Impact of Adopting Soil Conservation Practices on Wheat Yield in Lesotho

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Abstract

This study assesses the impact of adopting soil conservation practices on wheat yield in Lesotho. The study uses input-output data collected from 50 smallholder farmers in Mafeteng and Maseru districts, the major wheat growing areas in the country. A system of equations was used to estimate factors affecting adoption of soil conservation measures, and impact of soil conservation measures on wheat yield. For each farmer's wheat field, based on the soil conservation practices adopted by the farmer, two soil conservation variables related to farmer's soils erosion control methods were constructed. Two Tobit models and a modified Cobb-Douglas production function were used to model adoption, and impact of, soil conservation measures respectively. The adoption of two soil conservation measures was modeled as function of household's demographic characteristics and availability of extension services. The yield equation was modeled as a function of inputs used in production and soil conservation efforts. The results indicate that soil conservation efforts were superior to inorganic fertilizer application in terms of increasing wheat yield. Increase in soil conservation efforts, coupled with low inorganic fertilizer use has a potential of increasing wheat production among smallholder farmers in the area.

Key words: Adoption, Impact, Improved Wheat Varieties, Lesotho, Soil Conservation

Introduction

Information on the causes and effects of soil erosion on Lesotho's agricultural productivity is quite limited, despite considerable erosion being visible in many parts of the country. It is evident that soil loss and land degradation have escalated in recent years with a consequence of decreasing agricultural productivity in the country. Coupled with Lesotho's topographical and climatic variation, soil erosion is severe in most parts of the country. Only 13% of land is arable for growing crops and in recent years, soil erosion has reduced this to 9% (LMRG, 1996). Because of high human population in the lowlands, even with a moderate livestock population, extensive overgrazing, soil erosion and rapid deterioration of water and soil resources occur at an alarming rate. Everywhere, the plateau and hill slopes are marked by signs of heavy erosion by water and wind, leaving behind bare bedrock, laterite hard pans and stony soils lacking in organic matter.

According to the Kingdom of Lesotho's report to the United Nation conference on environment and development (1980), about 54% of cropland and 28% of those in the mountains are subject to severe sheet erosion (KoL, 1980). Further, about 40% of the cultivated area should ideally be under fodder or pasture. Soils are low in organic matter; yields are low and decreasing, and cultivated area is diminishing. About 50-60% of rangelands show severe soil erosion and degradation. Significantly, in quantitative terms, soil losses per year amount to 15 million tonnes from croplands and 23 million from rangelands, and 1 million tonnes from gully erosion (LMRG, 1996).

To increase agricultural productivity, soil conservation is of paramount importance to farmers involved in crop production. Replenishment of soil fertility by artificial fertilizer would be very expensive. Even then, the use of inorganic fertilizers does not compensate for the loss of soil organic matter. This study assesses the potential impact of adopting soil conservation practices on wheat yield.

The focus is on conservation measures advocated by the extension department of the ministry of agriculture co-operatives and land reclamation. These farming practices include contour farming, crop residue management for the improvement of infiltration and planting of cover crops like fodder to increase land productivity. Structural methods include cut-off drains or diversion to cater for excessive run-off, terracing within cropland for reduction of steepness and length of slope, waterways to improve water disposal from the terraces and cut-off drains, and gully treatment by vegetative methods and the construction of silt traps to retard water flow (especially on the catchments area) (MoA, 1988).

A system of equations is used to estimate factors affecting adoption of short-term and long-term soil conservation measures and impact of adopted soil conservation measure on wheat yield. This study deviate from the past studies that assess the impact of soil conservation measures on crop yield in two folds. First, the methodology allows using the whole samples. Past studies that used systems of equations to estimate adoption, and the impact of soil conservation measure, dropped out non-adopters in the yield equation to take into account the sample selection bias. Second, the model takes into account the zero values in the explanatory variables by using the Battese's modified Cobb-Douglas hence BMCD production function. The basic assumption is that farmers who did not use some of the inputs should have different level of yield (thus intercept) from those farmers who used the corresponding inputs. This is important when estimating a system of equations that involve adopters and non-adopters. The modified production function incorporates both intercept and divergent shifts in the model.

