Parametric and non-parametric estimation of soil conservation impact on productivity in the northwestern Ethiopian highlands

Menale Kassie[1*], Stein T. Holden[2]

[1] *Environmental Economics Policy Forum of Ethiopia, P.O.Box 2479, Addis Ababa, Ethiopia*

[2] *Department of Economics and Resources Management, Norwegian University of Life Science, P.O.Box 5033, N-1432, Aas, Norway*

Contributed paper prepared for presentation at the international Association of Agricultural Economists Conference, Gold Coast, Australia,

August 12-18, 2006

* Corresponding author: Tel.: +251-115-538632; Fax: +251-115-505588; email address: dawitkassie@yahoo.com (Menale Kassie)

1. Introduction

Land degradation in the form of soil erosion and nutrient depletion presents a threat to food security and sustainability of agricultural production in many developing countries. Governments and development agencies have invested substantial resources to promote conservation practices to reduce land degradation, and there is growing literature on soil erosion and water conservation programs. However, there remains little understanding of soil conservation impact on land productivity. This paper assesses the land productivity impacts of a top-down approach to introducing physical soil conservation technology in a high rainfall area in the Ethiopian highlands. The study also adapted the Oaxaca-Blinder (OB) (1973) decomposition technique to investigate the sources of the non-conserved-conserved plots productivity gap. Sensitivity analysis is also conducted to check if some technical changes on bunds can result in higher productivity. The analysis is based on multiple plot level observations per household.

The key contribution of the paper is methodological compared to previous studies (e.g. Shively, 1998; Shively, 2001). First, the application of OB decomposition to determine the sources of productivity gap and their contributions between conserved and non-conserved plots is new in this kind of study. Second, the use of matching methods and switching regression analysis to assess the impact of conservation on productivity are also new elements of this paper. Finally, the nature of the data, cross section with multiple plots per household, allowed controlling for unobservable household characteristics through household fixed and random effects and for observable plot characteristics that have impact on technology adoption and production decisions.

The paper organized into five sections. The methodology and data source are presented in section two and three, respectively. Section four presents empirical results followed by conclusion in the final section.

2. Methodology

Assessment of the productivity gain of conservation based on non-experimental observations is not an easy task because the counterfactual of interest is not observed. That is, we do not observe the outcome of plots with conservation had they not had conservation structures (or the reverse). Ex-post assessment of the gains to conservation versus without conservation is also difficult using observational data because the unobserved household and plot attributes are likely to influence soil conservation (technology) adoption, input application choices and observed output. The failure to account for household and plot heterogeneity can lead to inconsistent estimates of the impact of technology adoption. Conservation measures may be introduced externally through projects or development agents (DAs)[2]. If project experts and DAs select households and plots based on some unobserved factors for the econometricians (selection bias), the impact of technology on productivity will not be estimated consistently without controlling for the selection criteria. The estimation methods most suitable to solve these problems and achieve our objectives with the available data are switching regression models, matching methods, and stochastic dominance analysis.

The OB decomposition provides an empirical methodology for investigating the contribution of factors underlying the conserved and non-conserved plots productivity gap. It separates the portion of the gap resulting from differences in plot characteristics (endowments) of conserved and non-conserved plots from the portion that resulted from the returns to those characteristics (coefficients). The decomposition requires two steps. The first step is to estimate separate regression equation for the two plots. The second step is to use the regression results to decompose the difference in mean output value per ha between the plots[3].

---

[2] In the study area Soil Conservation Research Project (SCRP) was established in 1984 as a collaborative project between the Ethiopian and Swiss governments to identify suitable conservation technologies for different areas.

[3] The detail specification of each method is available on Kassie (2006).

Our empirical model is based on a theoretical dynamic household model where expected utility maximization framework is assumed to represent investment and production decisions made under uncertainty. The key outcome of interest in this study is output value per hectare[4].

3. Data source and soil conservation technology

The study village (Anjeni) is located in Northwestern Ethiopian highlands. It is characterised by high rainfall (1690 mm per annum) regime and deep to medium soil depth.

The data are drawn from a random sample of 148 farm households, operating 1290 plots, collected in 2001. Household and plot level variables were collected for the 2000 production year. Among the variables collected, plot size, plot slope and space occupied by conservation structures were measured using measuring tapes and inclinometer.

