Alternative cropping practices in Ethiopia: A literature review

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Working Paper 2002-05

Policies for Sustainable Land Management in the Ethiopian Highlands

IFPRI-WUR project *Policies for Sustainable Land management in the Ethiopian Highlands*

Land degradation problems--including soil nutrient depletion, soil erosion, deforestation and other concerns--are severe in the Ethiopian highlands. These problems are contributing to low and declining agricultural productivity, poverty and food insecurity. The proximate causes of these problems are relatively well known. Underlying these proximate causes are many more fundamental causes. These more fundamental causes are affected by many aspects of government policy. Assessing the impact of different causal factors and identifying effective policy strategies to improve land management is a critical research challenge that has not yet been solved. In part, this is due to the complexity of factors influencing the problem. "One-size-fits-all" policy or program approaches are unlikely to be broadly successful. There is thus a general need and desire for more effective targeting of policy strategies towards specific regions and groups, although this depends on improved information about the potential impacts of alternative strategies.

The long-term goal, immediate purpose and specific objectives of the project are as follows:

Long-Term Goal:
To contribute to improved land management in the Ethiopian highlands, in order to increase agricultural productivity, reduce poverty and ensure sustainable use of natural resources.

Immediate Purpose:
To help policy makers in Ethiopia identify and assess strategies, including technology development policies, to achieve that goal.

Specific Objectives:

- To identify the key factors influencing land management in the Ethiopian highlands and their implications for agricultural productivity, sustainability and poverty;
- To identify and assess policy, institutional and technological strategies to promote more productive, sustainable, and poverty reducing land management;
- To strengthen the capacity of collaborators in the Ethiopian highlands to develop and implement such strategies, based upon policy research; and
- To increase awareness of the underlying causes of land degradation problems in the Ethiopian highlands and promising strategies for solving the problems.

The research takes place in Tigray, Northern Ethiopia. The project started in January 2001 and will continue until December 2003.

The WUR component of the project is funded by the Dutch Ministry of Foreign Affairs, Cultural Cooperation, Education and Research Department, Research and Communication Division (WW132171), Wageningen University (RESPONSE programme) and the Netherlands Ministry of Agriculture, Nature Management and Fisheries (North-South Programme). Their support is gratefully acknowledged.

More information can be found at the project web site:
www.sls.wau.nl/oe/pimea

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PIMEA WORKING PAPER 2002-05

Alternative cropping practices in Ethiopia: A literature review

G.W. Meijerink

Wageningen, December 2002

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Introduction

In many parts of the world, land degradation is affecting the livelihoods of farmers. Land degradation problems are quite severe in many parts of the Tigray highlands in Ethiopia. Soils are poor and erosion is often grave (see table 1). High rain erosivity is an important factor of soil erosion in the Highlands (Nyssen, 2001). To counter these problems, many organisation such as NGOs and research institutes, as well as innovative farmers are coming up with alternative practices. In some areas there are well-developed indigenous conservation practices. Indigenous conservation knowledge appears to have been developed especially in those areas where the natural resources base in under severe pressure from local communities, the ecosystems are fragile and there is a long history of adaptation to adverse conditions (Krüger et al., 1996).

Alternative technologies for sustainable land management all refer to the use of land resources such as soils, water, animals and plants for the production of goods to meet changing human needs, while assuring the long-term productive potential of these resources, and the maintenance of their environmental functions[1]. These include indigenous technologies that have been developed in a particular area, but may well be suited to apply in another. The term is restricted to technologies that improve soil and water conservation, although some technologies may have more than one purpose.

Table 1 Estimated rates of soil loss by sheet and rill erosion on slopes, for various land uses in Ethiopia

Land Cover	Area (%)	Soil loss (t ha^{-1} y^{-1})
Grazing	47	5
Uncultivable	19	5
Cropland	13	42
Woodland/bushland	8	5
Swampy land	4	0
Former cropland	4	70
Forests	4	1
Perennial crops	2	8
Total for the Highlands	100	12

Source: Hurni, 1990; Bojö & Casells, 1995

Several alternative cropping practices have been introduced in Tigray in the past but, for unclear reasons, were not successful (ICRA, 1997). Various authors have identified reasons for non-adoption of alternative practices. Corbeels et al., (2000) report that land fragmentation is cited by farmers as the main constraint to traditional practices. Land fragmentation hampers manure transportation, as many fields are far from the homestead. Herweg and Ludi (1999) report that farmers in areas of secure high rainfall has serious complaints about SWC structures. The main arguments are that (i) SWC structures occupy precious cropping area, (ii) because the area occupied by SWC structures is not ploughed weeds and rodents habitats are no longer destroyed leading to an infestation of cultivated fields, (iii) waterlogging is frequently observed along a narrow strip above the SWC structure (iv) maintenance requires unacceptable labour inputs

[1] This definition is based on WOCAT, 2000

(also observed by MacKenzie 1987a and b), (v) farmers have problems carrying out their traditional farm operations. Narrow terrace spacing makes it difficult or impossible to plough the slope in diagonal lines and turn the ox-drawn plough. Shiferaw and Holden (1998) find for Ethiopia that households with low land-man ratios were more likely to have removed conservation structures.

Concluding, technologies cannot be automatically transplanted from one region to another. As Hudson (1987, p. 9) states: “Possible new techniques should have the same basic characteristics as traditional practices, they should be easy to understand, simple to apply, have low inputs of labour or cash, and must show a high success rate i.e. a high rate of return.” Herweg & Ludi (1999) point out that successful SWC is frequently connected with the following attributes: technical feasibility and adaptability, ecological soundness, economic viability, and social acceptance. Krüger et al. (1996) observe that SWC structures are frequently site specific and accordingly vary in purpose. They emphasise the fact that the success of many SWC systems in Ethiopia depends on a combination of measures and effects rather than on a single technique. Eyasu (2000) points out that there is a high variety between field types, socio-economic groups and agro-ecological zones with respect to the techniques farmers apply.