Literature Review

Feder, Just and Zilberman (1985) define adoption as the degree of use of a new technology in long run equilibrium when a farmer has full information about the new technology and its potential. Therefore, adoption at the farm level describes the realization of farmer's decision to apply a new technology in the production process. On the other hand, aggregate adoption is defined as the process of spread or diffusion of a new technology within the region. Therefore, a distinction exists between adoption at the individual farm level and aggregate adoption within the targeted region. Adoption at the farm level is often quantified or represented by a binary variable (adoption = 1, non-adoption = 0). In the case of a divisible technology, a continuous variable describing the intensity of adoption (e.g., hectares devoted to a new technology or number of livestock under a new treatment) or extent of adoption (e.g., share of land devoted to a new technology) are used. Other researchers suggest other variables which include the earliness of adoption; the time the technology was first used by the farmer; the thoroughness of adoption; the number of technical components adopted by farmer from the recommended package and an index of innovativeness which aggregate the adoption dimensions mentioned above. In most cases, the adoption response depends on the problem at hand, study objective, available data, and sometimes the available computer package (Feder, Just and Zilberman, 1985).

A particular technology is adopted when the anticipated utility from it exceeds that of non-adoption (Rahm and Huffman, 1984). Since utility is not observable, change in utility can be inferred from farmers' decision of adopting or not adopting a technology (incidence of adoption) or adopting some continuous choice over a predefined interval (Kazianga and Masters, 2001). When assessing the incidence of adoption implies using Probit models (Maddala, 1992). To consider intensity or extent of adoption involves using Tobit models as in Baidu-Forson (1995). Sometimes, a two stage procedure is used to model adoption when it is observed that adoption of one innovation leads to adoption of another complementary farming techniques (Nkonya, *et al.*, 1997; Kaliba, *et al.*, 1999).

Assessing adoption of soil conservation measures, involves defining the soil conservation variable or index, which varies from researcher to researcher. The tendency is to choose one specific soil conservation measure as an indicator of adoption. For example, see Shively (1999) on adoption and impact of contour hedgerows in the Philippines for the case of Probit model, and Kazianga and Masters (2001) on adoption and impact of field bunds and micro-catchments in Burkina Faso for the case of Tobit Model. The difficulty arise when there are several soil conservation measures or a package of soil conservation innovations. Nowak (1987) used the ratio of adopted practices related to total numbers available in the package to define the soil conservation variable for each farmer. This approach is simple because it involves just observing soil conservation practices adopted by the farmer. Kastens and Dhuyvetter (1999) used the ratio of total farm costs relative to the costs of adopted soil conservation measures. This procedure evaluates all inputs used in production at market prices and requires proper record keeping. This study adopted the former approach due to its simplicity and unavailability of price data on all input used in production.

From the literature, factors influencing adoption of new agricultural innovation can be divided into three major categories: farm and farmers' associated attributes, attributes associated with the technology (Adesina *et al.*, 1992) and the farming objective (CIMMYT, 1988; Ockwell, 1991). In the first category, factors discussed in the literature include human capital represented by the level of education of the farmer (Rahm and Huffman, 1985; Goodwin and Schroder, 1994), the risk and risk management strategies (Saha and Love, 1994), the institutional support system, such as marketing facilities, research and extension services, transportation etc (Feder, Just and Zilberman, 1985), availability of production factors and factor endowment such as farm size, number of livestock owned (Rahm and Huffman, 1984), and the level of off-farm income and income sources (Kimhi, 1994). The second and third categories depend on the type of technology and are important when farmers have access to different types of technical innovation e.g., different type of crop varieties with differences in production characteristics and performance, or when dealing with heterogeneous farmers with different farming objectives e.g., small and larger farmers, subsistence and market oriented farmers. Therefore, the influence of each exogenous variable on adoption responses is unique and specific to the study area. These characteristics make adoption studies site specific and often incomparable.

