visited were Zimbabwe, South Africa and Tanzania. Throughout the region the term ‘conservation tillage’ is used to denote all soil-conserving cropping methods, i.e. no-tillage, minimum tillage and mulch planting as distinct from ploughing.

4.2.1 Agro-ecological Framework Conditions

The region covered by the study extends from the semiarid south of the region to its subhumid north with a bimodal rainy season. Rainfall is uncertain and unevenly distributed, and diminishes towards the south. Drought years are frequent. The entire region lies at a relatively high altitude, on average over 1,000m. On account of the lower mean temperatures caused by the altitude, organic matter is broken down more slowly.

The soils are generally of higher natural fertility than the soils of West Africa. However, soil degradation is far advanced at many locations. The main contributory factor to this has been ploughing with mould board ploughs or disk ploughs. Hard pans (plough soles) are widespread, and even occur where animal traction is used for mechanisation. The destruction of the soil structure by the disk plough and the accelerated degeneration of organic matter has resulted in the soils becoming more susceptible to erosion and in a reduction in their water storage capacity. As a consequence, the risk of drought stress has increased further. Soil degradation is the prime motive for large farms, in particular, to turn to minimum tillage. A further aspect is that minimum tillage enables farmers to make better use of the limited and unreliable rainfall by avoiding evaporation losses and by planting at the appropriate time.

Favourable conditions for no-tillage practices are to be found in the high-rainfall areas at the foot of Mt. Kilimanjaro and on the edge of the Rift Valley in Tanzania, as well as in Mozambique and the province of Kwazulu-Natal in South Africa, and in the irrigation farming areas of Zambia and Zimbabwe. In the other regions the amount of biomass produced is often too small to provide a groundcover due to the short growing season, which does not allow for growing green manures either as a relay or a catch crop.

The sandy soils found across southern Africa tend to become compacted. It is therefore recommended that sub-soiling be carried out at regular intervals, even when employing no-tillage.

4.2.2 Socio-economic Framework Conditions

The socio-economic framework conditions, including the agrarian structure, vary from country to country. In Zimbabwe and South Africa infrastructure is relatively well developed, whereas infrastructure in Tanzania is poor outside of the Kilimanjaro region. This applies not only to roads, but also to the supply of agricultural inputs and access to information. In contrast to West Africa, large commercial farms and small farms co-exist side by side, particularly in Zambia, Zimbabwe and South Africa. Small farms in some cases arrange for private contractors or larger farms to plough for them. Also grain harvesting, especially wheat, is often carried out by private contractors with combine harvesters. The most important export crop is cotton, as well as coffee and tea in some high-altitude areas.

There is an increasing shortage of labour in small-scale agriculture. Consequently there is a demand for methods which can help to reduce peak labour loads.

Deregulation and rapidly changing economic policy (import policy, taxation) in Tanzania are constraining investment in agriculture and therefore also the adoption of new production techniques such as no-tillage or minimum tillage.

Much as in West Africa, animal production in the dry savannas is one important sector competing for the crop residues. Here, too, the right of use is restricted by traditional land rights to the cropping period.

4.2.3 Technical Framework Conditions

Work on the development and dissemination of soil-conserving production systems is being undertaken in almost all countries of south-eastern Africa. On large farms minimum tillage and in some cases even no-tillage have been successfully practised for some considerable time. These techniques are employed in order to render labour-intensive erosion protection measures such as contour strips or ridges superfluous, to improve soil fertility and above all to increase water infiltration and water-use efficiency.

<u>Soil preparation</u>

Ploughing (mould board or disk plough) with the aid of draught animals, oxen or donkeys, or tractors is widespread throughout the region.

Minimum tillage is also increasingly being tested by small farms in the form of ripping - opening the seed rows with a chisel plough. The implements used come from Zambia. Ridging systems and tied-ridging systems have become established in only a few regions where there are either problems of waterlogging or an increased risk of drought because of the high labour input.

