DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION

WORKING PAPER

AN ECONOMIC EVALUATION OF SOIL CONSERVATION MEASURES IN ZVIMBA AND CHIRAU COMMUNAL LANDS

by

FLORIAN GROHS

WORKING PAPER AEE 8/ 91

DEPARTMENT OF AGRICULTURAL ECONOMICS & EXTENSION
FACULTY OF AGRICULTURE, UNIVERSITY OF ZIMBABWE
P.O. BOX MP 167, MOUNT PLEASANT, HARARE
ZIMBABWE

An Economic Evaluation of Soil Conservation Measures in Zvimba and Chirau Communal Lands

by

FLORIAN GROHS

Working Paper AEE 91

Department of Agricultural Economics and Extension
Faculty of Agriculture
University of Zimbabwe
P O Box MP167
Mount Pleasant
HARARE
Zimbabwe

August, 1991

Florian Grohs is a Visiting Research Associate in the Department of Agricultural Economics and Extension, University of Zimbabwe from the University of Hohenheim, Germany.

Working Papers are published with minimum formal review by the Department of Agricultural Economics and Extension.

Acknowledgement:
This paper has benefitted from the helpful comments of Dr T Jayne, Dr J MacMillan, Dr H. Elwell. H. Nyachowe and E. Chikava helped with interviews and data analysis.

INTRODUCTION

Soil erosion is an increasingly important problem in Zimbabwe. Whitlow (1988) states that 4.7% of the country or 1.8 mio hectares of land are actually eroded, the bulk (1.5 mio hectares) located in the Communal Lands. Arable and grazing lands are equally effected by erosion. The influence of human factors, especially population density and tenure system explained most of the variations of erosion in the Communal Lands (Whitlow 1988). At present most of the arable lands are more or less protected against rill and gully erosion through countor ridges, mostly built in the late sixties. Contours, however, do not sufficiently reduce sheet erosion so that high soil losses from arable land still occur. The farmers crops are thereby not only affected by the loss of fertile topsoil and fertilizers washed away but the infiltration capacity of the soil is reduced and water-runoff increases, leaving the crops with less water to grow. Also, the structural stability of the soil may collapse (Elwell 1989). Stocking (1986) estimates that in average 75 t/ha of topsoil are lost every year from the communal grazing areas and about 50 t/ha from the arable lands in communal areas. If the loss of topsoil is calculated in terms of nutrients, farmers would yearly lose nitrogen and phosphorus worth Z$ 120 from grazing lands and Z$ 80 from cropland, calculated in 1985 fertilizer prices. This is more than the average application of fertilizers that amounted up to Z$ 55/ha in 1989/90 and often more than the gross margin per hectare (MLARR 1990). Erosion presents a major hidden farming cost not only for future farming but also for current agricultural enterprises.

The high economic costs induced by erosion might lead to the assumption that farmers behave irrationally because they do not sufficiently prevent erosion. Several reasons might explain the behavior of farmers:.

1) Ownership of and the right of access to the resource influence soil conservation efforts. The bulk of the grazing land in Communal areas is still common property allowing all persons with access to the grazing area to hold as many animals as they want. The combination of communal grazing rights and private animal ownership (the tragedy of the commons) gradually converts the grazing land, if not controlled by the community, to an open access resource and often esults in its continuous deterioration. There are no incentives to improve the grazing areas because access to the resource is not restricted. The benefits of any improvement is shared between all users whereas the costs are only born by the individual. Attempts to establish grazing schemes are built on the concept of "resource management communities" and hope that in the process the "community" develops sets of rules for sustainable management of shared resources (Cousins 1989). Ownership of cropland resembles more the type of permanent leasehold. Land is given to the farmer by the kraal head as long as he intends to use it. Long-term investment on cropland could therefore be undertaken by individuals without the fear of losing the land-use right in the near future. The interest of individual farmers to improve soil fertility or moisture conservation on cropland are likely to be

higher and more rewarding than on grazing land. Farmers seem to prefer conservation measures that have immediate impact only on cropland but not on the entire ecological system of their area (Mehretu & Mudimu 1991).

2) The time dimension of the costs of soil erosion and the time preference of the farmers. Not all costs will be immediately effective for the farmer but soil erosion reduces the future soil productivity. Soil productivity of cropland can be interpreted as a farming asset at the farmers disposal. If a farmers financial resources are limited and he just produces enough for a living he is not in a position to invest in soil conservation for the future but has to live from his assets, the inherent soil productivity. The immediate costs of erosion are the crucial variable for the farmer that he seeks to reduce (Kirschke & von Maydell 1991).

3) The perception of erosion as a farming cost. If soil erosion is not seen as a problem on the farm then farmers are not interested to reduce the problem.

It is often argued that technical solutions to reduce erosion and increase agricultural production are available and that the difficulties are not technical but socioeconomic (Whitlow 1988). Consequently comparisons between existing and soil conserving tillage techniques should not only be weighed according to ecological criteria but also according to economic cost and benefit calculations (Truscott 1991).

OBJECTIVES

This paper explores soil conservation methods on cropland and compares conventional tillage with two tillage techniques that reduce soil erosion, annual ridges and tied-ridges. The paper concentrates only on cropland erosion and does not deal with erosion from grazingland. The aim of this survey is to:

- analyse farmers perception of erosion on his farm,
- understand the benefits and constraints of the different tillage system,
- identify factors affecting adoption or non-adoption of a tillage practice,
- determine net effects on yields of farm inputs and tillage systems using a multiple regression analysis,
- calculate gross margins and returns to labour and inputs for the two soil conservation measures and the conventional tillage method,
- identify characteristics of soil conservation techniques that allow farmers to adopt them.

It is hypothesized that successful soil conservation measures not only have to conserve the soil but have to outperform existing farm practices to be adopted by farmers. They have to increase the immediate net benefits for the farmer (Low 1991). New technologies either have to increase production while leaving inputs constant thereby reducing average production costs, or directly reduce production costs per unit of output through mechanizing farm operations (Reisch & Zeddies 1983). New conservation technologies have to be simple, cheap and visibly effective to be adopted by farmers with limited resources; a rather demanding feature. The problem of food insecurity for the majority of the communal land farmers would not allow the farmer to adopt practices that would reduce immediate family income for the sake of conserving the future production potential of the soil. On the other hand new soil conserving tillage techniques not only have to be superior to tillage techniques used by average farmers but have to be better than tillage techniques used by the above average farmers in order to be adopted.