Two techniques are commonly used to study the impact of soil conservation practices on crop productivity. The first approach is the crop modeling system, which uses several ecosystem factors to evaluate the dynamics of crops and soils processes that include soil conservation measures. The technique requires a lot of data and experience in system modeling (Cox, Hammer and Robertson, 2001). The second approach uses abstract models such as a production function based on relatively few variables to relate production to soil conservation activities (Kazianga and Masters, 2001). This technique concentrates on modeling the response of crop growth relative to several exogenous variables that ensure the survival and growth of the crop. The commonly used production functions are the Cobb-Douglas and the translog. The unrestricted translog production function is sometimes preferred because it is general and flexible and allows analysis of interaction of variables (Byiringiro and Reardon, 1996). The Cobb-Douglas is a special case of a translog function, when the interaction terms have zero coefficients (Gujarti, 1995). Unlike the Cobb-Douglas, the translog function does not always generate elasticities of substitution of one, and the isoquant and marginal products derived from the translog depend on the coefficients on the interaction terms. However, under low-input agriculture, most smallholder farmers produce on the increasing side of the production function, and the translog production function may not represent an actual data generating process. Whereas the translog functions are superior when the objective is to calculate the optimal mix of inputs, Cobb-Douglas function often behaves better when the objective is tracing the production frontier under low input agriculture (Shively, 1998).

Empirical Model and Estimation Procedure

To rationalize the model, consider a farmer who chose to adopt some or all soil conservation measures as advocated by the Extension Department in Leshoto. The farmer has two choices: to adopt innovations from short-term soil conservation package (i.e., contour ploughing, crop residue management and cover crops); and /or from long term soil conservation package (i.e., structural methods that include cut-off drains, terracing, gully treatment, and slit traps). Let Ai_j represent percent of innovations adopted from any package (extent of adoption) such that Ai_j=0 for non-adopter, and (0<Ai_j100) for adopters. Also, a binary variable dij (incidence of adoption) can be created such that dij=0 for non-adopter, and di_j=1 for adopter. Formally, this relationship can be presented as follows:

$$\sum_{j=1}^{2} A_{ij}^{*} = \mathrm{B}_j^T Z_{ij} + \varepsilon_{ij}\ , \quad \sum_{j=1}^{2} d_{ij}^{*} = \theta_j^T X_{ij} + \nu_{ij}\ , \tag{1}$$

$$d_{ij} = \begin{cases} 1 & if \quad d_{ij}^{*} > 0 \\ 0 & if \quad d_{ij}^{*} = 0 \end{cases},$$

$$A_{ij} = d_{ij} A_{ij}^{*} \qquad (i = 1, 2, ..., T;\ j = 1, 2).$$

In the equations, A^*_{ij} is the latent variable representing extent of adoption and is generated by the classical linear regression, d^*_{ij} is the latent variable representing incidence of adoption and is generated by the classical Probit regression,$_j$ and θ_j are parameters of the models, superscript T is the transpose function, matrices Z_{ij} and X_{ij} contains variables associated with adoption such that matrix X is contained in matrix Z, and e_{ij} and v_{ij} are random errors. The basic assumption is that the farmer takes a two-step decision process. First, the farmer decides either to adopt or not to adopt any soil conservation innovation. Second, if the farmer decides to adopt, a decision is also made on the number of innovations from the advocated technical innovations from the package. The system represents simultaneous double-bounded Tobit equations, were the lower limit is zero and the upper limit is 100. In the system (j=1) represent extent of adopting short-term soil conservation measures, and (j=2) represent the extent of adopting long-term soil conservation measures. As shown by Shonkwiler and Yen (1999), the unconditional mean of A_{ij} in Equation (1) can be also represented as:

$$A_{ij} = \Phi(\theta_j^T X_{ij})(\beta_j^T Z_{ij}) + \delta_{ij}\varphi(\theta_j^T X_{ij}) + \eta_{ij}, \qquad (\eta_{ij} \sim N(0, \sigma_{u_j})), \tag{2}$$

Such that:

$$E(A_{ij} \mid Z_{ij}, X_{ij}) = \Phi(\theta_j^T X_{ij})(\beta_j^T Z_{ij}) + \delta_{ij}\varphi(\theta_j^T X_{ij}),$$

were Φ(.) and φ(.)are cumulative distribution function and univariate standard normal probability density function, E(.) is the expectation operator and η_{ij} is the identically normally distributed error term. Notice that in the adoption equations, previous decision to adopt some of the long-term soil conservation measures may induce a farmer to adopt specific measures from the short-term soil conservation package and vise versa.