Table 1 provides the characteristics of the sample for conserved and non-conserved plots for the entire sample and for the sub-sample of barley plots. Barley is the major crop in the study area and the number of plots planted to barley were relatively bigger than those planted to other crops. The returns to conservation may change over time. We differentiated plots into two: plots with 15 years old conservation bunds and plots with less than 15 years old conservation bunds. About 32.7% of the sample plots had conservation structures and 61% of these had structures that were 15 years at the time of the survey.

The conservation technology considered in this study was *fanya juu* bunds[5] introduced by the SCRP; traditional ditch (furrow) being one of alternative indigenous conservation measures being practiced in the area.

Even if physical conservation measures may not directly increase crop productivity, they can be used for producing natural fodder grass on bunds, besides reducing the soil loss. During the rainy

[4] We used values instead of physical output per ha since more than one crop is grown on a plot and farmers cultivate many crops simultaneously. We use productivity and output value per ha interchangeably in this paper.
[5] Project experts and DAs mobilized community labour for constructing the *fanya juu* terracing on 78% of all conserved plots. Initially, the SCRP built a health clinic for the village as an instrument to motivate farmers to construct and maintain the terracing on their own plots.

season when grazing is restricted, grass from conservation structures is fed to the oxen. Farm households reported that fodder grass on bunds covered 9.5% of the total livestock feed requirements. The estimated grass productivity on bunds ranges from 0-180 kg dry matter per plot (1995 kg per hectare). This benefit is considered as an output of the system, in addition to the crop output. Since there is no market for grass or hay in the area, the value of the grass from bunds is expressed in terms of the animal feed for oxen.

4. Results

Fixed and random effects models were used on the entire sample plots and barley sub-sample plots, respectively. The use of fixed effects on relatively small sample size inflates the standard errors of estimates (Mundlak, 1978). Under parametric analysis endogenous and exogenous switching regression models were estimated[6].

4.1. Adoption of conservation

Results are presented in Table 2[7]. The probit model was estimated to serve as an input for endogenous switching regression models[8]. Therefore, the results are presented briefly based on the entire sample plots. For the barley sub-sample plots we did not find as many significant variables as the entire sample. Results indicated that rented-in plots and plot slope (quadratic) were negatively correlated with adoption probability. Adoption probability was positively correlated with plot size, plot distance and plot slope (linear term).

4.2. Conservation impact on productivity

4.2.1. Parametric model

[6] Some methods have been developed to correct for selectivity bias in panel data context (e.g. Vella and Verbeek, 1999; Wooldridge, 1995). Although it is not clear to what extent these methods can be extended to the data structure we have (cross section multiple observations per household), we tried the Wooldridge (1995) method. However, this method did not fit our data, sine the covariance matrix was singular and coefficients and predicted values were inflated. We thus switched to a cross section endogenous switching regression model.

[7] The model was also estimated with household level variables but results are not reported to save space.

[8] The Probit (selection) model used to derive the correction factor (Inverse Mills ratio) that helps to correct bias introduced when conservation induced changes in productivity are accompanied by self-selection in the technology adoption process.

Results are reported in Tables 3, 4, 5 and 6. The Chow test rejected the hypothesis that coefficients from conservation and non-conservation productivity regressions were the same. So separate productivity estimation was important to get consistent estimates of the impact of conservation technology on productivity.

To determine the effects of conservation adoption on productivity, we compared the predicted mean productivity obtained from plots with and without conservation regime. The mean predicted productivity was determined holding all the explanatory variables at their representative value (mean) except the variable plot slope in order to get variation for statistical testing purpose[9].

We found that the mean productivity was lower on conserved plots than on non-conserved plots for each specification (Table 5)[10]. The age of conservation structures did not change the overall results; we used barley plots to examine conservation age effect on productivity. These results were in line with those from non-parametric analysis discussed in section 4.2.2.

4.2.2. Stochastic Dominance Analysis and Matching Methods

Results from test of first order stochastic dominance analysis revealed that the cumulative density function (CDF) for productivity without conservation unambiguously dominated the productivity distributions with conservation for all productivity levels (Figures 1 and 2). This implies that the chance of getting higher productivity was higher for plots without conservation than plots with conservation, at each CDF level.