This paper presents a number of alternative technologies found in literature, which are traditional or introduced recently in Ethiopia. This literature survey is to be used for subsequent research components of the PIMEA project.

1 Water harvesting

Rockström et al., (2002) conclude that water related problems in rainfed agriculture is water scarcity prone tropics are often related to high intensity and large spatial and temporal variability of rainfall, rather than low cumulative volumes of rainfall. Especially in Ethiopia rainfall is highly erratic, and rain often falls with high rainfall intensity and extreme spatial ad temporal variability (Nyssen, 2001). Water harvesting can be broadly defined as the concentration of surface water run-off for production purposes. Water harvesting for dry spell mitigation can play a critical role in reducing the risk of crop failure during rainy seasons with severe dry spells and can be an interesting option to increase water productivity at production system level (Rockström et al., 2002). However, Rockström et al. (*ibid.*) indicate that full benefits of water harvesting for supplemental irrigation can only be met by simultaneously addressing soil fertility management.

We discuss three water harvesting technologies: tied ridges, pits and half moon structures. Some techniques can also be used to reduce soil erosion through run-off.

1.1 Tied ridges

The principle of tied ridges is to increase surface storage by first making ridges and furrows, then damming the furrows with small mounds, or ties. Graded ridges alone will usually lead to an increase of surface run-off compared with flat planting, while tied ridges will decrease the run-off and increase the storage (Hudson, 1987). On the heavier clays such as vertisols poor drainage and sheet erosion can be serious problems. Here the water retention device such as a tied ridge often has to be knocked down in high rainfall years. (Source: Georgis et al., no date).

Tied ridging is usually associated with mechanised farming. There have been some attempts at achieving it with ox-drawn implements, but the system really needs high draught for speed and precision, which is required if the ridges are to be re-ridged or split in subsequent years. Either ridging alone or tied ridging has occasionally been practised using hand labour. However, the high labour requirement usually makes this unpopular with subsistence farmers, and hand-made ridges are usually less efficient. They are more likely to depart from a true contour and to have variations in the height of the ridge, both of which will increase the risk of overtopping. A variation called tied-mounding is suitable for hand work, and has been tried on a limited scale in Burkina Faso (Hudson, 1987). ICRA (1997) mentions for Ethiopia that tied ridging to improve water availability during the growing season needs two persons to be operated and is therefore not attractive to farmers. Secondly, especially at vertisols (dominant in large parts of Tigray) tied ridges may result in water logging problems, while at the more sandy soils ridges are washed away by intensive showers. Ridging seems also less suitable for broadcasted crops which need to be covered by a soil layer (wheat and barley) .

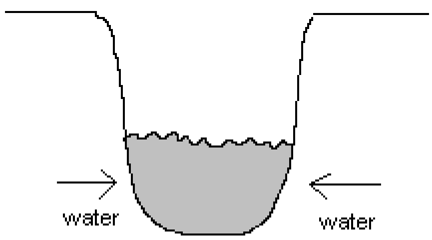
However, Esser et al., (2002) cite a study by Barber (1984), which indicates that prevention of run-off through tied ridging in the Hareghe Highlands in Ethiopia, led to marked increases in sorghum and maize yields. Also Tenaw et al., (2001) report that experiments with tied ridges showed that tied ridging produced more yield (one average 598 kg/ha) than flat planting (see also Shapiro and Sanders, 2002).

1.2 Pits

Rockström (2002) describes a water harvesting method that was successfully applied in Burkina Faso and Kenya. Surface runoff from small catchments (1-2 ha) was harvested and stored in manually dug farm ponds (100-250 m^3 storage capacity). Simple gravity-fed furrow irrigation was used. Supplemental irrigation amounted on average to 70 mm per growing season, with a range of 20-220 mm.

Deurloo & Haileselassie (1996) describes a farmer in Tseyet (Tigray) who applied a method of water catchment that consisted of digging a pit of 6 m^2 in which water from heavy rain run-off would accumulate. Meijerink (2001) describes a farmer in Tigray who introduced digging deep had-dug wells, or pits from Sudan, which store water, and also attract water (see plate 1).

Plate 1 Hand-dug well

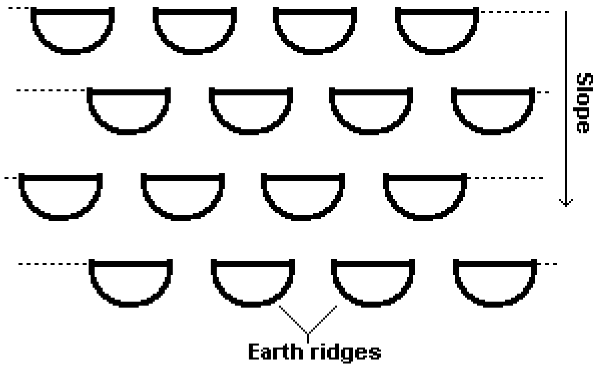


1.3 Half moon structures

The half-moon (see plate 2) is a water collection device, implemented on bare and crusted soils with gentle slopes (<3%). Animal manure can be brought in the basin to optimise crop growth. The diameter of the half moons are around 4 meters and the distance between two half moons is

2 meters. The Distance between upper and lower half moons differs according to slope. The basin is dug (10-15 cm) and the excavated earth is used to form a bund (10-15 cm) (Zougmore et al., 2003).