To evaluate the impact of adopting soil conservation measures on wheat yield, consider a Cobb-Douglas production function that relates agricultural input and soil conservation measures to yield. The function accounts for the fact that expected yield depend on inputs used in production and current or past decisions to adopt soil conservation measures. If Yi represents the yield observed on plot i, the corresponding Cobb-Douglas production function is:

$$Y_i = \alpha_0 M_i A_{i1}^{\alpha_{21}} A_{i2}^{\alpha_{22}} \mu, \qquad \mu \sim N(0,\sigma_\mu). \tag{3}$$

In Equation (3), α 's are parameters to be estimated, M is the matrix of production inputs used to produce wheat on plot i, and other variables are as explained before. Using information contained in Equations (1) to (3), the adoption and yield equations can be formulated as follows:

$$A_{i1} = \Phi(\theta_1^T X_i)[\beta_{10} + \beta_2 A_{i1} + \beta_{11} z_1 + \beta_{21} z_2 + \beta_{31} z_3 + \beta_{41} z_4 + \beta_{51} z_5 + \beta_{61} z_6 + \beta_{71} z_7] + \delta_1 \varphi(\theta_i^T X_i) + \eta_{i1} \tag{4}$$
$$A_{i2} = \Phi(\theta_2^T X_i)[\beta_{20} + \beta_1 A_{i2} + \beta_{12} z_1 + \beta_{22} z_2 + \beta_{32} z_3 + \beta_{42} z_4 + \beta_{52} z_5 + \beta_{62} z_6 + \beta_{72} z_7] + \delta_2 \varphi(\theta_i^T X_i) + \eta_{i2}$$
$$LY_1 = \alpha_0 + \alpha_1 LnL_i + \alpha_2 LnF_i + \alpha_3 LnA_{i1} + \alpha_4 LnA_{i2} + \alpha H_i + (\alpha_0 - \lambda) DF_i + \mu_i$$

In the adoption equations, z_1 is sex of the household head (z_1=1, if respondent is male; z_2=0, otherwise), z_2 is age of respondent in years, z_3 is education of the respondent in years, z_4 is the number of adults in the households, and z_5 is the estimated monthly income of the respondent in Lesotho's Maluti. Other variables were defined as: z_6 the experience of the farmer measured as years in growing wheat, and z_7 is a variable representing availability of extension services to the farmer. The last but one item, φ(.), is known as the correction factor**,** and η_{ij} are random errors. The extension service variable was constructed as in Kaliba *et al.* (2000).

In the yield equation, Ln is the natural logarithm function, Y_i is yield for plot in bags/acre (one bag is 90 kg), L_i is labor used in production in mandays equivalents (family and hired labor was combined together because few farmers used hired labor). Other variables are: F the quantity of NPK (3:2:1) fertilizer used per plot in 25kg bags; A_{i1} and A_{i2} are extent of adopting short and long terms soil conservation measures; Hi the dummy variable representing hybrid wheat varieties (H=1 if used hybrid seeds, H=0 otherwise); and D_Fk is dummy variable introduced to capture the influence of non use of fertilizer as suggested by Battese (1997), and ìi is the identically normally distributed error term. The dummy variable is such that: D_Fk=1 if the farmer did not use any fertilizer, D_Fk=0 if the farmers reported the use of fertilizer. However, the zeros (non-use of fertilizer) in the fertilizer variable (F_i) are replaced by ones for the model to be identified. The important assumption of the MCD model is that farmers who did not use any fertilizer have different intercept from those who used fertilizer. This assumption is true if the parameter λ is statistically different from zero. The use of manure and other organic fertilizer are very limited as animals usually stay away from the cropland.