Comparing the productivity distribution of old and new conservation structures, we did not see clear pattern for the entire sample plots (figure 1). For the barley plots, however, those with old conservation structures seem to dominate except for some productivity ranges to the right of the productivity distributions (figure 2).

---

[9] There was no mean plot slope difference between conserved and non-conserved plots. The mean predicted productivity was also determined using the observed distribution of all explanatory variables; the conclusion remained the same.

[10] The results were robust even when all the conventional inputs were excluded. We tried also the random effects models for the entire sample; however, the conclusion remained the same as in the fixed effects models.

The results of the matching estimators are presented in Table 6. The matching estimates showed a significant negative effect of conservation on mean productivity (Column E).

4.2.3. Productivity gap decomposition

The OB decomposition is presented in Table 7. The OB decomposition revealed that there was little difference in plot characteristics between conserved and non-conserved plots. However, the returns to those characteristics were higher for non-conserved plots. Considering barley plots, conserved plots had higher total endowments than non-conserved plots. However, the returns to those characteristics were lower on conserved plots than on non-conserved plots. Specific results for endowments of soil fertility and soil depth between plots with and without conservation indicated little differences although the returns to these variables were higher for plots without conservation. This finding implies that *fanya juu* bunds are inappropriate to the local conditions under the existing condition. Farmers reported that these bunds have problem of water-logging, reduce land available for production, and create difficulties in turning ox-drawn plough due to narrow bund spacing. Apart from these, *fanya juu* bunds is not integrated with productive augmenting land management activities.

4.2.4. Sensitivity analysis (SA)

The economic performance of conservation bunds could be improved if bunds themselves can be used in a productive manner by planting fodder grass with an economic value[11]. Overall, the results suggested that there are possibilities to make conserved plots as productive as non-conserved ones (Table 6 column F and Figure 3 and 4). However, these results are not conclusive. Detailed studies regarding grass and other improved forage fodders and their impact on livestock could add to these findings. In addition, one can also consider other scenarios such as planting high value crops just behind bunds.

[11] We tested this hypothesis by increasing the grass production on terracing from the current level of production (1995 kg per ha) to 5986 kg per ha; the estimated native pasture productivity from communal grazing land in Ethiopia ranges between 3000–6000 kg per ha (Mengistu, 1987).

5. Conclusions

This paper measures the impacts of *fanya juu* bunds on productivity in a high rainfall area of the Ethiopian highlands. Findings suggest that these bunds are counter-productive in a high rainfall area in the Ethiopian highlands. The OB productivity decomposition results showed that there was little difference in endowments between conserved and non-conserved plots. However, the overall returns to these endowments were higher for non-conserved plots. The sensitivity analysis results suggest that there are possibilities to make conserved plots as productive as non-conserved ones.

The results imply that there is a need for efforts to increase the economic performance of *fanya juu* bunds through some technical changes such as natural grass production or planting better fodders such as annual and perennial forage legumes on bunds. This can also help to reduce the severe livestock feed and fuel wood shortage in the Ethiopian highlands. Finally, we note that Ethiopia has diverse agro-ecological conditions, which has implications on technology performance. Further studies are, therefore, necessary to assess the effects of soil conservation on productivity in moisture stress areas and its influence on production risk. This may help to understand the role of soil conservation for the diverse agro-ecological conditions and to design better soil conservation strategies that have both physical and economic benefits as well as that fit the local conditions.

References

Blinder, S. A., 1973. Wage Discrimination: Reduced Form and Structural Estimates. Journal of Human Resources, 18: 436-455.

Mengistu, A., 1987. Feed resources in Ethiopia. In: Kategile, J.A., Said, A.N. and Dzowela, B.H. (eds.). Animal feed Resources for Small Scale Livestock Producers. Proceedings of the second Pasture Network for eastern and Southern Africa (PANESA) workshop, held in Nairobi, Kenya, 11-15 November 1985. IDRC

Mundlak, Y., 1978. On the pooling of time series and cross section data. Econometrica,46:69-85.

Nicholson, C. F., Lee, R. D., Boisvert, N. R., Blake, W. R., Urbina, I. C. 1994. Optimisation model of the dual-purpose cattle production system in the humid lowlands of Venezuela. Agricultural Systems 46(3): 311-334.