If changes in the farming system of small farmers are advocated, we need to know more about:

- the ecological benefits of the conservation measure,
- the complexity of the farming system and the objectives of the farm household,
- the costs and benefits of the new technology compared to the existing one, in terms of capital inputs and labour requirements and
- the resource endowment and the capacity of the farmer.

SOIL EROSION AND CONSERVATION MEASURES

A brief assessment of soil conservation tillage

The predominant cultivation technique in the Communal areas is conventional ploughing using an ox-drawn mouldboard plow. The recommended practice is winter ploughing shortly after harvest as long as the soil is still moist. Annual ploughing in conjunction with leaving the soil bare in the winter months, removing of crop residues and continuous planting of row crops has brought about a rapid decline in the condition of the soil (Elwell 1989). "One of the foundation stones of modern agriculture has been annual ploughing, promoted widely by research and extension, yet it is apparent that its effects on our soils are nothing short of disastrous" (Elwell 1991).

No-till tied ridging is now advocated as a tillage method for farmers to reduce soil erosion, improve yields, and at the same time save draft power requirements. Permanent ridges of about 250 mm are constructed about 90 cm apart following the contour at safe gradients. These ridges act as miniature contours and can be connected through ties of half the contour size. Land preparation and weeding should ideally be done through re-ridging with a plough a ridger. AGRITEX has launched a national campaign to promote the use of tied-ridging among farmers and since 1988 extensive on-station and on-farm trials have been started by the IAE in conjunction with the GTZ to test the performance of tied ridging in different natural environments (Vogel 1991).

Mulch ripping into a trash cover of crop residues is another soil conserving tillage technique tested on the IAE research station. The soil is not plowed but only strip tilled with a tine ripper. The combination of reduced tillage and crop residue cover reduces soil erosion and increases soil fertility by returning organic matter to the soil. Its major disadvantage is the scarcity of crop residues in the Communal areas needed for feeding cattle in the dry season (Norton 1987).

Clean ripping has gained interest, because it saves time and draft power requirements especially to achieve timely planting when compared with conventional ploughing. This method is controversial because it might increase soil erosion and should be only used on less erodible soils and light slopes (Norton 1987). AGRITEX has promoted this system and it is already been tentatively used in some of the Communal and Small-scale farming areas (McMillan et al. 1991).

Annual ridging is a method used by many farmers in the Zwimba and Chirau area and also in other areas of the country (McMillan et al. 1991, Mehretu & Mudimu 1991, World Bank 1990). The crops are planted on the flat and then ridged 2 - 3 months after planting with a ridger, plough cultivator. The ridges vary in height and are seldom higher than 200mm. Though not a very effective soil conservation measure they do help to conserve moisture and reduce losses of top-dressed fertilizer applied.

The study area

Zwimba and Chirau Communal Lands are located about 80 km west of Harare. The majority of the area belongs to the higher rainfall areas Natural Region IIa with parts going into NR IIb. In average the area receives about 750 - 900 mm of rain. The soils are mostly coarse grained sand derived from granite and belong to the most predominant soils in Zimbabwe. They have, in general, relatively low inherent fertility and low available water capacity. Under continuous cropping these soils tend to lose productivity if nutrients are not added. The decline in productivity in conjunction with poor vegetative cover can lead to serious erosion (Thompson & Purves 1978). The altitude varies between 1200 and 1300 m with gentle slopes ranging from 2 - 4 %. Zwimba and Chirau have been identified as areas with a high level of land use stress (Mehretu & Mudimu 1991). Nearly all the cropland in this area is protected by contour ridges but sheetwash erosion remains a significant problem.

The sample of farmers

With the exception of annual ridging most of the described conservation tillage practices are not commonly used in the Communal areas of Zimbabwe. Very few farmers have started to use no-till tied ridging and mulch ripping is not very common. In May and June 1991, 50 farmers were interviewed in Zwimba and Chirau plus five farmers practising tied ridging in

Zowa, an adjacent small-scale farming area. These farmers had to be added to the sample because only two farmers used tied ridging in Zwimba and Chirau. The farmers were either randomly selected or, when using tied-ridges, pointed out by AGRITEX extension workers. All the farmers were visited and interviewed on site. The Communal farmers in the sample have a mean average size of 3.9 ha of cropland. Of the total area 0.8 ha is left fallow, 2.2 ha is cultivated with maize, 0.2 ha with sunflowers, 0.2 ha with cotton, 0.2 ha with groundnuts, and the remainder with rapoko and bambara nuts. Nearly all of the farmers cultivate in pure stands with maize being the main subsistence and cash crop.

Status of soil conservation on the sampled farms

The major existing conservation structure protecting the cropland of the sampled farms are contour ridges. The construction of contour ridges and grassed waterways started in 1951 under the compulsory Native Land Husbandry Act (NLHA) of the former colonial Rhodesian Government. Today most of the cropland is protected by contour ridges built in the fifties and early sixties although construction and maintenance of contour ridges were and are not universally of high standard (Whitlow 1988).

Contour ridges in the sample area were constructed in the early and mid-sixties according to the sample farmers. All of the farmers acknowledge the value of contours in preventing soil erosion and most of them maintain them regularly. They themselves or sometimes employed casual labour, spend, on average, 4.5 work days per year to repair spills and holes in the ridges. 17 farmers (34%) even constructed new contour ridges on their cropland spending on average 57 work days for this laborious task. Even though their construction was compulsory and very unpopular before independence, farmers in this area appreciate the benefits of contour ridges. It is still the major anti-erosion measure in the Communal lands. Two thirds of the interviewed farmers mentioned that AGRITEX extension workers always advise them to maintain their contours.

Nevertheless, sheetwash erosion is still widespread in spite of the mechanical protection through contours. To estimate actual sheet erosion still occurring on the cropland a soil loss estimation model the, Soil Loss Estimator For Southern Africa (SLEMSA), is used in the survey. SLEMSA was mainly developed by Henry Elwell in Zimbabwe to estimate average annual soil loss from sheetwash erosion. Its purpose is to assist planners and the extension service to design safe rotational systems for arable lands protected by contour ridges. Different combinations of farming practices can be tested and the practice that reduces soil erosion to a pre-set target level can be advised. The influence of the following variables at the specific site are entered in the model (Elwell 1980).