The inclusion of adoption variables as independent variables introduces endogeneity and contemporaneous correlation problem in the model (i.e., cov(η_{ij}, μ_i) ~ 0). Zero observations in the fertilizer variable imply that users and non-users have different intercepts. In order to increase the efficiency of the estimated parameters and to correct for correlation between errors, Equation 4 was estimated in a two-step procedure. First, the estimates of θ_j were obtained using maximum likelihood probit (Maddala, 1992) where the dependent variables were the binary outcome of d_{ij}=1 and d_{ij}=0 for each j but without including corresponding A_{ji} as independent variable in each adoption equation. Second, the results were used to estimate $\Phi(\theta_j X_{ij})$ and $(\theta_j X_{ij})$ in Equation (2). The estimated of β, α and δ in Equation (4) were estimated using nonlinear seemingly unrelated regression (SHAZAM, 1997) as suggested by (Shonkwiler and Yen, 1999). Table 42.1 list the variables included in the model, expected signs and reasons.

Source of data

This study uses cross-sectional data collected through a survey using a structured questionnaire. The survey covered a sample of 50 smallholder farmers selected randomly from Maseru (25) and Mafeteng (25) districts. The districts are the main wheat growing regions and are easily accessible from the National University of Lesotho. The sample size took into consideration the budget constraint. The data collected were on inputs used in production, wheat varieties grown and the demographic characteristics of the respondent. Soil conservation measures for each farm field were determined by observation. A soil conservation variable was then developed based on the number of soil conservation practices adopted by the farmer out of the soil conservation package as advocated by extension agents working within the area. The major respondent was the household head.

Results and Discussion

Summary statistics of the variables

Table 42.2 presents summary statistics of the variables used in the model. On average, every respondent farmed nearly five acres of wheat with a standard deviation of about 4.91. The total harvest was roughly 33 bags of wheat per plot (6.6 bags/acre). The respondents used about 9.5 man-days equivalent (about 77.5 hours) to complete all field activities involving wheat production. This included family and hired labor. About 6 bags of NPK fertilizer were applied in the five acres plot. About 48% of respondents were growing hybrid varieties and about 16% of respondents did not use inorganic fertilizer in their wheat field. On average, the farmers adopted four measures of soil conservation out of the package with nine recommendations (see also Table 42.3). Whereas few respondents have no formal education, about 38% of respondents indicated that an extension agent to discuss wheat production has never visited them. On average, a respondent had attended a two-day formal training on wheat production. These formal training included seminars, workshops and attending field days organized by the extension services department, or any other non-governmental organization involved in agricultural development.

Table 42.1: Exogenous variables included in the model, expected signs and justification

Variable	Expected sign	Justification
Adoption Equations		
Sex	+	Male headed households have more resources and are more likely to adopt new innovations than female headed households
Age	+	Older farmers have more resource than younger farmer and are more likely to adopt new innovations
Education	+	Educated farmers are best farmers as they know the benefits of soil conservation
Number of adults in households	+	Availability of adult labor increase the ability to adhere to all important agronomic practices
Income	+	High income avails necessary inputs for better farming methods such as soil conservation
Experience in farming	+	Farmer's experience increase the likelihood of understanding the benefits of soil conservation
Extension services	+	Extension services increase productive performance
Yield Equation		
Labor (mandays equivalent)	+	Availability of labor improve crop management
Quantity of fertilizer	+	Fertilizers increase soil nutrient and crop growth
Soil conservation measures	+	Conservation improves soil structure and texture and thus yields
Hybrids	+	Hybrid are high yielding than local varieties

Table 42.2: Summary statistics of variables used in the regression analysis

Variable	Unit	Mean/ Percent	STD Deviation
Total production per plot	Bags/kg	32.62	26.36
Size of the plot	Acres	4.91	3.51
Total Labor used per plot	Man days	9.68	7.03
Fertilizers (NPK:3:2:1)	25 kg bag	6.28	4.74
Age of household head	Years	39.96	5.59
Experience of the farmers	Years	15.78	6.89
Education of household head	Years	4.75	10.56
Monthly income	Maluti	670.76	890.54
Training in wheat production	Days	2.34	4.79
Extent of short-term soil conservation measures adopted	%	0.40	0.18
Extent of long-term soil conservation measures adopted	%	0.40	0.18
Sex of household head: (male)	%	76.00	
Farmers growing hybrid varieties	%	48.00	
Extension visits: Always	%	30.00	
Sometime	%	32.00	
None	%	38.00	