Plate 2 Diagram of half-moon structure



Source: Zoumore et a., (2003)

2 Tillage

There is ample research indicating that the conventional farming system in the tropics based on soil inversion using plough and hoe contributes to soil erosion and soil desiccation (Rockström et al., 2002). Nyssen et al (ibid.) found for Tigray that tillage erosion can be held responsible for half of the sediment deposited behind newly constructed stone bunds. Alternative tillage techniques can therefore reduce the harmful effects of ploughing. In this section we only discuss conservation tillage.

Different types of tillage all involve some re-shaping of the soil surface, and so require substantial inputs of energy (Hudson, 1987). In Ethiopia, tilling is the most demanding farming activity in terms of labour and energy (Corbeels et a., 2002; Meijerink, forthcoming). Farmers mainly use oxen to pull the transitional plough called *maresha*. The plough is pulled by two oxen (Nyssen et al,. 2000a). Goe (1999, cited in Nyssen et al 2000a) reports that the design allows it to be used on plots with different biophysical characteristics (few or many stones, flat, gentle sloping or steep lands). However, Meijerink (forthcoming) and Amede et al. (2001) report that farmers in Tigray consider ploughing to increase soil productivity. Nyssen (2001) observes that in Tigray that there was only substantial runoff more than one month after the beginning of the *kremt* rains[2]. In the beginning of the rainy season, most rain infiltrated quickly in the dry, tilled fields. Marque & Rosenwald (1997:24, cited in Nyssen, 2001) stress the importance of tillage for moisture conservation in the Northern Ethiopian Highlands.

2.1 Conservation tillage

Conservation tillage aims at maximising soil infiltration and soil productivity, and minimising water losses while conserving energy and labour. This umbrella term can include reduced tillage, minimum tillage, no-till, direct drill, mulch tillage, stubble-mulch farming, trash farming, strip tillage, plough-plant. The application is mainly in mechanised high production

[2] beginning of the main summer rainy season

farming with good rainfall, or for the control of wind erosion where there is large-scale mechanised cereal production. Conservation tillage also has the advantage of reducing the need for terraces or other permanent structures (Hudson, 1987).

Although it has been successfully introduced in several Sub-Sahara African countries such as Ghana, Nigeria, Zimbabwe, Tanzania, South Africa and Zambia (Rockström et a., 2002), it is probably less applicable to low input level crop production, or subsistence agriculture. And there are several disadvantages which hinder the application of conservation tillage in semi-arid conditions:

- dense plant covers that are usually needed for conservation tillage may be incompatible with the well-tested strategy of using low plant populations to suit low moisture availability;
- crop residues may be of value as feed for livestock;
- planting through surface mulches is not easy for ox-drawn planters although there may be no problem with hand jab planters (Hudson, 1987).

Also, ploughing is considered very important by farmers in Tigray. For a crop like teff, fields are ploughed a minimum of five times. Ploughing is also used to incorporate crop residues into the soil, or to destroy weeds (Corbeels et al., 2000). Therefore, it is speculative whether farmers will accept technologies that entail reduced ploughing. However, Astatke et al., (2003) report that in participatory experimentation with tillage practices, farmers were willing to try the minimum tillage technology, although none of them were willing to include the zero tillage option in the trial. Amede et al. (2001) report that the African Highlands Initiative (AHI) and the Ethiopian Agricultural Research organisation are planning on-farm experiments concerning minimum tillage with improved ploughs and donkey traction.

2.2 Broad Bed and Furrow System (BBF)

The Broad Bed and Furrow system is a modern version of the very old concept of encouraging controlled surface drainage by forming the soil surface into beds. In medieval times in Britain this was used for improving pastures and called "rig and furrow" (Hudson, 1987). The BBF system is suitable for vertisols. Vertisols are regarded as problematic soil in Ethiopia due to their hydro-physical properties, which lead to a high incidence of prolonged water-logging during the main rainy season. The recommended ICRISAT system consists of broad beds about 100 cm wide separated by sunken furrows about 50 cm wide. The preferred slope along the furrow is between 0.4 and 0.8 percent on vertisols. Two, three, or four rows of crop can be grown on the broad bed, and the bed width and crop geometry can be varied to suit the cultivation and planting equipment. There are extensions of this work on similar soils in Ethiopia (ILCA 1985) with an interesting development of a very simple ridging implement (Hudson, 1987).

Astatke et al., (2003) describe a more recent application of the BBF system which included a modified *maresha* plough. This plough can create 80 cm wide raised seedbeds separated by 40 cm wide furrows. This BBF technology was tested on-farm and later disseminated by the Ministry of Agriculture and several NGOs.

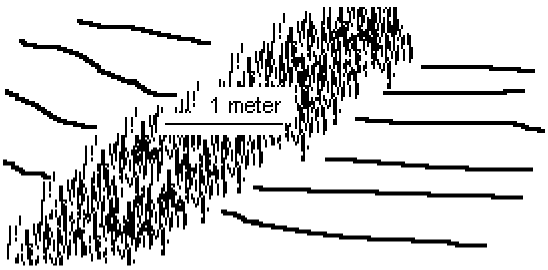
3 ‘Stop-Wash lines’

Hudson (1987) termed for simple structures on the contour as 'stop-wash lines' which correctly defines their purpose. Such lines can be made from any materials that are available. On stony ground, using the stones to build rock lines serves the dual purpose of clearing them from the field as well as building the stop-wash lines. However, lines can also be formed by piling up crop residues, perhaps with a few shovels of soil, and progressively built up later by adding weeds from hand hoeing. This technique is practised in Ethiopia. No design is necessary, but the general principle is that in general a larger number of small barriers will be more effective than a small number of large structures.