Oaxaca, R., 1973. Male-Female Wage Differentials in Urban Labour Markets. International Economic Review, 14: 693-709.

Shively, G. E., 2001. Poverty, Consumption risk, and soil conservation. Journal of Development Economics, 65:267-290.

Shively, G. E., 1998. Modelling impacts of soil conservation on productivity and productivity variability: Evidence from a heteroskedastic switching regression. Selected paper at annual meeting of the American Agricultural Economics Association 2-5 August 1998, Salt Lake City, Utah.

Vella, F.,Verbeek., M., 1999. Two-step estimation of panel data models with censored endogenous variables and selection bias. Journal of Econometrics, 90: 239-263.

Wooldridge, J. M., 1995. Selection correction for panel data models under condition independence assumptions. Journal of Econometrics, 68: 115-132.

Table 1. Descriptive statistics

Variables	Entire sample				Barley plots							
					Entire barley plots				Old conservation		New conservation	
	With conservation		Without conservation		With conservation		Without conservation					
	mean	sd	mean	sd	mean	sd	Mean	sd	mean	sd	mean	sd
Hectares devoted to conservation (continuous)	0.02	0.01	0.00	0.00	0.02	0.01	0.00	0.00	0.02	0.02	0.01	0.01
plots with good fertile soil (dummy)	0.17	0.38	0.20	0.40	0.22	0.41	0.21	0.41	0.23	0.42	0.19	0.39
Plots with medium fertile soil (dummy)	0.48	0.50	0.52	0.50	0.47	0.50	0.54	0.50	0.47	0.50	0.49	0.50
Plots with poor fertile soil (dummy)	0.35	0.48	0.28	0.45	0.31	0.46	0.25	0.43	0.30	0.46	0.32	0.47
Plots with shallow soil depth (dummy)	0.29	0.45	0.23	0.42	0.27	0.44	0.19	0.40	0.22	0.42	0.34	0.48
Plots with deep soil depth (dummy)	0.39	0.49	0.44	0.50	0.42	0.49	0.47	0.50	0.41	0.49	0.43	0.50
Plots with medium soil depth (dummy)	0.32	0.47	0.33	0.47	0.32	0.47	0.34	0.47	0.37	0.49	0.23	0.42
Plot's slope in degree (continuous)	17.06	6.63	17.53	10.22	16.64	7.41	19.01	12.95	15.84	5.21	17.92	9.92
Intercropped plots (dummy)	0.24	0.43	0.23	0.42	0.20	0.40	0.08	0.27	0.22	0.42	0.17	0.38
Plot distance in minutes from homestead (continuous)	14	16	18	32	14	16	14	18	13	16	15	16
Plot size in ha (continuous)	0.26	0.14	0.24	0.14	0.30	0.13	0.28	0.14	0.30	0.14	0.30	0.13
Rented in plots (dummy)	0.09	0.28	0.18	0.38	0.12	0.32	0.12	0.33	0.14	0.35	0.08	0.27
Output value per ha (continuous)	696.86	577.34	888.47	742.20	520.94	331.50	615.96	417.12	542.66	330.14	485.70	333.80
Fertilizer value per ha (continuous)	128.91	175.93	91.81	190.61	82.55	107.34	41.05	102.55	88.72	116.66	72.54	90.36
Seed value per ha (continuous)	106.81	104.78	132.34	148.44	138.77	77.18	143.15	94.08	137.10	70.13	141.48	88.07
Ploughing labor per ha (continuous)	14.79	19.14	18.00	24.04	9.84	6.12	12.24	9.37	9.86	6.46	9.81	5.57
Weeding labor per ha (continuous)	13.89	20.74	20.90	34.49	0.69	2.76	1.34	4.27	0.61	2.44	0.81	3.22
Number of observations*	422(124)		868(147)		139(77)		263(118)		86(53)		53(35)	

* Figure in parentheses refer to household number.