- climate
  * average annual rainfall

- soils
  * erodibility of the soil type
  * tillage practice
- topography
  * slope of the plot
  * length of the plot
- crop cover
  * crop
  * planting date
  * average yield

During this survey one plot cropped with maize or cotton was chosen on every farm and the necessary control variables for this plot, i.e. mean annual rainfall, soil type, length and slope of the plot, crop yields and planting dates, were recorded. The average annual rates of soil loss were estimated using the model. The average rate of erosion reported on all farms equalled 11.2 t/ha/year. This amount of soil loss exceeds the 5 t/ha/year seen as sustainable for the predominantly sandy fersiallitic soils of Zimbabwe (Vogel 1991). Only on 20% of the plots a "sustainable loss" of soil has been estimated. The majority of the plots are experiencing slightly more (6-10 t/ha) sheetwash erosion. The maximum soil loss estimated for a single field averaged 46,9 t/ha.

soil loss (t/ha)	no. of cases
0 - 5	10
6 - 10	23
11 - 20	8
21 - 30	7
31 - 50	1

Table 1 Average rates of sheetwash erosion estimated with SLEMSA

Even in the only moderately sloped area of Zwimba and Chirau soil losses seem to exceed the limits of sustainable agriculture. But how do the farmers themselves see the problem of soil erosion?. Only if farmers perceive erosion as a problem that seriously hampers production success will they be willing to introduce measures against it.

As part of the survey, the same farmers expressed three dominant farming problems, unreliable rainfall, lack of money for inputs, and insufficient draft power. These problems belong to the most often mentioned farming problems in Zimbabwe (Elliot 1989, Rukuni 1985). Soil erosion was only named once as a farming problem and was not prioritized by the farmer. When asked directly if erosion was a problem on their farm, 44% of the respondents stated it was. All respondents were asked to rank their perception of erosion according to a four point scale. Only one third of the farmers would rank erosion as a moderate or serious problem on their farm. Nearly half of the respondents (43%) stated, that erosion is becoming worse on the grazing lands, but only 18% of the farmers see a change for the worse on cropland. It is interesting to note that sheetwash erosion had sometime noticeably affected 74% of the farms, whereas gully erosion only affected 24% of the farms.

Problem	Number
unreliable rainfall	27
lack of money for inputs	22
insufficient draft power	9
roaming cattle delaying planting	8
inadequate supply with farm assets	6
not enough labour	6
insufficient farm assets	5
not enough grazing land	4
no water for garden	4
infertile soil	3
not enough cropland	3
transport problems	3
others	4

Table 2 Dominant farming problems expressed by respondents (three answers possible)

A comparison of the rates of annual sheetwash erosion estimated with SLEMSA and farmers perception revealed that those farmers who saw erosion as a problem on their farm, also had higher sheet erosion estimates on their fields. This result must be interpreted cautiously because of the small sample size and because SLEMSA estimates were taken only for one field on each farm.

Erosion is a problem on my farm	est. annual rate of sheet erosion
yes (22)	13.4 t/ha
no (27)	9,4 t/ha
average (49)	11.2 t/ha
ANOVA analysis	(F = 3.44)

Table 3 Comparison of estimated and perceived actual erosion

All farmers have at least heard about erosion, most of them have noticed it and nearly half think erosion is a problem on their farm, though only a minor one. A recent study in the same area interviewing 154 farmers on their perception and cognitive behavior of erosion came to the conclusion, that 1% named gully, 20% named sheet erosion, and 32% loss of nutrients as a cause for the decline in productivity of their land (Mehretu & Mudimu 1991). A similar study in Svosve Communal Lands concluded that two thirds of the interviewed farmers perceived erosion in the cropland to be at least a moderate hazard or worse (Elliot 1989). Erosion seems to be well recognized by farmers and description given; i.e. washing away of topsoil, fertilizer, nutrients and seeds show that most of the farmers understand the problem. Nevertheless, farmers seem to fail to see the severe long-term implications of the problem considering the importance of soil degradation and overgrazing in affecting agriculture in the Communal Lands (Mehretu & Mudimu 1991).

ANNUAL RIDGES, A POSSIBILITY TO REDUCE SOIL EROSION

Annual ridging is a common method used in the study area. In Zwimba and Chirau nearly half of the farmers seem to always ridge their row crops. Also in other study areas at least one third of the farmers always use this technique (Mehretu & Mudimu 1991, World Bank 1990). Conversely a group of nearly the same size never ridged their crop. Ridging, though common, is not used in all parts of the country.

The effects of annual ridges on soil erosion has so far never been investigated on research trials. They seem to reduce the erosion and runoff particularly after late rains and increase moisture conservation. Experience at the Institute of Agricultural Engineering suggests that small ridges not constructed at a gradient between 1% and 2% would definitely break after strong rainfall storms and might even cause rills and increased erosion. Annual ridging is not seen as a sustainable tillage practice because generally soil erosion rates are not reduced to sustainable levels (less than 5 t/ha). Nevertheless, ridges reduce erosion, increase moisture conservation and are seen as an improvement to conventional tillage (Elwell, 1991 personal communication).

Of the 55 farmers interviewed in this study, 28 farmers were ridging, 7 farmers used tied-ridges and 20 farmers were not ridging. In the following discussion the farmers presently using ridges will be called "ridging (RG) farmers", those not ridging will be called "non-ridging (NR) farmers" and those using tied-ridges will be called "tied-ridging (TR) farmers".

The ridges are constructed between one and four months after planting, the majority in December or January. The size rarely exceeds 200 mm and several farm implements can be used for this task. 53% of the RG farmers used a cultivator, the remainder used either a ridger or a plough. On average, the tools used for ridging had been bought more than 13 years ago and ridgers even tended to have an age of 20 years.

Ridging is not a new technology in Zwimba and Chirau. RG Farmers have a long experience, on average 18 years. Nearly all of the NR farmers have at least heard of, seen or used ridges themselves. Agritex extension workers advised 63% of the RG farmers to use ridges, another 27% inherited this measure from their parents and a minority were introduced through neighbors. An astonishing pattern of technology adoption could be found in the area. Farmers who ridge were not randomly scattered throughout the area but in some villages nearly all farmers would ridge and in other villages hardly one ridging farmer could be found. Differences in the natural environment, slope, soil type or rainfall did not vary between adopters or non adopters.