3.1 Grass strips or dagets

Grass strips are strips of about 1 meter length that are grown in between fields (see plate 1), (Herweg & Ludi, 1999). These strips will reduce erosion and capture soil that runs off. A 'daget' (or lynchet) is a traditional SCW measure practised in Tigray consisting of an untilled strip of about 2 m wide and between 0.5 to 3 meters high (Nyssen et al., 2000; Corbeels et al., 2000). Dagets usually develop on small strips of uncultivated land at the bottom of slopes (or fields) where farmers deposit stones, weeds and bushes, and are also built up by sedimentation (Corbeels et al, 2000). Nyssen et al (2000) report that between 1974 and 1994, 20.7% of the major dagets (more that 1 metre high) have disappeared, but recently the building of stone bunds is combined with the traditional knowledge of daget. Most common grasses on dagets are *Cynodon dactylon* (t'hag), *Pennisetum* sp. (tsada saeri). Sometimes also shrubs are grown on dagets as a reinforcement, such as *Acacia* div.sp., *Rumex nervosus* and *Nicotania glauca*. Nyssen et al (ibid.) also state that because stone bunds are promoted by extensionists without taking into account existing SWC such as dagets, farmers may be tempted to destroy dagets. Also, since the 1984-1985 famine, many smaller dagets have been destroyed to increase field sizes and to recover the organic matter accumulated in the daget soil. Corbeels et al (2000) also report that farmers have recently ploughed in many dagets to make more land available for crop production.

Plate 3 Grass strip



4 Ditches

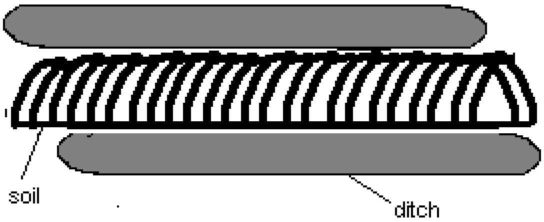
Ditches are another traditional Ethiopian technique (Alemayehu, 1996) and are made to allow excess water to infiltrate easily and drain out of cultivated land, to the side of an artificial or natural waterway. A ditch may sometimes be dug on the upper side of the cultivated land to act as a cut-off drain the protect the plot from the run-off of a higher plot. In Ethiopia they are quite common, and usually constructed by a maresha plough (Shetto, 1999).

The width, depth, length, spacing and gradient of ditches differ per area. The width is determined by the ox-plough (30-50 cm), depth is determined by the depth of the soil (5-25 cm). The length of the ditch is determined by the length of the field. Farmers construct different types of ditches, according to what the ditch needs to do (Alemayehu, 1996). Herweg & Ludi (1999) describe a technique called ‘double ditches’ which consists of two small ditches whereby the dug earth is put in between (see plate 2). However, it appears that traditional ditches are generally used for two purposes:

1. Protect the soil from being washed away by run-off
2. Drain excess water from almost flat cultivated land during the long rainy season.

(Alemayehu, 1996). This is why ditches can be seen on sloping as well as flat fields.

Plate 4 Double ditch



Traditional ditches are moved occasionally to other cultivation fields in different cropping seasons. This is done to avoid a gradual widening and deepening of the ditches over time. However, inappropriate construction of ditches does lead in some instances to erosion For instance, ditches that function as drainage pose a severe erosion hazard on steep slopes with erodible soils (Alemayehu, 1996).

5 Terracing and contour bunds

Terracing is an umbrella term for different types of structures, which have different purposes. Hudson (1987) identifies the following objectives of terraces:

1. to modify the soil slope
2. to influence the surface run-off
3. to allow the agricultural use of steep slopes

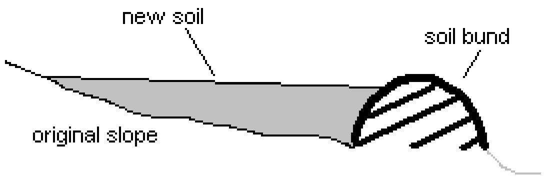
The first objective can be met by building level terraces for irrigation , bench terraces built in a single operation or a progressive reduction of slope (fanya juu). The second objective can be met by various water harvesting techniques such as (tied) ridging but also by contour bunds (soil or stone), which may turn into terraces. Finally, cultivation of steeps slopes can be enabled by terraces such as orchard terraces, platforms o hillside ditches.

Contour bunds are the most important SWC measures in Ethiopia. They are used for a combination of soil conservation and water conservation. The bunds are built on level grade with ties in the basin. In Ethiopia, bunds are made of soil or stone. In a study including 198 households in Tigray, Pender et al. (2001) calculated that in 1998/99, 4.1% had invested in stone bunds (terraces), while only 1.6% had invested in soil bunds.

5.1 Soil bunds

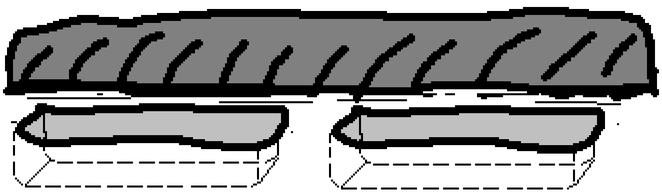
A traditional technique that consists of soil bunds is called *armos* in Tigray (Eweg et al., 1998; Deurloo & Haileselassie, 1996). However, according to Nyssen (1998), an *armo* stands for any plot limit, even an alignment of stones without any riser. In hillside areas the technique is often traditional, in other areas the technique has been applied only recently. To construct a bund, the excavated material of the ditch is thrown 'downhill. In th Fanya yuu system, the earth is thrown 'uphill' to build a dam. The Fanya juu type has been developed in Kenya as a modified form of the contour terrace (Herweg & Ludi, 1999). In time, the dams transform the plot into a terrace (see plate 3).