Table 2. Results of Probit analysis of soil conservation adoption

Independent variables	Entire sample plots	Barley plots
Plots with good fertile soil	-0.113(0.161)	0.092(0.210)
Plots with medium fertile soil	-0.083(0.123)	-0.098(0.171)
Plots with good soil depth	-0.122(0.131)	-0.259(0.192)
Plots with medium soil depth	-0.112(0.144)	-0.156(0.195)
Plot slope	0.036(0.016)**	-0.002(0.019)
Plot slope square	-0.001(0.000)**	-0.000(0.000)
Ln (plot distance from residence)	0.057(0.045)	0.113(0.053)**
Ln (plot size)	0.164(0.062)***	0.225(0.121)*
Rented in plots	-0.590(0.175)***	-0.119(0.208)
Constant	-0.443(0.260)*	0.027(0.370)
Observations	1290	402
Percent correctly predicted	67	66
Model test	Wald chi2(10)= 82.15(0.000)***	Wald chi2(9) = 16.07(0.066)*
Figure in parentheses refer to standard errors		
* Significant at 10%; ** Significant at 5%; *** Significant at 1%		

Table 3. Determinants of output value (Dependent variable = logarithm of output value per ha)

Independent variables	Endogenous switching regression model			
	Entire sample		Barley plots	
	With conservation	Without conservation	With conservation	Without conservation
Input variables				
Ln (ploughing labour per ha)	0.152(0.080)*	0.293(0.045)***	0.083(0.112)	0.211(0.100)**
Ln (weeding labour per ha)	0.111(0.030)***	0.110(0.017)***	0.094(0.070)	0.017(0.051)
Ln (fertilizer value per ha)	0.046(0.015)***	0.019(0.009)**	0.042(0.022)*	0.037(0.017)**
ln (seed value per ha)	0.165(0.044)***	0.232(0.023)***	0.368(0.133)***	0.402(0.112)***
Plot characteristics				
Ln (plot slope)	0.019(0.077)	0.075(0.052)	0.117(0.127)	0.090(0.068)
Plot distance from residence	-0.011(0.029)	0.026(0.016)	0.028(0.055)	0.005(0.027)
Rented in plots	0.156(0.098)	0.215(0.063)***	0.087(0.151)	0.054(0.101)
Plots with good fertile soil	0.187(0.097)*	0.163(0.070)**	0.175(0.169)	0.079(0.146)
Plots with medium fertile soil	-0.008(0.074)	0.084(0.053)	-0.051(0.121)	0.120(0.103)
Plots with good soil depth	-0.017(0.084)	0.065(0.070)	-0.045(0.134)	0.087(0.127)
Plots with medium soil depth	-0.051(0.087)	-0.028(0.064)	-0.014(0.161)	-0.059(0.105)
Intercropped plots	0.467(0.077)***	0.232(0.065)***	0.290(0.130)**	0.391(0.116)***
Mills ratio	-0.046(0.139)	0.138(0.149)	-0.208(0.176)	0.089(0.233)
Constant	4.789(0.311)***	4.082(0.262)***	3.779(0.724)***	3.392(0.546)***
Observations	422	868	139	263
R-squared	0.33	0.41	0.22	0.32
Model test	F(13, 125) = 14.49(0.000)***	F(13, 146) = 29.79(0.000)***	F(13, 76) = 2.79(0.003)***	F(13, 117) = 5.68(0.000)***
Figure in parentheses refer to bootstrapped standard errors adjusted for clustering effect				
* Significant at 10%; ** Significant at 5%; *** Significant at 1%				

Table 4. Determinants of output value (Dependent variable = logarithm of output value per ha)