RG farmers perceived ridging as a very useful tillage technique and mostly named several benefits of ridging when compared to the situation without ridges. Also NR farmers mostly could name several benefits of the measure when asked. Altogether 8 NR farmers (40%) had already used ridges but gave it up.

benefits of ridging	RG	NR farmers
higher yields	27	10
moisture conservation	20	13
soil and fertilizer not washed away	15	8
reduces weeding	11	5
good maize stand	6	4
reduces work	3	0

Table 4 Benefits of ridging as perceived by RG and NR farmers (several answers possible)

The most important benefits are clearly related to soil and water conservation. Ridges reduce water runoff and prevent the loss of valuable topsoil and top-dress fertilizer. Additionally it reduces labour requirements especially for the very time consuming and laborious weeding operation mainly done by hand with a hoe. Some farmers see an additional benefit through better maize stands due to the ridges. Nearly all RG farmers (90%) reported higher yields on the ridged fields than on fields without ridges, the other 10% said yields were comparable and no farmer reported lower yields. Also half of the NR farmers said ridges increase yields though 4 farmers said yields were lower. The yield increase does not seem to be tremendous but a slight yield increase.

Disadvantages of ridging	RG	NR farmers
no disadvantages	17	6
transport of crops with scotch-cart difficult	5	6
trenches in the furrows	2	2
have to be destroyed in years with much rain	2	1
no tools for ridges, hiring is expensive	1	7
more work	1	0
ridges disturb ploughing	0	4

Table 5 Disadvantages of ridging as perceived by RG and NR farmers (several answers possible)

The disadvantages named by the RG farmers do not seriously hamper the farming operations. The observation that trenches in the furrows could occur shows that ridging is not altogether unproblematic and could enhance soil erosion. Only two RG farmers did not have sufficient draft power and farm implements to ridge their crops and had to hire oxen and a cultivator from relatives. The overall impression is that RG farmers are very satisfied and 63% have recommended this measure to their neighbors.

NR farmers named a variety of reasons for not ridging. At least half of the farmers owned enough farm implements and draft power for ridging. The other half of the farmers would have to rely on hiring oxen and a cultivator. The main reasons named by NR farmers for not ridging were not enough equipment or money to hire equipment. A small number of NR farmers were to old or did not have enough labour. Difficulties with transport of the crops after harvest and the difficulties ploughing ridged fields have lead a number of farmers to give up ridging. Differences in the farming system of RG and NR farmers might account for adoption or non-adoption of ridging.

Factors influencing performance of farmers

Several studies in the recent years have shown that household income patterns in Zimbabwes Communal Lands are highly skewed not only between but also within regions (Stack & Chopak 1990, Jackson & Collier 1988, Rohrbach 1989). The top 20 % of producers account for 50 - 60% of total grain production and even more of the marketed amount of grain (Jackson & Collier 1988, Rohrbach 1989). Farmers that have a higher grain production show a significantly higher use of new technologies (improved seeds, fertilizers, draft power). If new soil conservation technologies are to be introduced they have to take these differences into consideration. A number of factors have been identified that account for differences in agricultural performance and household income.

- Size of the agricultural enterprise
  Farm size, household size and cattle ownership are positively correlated to household income (Stack & Chopak 1990). The ownership of sufficient draft power allows farmers to reduce labour requirements in peak periods, especially land preparation and weeding and to expand crop land. Households with draft power plant early, need less time for weeding, use more manure and have higher yields (Rukuni 1985).
- Ownership of farm implements
  Lack of sufficient farm implements "is a major factor affecting agricultural performance of the communal farmer" (MLARR 1989). Non-owners of farm implements are forced to hire at rates which are found to be prohibitive.
- Diversified income sources
  Households whose incomes are based solely on agriculture have lower incomes. Household income is positively related to the number of farming and non-farm activities household members are engaged in (Jackson & Collier 1988). Other income sources, especially urban employment support the farming activities by often financing the purchase of external inputs or improved technologies.
- Education
  The level of schooling and participation in master farmer courses or other farm groups might also explain the difference in performance though this has not been significantly proved so far (Rohrbach 1989).

The following factors are analyzed for the study farmers to measure the influence of these factors on adoption or non-adoption of ridging.

Factor influencing adoption	RG	NR farmers
farm size (ha)	3.4	2.5
no. of residents	5.5	5.6
percentage of farmers owning:		
sufficient draft power	70%	60%
plow	97%	85%
cultivator	83%	60%
ridger	23%	5%
scotchcart	80%	55%
gross income from crops (Z$)	1996	1241
value of fertilizer used (Z$/ha Maize)	303	171
at least 1/4 of total income from non-farming activities	70%	60%
HHhead completed primary	47%	40%
Percentage of master farmers	50%	20%

Table 6 Factors influencing the adoption or non-adoption of ridging.

All of the above mentioned factors show that RG farmers have a significantly better resource endowment they can rely on. They operate more cropland, have more draft animals at their disposal, own more implements, use more external inputs, have a higher off-farm income, are better trained and educated and supposedly, though not measured, have a higher total household income than the NR farmers. Nevertheless, even if farmers with an above average resource endowment ridge more frequently farmers with less resources could also use ridging if it is economically beneficial, i.e. an investment in ridging produces a net incremental benefit.

Economics of annual ridges

In order to calculate the economic benefits of ridging, gross margin calculations for maize and cotton are computed. The information needed on variable costs and labour requirement were collected through interviews with the farmers for one plot per farm. Yield data were obtained through farmers estimates and might be overestimated. The yield differential between RG and NR farmers (RG 3.7 t/ha maize, NR 2.5 t/ha maize) can not be explained alone through ridging but a variety of factors contribute to the better performance of the RG farmers i.e. better management practices and higher use of external inputs (compare also MacMillan et al. 1991).