Plate 5 Terrace through soil bund



In Ethiopia (Tigray) soil bunds are also combined with water harvesting ditches, dug uphill (see plate 4), also called graded bunds (Amede et al., 2001). The earth bunds are 30 cm in hight, the ditches are 50 cm deep and 1.5 m wide (Shetto, 1999; Asrat et al. 1996).

Plate 6 Soil bund with ditch



Amede et al. (2001) report considerably soil loss reductions with soil bunds farmers are reluctant to adopt this strategy. Farmers are aware that they have a positive effect on soil fertility, conservation of soil moisture and reduction of erosion. However, the main constraints listed by farmers are that with soil bunds, they have less land for cultivating crops, less availability of fodder crops and fuel, and they need extra labour and effort for ploughing. As Amede et al. (ibid., p. 16) state "where land holdings are small, every inch matters".

Shiferaw & Holden (1999) report that a graded fanya-juu system is more effective in reducing soil loss than graded bunds, or traditional technologies (control). See table 1 for results.

Table 2 Mean soil loss and crop yields from different conservation measures at Anjeni, East Gojjam

Technology	Crop	Slope (%)	Soil loss (t/ha)	Yields (kg/ha)
Traditional	Teff	12	179	285
Graded bunds	Teff	12	117	255

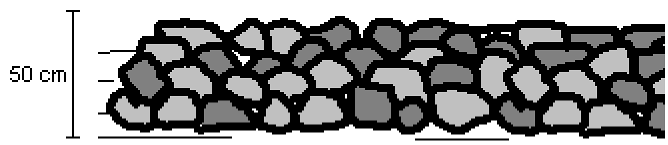
Graded fanya-juu	Teff	12	46	195
Traditional	Wheat	28	142	595
Graded bunds	Wheat	28	90	610
Graded fanya-juu	Wheat	28	81	717
Traditional	Faba beans	12	79	380
Graded bunds	Faba beans	12	31	380
Graded fanya-juu	Faba beans	12	28	478

Source: Shiferaw & Holden (1999)

5.2 Stone bunds

Stone bunds consist of barriers of stones placed at regular intervals along the contour. This amounts to the same technique as soil bunds, but stone bunds can also be built without a ditch (see plate 5). The size of the bunds varies between o.5-2 meter and my be 5 to 10 meters long. Stone bunds have been used for generations in Ethiopia and are locally known as *dhagga* in Tigray (Shetto, 1999; Asrat et al., 1996). In the South, they are called *kella* (Eyasu, 2000).

Plate 7 Stone bund



Stone bunds can also lead to terracing of the land, by trapping the soil that washes with run-off. Nyssen et al (2000) cite the 1997 Bureau of Agriculture and Natural Resources recommendations for spacing of stone bunds in Tigray (table 3).

Table 3 Recommended spacing for stone bunds in Tigray

Slope %	Horizontal interval (m)
5	20
6	17
7-8	14
9-11	13
12-15	12
16-17	11
18-19	10
20-23	9
24-25	8
26-29	7
30-34	6
>35	5

Deurloo & Haileselassie (1996) report for study sites in Tigray that terracing (through stone bunds) is the most applied erosion control methods. In Adi Momena and Work Amba the method is traditional, in other sites it has been applied only very recently. Hudson reports that terraces are a traditional Ethiopian SWC measure (1987). According to Krüger et al. (1996) the design and function of stone bunds vary considerably within and between households. Some are continuously built up and developed into bench terraces, while others are dismantled every two to five years to redistribute the soil accumulated behind the bunds.

Vagen et al. (1999) report that analysis of the effects of stone terracing on plant available phosphorous on highly degraded slopes in Tigray shows that terrace benches increase plant available P with some 30% compared to non-terraced land. Gebremedhin et al., (1999) report that in a study on the effects of stone terraces on yields, grain and straw yields both wheat and faba beans were significantly higher in the soil accumulation zone than in the soil loss zone or in the non-terraced control plots. Esser et al. (2002) cite several studies that demonstrate the effectiveness of stone bunds in Ethiopia in controlling soil erosion (see also Amede, 2001) and increasing yields (of maize, wheat and faba bean; see also Gebremedhin et al., 1999).

However, ICRA (1997) report that stone bunds are widespread in Tigray but maintenance is a problem due to labour shortage. Short-term benefits are unclear (not quantified). Problems with bunds relate to pest infestation (rats, weeds and plant diseases) and destabilization due to heavy rainfall or trampling and grazing damage of animals. Disadavantages are also loss of land required by bunds (Meijerink, forthcoming; Herweg & Ludi, 1999). Herweg & Ludi (1999) list other complaints of farmers which include that respite a drainage gradient of 2% or higher, waterlogging is frequently observed along a narrow strip above the SWC structures and farmers have problems carrying out their traditional farm operations. Narrow terrace spacing makes it difficult or impossible to plough the slope in diagonal lines and turn the ox-drawn plough.

Although MacKenzie (1987a) reports for Debre Berhan in Tigray that terracing has increased barley yields from 300 to 1000 kg/ha by retaining water while controlling erosion, she reports that terraces of stone bunds are not popular in Debe Berhan (1987a) or northern Shoa (1987b) because it is regarded to be not worth the labour.

Deurloo & Haileselassie (1996) report that a farmer in Tigray commented that terracing on hill sides is not effective, because it reduces the size of land. However, Gebremedhin et al., (1999) estimate that over a 30-year planning horizon, stone terraces yield a 50% rate of return (roughly equivalent to reported farmer discount rates in Ethiopia).