Throughout the region the agricultural services have in the past successfully propagated ploughing. The official agencies therefore still have a sceptical attitude to the development and introduction of new, soil-conserving methods. Even the many years of work on alternative techniques, such as that by the Contill project in Zimbabwe promoted by the GTZ, have had little effect in changing this stance. In commercial agriculture, on the other hand, conservation methods of tillage without ploughing are becoming ever more widespread (approximately 20% of farms in Zimbabwe).

Ground cover

As in the semiarid areas of West Africa, the application of no-tillage practices is limited by uncontrolled grazing of the fields after harvesting. This applies in particular to small farms. On large farms increasing efforts are being made to control grazing and to leave a minimum ground cover of roughly 30%. This has a positive effect on water infiltration and erosion protection.

The limited growing season and the low levels of residual soil moisture are insufficient to allow green manuring, whether as an undersowing or an intersowing. Especially in areas with less than 500 mm precipitation, any kind of post-harvest growth is suppressed in order to retain the residual moisture for the succeeding crop.

As the short-strawed varieties of wheat become increasingly widespread, the amount of available crop residues is reduced yet further. At the same time, weed pressure increases because the soil is not sufficiently shaded during the growing season.

Crop rotation

The major crops are maize and sorghum; wheat is only produced at high altitudes in Tanzania and in South Africa in rain-fed farming, whereas in Zambia and Zimbabwe it is produced with irrigation during the cool dry season. In addition, cotton is grown as an export crop. Cassava and other root crops are restricted to the high-altitude areas where there is more precipitation.

Pigeonpea (*Cajanus cajan*) is frequently grown between maize and sorghum. There is usually no rotation of crops; maize, in particular, is grown as a monoculture in many areas because of the good market price. The same is also true of wheat in the low-rainfall areas (< 300 mm) of the Highveld in South Africa.

Where there is no crop rotation, no-tillage can cause reinfection via the crop residues and therefore increase the infestation of wheat or maize with disease. This is why development work on no-tillage techniques was abandoned for several years in South Africa. With different planting devices, however, which push the straw and stubble off the seed row, it was possible to solve the problem without changing the cropping sequence.

Fertilisation

Fertilisation with animal manure and mineral fertilisers is widespread. Especially in Zimbabwe and South Africa, even small farms have relatively good access to mineral fertilisers. On mechanised farms employing minimum tillage, mineral fertiliser is deposited in the planting row in one pass. For small farms there are also fertiliser spreaders which can be mounted on a chisel plough. Implements such as these are not widely used, however. To some extent this is due to their price, but it is also due to their susceptibility to failure and the lack of accuracy of placement. So far no implements have become available with which mineral fertilisers can be incorporated into the soil through a layer of mulch. On irrigated farms this is no problem, but in rain-fed farming it can lead to root formation close to the surface and increase the risk of drought.

Weed control and plant protection

Herbicides are usually used for controlling weeds on commercial farms. Where no-tillage is practised, a good level of control is achieved with a pre-emergence application of glyphosate. Weeds emerging later can then be combated selectively and relatively quickly with the hoe or knapsack sprayer. On smallholdings where minimum tillage is practised, hoeing is carried out by hand between the rows or with a plough or duck-foot share. This work is made more difficult by plant residues, however. It is very important to continue with the weed control measures during the dry season in order to prevent seed formation and water loss. Especially in small-scale agriculture, however, it is very difficult to convince farmers of the need for these additional operations.

The application of pre-emergence herbicides is made more difficult by the crop residues. As a result there may be an uneven, inadequate effect. Glyphosates on the other hand only exhibit their effect on living plants, and are therefore not used until after the weeds begin to emerge following the first rains, or are used where drought-resistant grasses and root-stock weeds occur.

Much as in West Africa, the use of herbicides on small farms is limited by the prices of and poor access to herbicides, as well as by the poor availability of spraying apparatus and the problem of safe, effective use.

Implements for no-tillage and minimum tillage

On large farms no-tillage implements from Zimbabwe, Brazil, New Zealand or the USA are used. All of the implements have advantages and disadvantages. The implements from Zimbabwe (*Super Nova*) do not become choked so easily even on moist, heavy soils, thanks to the particular design of seed coulter. The implements from New Zealand use a completely different type of technology (*T-slot*), with even seed distribution and little tendency to become choked. For minimum tillage there are also suitable large implements available which allow simultaneous fertiliser application.