A multiple linear regression analysis (OLS) was used to identify the impact of a number of factors influencing yields. The model chosen of the form

$$Y = a + b^*(X_1) + c^*(X_2) + d^*(X_3) + e^*(X_4) + f^*(X_5)$$

where Y, the yield of maize (T/ha) is a function of the use of chemicals (X_1) a discrete variable, the planting date (X_2), annual ridges (X_3) expressed in labour hours per hectare, fertilizer use (X_4) expressed in Z$/ha, and ownership of tools (X_5), expressed as the number of ploughs, cultivators and scotchcarts owned gave the following results (t-statistics in parenthesis)

$$Y = -1{,}15 + \underset{(3{,}35)}{2{,}14(X_1)} + \underset{(1{,}45)}{0{,}02(X_2)} + \underset{(2{,}41)}{0{,}03(X_3)} + \underset{(2{,}81)}{0{,}004(X_4)} + \underset{(4{,}64)}{0{,}61(X_5)}$$

$$R^2 = 0{,}47 \quad DW = 2{,}39 \quad F = 8{,}65$$

All the coefficients are highly significant at the 0,05 level except the influence of planting dates that was only significant at the 0,15 level and also indicates that waiting a day would result in an increase of yields. This result is contrary to most other studies, but in line with the results of a recent survey by MacMillan et al. (1991). The correlation matrix did not indicate any correlations between independent variables higher than 0,36 as between ridging and use of fertilizer. The use of chemicals has the highest impact on yields followed by the ownership of tools. These results are in line with findings of the MLARR study (MLARR 1989). Annual ridges significantly influence yields and an additional hour spend on ridging is associated with a yield increase of 30 kg/ha. On average farmers were spending 30 hrs on ridging so that ridging would contribute to an additional 900 kg of maize per hectare, a 36% yield increase.

The effects of annual ridges on crop yields have otherwise only once been quantified in Zimbabwe for sorghum and showed a 9% yield increase compared to planting on the flat (Mackenzie 1987). In general, soil conservation practices have improved yields in dry and average seasons, but have shown little advantage in good rainfall years. The marginal value of a unit of water saved is likely to be higher in dry years when rainfall is lower.

The main economic benefits associated with annual ridges are:

- Increased yields of maize and cotton due to conservation of topsoil and water.
- Reduction of the loss of topsoil, fertilizer and seeds.

Gross margins were calculated for all farm types based on yields, market prices and information provided by the farmers. The results are shown in table 7. Four economic factors were analyzed to evaluate the economic performance of the different tillage practices; gross margins, return to own labour, total labour hours and labour hours needed for weeding.

Farming season 1990/91

	NR Maize	RG Maize	RG Cotton	TR Maize	TR Cotton
Farmers planting (no)	19	25	3	4	3
yields (t/ha)	2.48	3.74	1.12	4.44	0.82
INPUTS (Z$/ha)					
Seeds	41.88	47.04	4.74	84.29	9.52
Chemicals	7.60	8.90	83.75	56.59	196.45
Fert. AN	98.14	145.12	13.35	134.49	16.29
Fert. D	72.37	157.66	28.52	218.43	46.07
Fert. L	0	0	143.48	0	262.28
Total	219.99	358.72	273.84	493.80	530.61
DRAFT POWER (Z$/ha)					
Field Prep.	111.00	140.00	130.00	130.00	98.00
Cultivator	52.00	69.00	77.00	33,00	33.00
HIRED LABOUR (Z$/ha)					
Harvest	0	0	56.00	0	41.00
OWN LABOUR (hrs/ha)					
Win.Plow	26.29	43.78	16.03	24.70	39.52
Plant	86.94	80.30	28.60	58.66	39.48
Chem.App.	44.02	47.68	22.50	61.75	88.18
Weed	281.19	136.90	148.42	276.02	244.15
Ridge	0	29.57	16.91	89.54	25.33
Harvest	155.88	191.17	295.30	95.10	336.36
Total	594.32	529.40	527.76	605.77	773.02
TOT.VAR.COSTS (Z$)	382.99	567.72	536.84	656.80	702.61
GROSS INCOME (Z$)	669.60	1009.80	1456.00	1198.80	1066.00
GROSS MARGIN (Z$)	286.61	442.08	919.16	542.00	363.39
RETURNS TO OWN LABOUR(Z$)	0.48	0.84	1.74	0.89	0.47

Notes: NR = Non-ridging, RG = ridging, TR = Tied-ridging farmers
All costs are valued at the site average for bought or hired items.
Draft power for field preparation and weeding are valued with the avg costs for hiring * avg no. of operations.
Hired labour for cotton harvest is assumed to amount up to half of total labour requirements for harvest.
Costs for fertilizer include transport.
Prices used: price maize = 0,27$/kg, cotton = 1,3$/kg, hired labour 0.1$/kg cotton picking
Price for hiring: cultivator = 33$/ha, plow = 78$/ha.

Table 7 Gross margin calculations for five different tillage practices

Gross margins were considerably higher on ridged than on non-ridged fields. The highest gross margin was achieved with ridged cotton ($919/ha). Return to family labour was twice as large on the ridged compared to the non-ridged variant. Total labour requirements as well as labour requirements for weeding were noticeably lower on the ridged variant. All four economic factors showed the superiority of the ridging variants compared to the non-ridging variant.

Labour calculations for maize and cotton show that only 6% (29.57 hrs/ha) of total labour requirements are used for ridging in maize and only 2% (16.91 hrs/ha) of total labour requirements are used for ridging in cotton (table 7). At the same time ridging is one of the on average two to three cultivator operations against weeds. The effect of reduced labour requirements for weeding have to be added to the benefits of ridging. The annual costs of wear and tear of ox-drawn farm equipment are very low and have been neglected for gross margin calculations. Ridging seems to be a profitable method for owners of the necessary equipment and opportunity costs of family labour for ridging are lower than the average rate for hiring (labour hours * return per hour for maize = $25/ha, cotton = $29/ha)

The annual yield increment necessary for a NR farmer to cover the costs of hiring a tool for ridging would equal 121 kg of maize (or $33). This is a relative increase of 5% for maize given the average on site yields NR farmers averaged in this survey. Cotton yields would only have to increase by 25kg or 2% of total harvest of this survey to break even with the additional costs. The results of the regression analysis indicate that a yield increase of at least 10% seems to be possible through ridging because of the high benefits of moisture conservation. The survey only relies on data collected in one season and still has to be verified in good and bad rainfall years.

Ridging is generally profitable for all farmers in the study area because of the joint effects of moisture conservation and saving labour for weeding. Non-owners of ridging tools have to hire the equipment and the necessary draft power. Shortage of money is a major problem on NR farms and cash or credit constraints may prevent a large number of farmers from hiring a ridging tool.

NO TILL TIED-RIDGING, THE SUSTAINABLE TILLAGE TECHNIQUE FOR COMMUNAL FARMERS?