5.3 Mass community action

Terraces through stone bunds are constructed by farmers individually, working on the terracing whenever they can, or in community efforts as part of the Terracing Program that was started in 1989 (Deurloo & Haileselassie, 1996), see also plate 1. This is also called "mass community SWC". Mass community action has its roots in 1971 when an afforestation and bench terracing programme was started in Tigray under the auspices of a USAID Food for Work programme. From then on, several initiatives were taken by different international organisations and consecutive governments of Ethiopia. Nowadays, the Relief Society of Tigray (REST) is predominantly responsible for the soil and water conservation programmes through Food for Work programmes. Table 4 gives an overview of the extent of the program.

Table 4 Extent of soil and water conservation work organised by REST and TPLF

Year	Area terraced (ha)	Source
Before 1988	2000	REST, 1993
1989	n.a.	
1990	56000	TTAC, 1991
1991	n.a.	
1992	104000	Bisrat News Magazine, 1995
1993	96100	Ibid.
1994	86100	Ibid.
1995	74300	Ibid.
Total	418500	

Source: Esser et al., 2002

The fact that most SWC programmes are part of Food for Work programmes may have as an effect that the farmer considers SWC work as paid work (i.e. food), and no longer as improvements made to their fields made by responsible farmers (Nyssen, 1998).

6 Tree planting

Trees are grown in strips or planted around fields to act as a boundary and to stop soil erosion. Wezel & Rath (2002) report that attempts at reforestation in the West African Sahel have, with some exceptions, not met with any long-term success, even when indigenous species were planted. They conclude that regeneration of spontaneous woody vegetation and managing existing forest areas are safer bets, although community-based management schemes need clear rules with respect to planting, cutting grazing etc. In Tigray, most communities have a woodlot that are managed by the community (village or *tabia*[3]). The characteristics are given in table 5.

Table 5 Characteristics of community woodlots in Tigray

Percentage of tabias with a woodlot	87.6
Number of woodlots per tabia	9.0
Area of woodlots (ha)	7.9
Percentage of woodlots established since 1991	78.0
Percentage of woodlots promoted by a program or organisation:	95.5
BoANRD	79.5
REST	3.7
BoANRD & REST	5.3
World Vision	3.8
Percentage of woodlots where users are:	
All tabia members	19.6
Only village members	79.1
Only the guard	1.1

Source: Gebremedhin et al., 2000

Eweg et al (1998) and Deurloo & Haileselassie (1996) report that indigenous and exotic seedlings are obtained from nurseries set up by NGOs (e.g. REST, Farm Africa), local communities or the BoNR. Old trees on the field are protected. Deurloo & Haileselassie (1996) mention that indigenous tree species such as *Cordia africana*, *Croton macrostachyus*, *Acacia* sp. are used, and exotic species such as *Eucalyptus* sp., *Sesbania sesban* and *Leucena* sp.. Eweg et al (1998) mention 'wooded banks' as a SWC measure with drought resistant plants such as *Agave* and *Euphorbia abyssinica* that are grown on field boundaries. Besides cactus plants such as *Agave* and *Euphorbia abyssinica*, Deurloo & Haileselassie (*ibid*) mention also *Opuntia* sp as one of the drought resistant plants that are grown by farmers to control erosion. They add that these plants are easy to propagate and apparently very effective in controlling erosion.

ICRA (1997) explain that introduction of afforestation for fire- and construction wood may reduce the use of manure for cooking purposes. However, Gebremedhin et al., (2000) report that the restrictions on collecting firewood from woodlots has led to an increase of the use of manure and crop residues for fuel, which may lead to an aggravation of soil nutrient depletion.

Fast growing species, for example, eucalyptus are popular with farmers for planting between fields or in riverbeds to reduce erosion. However, Jagger and Pender (2000) report that the regional government of Tigray imposed a ban on eucalyptus tree planting on farmlands due to concerns regarding potential negative environmental externalities associated with eucalyptus. Therefore the consequences of eucalyptus for undergrowth and water extraction for adjacent arable fields must be considered.

3 Tigray is divided up into four zones and 35 Woredas (administrative districts). Each district is sub-divided into Tabia's the lowest administrative units in the region. Each Tabia again divided into Kushets (villages). One Tabia can consist up to eight kushets.

7 Crop residue management

Crop residues management consists of recycling crop parts back into the soil. This can be done in several ways such as ploughing in the crop residues, burning the crop residues and ploughing them in, or through mulching. In general, because of the poor conditions in Ethiopia, crop residues are often used for different purposes instead. According to Corbeels et al. (2000), only few farmers use crop residues to maintain soil fertility. Crop residues are mainly used as animal feed, construction materials or fuel.

7.1 Crop residues

Amede et al. (2001) describe the multiple uses that are made of crop residues but few are used to restore soil fertility. Crop residues are used as livestock fodder, fuel, planting material. Wealthier farmers use crop residues mostly as livestock fodder. Poorer households, with fewer livestock use crop residues more often as mulch. Corbeels et al. (2000) reports for Tigray that all crop residues apart from wheat are cut at ground level. Wheat straw is left on the field because it is not considered to be good fodder after it has been stored. Most of the wheat stubble is grazed in the field.

7.2 Ash

Sometimes crop residues are burned by farmers who regard the ash as a fertiliser. For that reason weeds are also burned coupled with the fact that burning is an easy and quick way to get rid of weeds However, more and more farmers have started to use crop residues as well as weeds as livestock fodder, sometimes selling it at the market place (Corbeels et al., 2000).