Table 42.3: Percentage of farmers adopting soil conservation practices

Soil conservation variables	%
Long-term Soil Conservation Measures	
Terraces	11
Silt traps	4
Water ways	15
Sandbags	2
Short-term Soil Conservation Measures	
Crop rotation	24
Inter-planting	2
Fallowing	16
Contour ploughing	12
Vegetation cover	13

Table 42.3 indicates the types of soil conservation variables adopted by different respondents in their wheat fields. From this table, the most common measure adopted by the farmers is crop rotation, (24% of respondents). Other popular soil conservation measures were fallowing (16%), construction of waterways (15%), vegetable cover (13%) and contour farming (12%). Sandbag construction and interplanting were the least common among the respondents. However, all respondents have adopted at least one soil conservation measure in their wheat fields.

Regression Results

Table 42.4 presents the results on factors affecting extent of adopting short-term soil conservation measures. During the analysis, the lower limit for the Tobit mode was set at 0 and the upper limit 100. The likelihood ratio statistics for the null hypothesis that all parameters in the model are zero was rejected at 1% probability level, meaning that variables included in the model explain some of the variation in extent of adopting short-term soil conservation measures. Positive and negative signs on the exogenous variable indicate that the variable's marginal effect on short-term soil conservation measures were positive (increasing extent of adoption) or negative (decreasing extent of adoption).

Table 42.4: Factors affecting adoption of short-term soil conservation measures

Variable name	Estimated coefficient	Asymptotic T-Ratio
Constant	-0.2478	-0.6992
Long-term soil conservation measures index	1.4123	2.2450**
Sex of household head (Male=1,0 otherwise)	-0.1081	-0.8986
Age of household head in years	0.0418	1.0119
Education of household head in years	0.1078	2.1568**
Number of adults in the households (> 18 years)	-0.0303	-2.3481**
Household monthly income in maruti	-0.0750	-2.2271**
Experience of growing wheat in years	0.0012	-0.4000
Availability of extension services variable	-0.0116	-1.1016
Correction factor (δ_1)	1.5487	2.6655**
R-square (%)	59.4**	
Log of Likelihood ratio test	88.0313**	

Double and single asterisks denote statistically significance at 5% and 10% level

The statistically significant variables and variables with positive influence were adoption of long-term soil conservation measures, education of household head, and the correction factor. Sex, age, and experience of the household head and availability of extension services have no influence on the extent of adopting short-term soil conservation measures as anticipated. Other statistically significant variables but with unexpected negative influence were number of adults in the households and household monthly income.

The results of Tobit models that examine factors affecting the adoption of long-term soil conservation measures are presented in Table 42.5.

Again, positive and negative signs on the exogenous variables indicate that higher values of the variables will increase or decrease adoption of long-term soil conservation measures. The likelihood ratio test statistics was significant at 1% probability level. The statistically significant variables included extent of adopted short-term soil conservation measures, number of adults in the households and household monthly income.

Table 42.5: Factors affecting adoption of Long-term soil conservation measures

Variable names	Estimated coefficient	Asymptotic T-Ratio
Constant	-0.3619	-1.1753
Short-term soil conservation measures index	1.1739	2.2780**
Sex of household head (Male=1,0 otherwise)	0.1144	1.0930
Age of household head in years	-0.0413	-1.1921
Education of household head in years	-0.0976	-2.0435**
Number of adults in the households (> 18 years)	0.0296	2.7527**
Household monthly income in Lesotho Maruti	0.0573	1.7968*
Experience of growing wheat in years	0.0018	-0.0660
Availability of extension services variable	0.0103	1.1280
Correction factor (δ^2)	0.7465	1.6193
R-square	44.62	
Log of Likelihood ratio test statistic	94.25**	

Double and single asterisks denote statistically significance at 5% and 10% level

Table 42.6: Multiple Regression Results on Wheat Production per Plot

Variable	Estimated coefficients	Asymptotic T-Ratio
Constant	1.9285	4.7994
Log of total labor (mandays)	0.0308	0.2023
Log of quantity of fertilizer (25 NPK bags)	0.0887	2.2553**
Log of short-term soil conservation variable	0.0892	2.1995**
Log of long-term soil conservation variable	0.1141	1.9452*
If used Hybrid (yes=1, No=0)	0.1256	0.8537
Dummy for quantity of fertilizer (Dk)	-1.4995	-3.4716**
R-squares (%)	77.5600	
F-statistics (zero slopes)	85.11**	