Independent variables	Exogenous switching regression					
	Entire sample		Barley plots			
	With conservation	Without conservation	With conservation	Without conservation	Old conservation	New conservation
Input variables						
Ln (ploughing labour per ha)	0.129(0.091)	0.314(0.047)***	0.080(0.109)	0.204(0.099)**	0.323(0.162)**	-0.221(0.113)*
Ln (weeding labour per ha)	0.114(0.037)***	0.112(0.018)***	0.092(0.071)	0.040(0.048)	0.036(0.097)	0.177(0.110)
Ln (fertilizer value per ha)	0.043(0.018)**	0.020(0.009)**	0.040(0.022)*	0.046(0.015)***	0.066(0.022)***	0.050(0.054)
Ln (seed value per ha)	0.161(0.052)**	0.225(0.021)***	0.354(0.130)***	0.406(0.110)***	0.233(0.190)	0.587(0.148)***
Plot characteristics						
Ln (plot slope)	0.062(0.113)	0.081(0.042)*	0.080(0.125)	0.119(0.057)**	0.030(0.201)	0.211(0.209)
Ln (plot distance from residence)	0.018(0.046)	0.032(0.019)*	0.034(0.055)	-0.003(0.027)	0.013(0.067)	0.083(0.103)
Rented in plots	0.191(0.153)	0.208(0.068)***	0.096(0.151)	0.012(0.105)	0.189(0.135)	-0.032(0.369)
Plots with good fertile soil	-0.005(0.166)	0.149(0.084)*	0.163(0.171)	0.117(0.147)	-0.025(0.173)	0.343(0.361)
Plots with medium fertile soil	-0.093(0.120)	0.119(0.061)*	-0.079(0.115)	0.156(0.102)	-0.184(0.116)	-0.081(0.283)
Plots with good soil depth	0.045(0.128)	0.111(0.076)	-0.070(0.129)	0.061(0.121)	-0.162(0.150)	0.003(0.209)
Plots with medium soil depth	-0.067(0.142)	-0.000(0.075)	-0.055(0.161)	-0.075(0.105)	0.007(0.183)	-0.284(0.268)
Intercropped plots	0.419(0.103)***	0.258(0.059)***	0.304(0.131)**	0.450(0.109)***	0.518(0.149)***	-0.192(0.319)
Constant	4.707(0.406)***	3.905(0.186)***	3.771(0.727)***	3.253(0.433)***	4.028(0.960)***	2.842(1.094)***
Observations	422	868	139	263	86	53
R-squared	0.48	0.56				
Model test	F(12, 284) = 7.51(0.000)***	F(12, 709) = 37.62(0.000)***	Wald chi2(12)= 34.37 (0.001)***	Wald chi2(12)= 90.19(0.000)***	Wald chi2(12) = 41.33(0.000)***	Wald chi2(12) = 42.78(0.000)***
Figure in parentheses refer to standard errors adjusted for clustering effect						
* Significant at 10%; ** Significant at 5%; *** Significant at 1%						

Table 5. Parametric estimation results

Regression types	Exogenous switching regression		Endogenous switching regression		Mean productivity difference due to adoption	
	Predicted mean productivity with conservation	Predicted mean productivity without conservation	Predicted mean productivity with conservation	Predicted mean productivity without conservation		
	A	B	C	D	E= A-B	F=C-D
Entire sample plots	6.283	6.515	6.088	6.639	-0.232(0.004)***	-0.551(0.001)***
Barley sub-sample plots						
Entire barley plots	6.081	6.221	6.124	6.379	-0.140(0.008)***	-0.255(0.004)***
Old conservations	6.134	6.221			-0.087(0.005)***	
New conservations	6.015	6.221			-0.206(0.005)*** [-0.119(0.016)]***	

Notes: (A) [ ] denotes mean productivity difference between new and old conservation; (B) Robust standard errors adjusted for clustering in parenthesis; and (C) *** denote significant at 1%

Table 6. Non-parametric estimation results (matching methods)

Matching methods and types of plots	Number of treated group (conserved plots)		Number of control group (non-conserved plots)		Treatment effect (differences in means)	
	Before increasing grass production on bunds	After increasing grass production on bunds	Before increasing grass production on bunds	After increasing grass production on bunds	Before increasing grass production on bunds	After increasing grass production on bunds
	A	B	C	D	E= A-C	F= B-D
Entire sample plots						
Kernel Matching	422	422	807	811	-154.6(35)****	-81(35)***
Nearest neighbour	422	422	303	303	-192.3(66)***	-123.5(65)*
Stratification	422	422	808	808	-135.8(35)***	-66.9(36)*
Entire barley plots						
Kernel Matching	139	139	245	245	-85.5(31)***	-23.6(33)
Nearest neighbour	139	139	110	110	-78.8(64)	-16.9(65)
Stratification	139	139	246	247	-76.3(36)***	-13.9(36)

Notes: (A) The propensity score is estimated using a probit of treatment status on plots with good fertile soil, plots with medium fertile soil, plots with good soil depth, plots with medium soil depth, plot distance, plot size, plot slope, plot slope square and rented in plots; (B) Figures in parenthesis are bootstrapped standard errors with 200 replications; (C) balancing property satisfied.