7.3 Mulching

In many Sub-Saharan African countries, mulching is a commonly applied method to reduce soil fertility decline. Crop residues are left on the field. This minimises the export of nutrients via harvested crops or even imports nutrients when using mulch material produced elsewhere, Mulching increase not only nutrients and organic material content of soils, but also reduces soil erosion, enhances water conservation and increases infiltration (Wezel & Rath, 2002). Tenaw et al. (2001) report on experiments conducted in Ethiopia (Nazareth) with mulching (*cajanus cajan* and *sesbania sesban*). Availability of moisture increased by 22.7% and maize grain yields increased 19% over the control where mulch was not applied.

ICRA (1997) also suggest the introduction of mulch (leaving crop residues in the field) to increase soil organic matter content and reduce erosion. However, this may not be viable given the practice of letting livestock graze the stubbles after harvest and the need for fodder in the dry season. Hudson (1987) gives some other disadvantages of mulching:

- the amount of crop residue required may be more than is available from low-level production;
- problems of pest, disease, or nitrogen lock-up;
- the lack of implements which can plant or drill through the mulch;
- organic mulches are liable to be rapidly oxidised in high temperatures.

7.4 Composting

Farmers in Ethiopia use the composting technique to provide an additional fertiliser. Compost is made by digging a pit and filling it with household waste, weeds, manure and in some cases leftovers of straw fed to cattle. When the pit is full, it is covered with soil and left to decompose until it is applied on the fields (June) (Deurloo & Haileseliassie (1996). Meijerink (forthcoming) reports for two villages in Tigray that a only few farmers knew how to make compost, and that is were mostly women who were engaged in this practice. In a study including 198 households in Tigray, Pender et al. (2001) calculated that in 1991 2.3% practised composting. In 1998/99 this was 7.9%. Eyasu (2000) reports for South Ethiopia that resource-poor farmers with limited access to manure or mineral fertiliser use a range of other sources of nutrient, including compost. Composting was first introduced by WADU[4] and this was taken up by the Ministry of Agriculture. However, according to him, only a few farmers make and use compost. The main constraints are the high labour requirements. In the study (Kindo Koisha) area women collect household refuse, cow dung and chopped *enset* leaves[5] to make compost, while men collect leaf litter and grass.

8 Fallowing

Fallowing (mistigao) was traditionally the way to restore soil productivity. Corbeels et al., (2002) report for Tigray that the decision to leave a field fallow is not a matter for an individual farmer. Instead, a group of farmers will select a site where they want to create a uniform piece of grazing land for the village herds. Fallowing has been greatly diminished in practice due to shortage of land (Corbeels et al., 2000). Deurloo & Haileselassie (1996) describe that the traditional way of fallowing was that after tilling land for one year it is left fallow for a few years, giving soil time to recover. Weeds grow during this period and cover the soil to protect it from erosion processes. When such a plot is tilled again, the weeds add extra humus to the soil.

However, because there is a shortage of land, fallow is practised by farmers who still have enough land, or by farmers who have the means to rent extra rent so that they can leave their own land fallow for a year. Meijerink (forthcoming) reports that individual land that is left fallow is usually very infertile land located on (rocky) steep slopes. This land is so unproductive that it needs a long fallow. Nyssen (2001) describes the fallowing practice for a study area in Tigray (Dogua Tembien), a community in Tigray. Here, small patches of fallow land, grazed by livestock, are found throughout the arable land on very diverse soil types. Most fallow parcels are characterised by maintained stone bunds. Some fields on marginal lands, such as steep slopes or some degraded areas in Argaka, are used in a crop rotation between fallow and crops such as lentils or linseed, and sometimes also grass peas. There is a trend towards abandoning the practice of fallowing. In a study including 198 households, Pender et al. (2001) calculated that in 1991, almost 18% practised fallow. In 1998/99 this had reduced to 7.2%.

9 Crop rotation

Crop rotation affects the entire plant-soil ecosystem by altering the quantity and quality of organic residues returned to the soil, the soil moisture reserve, the erodibility of soil and the availability of nutrients. It is therefore an important technique in improving soil fertility and moisture content (Amede et al., 2001).

[4] Woillata Agricultural Development Unit
[5] *Enset ventricosum* or *musa ensete*, a banana indigenous to Ethiopia

Crop rotation is practised commonly by farmers in Ethiopia. Many use crop rotation as a means to conserve soil fertility by planting legumes (faba beans, haricots) one year and non-legumes (e.g. cereals) the following (Esser et al., 2002; Amede et al., 2001). Cobeels et al (2000) describe four crop rotations for Tigray:

- Barley – wheat – barley
- Teff – barley/wheat – teff
- Teff – vetch – teff
- Barley – chickpea – barley

According to Nyssen (2001), one year or two successive years of cereals are alternated with one year of legumes. *Blockwise rotation* is common. This entails that adjacent farmers in a certain area follow the same crop rotation scheme. Typically, such blocks count 10-20 parcels, with a total area of 4-7 ha. The creation of larger areas under the same crop rotation patterns aims to facilitate stubble grazing after harvesting the crop. According to Nyssen, (ibid.) cereals are grown for several successive years without rotation with any leguminous crop or fallow on fertile soils.

Cobeels et al. (2000) argue that the choice of crop rotation will depend on soil and rainfall pattern, personal preferences and economic consideration (such as price of the crop), and the desire to reduce the need for labour intensive land preparation or weeding. However, Nyssen (2001) could not find a significant relationship between the soil type and the different crop rotation schemes. He states that these schemes depend on non-edaphic factors such as seed price or availability, climatic conditions, advancement of the preparatory works for sowing, availability of labour force that is necessary for weeding tef. Moreover, due to poverty, the higher valued cereals are preferred above leguminous crops.