Double and single asterisks denote statistically significance at 5% and 10% level

The results of both models suggest the followings. First, a decision to adopt long-term soil conservation measures has a great influence on the adoption of short-term soil conservation measure and vise versa. However, once adopted, long-term soil conservation measures stay in the field and will always acts as benchmark for adopting short-term soil conservation measures. Extension efforts that promote soil conservation should therefore be directed more to long-term soil conservation measures in order to stimulate the adoption of short-term soil conservation measures. Second, the signs on the estimated parameters indicate that the two technologies are considered to be substitute to each other rather than complimentary. For example, households with more available labor (number of adults) will tend to focus more on adopting long-term soil conservation measures than both technologies. Relatively educated farmers will tend to adopt short-term rather that long-term soil conservation measures. Demonstration plots that show the benefit of adopting both technologies is highly recommended. Third, the indication that availability of extension services has no influence on adoption, surpass all logic. Nevertheless, this may be a sign of weak extension services in the country, meaning that the current extension services delivery system is too weak to influence any technological adoption

For the yield equation, the estimated coefficient of determination (R^2) was about 78%, indicating that the model explains at least 78% of the variation in wheat production as reported by sample respondents. The likelihood ratio test of the null hypothesis that all variables included in the model have zero slopes was rejected at 1% level of significance. All signs were as expected. Statistically significant variables were quantity of fertilizer, and both adoption of short-term and long-term soil conservation measures. The dummy variable for non-use of fertilizer was statistically significant and negative as expected, indicating that the yields of farmers not using fertilizers was more likely to be less than those of farmers using fertilizer.

Because the variables used in the model are in the logarithm form, the estimated coefficients for continuous variables are elasticities and for dummy variables, the coefficients are intercept shifters. Therefore, the average marginal product (AMP) of an input is the product of the estimated elasticity times the output-input ratio (i.e., AMP=ÄY/ÄX=áY/X). At the sample mean, the calculated marginal product of labor was 0.021, implying that increase in labor by one unit will increase yield by 0.02 bags/acre (0.3%). The marginal products of the fertilizer and short-term and long-term soil conservation efforts were respectively 0.024, 1.18 and 1.80, implying that a unit increase in the use of fertilizer, therefore, increases yields by 0.024bag/acre (0.3%). Adoption of additional one unit of short-term or long-term soil conservation measure, however, has a much greater impact, increasing yield by 1.18bags/acre (17.9%) and 1.8bags/acre (27.3%) respectively.

Conclusion and Policy Implication

The need to address the problem of soil erosion in Lesotho is widely known. The solution to this problem lies in reducing the negative impact of soil erosion on crop yields through soil conservation measures and improved land management practices. As indicated by the regression results, wheat farmers stand to gain more through increased soil conservation efforts than use of inorganic fertilizers alone. Given the limited availability of land, increase in acreage is not a viable solution. Agricultural intensification through adopting soil conservation measures may be best option for most farmers.

A thing to note is the limited influence of extension services on adoption of soil conservation measures. Extension services are important in enhancing the adoption of any new farming practices. Adequately trained, well-supported extension services can effectively induce the adoption of soil conservation practices. Field trials and demonstrations successfully create awareness on returns associated with soil conservation measures to farmers. It is therefore imperative that extension services need to be strengthened in order to enhance the adoption of soil conservation measures. Moreover, farmers will adopt the practices that give high returns. Farm management studies aimed at establishing soil conservation mixes that optimize returns to the farmers are highly recommended.

References

Adesina, A. and M.M. Zinnah (1992) *Adoption, diffusion, and economic impacts of modern mangrove rice varieties in Western Africa: further results from Guinea and Sierra Leone.* In: Towards a New Paradigm for Farming System Research/Extension. Working Paper for the 12th Annual FSR Symposium 1992. Michigan State University, 1992: 443-466.

Anderson, D. and Grove, R. (1987) *Conservation in Africa, People, Policies and Practices*, Cambridge University Press: Great Britain.