Table 7. Productivity decomposition

Endowments	Decompositions results for variables (as percentages)							
	Entire sample plots				Barley plots			
	Entire plots		Old conservation		Entire barley plots		Old conservation	
	Endowments	Coefficients	Endowments	Coefficients	Endowments	Coefficients	Endowments	Coefficients
Ln (ploughing labour per ha)	-2.6	-49.5	-4.1	-35.3	-1.3	-30.0	-5.6	29.6
Ln (weeding labour per ha)	-4.8	0.3	-4.5	-4.9	-1.1	1.5	-0.5	-0.3
Ln (fertilizer value per ha)	3.2	5.1	3.2	7.9	5.3	-0.6	9.2	2.0
Ln (seed value per ha)	-2.6	-28.1	-3.5	-23.0	0.7	-24.8	0.6	-82.6
Ln (plot slope)	0.2	-5.2	-0.0	-26.3	-0.3	-10.7	-0.2	-24.4
Ln (Plot distance)	0.1	-2.8	-0.2	4.3	0.8	7.2	0.2	-1.2
Rented in plots	-1.7	-0.3	-0.0	-3.6	-0.1	1.0	0.3	2.1
Plots with good fertile soil	**0.0**	**-3.1**	**0.0**	**-4.2**	**0.1**	**1.0**	**-0.1**	**-2.9**
Plots with medium fertile soil	**0.3**	**-10.9**	**-0.1**	**-4.4**	**0.5**	**-12.7**	**1.4**	**-18.6**
Plots with good soil depth	**-0.2**	**-3.0**	**0.1**	**-5.4**	**0.4**	**-6.1**	**1.0**	**-10.0**
Plots with medium soil depth	**0.1**	**-2.2**	**-1.3**	**-10.4**	**0.1**	**-0.7**	**0.0**	**2.5**
Intercropped plots	0.3	3.8	0.6	4.9	3.7	-1.2	7.3	0.5
Subtotal	**-7.6**	**-95.9**	**-9.9**	**-100.2**	**8.8**	**-74.5**	**13.5**	**-99.7**
Productivity gap	**Summary of decomposition results (as percentages)**							
-Due to endowments	-7.6		-9.9		8.8		13.5	
-Due to coefficients	-95.9		-100.2		-74.5		-99.7	

Note: (A) positive and negative number indicates advantage to plots with and without conservation, respectively.

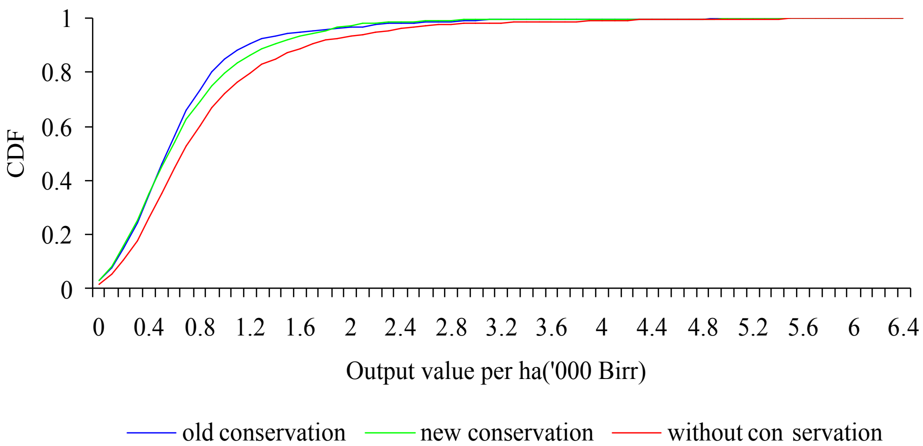

Figure 1. CDF for the entire sample plot s before increasing fodder grass production on bunds