10 Organic and mineral fertilisers

Organic fertiliser consists of different types of manure and is usually produced at the farm. Mineral fertiliser (also called inorganic fertiliser) is a cash-intensive input that has to be brought from outside the farm.

10.1 Manure

Corbeels et al (2000) report that farmers only use limited amounts of manure in their fields. Because the number of livestock owned per household is relatively small, availability of manure is also small. Besides the use of manure as fertiliser, dung is also often used for other purposes such as fuel, constructing grain silos and mixed with water it is used as a pesticide. Farmers distinguish two types of manure: *zikereme dukie or husse*, which is collected and allowed to decompose during the rainy season, and *zeykereme dukie* or *aleba,* which is collected during the dry season. The second type is less effective and increased the number of weeds in the fields. *Tsebra* is the Tigrigna term for fencing livestock in a particular field so that the manure is spread in that area, which saves time collecting it from different fields (Deurloo & Haileselassie, 1996).

However, according to Corbeels et al (2000) farmers reported negative effects of using manure as fertilisers, for instance, that manuring stimulates the appearance of shoot fly, and that it increases the number of weeds in the field.

Meijerink (forthcoming) reports for Tigray that farmers preferred manure as fertiliser above mineral fertiliser. Cobeels et al. (2000) reports farmers' experiments with different types of manure. These experiments showed that chicken manure was rated highest, followed by goat manure, sheep manure, cow manure and finally donkey manure, which contributed nothing to the land, regardless of the quantity applied. In a study including 198 households in Tigray, Pender et al. (2001) calculated that in 1991 almost 3.7% practised composting fallow. In 1998/99 this was 4.1%.

10.2 Mineral fertiliser

Corbeels et al (2000) mention that use of mineral fertilisers is very limited, mainly due to the lack of purchasing power of farmers. In a study including 198 households in Tigray, Pender et al. (2001) calculated that in 1991 2.2% practised composting fallow. In 1998/99 this had increased to 5.4%. It seems that more households have started using fertiliser.

However, Corbeels et al (ibid.) state that farmers cited several drawbacks of fertilisers. Some farmers in the study area mentioned also that low and unpredictable soil moisture content makes the use of fertiliser unprofitable. Meijerink (forthcoming) confirms this by citing farmers in the relatively flat study area who mention that mineral fertiliser is less effective when there is no rainfall, but also when the plots are waterlogged. According to farmers, urea functions better in these conditions that DAP. Deurloo & Haileselassie (1996) describe that farmers buy small amounts of fertiliser (values range from 10-58 birr per year) , or receive them from the Bureau of Agriculture (BoA) on credit. According to them, only farmers with no livestock were eligible to receive fertiliser by the BoA.

ICRA (1997) reports recommended crop and location specific fertiliser advice in Tigray. Current advice for entire Tigray is 100 kg DAP ha^{-1} and 50 kg urea ha^{-1} not specified for soil or crop type. There is no specific advice for P and K, although DAP contains P. Also the introduction of split applications can be considered to improve fine-tuning of temporal availability and requirements, and to reduce risk involved with using expensive inputs. Tenaw et al., (2001) report that experimentation with mineral fertiliser application increased grain yield of maize (see table 5).

Table 6 Fertiliser response and productivity index for three locations in Nazareth, Ethiopia

	Response to fertiliser application of maize yield (kg/ha) 1992/93		
	Unfertilised (F^0)	Fertilised	Yield increase over F^0
	1264	2124	168
	Productivity index (kg grain maize/kg fertiliser) 1992/93		
Fertiliser (kg/ha)	18/46 (100 DAP)	41/46 (50 urea/100 DAP)	64/46 (100 urea/100 DAP)
	6.4	13.8	8.9

Source: Tenaw et al., 2001

11 Conclusions

Alternative technologies for sustainable land management all refer to the use of land resources such as soils, water, animals and plants for the production of goods to meet changing human needs, while assuring the long-term productive potential of these resources, and the maintenance of their environmental functions. From this literature review, it has become clear that there are many alternative soil and water conservation strategies available, some of which have been tested and/or applied in the Ethiopian Highlands, some of which are potentially possible, but have not yet been tried and tested in Tigray. The soil and water conservation strategies are either agronomic (e.g. intercroppping, contour cultivation, mulching), vegetative (e.g. tree planting, hedging, grass strips), structural (e.g. bunds, terracing), or a combination of these three.

However, only a few have been taken up by the farmers of Tigray, and the most prevalent technologies such as stone bunds are part of Food-For-Work programmes and actively promoted by the public sector. It remains unclear whether farmers would invest in these technologies on such a large scale without these programmes. Some of the technologies described are indigenous to the Tigraian farmers (such as *dagets*) and have been around for centuries. These technologies seem to be effective, although some are disappearing due to the focus on the construction stone bunds.

It is clear that there still is much scope in investigating which alternative technologies are suitable for Tigray, and why they are or are not adopted by the farmers. Many technologies, however, have not been tested well with the active participation of farmers, which is a prerequisite if the farmers are to actively adopt them. A 'transfer-of-technology" approach is too often taken, with the technology being tested under researchers' control and then transferred to farmers. If farmers are to adopt technologies, they do not only need a demonstration, but also room to test the technology themselves, and adapt the technologies to their own needs and preferences. A Participatory Technology Development (PTD) approach will probably be more effective in disseminating alternative technologies. This is especially true for Tigray, where the conditions are harsh, with little and erratic rainfall, poor soils and very few off-farm employment or marketing opportunities. These conditions do not encourage farmers to take risks, and a technology has to be tried and tested before a farmer will use it.

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