Battese, G.E. (1997) A note on the Estimation of Cobb-Douglas Production Functions when Some Explanatory Variables have Zero Values, *Journal of Agricultural Economics* 48: 250-252.

Byiringiro, F. and T. Reardon (1996) Farm Productivity in Rwanda: Effects of farm size, erosion, and soil conservation investments. *Agricultural economics* 15:127-136.

CIMMYT (1993) *The adoption of agricultural technologies: a guide for survey design*. International Wheat and Improvement Center, Londres: Mexico.

Cox, H.W., Hammer, G.L., and Robertson, M.J. (2001) *Opportunities for crop modeling in barley*. Proceedings of the 10th Australian Barley Technical Symposium. The Regional Institute Ltd:Australia.

Feder, G., Just, R.E., and Zilberman, D. (1985) Adoption of agricultural innovations in developing countries: a survey. *Economic Development and Cultural Change* 33 (1985): 255-297.

Goodwin, B.K. and Schroeder, T.C. (1994) Human capital, producer education, and adoption of forward-pricing methods. *American Journal of Agricultural Economics* 76: 936-947.

Greene, W.H. (1997) *Econometric Analysis*, Prentice, Hall, Upper Saddle River: New Jersey.

Gujarati, D.N. (1995) *Basic Econometrics*. McGraw-Hill International,Singapore.

Hall, B.H. (1994) Time Series Processor User's Guide. TSP International: Palo Alto, CA.

Kaliba, A.R.M., Verkuijl, H.J.M. and Mwangi, W. (2000) Adoption of Maize Production Technologies in the Intermediate and Lowlands of Tanzania. *Journal of Agricultural and Applied Economics* 32(1): 35-47.

Kazianga, H. and Masters, W. (2002) Investing in Soils. Field bands and Micro-catchments in Burkina Faso. *Environmental and Development Economics*, 7(3):571-592.

Kimhi, A. (1994) Quasi maximum likelihood estimation of multivariate models: farm couples' labor participation. *American Journal of Agricultural Economics* 74(4): 828-835.

Kingdom of Lesotho (KoL). (1980) *National Papers on Environment and Development in Lesotho*.Government of Lesotho for the United Nation's Conference on Environment and Development, Maseru: Lesotho.

Kastens, T.L. and Dhuyvetter, K.C. (1999) *Management Factors: What is Important? Prices,Yield,Costs, or Technology Adoption?* Staff paper, Agricultural Economics Department, Kansas State University: Manhattan, Kansas.

Lesotho Mountain Research Group (LMRG). (1996) *Towards an Integrated perspective on Land Degradation in the Mountains of Lesotho.* A report on the Inaugural Meeting held at Malealea Lodge, Ministry of Environment, Maseru, Lesotho.

Maddala, G.S., 1992. *Introduction to Econometrics*. Macmillan Publishing Company: New York

Ministry of Agriculture (MOA). (1988) Soil Conservation Handbook for Lesotho, Conservation Division: Maseru: Lesotho.

Nkonya, E., Schroeder, T. and Norman, D. (1997) Factors affecting adoption of improved maize seed and fertilizer in northern Tanzania, *Journal of Agricultural Economics* 48:1-12.

Nowak, P.J. (1987) The Adoption of Agricultural Conservation Techniques: Economic and Diffusion Explanations. *Rural Sociology* 52(2): 208-210.

Ockwell, A.P. (1991) Characteristics of improved technologies that affect their adoption in semi-arid tropics of eastern Kenya. *Journal of Farming System Research and Extension* 2:6-18.

Rahm, M.R., and Huffman, W.E. (1984) The adoption of reduced tillage: the role of human capital and other variables. *American Journal of Agricultural Economics*. 66: 405-413.

Saha, A., Love, H.A. and Schwart, R. (1994) Adoption of emerging technologies under output uncertainty. *American. Journal of Agricultural Economics* 76: 836-846.

Shively, G.E. (1998) *Modeling Impacts of Soil Conservation on Productivity and Yield 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.

White, H. (1980) A Heteroskedasticity-Consistent Covariance Matrix and a Direct Test for Heteroskedasticity. *Econometrica* 48:721-746.