Since 1988 trials to test tied-ridging have been conducted at the Institute of Agricultural Engineering (IAE). The available results of the trials have demonstrated that erosion is reduced to sustainable rates of about 2 t/ha (Vogel 1991). Hopes are high that this system would allow farmers all over the country to sustainably produce crops and reduce soil erosion. At the same time the soil and water conservation branch of AGRITEX has launched a campaign to install trial farms in each administrative boundary. The results of the about 80 trial farms all over the country have never been evaluated fully, because the information was incomplete (Stevens 1989).

In this survey 7 trial farms using tied-ridging in Zwimba, Chirau and Zowa (an adjacent Small-Scale purchase area) have been interviewed. The trial plots never exceed one hectare, the majority only using a one acre trial plot to gain experience. Most farmers are using this method in their second year. Maize was planted on four and cotton on three plots. The following analysis can only be interpreted cautiously because of the small number of farmers, the short experience and the small size of the plots.

The most important benefit are higher yields compared to conventional ploughing. All farmers reported much higher maize yields also compared to plots with annual ridges. The only two farmers who measured yields, harvested 75% more maize from the tied-ridged plot than from neighboring plots. Yields for cotton are lower on TR farms than on RG farms but the very small number of farmers planting cotton might influence the results. Six farmers named improved moisture conservation as a benefit. Four farmers appreciated the reduced soil erosion and the minimized loss of fertilizers and seeds. On the other hand farmers named a number of disadvantages of the system. Three farmers named no disadvantages. Contrary to annual ridging, four farmers said tied-ridging is more labour consuming especially for the planting and weeding operations if the right tools or herbicides are not available. Late planting was named by two farmers as another disadvantage. The ridges have to be moist before planting which can in some years result in later planting than on the flat thus losing the benefits of capturing early rains.

Tied ridging is still seen controversially by the trial farmers. A minority was very satisfied with the system and want to increase the area under tied-ridges. These farmers had more farm implements to overcome labour constraints. They use a tine ripper to break the top of the ridges for planting and herbicides instead of hand weeding. Weeding especially is seen as a significant problem because farmers complain they can not use a cultivator and using a plough as recommended does not reduce weeds sufficiently. Using a hand hoe instead of a cultivator not only increases but also impedes work.

Gross margins for TR maize are higher than the ridged and non-ridged variant (table 7). The return to family labour is twice as large than the NR variant and marginally higher compared to the RG variant, Results of the labour requirement analysis show a contradictory picture. Total labour requirements are higher on tied-ridged than on ridged fields although they seem to be comparable with the non-ridged fields. More labour has to be used for weeding and ridging in maize on the tied-ridged fields than on the ridged fields and even slightly more than on the not ridged fields. Compared to the NR variant tied-ridging would have overall economic advantages. When compared to the RG variant, even though the gross margin as well as returns to family labour are higher, increased total labour and labour requirements for weeding might prevent farmers of adopting the new tillage technique.

Tied-ridging might be an adequate technology for resource poor below average farmers, because it reduces draft power requirements for field preparation and increases yields considerably. Following the adoption process, first adopters are generally better educated farmers with sufficient resources; land, finance, draft power and farm implements. These farmers are particularly interested in new technologies that are labour saving or at least labour neutral. Mudimu et al. (1989) mention that labour shortages at peak periods, particularly for land preparation, weeding and harvesting hamper production. The most frequently cited new technologies introduced in Zimbabwe in the Communal farming sector are either mechanical or biological technologies and generally do not require higher labour inputs. New mechanical technologies like the use of draft power and improved farm implements (cultivator, harrow or planter) are clearly labour saving technologies. The biological technologies (improved hybrid maize varieties, mineral fertilizers and plant chemicals) are at least labour neutral.

These preliminary results are only valid for the higher rainfall areas in Natural Region II. Even in these regions no till tied-ridging still has to prove that it could be used as a sustainable tillage method on a whole farm and not only on one or two plots. The yield increase seems to be very high but at the same time labour constraints hinder farmers to convert their farm totally to tied ridging. The system is being tested on trial farms managed mostly by master farmers or master farmers trainees. They have comparably highly mechanized farms use more implements and own sufficient draft power to reduce labour requirements at the peak times for field preparation and weeding. Every system that increases labour requirements at these peaks can only be adopted when the size of the total cropland is reduced or additional labour is hired. Even astonishingly high yield increases of 75% could then not persuade farmers to adopt the system completely.

SUMMARY AND CONCLUSIONS

There is need for conservation tillage systems and farmers in the study site are estimated to lose on average more than twice as much soil than would be sustainable. Erosion not only poses a long-term threat to farmers but immediate losses of fertilizer seeds and nutrients result in lower production. Farmers are aware of soil erosion but do not consider it a major farming problem. Soil conservation measures generally combine the effects of soil and water conservation and have improved yields in dry and average seasons. Annual ridges had a statistically significant impact on yields in this survey. New technologies also have to improve productivity of the production factors capital and labour and outperform existing tillage practices to be adopted by farmers. The empirical results of the study support the importance of socioeconomic analysis for successful adoptions of new conservation tillage systems.

New technologies are first adopted by better trained and better equipped farmers with above average cropland. The performance of a new technology therefore has to be compared with existing farming practices used by above average farmers. Three different tillage practices were compared considering socioeconomic surrounding of the farmers and the economic profitability of each tillage practice.

Farmers who did not use any conservation tillage practice had a lower overall grain production because of resource constraints: less cropland, draft animals, farm implements and non-farm income to finance external inputs as well as less training through extension workers. Annual ridging is a tillage practice that reduces erosion but not necessarily to sustainable levels. Ridging has been widely adopted by nearly half of the farmers in the study area. The benefits resulted in both higher yields and reduced labour requirements for weeding seem to explain the high rate of adoption. Tied-ridges reduces erosion to sustainable levels and has been promoted by the IAE and AGRITEX. So far only few farmers in the study area have at least partly adopted tied-ridging. The small group of farmers using tied-ridges consisted only of master farmers with a good basis of farm resources. Not more than one hectare of land has been converted to tied-ridging on individual farms.