No-tillage implements for animal traction have so far only been manufactured on an experimental scale (for example at ARC in South Africa). Recently, single-row planting devices have been imported to South Africa, Mozambique and Angola from Brazil for trial purposes. In Zambia (PALABANA) and Zimbabwe (ZIMPLOW) chisel ploughs are mass-produced for minimum tillage. Fertiliser attachments and planter units can be mounted on these chisel ploughs. Normally the plough beam is taken and instead of the mould board a chisel plough tine is bolted on. The problem with most implements, however, is the high cost and the uneven seed distribution.

Various organisations are producing relatively light and therefore lower-cost implements on a trial basis (for example AGRITEX in Zimbabwe). The aim is to have these implements manufactured under licence by village blacksmiths. However, most of these implements are not sufficiently sturdy and are consequently often in need of repair. All in all there are only a small number of chisel ploughs in use at present, whereas sales of ploughs continue unabated.

Economic efficiency

The primary incentives for changing the methods of cultivation are improvement of soil fertility and more efficient water use, together with the associated higher yields and greater yield stability. At the same time it is possible to dispense with buffer strips or ridges to protect against erosion. This facilitates and speeds up field work. The high costs of no-tillage implements and herbicides can be offset by the reduction in fuel consumption and in maintenance costs for the tractors, as well as by the higher yields (WINKFIELD, 1997).

The shortage of labour in conjunction with the low level of labour productivity leads to a delay in planting on many farms, and therefore to yield losses that are in some cases considerable. Estimates in Zimbabwe suggest that potential increases in yield of as much as 100% could be achieved simply by sowing at the correct time. By making the transition to minimum tillage or no-tillage, the risk of crop failures due to drought could be reduced – an important consideration for small farms.

Access to information

Only large farms with appropriately trained expert personnel are in a position to obtain information for themselves about new developments, usually from the USA or New Zealand.

Conversely, medium-sized and small farms are faced with a marked information gap. The representatives of the institutions visited all expressed a desire to form a regional network in order to meet the demand for information through workshops, training courses and newsletters. Establishing a network of this type would considerably accelerate the development of soil-conserving production methods. A number of potential partners were identified, from both the public and the private sectors. Quite fundamental to the success of any such network would be the involvement of all actors, in other words including the private sector, such as agricultural machinery manufacturers, the chemical industry, lending institutions and the distributive trades.

4.2.4 Summary of the Information from South-Eastern Africa

Ploughing is widespread throughout south-eastern Africa, including on smallholdings, with wide-area soil devastation being the consequence. Ploughing not only increases the susceptibility of soils to erosion, but also reduces the soils' water storage capacity due to the accelerated degradation of organic matter and the formation of plough soles. This results in a constant decline in yields and an increase in drought-related crop failures.

Minimum tillage methods are already being practised with notable success within the region. No-tillage, on the other hand, is still at the experimental stage and is being practised only in isolated cases on commercial farms.

Constraining factors

The most important constraining factors in the region are:

- Lack of sufficient ground cover, caused by the low level of biomass production and grazing of crop residues
- Wide distribution of sandy soils with a tendency to compaction
- Lack of access to information, credits and agricultural inputs, especially on small farms
- Government extension services and agricultural research take a negative attitude to minimum tillage and no-tillage practises; ploughing continues to be recommended
- Shortage of information on and experience with alternative cultivation methods
- Increased demands on the farm management

Conducive factors

The main factors conducive to no-tillage in the region are:

- Presence of a relatively well developed infrastructure (availability of means of production, agricultural machinery production plant, information systems) especially in Zimbabwe and South Africa
- Widespread practice of animal traction
- Large farms assume a pioneering role
- Existence of farmers' unions and private contractors

4.2.5 Appraisal of the potential of no-tillage techniques in southeastern Africa

No-tillage systems have a high to medium potential only on the commercial wheat farms in the highlands of Tanzania and on commercial irrigated farms in Zambia and Zimbabwe. There is a medium potential for small-scale farms in the more humid parts of Mozambique and Kwazulu-Natal, South Africa.