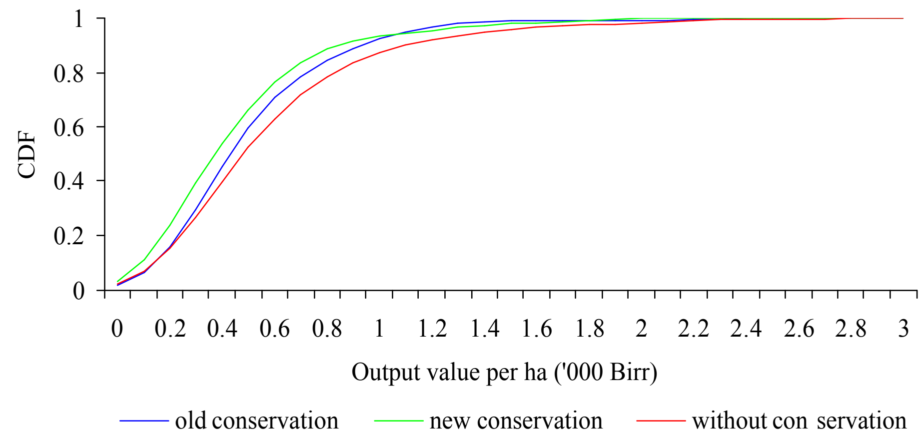

Figure 2. CDF for the Barley plot s before increasing fodder grass production on bunds

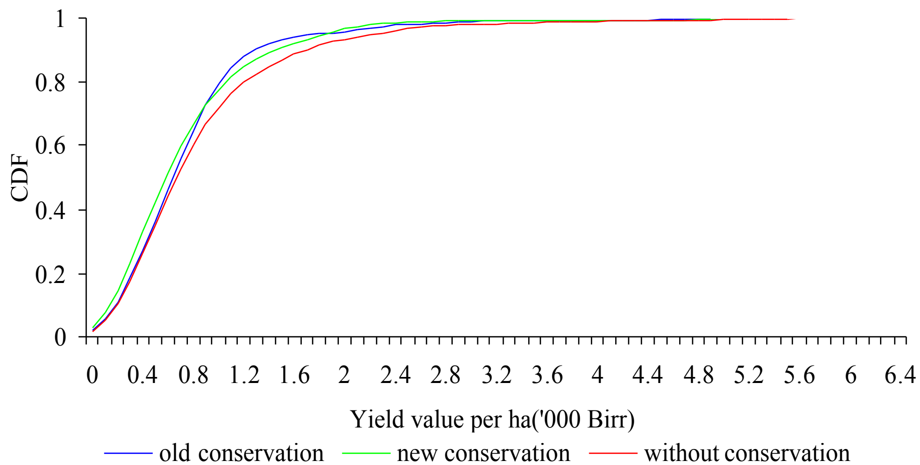

Figure 3. CDF for the entire sample plo ts after increasing fodder grass production on bunds

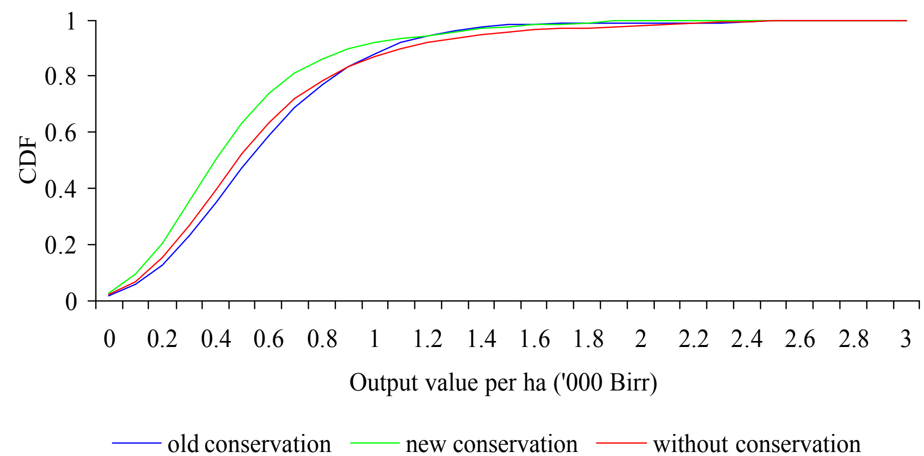

Figure 4. CDF for the Barley plots after increasing grass produc tion on bunds