The economic analysis of the tillage practices concentrated on four major economic indicators: gross margin, return to family labour, total labour requirements and labour requirements for weeding. Tied-ridging outperformed the non-ridging variant; higher gross margin, higher returns to family labour with equal labour requirements. Tied-ridged maize also had a higher gross margin than maize with annual ridges. On the other hand labour requirements for tied-ridging were considerably higher than for annual ridges, especially for weeding. The majority of the TR farmers named additional labour requirements as the major disadvantage. This disadvantage might prevent better mechanized farmers from adopting tied-ridges completely.

It is crucial to the success of conservation tillage technologies with long term benefits to ensure that incremental short term benefits outweigh additional short term costs. They have to outperform existing tillage systems in respect of labour efficiency and yields. Technologies that increase labour requirements in peak periods, especially for field preparation, planting and weeding are not attractive for Communal Land farmers. Especially the better mechanized Communal Land farmers in higher rainfall areas who lead the adoption process are interested in labour saving technologies.

Labour requirements for weeding in tied-ridges has to be reduced either through the development of a flexible cultivator or through the introduction of herbicides. Future problems due to the resistance of some weeds to herbicides have to be monitored carefully. Experience from large scale commercial farms suggests that chemical weed control is extremely difficult to manage in all no-till and conservation tillage systems (Oldrieve 1989). More labour saving conservation tillage based on reduced tillage like mulch ripping or zero tillage could be used by households with better resource endowments in the better natural regions. They often are in a position to fence their croplands against grazing animals and could keep a mulch cover on their fields.

Soil erosion on grazing lands has not been addressed in this paper even though the degradation process is more advanced. The implications for grazing lands from this study would be that investments in soil conservation on grazing areas also have to benefit individuals immediately to ensure widespread participation of the users of the resource. The economic data used to calculate the viability of different tillage variants pertained only on a limited study of a small number of farmers and only to the 1990/91 cropping season. Especially the group of farmers using tied-ridges was small and had only a limited experience with the new practice. Further research on conservation tillage systems must be accompanied by socioeconomic research to assure immediate productivity increases for farmers. The payoff of reducing erosion in terms of increasing yields seems to be higher in the high rainfall areas. Developing improved technologies for arable lands in semi-arid agriculture that on the one hand conserve the soil and on the other hand improve the productivity of farm resources is even more demanding.

General Reference

Cousins, Ben, "Community, class and grazing management in Zimbabwe's Communal Lands" In Ben Cousins (ed.) *People, land and livestock* Proceedings of a workshop in Masvingo 1988

Elliot, Jenny, *Soil erosion and conservation in Zimbabwe: Political economy and the environment* PhD. Thesis Loughborough 1989

Elwell, Henry, "A need for low-input sustainable farming systems" In: *Tillage, past and future* Proceedings of a workshop held at the Institute of Agricultural Engineering, Hatcliffe, Harare 1989 CIMMYT Networkshop report No. 22 Harare 1991

Elwell, Henry, "Soil structure" In. Malcolm Vowles (ed.) *Conservation tillage, a handbook for commercial farmers in Zimbabwe* Harare 1989

Elwell, Henry, *Design of safe rotational systems* CONEX February 1980

Jackson, J.C. and P. Collier, *Incomes, poverty and food security in the Communal Lands of Zimbabwe* Harare; Dept. of Rural and Urban Planning RUP Occasional Paper No. 11 May 1988

Low, Allan, "The economics of tillage" In: *Tillage, past and future* Proceedings of a workshop held at the Institute of Agricultural Engineering, Hatcliffe, Harare 1989 CIMMYT Networkshop report No. 22 Harare 1991

Mackenzie, S., "Practical application of economics of small scale dryland farming in the Communal Lands in the semiarid areas of Zimbabwe" In *Cropping in the semiarid areas of Zimbabwe* Proceedings of a workshop in Harare 1987

MacMillan J, et al., *Benefit Cost Analysis of farm research and demonstrations, Zimbabwe* Staff Working Paper Dept. of Agricultural Economics and Extension, University of Zimbabwe August 1991

Mehretu, Assefa and Godfrey Mudimu, *Patterns in land utilization and cognitive behavior on resource stewardship in communal areas of Zimbabwe: Toward a comprehensive design for land analysis and policy* Harare: Dept. of Agricultural Economics and Extension Staff working paper June 1991

Ministry of Lands, Agriculture and Rural Resettlement, *The first annual report of farm management data for communal areas farm units 1988/89 farming season* Harare 1990

Norton, A.J., "A systematic method of selecting and recommending tillage systems in Natural Regions III, IV and V. In *Cropping in the semiarid areas of Zimbabwe* Proceedings of a workshop in Harare 1987

Oldrieve, Brian, "Conservation tillage in action" In. Malcolm Vowles (ed.) *Conservation tillage, a handbook for commercial farmers in Zimbabwe* Harare 1989

Reisch, Erwin and Jrgen Zeddies, *Einfhrung in die landwirtschaftliche Betriebslehre, spezieller Teil* Stuttgart 1977

Rohrbach, David and J. Stack, B. Hedden-Dunkhorst, and J. Govereh, "Agricultural growth and national food security" In UZ/MSU Food Security Project *Integrating food, nutrition and agricultural policy in Zimbabwe* Proceedings of the First National Consultative Workshop on Integrating Food, Nutrition and Agricultural Policy, Juliasdale 1990

Rukuni, Mandivamba, *Comparative agricultural production constraints of a high and low rainfall communal area farming system* Staff Working Paper Dept. of Land Management Harare 1985

Stack, Jane and Charles Chopack, "Household income patterns in Zimbabwe's Communal areas" In UZ/MSU Food Security Project *Integrating food, nutrition and agricultural policy in Zimbabwe* Proceedings of the First National Consultative Workshop on Integrating Food, Nutrition and Agricultural Policy, Juliasdale 1990

Stevens, P.A., *Observational tillage trials.* Paper presented at the Agritex Technical Conference, October 16 - 20, 1989, Nyanga Zimbabwe 1989

Stocking. Michael, *The cost of soil erosion in Zimbabwe in terms of the loss of three major nutrients* Rome, Consultants Working Paper No.3 FAO 1986

Thompson J.G. and W.D. Purves, "A guide to the soils of Rhodesia *Rhodesia Agricultural Journal Technical Handbook No.3* Salisbury 1978

Truscott, Kate, "Women and tillage, strategic issues posed by farmers groups" In: *Tillage, past and future* Proceedings of a workshop held at the Institute of Agricultural Engineering, Hatcliffe, Harare 1989 CIMMYT Networkshop report No. 22 Harare 1991