In all other parts minimum-tillage or other forms of conservation tillage (e.g. tied ridging) have a good potential. However, the increased demand on the farm management together with other socio-economic constraining factors sets limits to this potential, especially for small-scale farming. The creation of a more conducive socio-economic environment, training and better access to information are required to disseminate conservation tillage practices to the smallholder sector

5 Conclusions and Final Recommendations

It can be concluded from the observations in the preceding sections that no-tillage ensures optimum soil protection and is therefore the system of choice; not only is it superior to conventional production methods, it is also superior to most other technologies with regard to protection of the soil. Having said that, no-tillage techniques are an appropriate option only for humid and subhumid areas, and for irrigated areas, where sufficient biomass can be produced to provide all-year-round ground cover.

The most important advantages of no-tillage practices are:

- Effective protection of the soil against erosion by water and wind
- Promotion of soil life
- Retardation of organic matter degradation and long-term enrichment
- Promotion of water infiltration and water storage
- Increased water-use efficiency
- Levelling-out of labour peaks for soil preparation and weeding
- Less labour and energy required for soil preparation
- Lower production costs
- Reduced time requirements for ploughing and seedbed preparation, thus allowing timely sowing
- No need for protective structures (ridges, walls, terraces) requiring maintenance
- No loss of land due to protective structures or contour strips

5.1 Conducive and Constraining Factors for No-tillage Practices

The evaluated literature, the interviews with the experts and the field studies in West and south-eastern Africa were used to identify both the conducive and the constraining ecological and socio-economic factors.

It is not always possible to distinguish between ecological and socio-economic factors since ecological factors, in other words the natural environment, in many ways also shape economic and social conditions.

5.1.1 Conducive Factors

Ecological

- High precipitation in conjunction with a long growing season
- Soils with > 20% clay content

Socio-economic

- Growing of cash crops (generation of income to purchase inputs)
- Demand for various agricultural products
- Well-developed infrastructure
- Shortage of labour, high wages

5.1.2 Constraining Factors

Ecological

- Low precipitation – low biomass production
- Short growing season
- Sandy soils with a tendency to compaction
- Soils at risk of waterlogging

In the semiarid and arid areas, the amount of biomass available for ground cover is the limiting factor for the introduction of no-tillage practices, given the inadequate level of biomass production over what is in any case only a limited period, and the competition from animal husbandry. The most obvious alternative option here is minimum tillage.

Socio-economic

- Strong demand for crop residues as forage for livestock
- Uncertain land use rights
- Poorly developed infrastructure (lack of access to markets and credit, absence of or poorly trained extension service)
- Distinct market preference for one crop (e.g. maize)
- High demand on the farm management

5.2 Appraisal of the Potential for No-tillage Practices

Ecological regions with high potential do not necessarily coincide with economic regions with high potential for no-tillage practices. An overall appraisal of the potential for no-tillage is therefore not a straightforward matter, since careful distinctions need to be made.

Nevertheless, this study does provide an initial assessment on the basis of which the need for action can be defined.

High-potential regions

These regions include the humid and sub-humid areas of West Africa and of the East African highlands (> 1,000 mm). They display the following characteristic features:

- Sufficient precipitation for diversified crop rotation,
- Growing of green manure possible,
- High biomass production as a prerequisite for good ground cover
- No significant large livestock husbandry or competition for crop residues

Generally speaking, areas with good market links offer positive potentials. Areas that are particularly suitable are those in the vicinity of large cities with labour shortages and/or high opportunity costs.

Soils with a tendency to waterlogging offer only limited potential. Areas with such soils include parts of the moist savanna of West Africa.

Medium-potential regions

In West Africa these regions include the southern Sudan savanna (800 - 1000 mm). No-tillage is possible here, subject to certain restrictions. The prerequisite is controlled grazing of the fields. Here, too, the potential is dependent on the level of infrastructure development, and is therefore higher in the vicinity of larger towns than in areas far from the markets.

In large areas of south-eastern Africa the sandy soils with a tendency to compaction require sub-soiling at certain intervals even when no-tillage techniques are used.

Large farms with access to credit, information and markets, and which are able to engage in controlled grazing management, can apply no-tillage methods successfully even in areas of average potential.

Low-potential regions

These include all regions with precipitation of less than 800 mm and a significant amount of livestock production. In these regions no-tillage is only appropriate on large commercial farms with irrigation.

The potential is also low in areas far from markets and in areas with poorly-developed infrastructure. Most of the farms there are small and lack capital, and have neither the inducement nor the opportunity to change their cropping system.

5.3 Minimum Tillage as an Alternative to No-tillage

In regions and under conditions where no-tillage is not possible due to insufficient ground cover, and therefore particularly in the dry savannas of West and south-eastern Africa, one obvious alternative (the second best choice) is minimum tillage.

The advantages of minimum tillage are comparable to those of no-tillage, although not so pronounced. Weeding is still performed mechanically, by hand or with the aid of animal traction.

- Reduced labour and energy is required for soil preparation
- Reduced time requirements for ploughing and seedbed preparation, thus allowing timely sowing
- Improved water-use efficiency
- Avoidance of plough soles (hard pans)
- Reduced soil erodibility

<u>Conducive and constraining factors:</u>

Essentially the same factors apply to minimum tillage as to no-tillage. The lack of infrastructure is a less significant constraining factor in many regions, however, as the agricultural input (implements, mineral fertilisers, herbicides) and information requirements are lower than for no-tillage techniques. The switch from ploughing to minimum tillage is a considerably smaller step than the direct transition to no-tillage.

Where there are already hard pans, for example plough soles, sub-soiling must first be carried out, as in the transition to no-tillage. This may act as a constraint due to the relatively high cost. A major constraint especially for small-scale farmers is the increased demand on the farm management. This applies primarily for weed control, the crucial issue of no- and minimum-tillage as well as on crop residue management.

Appraisal of potential:

In sub-Saharan Africa, the potential for minimum tillage is greater than that for no-tillage. Almost all ecological regions that are suitable for arable farming are suitable for minimum tillage. In much the same way as with no-tillage, the greatest potential is to be found in regions with a well-developed infrastructure. Areas which are a long way from the markets and with poor institutional access have little potential, just as they do for any other innovation.

The availability of animal traction and a certain level of mechanisation increase the probability of a transition from conventional tillage to minimum tillage. Although minimum tillage is possible using entirely manual labour, the greater effort involved in weed control reduces the benefits considerably. The greatest potential is found in the dry savannas (800 - 300 mm), and within those regions in areas where ploughing is widespread. The growing of commercial crops and the presence of promoting companies and marketing systems, such as in cotton production, also help create a conducive framework.

Conditions in south-eastern Africa are highly favourable since experiences with minimum tillage are already an hand there. This applies particularly to Zimbabwe and Zambia. In both of these countries there are also manufacturers of implements for minimum tillage.

5.4 Promotional Measures

General promotional measures:

All measures designed to improve rural infrastructure, and in particular to improve access to markets, credits and information, as well as to secure land-use rights, also help create a framework more conducive to the introduction of no-tillage.

Special promotional measures:

- Promoting the exchange of information:
  - Better networking of the many individual initiatives in research, development and application, particularly in West Africa and in south-eastern Africa
  - Access to information from Latin America, especially from the fields of science, technical procedures and implement technology
- Preparation of extension materials
- Training courses for extension staff
- Strengthening of South-South cooperation (Africa - Latin America)
  - Fact-finding missions by researchers, extension specialists and practitioners
  - Translation of literature and videos from Portuguese/Spanish into English and, where appropriate, French
- Cooperation with the private sector
  - Adaptation of implements to local conditions
  - Promotion of joint-ventures between manufacturing enterprises

6 List of Contacted and/or Visited Organisations

Benin

CBRST	Centre Béninois de la Recherche Scientifique et Technique, Cotonou
CENAP	Centre National d'Agro-Pédologie, Cotonou
DA	Direction d'Agriculture, Cotonou
FSA	Faculté des Sciences Agronomiques, Cotonou
INRAB	Institut des Rechercher Agronomiques du Bénin, Cotonou
IITA	International Institute for Tropical Agriculture, Cotonou