Vogel, Horst, "Conservation tillage for small-scale farming in Zimbabwe" Accepted for publication In *Soil and Tillage research* Proceedings 12th international conference - Tillage for sustainable crop production, Nigeria July 1991

Whitlow, Richard, *Land degradation in Zimbabwe, a geographical survey* Harare 1988

World Bank, *Zimbabwe, Agricultural Sector Memorandum* Washington May 31, 1991

APPENDIX I

Estimating Annual Sheetwash Erosion from Cropland with SLEMSA

$Z = K * X * C$

HHNUM	SLEMSA Fb	K	i	C	X	Z
1	4.0	79.51	33	0.14	0.56	6.17
2	4.0	79.51	66	0.02	0.56	0.85
3	3.5	115.82	20	0.30	0.60	20.89
4	3.5	115.82	18	0.34	0.71	27.92
5	4.0	79.51	48	0.06	0.71	3.17
6	4.0	79.51	31	0.16	0.56	6.95
7	3.5	115.82	19	0.32	0.60	22.18
8	4.0	79.51	37	0.11	0.89	7.68
9	4.0	79.51	25	0.22	0.56	9.96
10	4.0	79.51	38	0.10	0.89	7.23
11	4.0	79.51	39	0.10	0.71	5.44
12	4.0	79.51	25	0.22	0.56	9.96
13	3.0	168.72	16	0.38	0.77	49.72
14	4.0	79.51	59	0.03	1.09	2.50
15	3.5	115.82	24	0.24	0.56	15.41
16	4.0	79.51	26	0.21	0.56	9.38
17	3.5	115.82	21	0.28	0.56	18.45
18	4.0	79.51	37	0.11	0.56	4.85
19	4.0	79.51	25	0.22	0.56	9.96
20	4.0	79.51	28	0.19	0.46	6.76
21	4.0	79.51	35	0.12	0.36	3.52
22	4.0	79.51	26	0.21	0.46	7.63
23	4.0	79.51	30	0.17	0.56	7.38
24	4.0	79.51	30	0.17	0.60	7.87
25	4.0	79.51	31	0.16	0.60	7.41
26	4.0	79.51	31	0.16	0.46	5.65
27	4.0	79.51	37	0.11	0.36	3.12
28	3.5	115.82	22	0.27	0.56	17.38
29	4.0	79.51	25	0.22	0.56	9.96
30	4.0	79.51	37	0.11	0.60	5.17
31	3.5	115.82	29	0.18	0.77	15.65
32	4.0	79.51	32	0.15	0.71	8.27
33	4.0	79.51	36	0.12	0.71	6.51
34	3.0	168.72	20	0.30	0.89	45.18
38	4.0	79.51	51	0.05	0.46	1.70
52	4.0	79.51	28	0.19	0.56	8.32
53	4.0	79.51	29	0.18	0.56	7.84
54	3.5	115.82	32	0.15	0.89	15.10
55	4.0	79.51	40	0.09	0.56	4.05
56	4.0	79.51	32	0.15	0.56	6.55
57	4.0	79.51	36	0.12	0.36	3.31
58	4.0	79.51	33	0.14	0.36	3.97
59	3.5	115.82	22	0.27	0.56	17.38
60	3.5	115.82	21	0.28	0.56	18.45
62	3.5	115.82	21	0.28	0.56	18.45
63	3.5	115.82	17	0.36	0.56	23.46
64	3.0	168.72	12	0.49	0.56	46.12
65	3.5	115.82	19	0.32	0.56	20.80
66	4.0	79.51	22	0.27	0.36	7.67
67	3.5	115.82	12	0.49	0.36	20.36
68	4.0	79.51	54	0.04	0.36	1.12
69	4.0	79.51	28	0.19	0.56	8.32
70	3.5	115.82	19	0.32	0.60	22.18

Basic Statistics

Cases		54.00
Average	t/ha	12.36
Stdeviatio	t/ha	10.67
Varianz	t/ha	115.24
Min	t/ha	0.85
Max	t/ha	49.72

Frequency Distribution

soil loss t/ha	cases
0-2	3
3-5	8
6-10	25
11-15	0
16-20	8
20-30	7
30-50	3

APPENDIX 2

Variables used in the regression analysis

HHNUM	FBAG (t/ha)	FCHEM	FPLADAY	FRIDGE (hrs/ha)	FFERT (Z$/ha)
1	3.37	0	20	39.52	248.53
2	10.79	0	8	47.42	399.65
3	3.00	1	50	19.76	130.19
4	1.44	0	35	5.93	111.43
6	6.74	0	50	49.40	150.24
7	2.70	0	50	29.64	68.10
8	3.60	0	5	49.40	205.75
10	4.50	0	20	19.76	316.70
15	1.35	0	5	23.05	312.70
16	2.25	0	20	39.52	312.70
17	1.35	0	20	65.87	145.66
18	3.60	0	5	19.76	994.13
19	2.92	0	35	9.88	184.36
20	3.37	0	30	14.82	312.70
21	3.15	1	5	29.64	186.40
22	2.25	0	20	29.64	250.57
25	4.50	0	30	9.88	274.20
26	4.50	0	25	29.64	312.70
27	5.99	0	35	82.33	828.44
28	2.25	0	35	39.52	248.53
29	3.00	0	35	9.88	208.47
30	5.99	0	35	9.88	416.94
31	3.60	0	35	19.76	360.78
32	3.30	0	20	23.05	165.69
33	4.05	0	20	22.23	372.80
52	1.98	1	1	0.00	100.91
53	4.27	1	30	0.00	156.35
54	3.60	1	20	0.00	64.10
55	5.09	0	20	0.00	283.16
56	3.37	0	20	0.00	314.70
57	4.20	1	20	0.00	253.25
58	3.71	0	20	0.00	278.58
59	1.35	0	20	0.00	110.22
60	1.80	0	30	0.00	99.41
62	1.12	0	20	0.00	60.10
63	0.45	0	5	0.00	186.29
64	0.45	0	35	0.00	0.00
65	0.90	1	20	0.00	72.10
66	1.24	0	15	0.00	190.44
67	0.75	0	60	0.00	185.72
68	6.74	1	1	0.00	180.29
69	2.02	0	5	0.00	124.27
70	1.80	0	35	0.00	248.53
71	2.25	0	10	0.00	331.38