Burkina Faso

C.N.E.A.	Centre National d'Equipment Agricole, Bobo-Dioulasso
FAO	Programme Spécial pour la Securité Alimentaire, Bobo-Dioulasso
GERN	Projét Gestion des Ressources Naturelles, Bobo-Dioulasso
SEP	Service Etudes et Planification, Bobo-Dioulasso
SPA	Service Provincial d'Agriculture d'Houndé, Bobo-Dioulasso
SOFITEX	Societé des Fibres et Textiles, Bobo-Dioulasso

Côte d'Ivoire

BNEDT	Bureau National d'Etudes Techniques et de Développement, Abidjan
CIDT	Compagnie Ivoirienne du Développement du Textile, Bouaké
IDESSA	Institut des Savannes, Sakassou
MINAGRA	Ministère de l'Agriculture et des Ressources Animales, Abidjan
UC	Université de Cocody, Abidjan
WARDA	West African Rice Development Association, Accra

Germany

DED	Deutscher Entwicklungsdienst
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn
Universität Hohenheim	Institut für Agrartechnik in den Tropen und Subtropen, Stuttgart

Ghana

CRI	Crops Research Institute, Kumasi
MOFA	Ministry of Food and Agriculture, Accra
SRI	Soil Research Institute, Kumasi
UG	University of Ghana, Accra
UST	University of Science and Technology, Kumasi

Niger

ICRISAT	International Crops Research Institute for the Semi-arid Tropics, Sahelian Center, Niamey
GTZ/PASP	Projét de Protection Integrée des Ressources Agro-Sylvo-Pastorales, Niamey
INRAN	Institut des Recherches Agronomiques du Niger, Niamey
MAG/EL	Ministère de l'Agriculture et de l'Elevage, Niamey

Nigeria

IITA	International Institute for Tropical Agriculture, Ibadan

South Africa

ARC	Agricultural Research Council, Pretoria (with Makahinti Research Station, Grain Crops Institute, Potchefstroom and Small Grains Institute, Bethlehem)
ART	Agricultural Research Trust

Tanzania

	Himo Project, Himo
LAMP	Land Management Project, Babati
	Namuai Farm, West Kilimanjaro
SCAPA	Soil Conservation and Agroforestry Programme, Arusha
SECAP	Soil Erosion Control and Agroforestry Project, Lushoto
SARI	Selian Agricultural Research Institute, Arusha
SIDA/ORGUT	Swedish International Development Agency/Orgut Consulting
TFA/AMM	Tanzanian Farmers Association/Agricultural Mechanisation Management
TFSC	Tanzanian Farm Service Center

Zimbabwe

	Africa Agri Services
ACFD	African Center for Fertilizer Development, Harare
AGRITEX/IAE	Department of Agricultural Technical and Extension Services, Institute of Agricultural Engineering, Borrowdale
ART	Agricultural Research Trust, Harare
FAO-FARMESA	Farm Level Applied Research Methods in Eastern and Southern Africa
	Hinton Estate, Bindura
ICRISAT	International Crops Research Institute for the Semi-arid Tropics, Bulawayo
ICFU	Indigenious Commercial Farmers Union, Harare
ZIMPLOW	Zimplow Implement Factory, Bulawayo

7 List of Consulted Experts

Benin

G. Agbahungba	INRAB, Cotonou
C.S. Ahouansou	DA, Porto Novo
N. Aho	CBRST, Cotonou
D. Aly	DA, Porto Novo
E. Amoussou	Farmer, Mowodani
C. Chodaton	MDR, Cotonou
M. Egbebi	Farmer, Ayekou
A.C. Eteka	IITA, Cotonou
T. Gnonlonfoun	Farmer, Sodji
K. Issaka	FSA, Cotonou
A. Lagbadohossou	MDR, Cotonou
H. Lankpeko	INRAB, Cotonou
C. Modemoun	MDR, Cotonou
J. Ogourole	Farmer, Mowodani
P. Onibon	GERAM, Bohicon
J.L. Sevin	PPAB, Cotonou
F. de Wild	SNV

Burkina Faso

S. André	SEP, Bobo-Dioulasso
D. Binart	FAO, Bobo-Dioulasso
J. Fechter	GERN, Bobo-Dioulasso
D. Konaté	SOFITEX, Bobo-Dioulasso
C. Traore	SPA, Bobo-Dioulasso
L. Yé	GERN, Bobo-Dioulasso

Côte d'Ivoire

A. Assa	UC, Abidjan
T.J. Dalton	WARDA, Bouaké
Doumbia	IDESSA, Bouaké
N. van de Giesen	WARDA, Bouaké
N. Hanssens	WARDA, Bouaké
D.E. Johnson	WARDA, Bouaké
M.P. Jones	WARDA, Bouaké
N. Kouamé	BNETD, Abidjan
B.N. Singh	WARDA, Bouaké
J. Stessens	IDESSA, Bouaké

Ghana

S. Abenney-Mickson	UG, Accra
E. Amankwaa	Sunyani
C. Amoatey	UG, Accra
J. Anthofer	DED/GTZ, Sunyani
J.J. Ayisi	MoFA, Sunyani
J.A. Baah	CSD/MoFA, Accra
K. Boa	CRI, Kumasi
G. Bolfrey-Arku	CRI, Kumasi
I.K. Buadee	SRI, Kumasi
E.A. Canacoo	UG, Accra
C.P.K. Dugbena	SRI, Kumasi
C. Henckes	GTZ, Sunyani
H. Loos	GTZ, Sunyani
A.A. Mahama	UG, Accra
R. Mensah	Student UG, Sunyani
N. Menu	Farmer, Sunyani
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I.K. Ofori	UG, Accra
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E. Owusu	SRI, Kumasi
S.A. Peprah	SRI, Kumasi

Kenya

S. Collins	MONSANTO, Nairobi

Niger

I.K. Abdourhamane	INRAN, Niamey
H. Adamou	INRAN, Niamey
A. Basso	INRAN, Niamey
C. Bielders	ICRISAT, Niamey
I.S. Coulibaly	GTZ-PASP, Niamey
S. Hama	INRAN, Niamey
H. Jörg	GTZ-PASP, Niamey
A. Tassiou	INRAN, Niamey
H. Toukou	GTZ-PASP, Niamey

Nigeria

G. Kirchhoff	IITA, Ibadan

South Africa

A. de Beer	ARC, Potchefstrom
B. Berry	ARC, Cedara
J. Findley	MONSANTO
R. Fowler	ARC, Cedara
J. Grobbelaar	ARC, Pretoria

D. Hanekom	ARC, Pretoria
F. Hugo	ARC, Pretoria
L. Korentajer	ARC, Pretoria
A.A. Louw	ARC, Pretoria
D. van der Merwe	ARC, Pretoria
W. du Toit	ARC, Potchefstrom
J. Tolmay	ARC, Bethlehem
A.A. Wanders	IMAG-DLO (Wageningen)

Tanzania

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R. Blenthem	Namuai Farm, Arusha
E. Brunner	AMM, Arusha
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G. Hoops	Arusha
L.-O. Johnson	AoA, Dar es Salaam
M. Lieke	TSFC, Arusha
W. Mariki	SARI, Arusha
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E. Oosterhuis	Namuai Farm, Arusha

Zambia

P. Aagard	Conservation Farming Unit
D. Gibson	Conservation Farming Unit
P. Stevens	SAMeP, Lusaka

Zimbabwe

M. Cassim	ZIMPLOW, Bulawayo
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J. Dixon	FAO - FARMESA
C. Dunlop	Africa Agri Services, Harare
H. Elwell	Consultant, Harare
T. Lourenco	ZIMPLOW, Bulawayo
G.M. Heinrich	ICRISAT, Bulawayo
G. Meikle	ART, Harare
S.C. Muchena	ACFD, Harare
A.J. Norton	Hinton Estate, Bindura
I. Nyagumbo	AGRITEX, Harare
B.H. Oldrieve	Hinton Estate, Bindura
D. Rohrbach	ICRISAT, Bulawayo
S.L. Dahl	FAO - FARMESA
R. Winkfield	ART, Harare

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Im Auftrag des Bundesministeriums für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ)