Ecology, Economy and Society–the INSEE Journal 4 (2): 95-117, July 2021

RESEARCH PAPER

Adoption of Soil Conservation Measures: Evidence from Rain-fed Watershed Areas of Telangana

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Abstract: Land degradation resulting from soil erosion is a major problem in rain-fed agricultural areas in India. This study analyses the key determinants of farmers' decisions to adopt on-farm soil and water conservation (SWC) measures in the rain-fed watershed areas of Siddipet district in Telangana. Here, SWC measures have been undertaken by the government and NGOs at the sub-watershed/community level and by individual farmers at the farm level. The study is based on a primary survey of over 400 farmers conducted in January–March 2018. In addition to estimating the influence of biophysical and market access variables on farmers' decisions to undertake SWC practices, the study includes a logistic model that found a complementarity between community and individual plot-level interventions to improve soil health. The findings also highlight the influence of conservation measures practised in the neighbourhood on farmers' decisions to implement SWC measures.

Key words: Land Degradation; Soil and Water Conservation; Sub-watershed; Telangana, India.

JEL Classification: C11, C13, 21, Q2

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Published by Indian Society for Ecological Economics (INSEE), c/o Institute of Economic Growth, University Enclave, North Campus, Delhi 110007.

ISSN: 2581-6152 (print); 2581-6101 (web).

DOI: https://doi.org/10.37773/ees.v4i2.273

1. INTRODUCTION

The backbone of rural livelihoods in developing countries is the land ecosystem. Unsustainable land management practices have led to extensive land degradation across the world over the last few decades (Millennium Ecosystem Assessment Panel 2005; Brevik *et al.* 2015). In terms of on-site impacts, it is widely acknowledged that soil erosion leads to reduced agricultural yield and productivity (Mbaga-Semgalawe and Folmer 2000; Bravo-Ureta *et al.* 2006; Kumar *et al.* 2019). Moreover, beyond a certain threshold, soil erosion can make soil cover regeneration difficult and can adversely affect future livelihoods. Therefore, the link between on-farm soil erosion and agricultural productivity has both intra-generational and intergenerational implications. Soil degradation affects other natural resources as well—for instance, a reduction in crop yields may force farmers to intensify deforestation (Lopez 2002). Soil erosion also leads to significant negative externalities such as water pollution, reduction in soil water-carrying capacity, and disturbances in hydrological cycles (Somanathan 1991; Mbaga-Semgalawe and Folmer 2000). Most of these concerns have also been expressed in the context of Indian agriculture (Kerr 2002; Reddy and Syme 2019).

The issues caused by soil erosion can be minimized or limited through adequate on-site and off-site soil conservation practices. Over the past four decades, the Indian government has been undertaking soil and water conservation (SWC) measures[3] at the community level to prevent land degradation. A growing body of literature suggests that farmers are the main stakeholders and undertake on-site SWC measures based on the perceived level of soil erosion on their plots. These measures include terracing, contour practices, fallow practices, land drainage, crop mixture, bunding, slope levelling, agroforestry, and crop residue management, which are common practices to reduce soil erosion around the world[4] (Scherr 1999). These SWC measures provide benefits ranging from the local (crop yield improvements) and regional (flood control) to the global level (carbon

[3] The literature on farm-level conservation measures adopted by farmers to prevent soil erosion refers to such measures interchangeably as "soil conservation measures" and "soil and water conservation measures" given the close linkages between conservation of soil and water resources. Accordingly, this study refers to farm-level conservation measures as SWC measures.

[4] Recent literature has argued that small and marginal farmers adopt some of these measures to increase their resilience to climate variability and climate change (Tambo and Mockshell 2018; Makate *et al.* 2019). Therefore, SWC measures and conservational agricultural measures often overlap, and the benefits accruing from such interventions have multiple and overlapping benefits.

sequestration) and can be both short term and long term in nature (Lal Rattan 2001; Bouma, Van Soest, and Bulte 2007; Singha 2019).

The right combination of on-site SWC measures adopted by individual farmers and communities can prevent soil erosion to a great extent (Pattanayak 2004). The SWC practices undertaken by farmers are primarily based on the costs and benefits realized from avoiding soil erosion losses (Lutz, Pagiola, and Reiche 1994). Empirical studies have identified a wide range of predominant factors, including plot-level and household characteristics, which influence farmers' implementation of SWC measures (Adimassu, Langan, and Johnston 2016). Some predominant socio-economic factors include membership in farmers' organizations, formal education of the household head (Sidibe 2005), spouse's education, household wealth, labour availability, market accessibility, access to extension services (Teklewold *et al.* 2013), crop mix under cultivation, perceived level of soil erosion in the plot, farm size (Feder and Slade 1985; Mbaga-Semgalawa and Folmer 2000), and existence of formal credit markets (Wossen, Berger, and Di Falco 2015). The literature also suggests that farm characteristics such as soil type, depth of soil, and slope of the land (Teklewold *et al.* 2013) significantly influence farmers' decisions to implement SWC measures. There have also been assessments of the role of institutional interventions (such as the Integrated Water Management Programme [IWMP] in India) in influencing farmers to adopt new technologies in agriculture and practise SWC measures (Feder and Slade 1985; Mbaga-Semgalawa and Folmer 2000).

Despite the continuous prevention efforts of the government under various programmes, the problems of soil erosion and land degradation persist in India. The poor uptake of programmes and policy interventions at the field level is attributed to the top-down approach often adopted by the government and the absence of demonstration of programme benefits at the ground level. For instance, Palanisami *et al.* (2015) argue that only 22% of water management technologies developed by research networks and promoted by government agencies have been adopted by farmers. A few recent studies have explored the influence of neighbourhood conservational practices on farmers' decision-making regarding the same. Battaglini, Nunnari, and Palfrey (2012) showed that there can be strategic substitutability (free-riding) or strategic complementarities among neighbours while investing in public goods like soil conservation. The logic is provided in Tobler's formula—"everything is related to everything else, however, closer things are more related than distant things" (Drukker 2009, 4). There are two main strands of literature on the adoption of technologies or SWC measures that attempt to incorporate the interdependence of decision-making at the plot level. The first strand includes models of networks and social learning that explicitly account for the influence of neighbours (Mbaga-Semgalawa and Folmer 2000; Conley and Udry 2010; Bandiera and Rasul 2006; Moser and Barret 2006; Teklewold *et al.* 2014). These models are rooted in Manski's 1993 law, "the propensity of an individual to behave in certain way changes with the behaviour of the individual's social group" (cited in Läpple and Kelley 2015, 3).

The second strand of literature attempts to capture the role of interactions on the decision to adopt a given technology using spatial econometrics techniques to model "spatial dependence either in the outcome variable (adoption) or in the error term, or both" (Singha 2019, 18). The spatial dependence framework is suitable for analysing the determinants of adopting SWC measures for many reasons. First, soil conservation practices in one farm can assist or constrain the implementation of such practices on adjacent farms. The assumption is that farmers with fields located next to each other exhibit similar behaviours (Holloway and Lapar 2007). Factors such as flow of inter-farm information and neighbourhood competition or cooperation can encourage similar adoption behaviours among farmers (Abdulai and Hoffman 2005). Second, soil conservation practices can be location-specific, with some SWC practices being suitable for particular types of land. Agricultural productivity also depends on various localized factors including soil type, soil quality, soil moisture, and land topography (Colney 1999). Similarities in these factors may lead to similarities in farming and conservation practices (Pattanayak and Butry 2005). Empirical studies have analysed the influence of practices in the neighbourhood on farmers undertaking SWC measures using a spatial probit model (Holloway and Lapar 2007; Wang, Iglesias, and Wooldridge 2013; Läpple and Kelly, 2015; Singha, 2017). The construction of a weight matrix is necessary to analyse spatial dependence. The literature suggests that there are six possible ways of constructing a matrix including Euclidean distance, competition along streets, a combination of the first two, nearest neighbours along streets, nearest neighbours in Euclidean distance, and neighbours that share a common boundary (Pinkse and Slade 1998). Ideally, to construct metrics, a common boundary that minimizes the bias of the result is appropriate. However, due to the lack of data availability and practical difficulties, empirical studies based on plot-level data use the Euclidean distance and nearest neighbours in Euclidean distance criteria to construct the spatial weight matrix to account for spatial interaction among farmers adopting new technologies or soil conservation measures (Holloway and Lapar 2007; Läpple and Kelly 2015). Despite the apparent objectivity in the construction of spatial matrices, the definition of "neighbourhood" is based on the researcher's subjective understanding.

Taking all the above factors and the limitations posed by the data collection process (discussed in the next section) into consideration, the present study attempts to account for the association between conservation practices followed in a neighbourhood and the farmer's decision to implement SWC measures. Thus, the present study does not undertake a comprehensive spatial econometric analysis.

Taking a cue from the literature discussed above, this study analyses field-level data collected from Siddipet district in Telangana to understand the role of socio-economic variables and farm-level characteristics in prompting farmers in Telangana to implement SWC measures. Further, the analysis attempts to address two relevant issues concerning the adoption of SWC measures: 1) the complementarity between community- and watershed-level SWC activities and adoption of individual, plot-level SWC measures; and 2) the association between the SWC practices followed in the neighbourhood and the conservation practices adopted by farmers. The rest of the paper is organized as follows: Section 2 describes the methodology followed in the study and discusses insights from the primary survey on conservation practices undertaken by the farmers. Section 3 discusses the results obtained. Section 4 provides the conclusion.

2. DATA COLLECTION AND METHODOLOGY

The analysis presented in this study is based on field-level data collected from Siddipet district in Telangana, India.[5] Telangana is one of the states worst-affected by land degradation, especially water erosion, in the country (SAC 2016). The Desertification and Land Degradation Atlas of India (SAC 2016) reveals that in Telangana, close to 3 million hectares of cropland area alone were degraded as of 2011–13. As per the Atlas, Telangana ranks fourth among the major Indian states, with 31.34% of the total geographic area in the state classified as degraded. Biswas *et al.* (2015) highlight that in Telangana, 37% of the total geographical area has degraded with a moderate rate of erosion (5–10 tonnes ha-1 yr-1), while about 20% is susceptible to an excessive rate of soil erosion at 10 tonnes ha-1 yr-1. Rain-fed agriculture is the dominant mode of cultivation in the state and is considered highly vulnerable to soil erosion and subsequently declining agricultural

[5] More details on the study area and data collection process are provided in Dayakar and Kavi Kumar (2020).

productivity. Adoption of proper SWC measures can halt top-soil erosion and arrest the land degradation process.

2.1 Study Area and Data Collection

The study was undertaken in two mandals of Siddipet district in Telangana, which lies approximately 130 km north of Hyderabad, the state capital. The selected area is located in a region highly vulnerable to drought, with an annual average rainfall of 650 mm, over 80% of which is received during the monsoon months of June–September (GoT 2015). The area lies in the Godavari river basin and has low and moderate levels of soil erosion, as assessed through satellite data. A purposive sampling method was followed to select the study area and village while accounting for wide variations across villages in terms of SWC technology experience, state of soil erosion, and socio-economic heterogeneity.

Twelve villages were selected from the Chinnakodur and Dubbak mandals for the field study, of which six are located in the Dubbak and Chinnakodur sub-watershed areas and are part of the IWMP. Under the IWMP, numerous activities are undertaken to restore the ecological balance by harnessing, conserving, and developing degraded natural sources such as soil, vegetation cover, and water. The other six villages are also located in the same sub-watershed areas but are not covered by the IWMP programme. The biophysical, topographical, and hydrological conditions of the selected villages are broadly similar. These villages predominantly have red loamy, red sand loamy, saline, and black soils. Paddy, maize, cotton, red gram, and vegetables are the major crops cultivated in the area. Soil erosion leads to nutrient loss, which ultimately reduces agricultural productivity and yield. Therefore, farmers traditionally practise SWC measures to control the perceived level of soil erosion (Kumar *et al.* 2015).

The data used in the study were obtained from a detailed household- and plot-level survey of 400 farmers in the two mandals. The survey was conducted during January–March 2018. The number of households selected for the survey in each village was based on the proportion of households in that village to the aggregate number of households across all the selected villages. Thus, the total number of households sampled in each village ranged between 13 and 67. In each village, the list of households was compiled from revenue and agricultural departmental data sets (GoT, 2015). Once the number of households was finalized, the specific households to be surveyed were selected from the complete list of households in the village following the simple random sampling approach. The final sample consisted of 206 households from IWMP villages and 197 households from non-IWMP villages. Across the entire sample, about 85%

of households had adopted at least one soil conservation measure in their plots.

2.2 Insights on SWC Measures

Group discussions and the pilot survey revealed that the farmers in the study area practise several SWC measures, with the most common ones being silt application, construction of grass and stone bunds, slope levelling, planting woody perennials, and digging stream trenches and farm ponds.

Table 1: Description of SWC Measures Practised in the Study Area

SWC measure	Description
Silt application	Farmers apply silt to improve soil quality, especially in eroded lands.
Construction of grass and stone bunds	Farmers construct grass and stone bunds against the slope of the farmland to prevent soil erosion.
Slope levelling	Farmers use tools to reduce the slope of the land to prevent soil erosion.
Planting woody perennials	Farmers plant woody perennials along the borders to control soil erosion.
Digging stream trenches and farm ponds	Farmers dig stream trenches and farm ponds as SWC measures.

Source: Data based on field study

Across all the villages surveyed, around 23% of farmers were found to practise SWC measures. While several farmers have adopted measures such as slope levelling, stream trenching, silt application, planting woody perennials, and farm pond construction, a smaller percentage has undertaken measures such as constructing grass and stone bunds (Figure 1).

Around 30% of farmers in IWMP villages have adopted at least one SWC measure, whereas only 15% of farmers from the non-IWMP villages have adopted one or more SWC measures. Further, the primary data shows that farmers from IWMP villages were willing to implement SWC measures that are long-lasting, such as constructing stone bunds, slope levelling, planting woody perennials, and digging farm ponds, compared to their counterparts in the non-IWMP villages. The levels of soil erosion severity and resource availability play an important role in determining the SWC measures adopted by farmers.

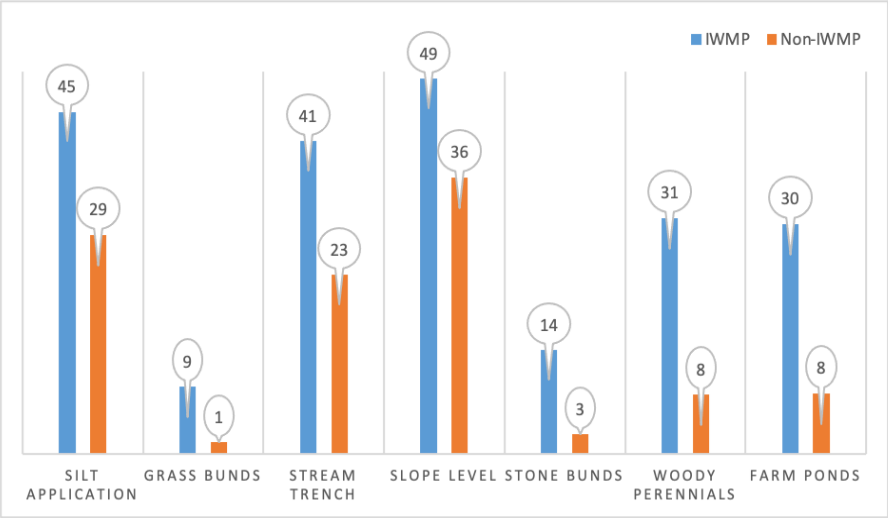

Figure 1: Category-wise Adoption of Soil Conservation Measures across Survey Villages (*in Percentages*)
Source: Data based on field study

Farmers often undertake multiple SWC measures, with a higher number of measures being adopted in relatively conducive environments. Figure 2 shows the percentage of farmers undertaking different numbers of soil conservation measures under conditions of "low" and "high" levels of soil erosion. Clearly, there is a tendency to implement more SWC measures if they perceive the severity of soil erosion to be high. Further, plot-level soil conservation measures are often considered supplemental to the measures implemented on common/private lands by governmental/non-governmental agencies under the IWMP. Farmers belonging to IWMP villages have undertaken a larger number of SWC measures than their counterparts in non-IWMP villages. As shown in Figure 2, a larger percentage of farmers in IWMP villages have undertaken more than three soil conservation measures compared to the farmers in the non-IWMP villages, suggesting that there is a complementarity between farm-level soil conservation measures and sub-watershed-level interventions to prevent soil erosion.

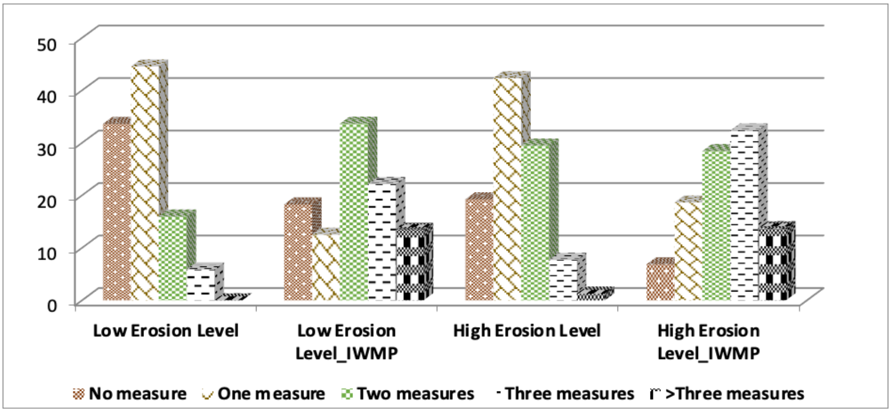

Figure 2: Distribution of Soil Conservation Measures across Different Levels of Soil Erosion Severity (*in Percentages*)
Source: Data based on field study

2.3 Empirical Specification

The random utility model provides the basis for adoption choices between alternative SWC practices. It has been extensively used in the empirical literature to study farmers' decisions to adopt SWC measures. Both logit and probit methods are well-established approaches in analysing the adoption of SWC measures. The choice of which models to use is a matter of computational convenience (Greene 2008). This study uses the logistic regression model to analyse the determinants of farmers' SWC adoption decisions. The parameters estimated using logistic regression can be interpreted easily in terms of the odds ratio. The odds ratio shows the strength of association between a predictor and the outcome of interest. The dependent variable in the model is the logarithm of the odds that a given farmer adopts SWC measures. The model is specified as follows (Gujarati 2009):

$P_i = (Y=1 \mid X_i) = (1 \mid 1+e^{-Z_i})$ …… (1)

Thus, the odds ratio in favour of adoption can be specified as:

$(P_i \mid 1-P_i) = e^{Z_i}$ ………………… (2)

where P_i is the probability of adopting SWC measures by the i^{th} farmer; $1-P_I = (1 \mid 1+e^{-Z_i})$ is non-adoption by the i^{th} farmer; Z_i is a linear function of explanatory variables (X), including socio-economic, institutional, and plot-specific variables and village-level factors. In the estimation of factors affecting the adoption of SWC measures, the dependent variable is coded as 1 when the farmer implements one or more than one SWC measure and 0 otherwise.[6] The explanatory variables used are as follows: (a) plot-level characteristics such as area of the plot, the extent of soil erosion as assessed by the farmer, irrigation status, adoption of SWC measures by neighbouring farmers, and crop diversity (i.e., the Herfindahl index [HHI)][7]); (b) socio-economic characteristics including age, sex, and educational status of the household head, size of the household, and social status of the household; (c) connectivity factors including the distance between the plot and the dwelling, road connectivity, and the distance between the plot and the market; (d) village characteristics such as community-level SWC measures implemented through the IWMP and whether the plot has benefited directly from IWMP interventions. The parameters of the logit were estimated using the maximum likelihood procedure in Stata software using the logit user-written command.

2.4 Summary Statistics

The definitions of the explanatory variables, the hypothesized direction of their influence, and their descriptive statistical properties are presented in Table 2. To assess the association of on-site SWC measures undertaken by other farmers in the neighbourhood with the soil conservation practices adopted by the surveyed farmers, detailed information about SWC activities in all the neighbouring plots (for each of the farmers/plots surveyed) was collected through the primary survey. A farmer's neighbours were defined as those whose plots share a boundary with their plot. If more than 50% of neighbouring plots have adopted a specific SWC measure, then the neighbours of the respondent are considered to have adopted that measure (coded as 1), and, otherwise, they are considered to have not adopted it (coded as 0). The summary statistics suggest that the average area under

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[6] Since farmers adopt more than one SWC measure, the literature suggests that the dependent variable becomes multinomial, and, therefore, the ideal model becomes multinomial logit/probit models. However, in this study, the results are estimated using the simple logit regression model. Since we have defined the dependent variable as 1 when the farmer implements more than one SWC measure and '0' otherwise, the estimated model can capture more numbers of SWC measures adopted. This specification is considered relevant since most of the conservation measures are determined by similar factors. Thus, the focus here is on identifying overall factors that influence the decision to adopt SWC measures in general, and not on the factors that influence the adoption of a certain number of SWC measures. We have also estimated the multinomial model and report the results in Appendix Tables A.1 and A.2.

[7] The Herfindahl index (HHI) represents "crop diversification and is estimated as the summation of all squared area shares occupied by crops in total cropped area. The value of this index varies from zero to one. It takes the value of one when there is full specialization and approaches to zero when there is full diversification" (Datta, 2015).

cultivation is 3.37 acres per plot, while the average total area of the surveyed households is 4.60 acres.

Table 2: Summary Statistics and Description of the Variables Used in the Analysis

Variable	Definition of the variable	H_1sign	Mean	Std. Dev.
Plot-level characteristics				
Area of the plot	Cultivated area (in acres)	+/-	3.37	2.48
Erosion	Farmers' perceived erosion (1 = yes; 0 = no)	+	0.45	0.50
Irrigation	Irrigation status (1 = yes; 0 = no)	+/-	0.81	0.39
Crop diversity	Crop diversity index	+	0.49	0.23
Neighbours' adoption	% of adjacent neighbours having adopted SWC	+	0.04	0.21
Socio-economic variables				
Age	Age of the household head (in years)	+/-	49.45	14.10
Sex	Gender of the household head (1 = male; 0 = female)	+/-	0.89	0.32
Caste	Social status (1 = socially forward class; 0 = socially backward classes)	+/-	0.23	0.42
Education	Years of education of the household head (in years)	+/-	5.29	5.57
Household size	Size of the household (members)	+/-	4.52	1.93
Market access variables				
Distance	Distance to dwelling (in km)	+/-	1.46	1.35
Road	Road connectivity of the plot (1 = yes; 0 = no)	+	0.32	0.47
Distance to market	Distance to the market from the plot (in km)	-	8.16	9.46
Village-level characteristics				
IWMP intervention	IWMP intervention covered in the village (1 = yes; 0 = no)	+	0.51	050

Source: Author's own calculations based on primary survey data.

The respondents thus own multiple plots and have a basis for comparison across the plots they own while responding to the survey questions. Crop diversity, as measured through HHI, had a sample mean value of 0.49, suggesting a low level of diversity in the study area. Across the villages, around 23% of farmers practised SWC measures. The average age of the respondents was 49 years with about five years of formal education. The average household size was close to five members with low variability across the sample. The average distance from the dwelling to the plot was 1.46 km and, on average, the plots had poor road connectivity. Around 50% of sampled farmers belonged to IWMP villages.

4. ESTIMATED RESULTS AND DISCUSSION

A logistic regression model was estimated to identify factors that influence farmers' decisions to adopt SWC measures. The model estimates suggest that out of the 14 variables that are hypothesized to influence the adoption of SWC measures, 6 are significant—soil erosion, crop diversity index, irrigation facility, neighbours' adoption of conservation measures, distance to dwelling, and presence of IWMP interventions. The logistic regression can be interpreted in terms of marginal effects and odds ratio.

The odds ratio shows the strength of association between a predictor and the outcome of interest. In the present study, the predicted probabilities of the parameters are interpreted in terms of the odds ratio. It may be noted that some of the characteristics of a plot, such as the extent of soil erosion, are assessed in the present study based on farmers' perceptions. While a more objective measurement of such characteristics is desirable, it is not uncommon in the literature to analyse SWC adoption based on farmers' perceptions of several characteristics like slope, soil depth, and soil quality (e.g., Tesfaye *et al.* 2014). To limit potential endogeneity problems that can arise due to the inclusion of variables based on farmers' perceptions, the present study incorporates only the extent of soil erosion as assessed by farmers as a binary variable. Table 3 reports the coefficients and odds ratios estimated based on the logistic regression. In Table 3, the coefficients and odds ratios are reported for two separate model specifications that differ in terms of the inclusion of conservation measures (Model 2) undertaken by farmers in the neighbourhood of surveyed plots.

Table 3: Factors Influencing Choice of SWC Practices: Estimates Based on Logistic Regression

Variables	**Model 1**				**Model 2**			
	Coef	P>|z|	Odds ratio	P>|z|	Coef	P>|z|	Odds ratio	P>|z|
Plot-level characteristics								
Area of the plot	0.066	0.34	1.068	0.34	0.052	0.47	1.053	0.47
Soil erosion	1.004***	0.00	2.730***	0.00	0.999***	0.00	2.715***	0.00
Crop diversity index	2.230***	0.00	9.299***	0.00	1.995***	0.00	7.349***	0.00
Irrigation	0.766**	0.04	2.150**	0.04	0.738**	0.05	2.092**	0.05
Neighbours' adoption					0.016***	0.00	1.016***	0.00
Socio-economic variables								
Sex of the household head	0.350	0.42	1.419	0.42	0.315	0.47	1.370	0.47
Age of the household head	-0.002	0.86	0.998	0.86	0.009	0.94	1.001	0.94
Years of formal education of the household head	-0.051*	0.07	0.950*	0.07	-0.041	0.14	0.960	0.14
Household size	-0.055	0.49	0.946	0.49	-0.087	0.23	0.917	0.23
Caste of the household	0.009	0.98	1.009	0.98	-0.272	0.455	0.762	0.45
Market access variables								
Road connectivity of the plot	0.200	0.51	1.221	0.51	0.272	0.38	1.312	0.38
Plot distance to dwelling	-0.181**	0.02	0.835**	0.02	-0.224***	0.01	0.800***	0.01
Plot distance to the market	0.009	0.65	1.009	0.65	0.008	0.68	1.008	0.68
Village-level characteristics								
Village under IWMP	0.902***	0.00	2.465***	0.00	0.789***	0.01	2.201***	0.01
Observations	403				403			
Pseudo R2	0.172				0.224			
chi2	61.69				60.75			
P	0.00				0.00			

Source: Author's estimations based on primary survey data;
Note: ***, **, * indicate significance at the 1%, 5%, and 10% probability levels, respectively; Model 1 specification does not include the neighbourhood dummy; Model 2 specification includes the neighbourhood dummy.

If farmers perceive that their plots suffer from soil erosion, they are 2.72 times more likely to adopt SWC measures compared to those who do not perceive soil erosion to be a major issue on their plots. This result is in line with similar studies conducted across the world, which have found a positive relationship between farmers' perceptions and adoption of soil conservation measures (Shiferaw and Holden 1998; Asrat, Belay, and Hamito 2004; Tesfaye *et al.* 2014). Similarly, the model results show that farmers are 2.09 times more likely to undertake SWC measures if they have access to an irrigation facility. The possible explanation for this is that farmers' willingness to invest more in sustainable land management activities is dependent on their access to irrigation facilities. This result is also in line with other similar studies (Knowler and Bradshaw 2007).

The literature suggests that diversified cultivation improves farmers' incomes and plays a significant role in sustaining agriculture and agriculture-based livelihoods (Jayne *et al.* 2010; Bigsten and Tengstam 2011; Birthal, Roy, and Negi 2015). The results from the present study suggest that farmers are 7.34 times more likely to practise SWC measures if they practise diversified cultivation in their plots. Diversified agriculture may yield higher profits to farmers, which may encourage them to invest more in SWC measures. The literature suggests a strong and negative association between the distance from the farmer's dwelling to the plot and the probability of implementing SWC measures (Knowler and Bradshaw 2007). Concurring with this, the results from the present study show that farmers are less likely to adopt SWC measures if the agricultural plot is far from their dwelling.

As highlighted above, SWC can be location-specific, with certain SWC practices being more suitable for particular types of land. Land is spatially contiguous, and the conservation practices suitable for one plot could also be suitable for nearby plots. Hence, these factors may lead to similarities in conservation and farm practices (Pattanayak and Butry 2005). Empirical studies suggest that neighbourhood activities have a positive influence on farmers' decisions to adopt new agricultural technologies as well as SWC measures (Holloway and Lapar 2007; Wang *et al.* 2013; Lapple and Kelly 2015; Palanisami *et al.* 2015, Singha 2019). Spatially contiguous information is required to rigorously analyse the neighbourhood impact on a farmer's decision to adopt SWC practices. In the present study, a full-fledged spatial econometric analysis could not be undertaken due to data constraints. Instead, there has been an attempt to capture the influence of conservation practices in the neighbourhood on a farmer's individual SWC practices. Model 2 in Table 2 accounts for neighbours' influence through the introduction of a dummy, which takes the value 1 when a majority of the neighbouring plots implement SWC and 0 otherwise. The significant and positive coefficient estimated for the neighbourhood dummy suggests an association between conservation practices in the farmer's plot and the neighbourhood plots. The estimated coefficient values of most variables are lower in Model 2 compared to those in Model 1, suggesting that the inclusion of the neighbourhood dummy in the model specification avoids omitted variable bias. The study also explored the role of neighbours in farmers' adoption decisions of different SWC measures (results reported in Appendices). Farmers are more likely to adopt stream trenches, slope levelling, stone bunds, woody perennials, and farm ponds if their neighbours adopted these SWC measures, keeping other exogenous variables constant. However, there is no significant association between farmers' adoption of grass bunds, silt application, and other measures and their implementation by neighbours (see Appendix Table A.3 and A.4). Among other things, the relatively low rate of adoption of these SWC measures among the farmers in the sample could be one of the reasons for the insignificant association.

As expected, the results show that there is a strong and positive relationship between community-level SWC activities and individual farm-level adoption of SWC measures. The results suggest that farmers are more likely to undertake SWC measures if they belong to IWMP villages compared to farmers from non-IWMP villages. The odds ratio suggests that farmers are 2.20 times more likely to adopt SWC measures if they belong to IWMP villages compared to their counterparts in non-IWMP villages, keeping all other variables constant. There is mixed evidence in the literature on linkages between community-level conservation practices and farm-level practices. For instance, Feder and Slade (1985) suggest that there is a complementarity between community-level SWC practices and individual plot-level SWC measures. Similarly, Palanisami *et al.* (2015) argue that the neighbours' adoption of water conservation measures positively influences farmers' decisions to adopt similar conservation measures. On the other hand, Singha (2017) finds no relationship between community and farm-level conservation practices given that one of the main objectives of programmes like IWMP is to demonstrate the effectiveness of conservation measures to farmers; the evidence from the present study provides support to such a claim.

Finally, the literature offers mixed results on the relationship between socio-economic variables and the adoption of SWC measures (Adimassu, Langan, and Johnston 2016). In the present study, variables such as area of the plot, sex of the household head, age of the household head, household size, formal education of the household head, road connectivity of the plot, and plot distance to the market were found to have no significant relationship with the adoption of SWC measures by the farmers.

5. CONCLUSION

This study focused on assessing the main factors that influence farmers' decisions to adopt SWC measures in the rain-fed watershed areas of Telangana, India. The data were collected through a primary survey of 400 farmers from two watershed areas and were analysed using a logistic regression model. The results suggest that plot-level variables, including the level of soil erosion, crop diversity, and availability of irrigation facilities, significantly influence farmers' decisions to undertake SWC measures. Further, farmers' perception of the extent of soil erosion on their plots positively and significantly influences this decision. Similarly, farmers are more likely to undertake on-site SWC measures if they have access to irrigation facilities. The farmers are also more likely to adopt SWC measures if they cultivate more diverse crops. The results also indicate that farmers are more likely to undertake on-site conservation measures if their neighbours undertake SWC measures. As expected, community-level SWC activities were found to have a strong influence on the farm-level SWC measures undertaken by farmers, thus highlighting their complementarity. These findings, particularly that of the associative influence of neighbourhood conservation practices on farmers' decisions to implement SWC measures, and the synergetic relationship between community and farm-level soil conservation practices, can provide crucial inputs for the formulation of effective government policies to promote soil conservation. The integration of local knowledge in SWC planning could help in overcoming behavioural constraints faced while advocating for conservation measures in countries such as India, which is dominated by rain-fed cultivation. Future studies could explore such extensions.

ACKNOWLEDGEMENTS

The paper is part of the doctoral thesis of Mr Dayakar Peddi submitted to Central University of Tamil Nadu. The authors express gratitude to Prof L Venkatachalam and Prof Brinda Viswanathan for their valuable comments and guidance throughout the work. The assistance provided by Mr Srinivas during the data collection process is gratefully acknowledged. The authors thank Indian Council of Social Science Research (ICSSR) for their financial support. Earlier versions of the paper were presented at the Indian Society for Ecological Economics (INSEE) (2019); Australian Agricultural and Resource Economics Society (AARES) (2021); and South Asian Economic Development (2021) conferences, and the authors would like to thank the participants for their valuable inputs. The authors would like to thank the two anonymous reviewers and the editor for their helpful comments. The standard disclaimer of assuming responsibility for all errors applies.

REFERENCES

bdulai, Awudu, and Wallace E Huffman. 2005. "The Diffusion of New Agricultural Technologies: The Case of Crossbred-cow Technology in Tanzania." *American Journal of Agricultural Economics* 87(3): 645-659. https://doi.org/10.1111/j.1467-8276.2005.00753.x

Adimassu, Zenebe, Simon Langan, and Robyn Johnston. 2016. "Understanding Determinants of Farmers' Investments in Sustainable Land Management Practices in Ethiopia: Review and Synthesis." *Environment, Development and Sustainability* 18(4): 1005-1023. https://doi.org/10.1007/s10668-015-9683-5

Asrat, Paulos, Kassa Belay, and Desta Hamito. 2004. "Determinants of Farmers' Willingness to Pay for Soil Conservation Practices in the Southeastern Highlands of Ethiopia." *Land Degradation & Development* 15(4): 423-438. https://doi.org/10.1002/ldr.623

Assessment, M. E. (2005). Ecosystem and Human Well-being: Biodiversity Synthesis. *World Resources Institute*, Washington, DC

Bandiera, Oriana and Imran Rasul. 2006. "Social Networks and Technology Adoption in Northern Mozambique." *The Economic Journal* 116(514): 869-902. https://doi.org/10.1111/j.1468-0297.2006.01115.x

Battaglini, Marco, Salvatore Nunnari, and Thomas Palfrey. 2012. "The Free Rider Problem: A Dynamic Analysis (No. w17926)." Cambridge, MA: National Bureau of Economic Research. https://doi.org/10.3386/w17926

Bigsten, Arne, and Sven Tengstam. 2011. "Smallholder Diversification and Income Growth in Zambia." *Journal of African Economies* 20(5): 781-822. https://doi.org/10.1093/jae/ejr017

Birthal, Pratap S, Devesh Roy, and Digvijay S Negi. 2015. "Assessing the Impact of Crop Diversification on Farm Poverty in India." *World Development* 72: 70-92. https://doi.org/10.1016/j.worlddev.2015.02.015

Bouma, Jetske, Daan Van Soest, and Erwin Bulte. 2007. "How Sustainable Is Participatory Watershed Development in India?" *Agricultural Economics* 36(1): 13-22. https://doi.org/10.1111/j.1574-0862.2007.00173.x

Bravo-Ureta, B. E., Solis, D., Cocchi, H., & Quiroga, R. E. (2006). The Impact of Soil Conservation and Output Diversification on Farm Income in Central American Hillside Farming. *Agricultural Economics*, 35(3), 267-276. https://doi.org/10.1111/j.1574-0862.2006.00161.x

Brevik, E. C., A. Cerdà, J. Mataix-Solera, Lily Pereg, J. N. Quinton, Johan Six, and K. Van Oost. 2015. "The Interdisciplinary Nature of Soil." *Soil* 1(1): 117-129. https://doi.org/10.5194/soil-1-117-2015

Conley, Timothy G., and Christopher R. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review* 100(1): 35-69. https://doi.org/10.1257/aer.100.1.35

Datta, Nirupam. 2015. "Evaluating Impacts of Watershed Development Program on Agricultural Productivity, Income, and Livelihood in Bhalki Watershed of Bardhaman District, West Bengal." *World Development* 66: 443-456. https://doi.org/10.1016/j.worlddev.2014.08.024

Dayakar, Peddi and Kavi Kumar, KS. "Farmers' Perceptions about Soil Erosion in Rainfed Areas of Telangana, India." *Journal of Public Affairs*: e2374. https://doi.org/10.1002/pa.2374

Drukker, David M 2009. "Analyzing Spatial Autoregressive Models Using Stata." In *Italian Stata Users Group Meeting.*

Feder, Gershon, and Roger Slade. 1985. "The Role of Public Policy in the Diffusion of Improved Agricultural Technology." *American Journal of Agricultural Economics* 67(2): 423-428. https://doi.org/10.2307/1240713

Govt. of Telangana (2015). State Action Plan on Climate Change for Telangana State, EPTRI, Hyderabad.

Greene, WH. 2008. *Econometric Analysis, 6th edition*. Upper Saddle River: Pearson Prentice Hall.

Gujarati, DN. 2009. *Basic Econometrics, 4th edition*. New York: McGraw-Hill, Inc.

Holloway, Garth, and Ma Lucila A Lapar. 2007. "How Big Is Your Neighborhood? Spatial Implications of Market Participation among Filipino Smallholders." *Journal of Agricultural Economics* 58(1): 37-60. https://doi.org/10.1111/j.1477-9552.2007.00077.x

Jayne, Thomas S., Nicole M. Mason, Robert J. Myers, John N. Ferris, David Mather, Nicholas Sitko, Margaret Beaver, Natalie Lenski, Antony Chapoto, and Duncan Boughton. 2010. "Patterns and Trends in Food Staples Markets in Eastern And Southern Africa: Toward the Identification of Priority Investments and Strategies for Developing Markets and Promoting Smallholder Productivity Growth." MSU Agricultural Economics International Development Working Paper (No: 104/2010), Michigan State University, USA.

Kerr, John. 2002. "Watershed Development, Environmental Services, and Poverty Alleviation in India." *World Development* 30(8): 1387-1400. https://doi.org/10.1016/S0305-750X(02)00042-6

Knowler, Duncan, and Ben Bradshaw. 2007. "Farmers' Adoption of Conservation Agriculture: A Review and Synthesis of Recent Research." *Food Policy* 32(1): 25-48. https://doi.org/10.1016/j.foodpol.2006.01.003.

Kumar, Prasanna, Dayakar, Peddi, Sandhya, V, and Reddy, Pakki. 2015. "Indigenous Coping Strategies to Climate Change in Agriculture." Presented at *The Second International Conference Bio-resource and Stress Management*, 7-10 January 2015, Hyderabad, India.

Kumar, M Dinesh, Charles Batchelor, and AJ James. 2019. "Catchment Management to Basin Management: International Perspectives and Overview of

Global Experience." *Current Directions in Water Scarcity Research* (1): 21-54. https://doi.org/10.1016/B978-0-12-814851-8.00002-1

Lal, Rattan. 2001. "Soil Degradation by Erosion." *Land Degradation & Development* 12(6): 519-539. https://doi.org/10.1002/ldr.472

Läpple, Doris and Hugh Kelley. 2015. "Spatial Dependence in the Adoption of Organic Drystock Farming in Ireland." *European Review of Agricultural Economics* 42(2):315-337. https://doi.org/10.1093/erae/jbu024

Lopez, Ramon. 2002. "The Economics of Agriculture in Developing Countries: The Role of the Environment." *Handbook of Agricultural Economics 2*: 1213-1247. https://doi.org/10.1016/S1574-0072(02)10004-1.

Lutz, Ernst, Stefano Pagiola, and Carlos Reiche, eds. 1994. *Economic and Institutional Analyses of Soil Conservation Projects in Central America and the Caribbean*. Washington DC: The World Bank. https://doi.org/10.1596/0-8213-2741-0

Makate, Clifton, Marshall Makate, Nelson Mango, and Shephard Siziba. 2019. "Increasing Resilience of Smallholder Farmers to Climate Change through Multiple Adoption of Proven Climate-Smart Agriculture Innovations. Lessons from Southern Africa." *Journal of Environmental Management* 231: 858-868. https://doi.org/10.1016/j.jenvman.2018.10.069

Mbaga-Semgalawe, Zainab and Henk Folmer. 2000. "Household Adoption Behavior of Improved Soil Conservation: The Case of the North Pare and West Usambara Mountains of Tanzania." *Land Use Policy* 17(4): 321-336. https://doi.org/10.1016/S0264-8377(00)00033-8

Moser, Christine M, and Christopher B Barrett. 2006. "The Complex Dynamics of Smallholder Technology Adoption: The Case of SRI in Madagascar." *Agricultural Economics* 35(3): 373-388. https://doi.org/10.1111/j.1574-0862.2006.00169.x

Palanisami, K, D. Suresh Kumar, Ravinder Paul Singh Malik, S Raman, G Kar, and K Mohan. 2015. "Managing Water Management Research Analysis of Four Decades of Research and Outreach Programmes in India." *Economic & Political Weekly* 26-27: 33-43.

Pattanayak, Subhrendu K. 2004. "Valuing Watershed Services: Concepts and Empirics from Southeast Asia." *Agriculture, Ecosystems & Environment* 104(1): 171-184. https://doi.org/10.1016/j.agee.2004.01.016

Pattanayak, Subhrendu K., and David T. Butry. 2005. "Spatial Complementarity of Forests and Farms: Accounting for Ecosystem Services." *American Journal of Agricultural Economics* 87(4): 995-1008. https://doi.org/10.1111/j.1467-8276.2005.00783.x

Pinkse, Joris, and Margaret E. Slade. 1998. "Contracting in Space: An Application of Spatial Statistics to Discrete-Choice Models." *Journal of Econometrics* 85(1): 125-154. https://doi.org/10.1016/S0304-4076(97)00097-3

Reddy, V. Ratna and Geoff Syme. 2019. "Addressing the Scale Issues in Watershed Development." *Current Directions in Water Scarcity Research* 1: 275-297. https://doi.org/10.1016/B978-0-12-814851-8.00010-0

Scherr, Sara J. 1999. "Soil Degradation: A Threat to Developing-Country Food Security by 2020?" Food, Agriculture and the Environment Discussion Paper no. 27, International Food Policy Research Institute, Washington DC.

Shiferaw, Bekelc and Stein T Holden. 1998. "Resource Degradation and Adoption of Land Conservation Technologies in the Ethiopian Highlands: A Case Study in Andit Tid, North Shewa." *Agricultural Economics* 18(3): 233-247. https://doi.org/10.1111/j.1574-0862.1998.tb00502.x

Sidibé, Amadou. (2005). "Farm-level Adoption of Soil and Water Conservation Techniques in Northern Burkina Faso." *Agricultural Water Management* 71(3): 211-224. https://doi.org/10.1016/j.agwat.2004.09.002

Singha, Chandan. 2017. "Analyzing Adoption of Soil Conservation Measures by Farmers in Darjeeling District, India." *Working papers 275*, Centre for Development Economics, Delhi School of Economics., New Delhi.

Singha, Chandan. 2019. "Impact of the Adoption of Vegetative Soil Conservation Measures on Farm Profit, Revenue and Variable Cost in Darjeeling District, India." *Environment and Development Economics* 24(5): 529-553. https://doi.org/10.1017/S1355770X19000226

Somanathan, Eswaran. 1991. "Deforestation, Property Rights and Incentives in Central Himalaya." *Economic & Political Weekly* 26(4): PE37-PE46. https://www.jstor.org/stable/4397242

Tambo, Justice A, and Jonathan Mockshel. 2018. "Differential Impacts of Conservation Agriculture Technology Options on Household Income in Sub-Saharan Africa." *Ecological Economics* 151: 95-05. https://doi.org/10.1016/j.ecolecon.2018.05.005

Teklewold, Hailemariam, Menale Kassie, and Bekele Shiferaw. 2013. "Adoption of Multiple Sustainable Agricultural Practices in Rural Ethiopia." *Journal of Agricultural Economics* 64(3): 597-623. https://doi.org/10.1111/1477-9552.12011

Tesfaye, Abonesh, Workneh Negatu, R Brouwer, and P Van der Zaag. 2014. "Understanding Soil Conservation Decision of Farmers in the Gedeb Watershed, Ethiopia." *Land Degradation & Development* 25(1): 71-79. https://doi.org/10.1002/ldr.2187

Wang, Honglin, Emma M. Iglesias, and Jeffrey M. Wooldridge. 2013. "Partial Maximum Likelihood Estimation of Spatial Probit Models." *Journal of Econometrics* 172(1): 77-78. https://doi.org/10.1016/j.jeconom.2012.08.005

Wossen, Tesfamicheal, Thomas Berger, and Salvatore Di Falco. 2015. "Social Capital, Risk Preference and Adoption of Improved Farm Land Management Practices in Ethiopia." *Agricultural Economics* 46(1): 81-97. https://doi.org/10.1111/agec.12142

Appendix

Table A.1: Factors Influencing Choice of SWC Practices

Multinomial Logit Model Estimates

Explanatory variables	**Moderate-level adoption**		**High-level adoption**	
	Coef	P>|z|	Coef	P>|z|
Base category	**Low**			
Plot-level characteristics				
Area of the plot	0.052	0.34	0.173*	0.10
Soil erosion	0.459*	0.07	0.342	0.51
Crop diversity index	1.960 ***	0.00	4.593***	0.01
Irrigation	0.183	0.59	0.962	0.35
Neighbours' adoption	0.009***	0.00	0.023***	0.00
Socio-economic variables				
Sex of the household head	0.374	0.34	0.986	0.40
Age of the household head	-0.003	0.78	-0.011	0.56
Years of formal education of the household head	-0.039	0.12	0.026	0.62
Household size	0.086	0.18	0.010	0.95
Caste of the household	-0.326	0.31	-1.186*	0.07
Market access variables				
Road connectivity of the plot	-0.080	0.77	-0.481	0.38
Plot distance to dwelling	0.030	0.75	0.063	0.70
Plot distance to market	-0.005	0.66	-0.031	0.36
Village-level characteristics				
Village under IWMP	1.723***	0.00	4.494 ***	0.00
Diagnostics				
Observations	403			

LR chi2	184.59
Prob > chi2	0.0000
Pseudo R2	0.2544

***, **, * indicate significance at the 1%, 5%, and 10% probability level, respectively.

Note: If the farmer adopts less than or equal to 1 SWC measure, then she is treated as having a "low" level of adoption; if she practices less than or equal to 3 SWC measures, then she is treated as having a "moderate" level of adoption, and if she practices more than 3 SWC measures a "high" level of adoption.

Table A.2: Marginal Effects: Multinomial Logit Model

Explanatory variables	**Low-level adoption**		**Moderate-level adoption**		High-level adoption	
	Marginal Effects	P>|z|	Marginal Effects	P>|z|	Marginal Effects	P>|z|
Plot-level characteristics						
Area of the plot	-0.010	0.23	0.004	0.69	0.006	0.20
Soil erosion	-0.078*	0.07	0.079 *	0.09	-0.001	0.97
Crop diversity index	-0.366***	0.00	0.218*	0.07	0.148**	0.04
Irrigation	-0.040	0.50	-0.000	1.00	0.040	0.40
Neighbours' adoption	-0.002***	0.00	0.001*	0.07	0.001***	0.00
Socio-economic variables						
Sex of the household head	-0.071	0.28	0.037	0.63	0.034	0.52
Age of the household head	0.001	0.73	-0.000	0.95	-0.000	0.57
Years of formal education of the household head	0.006	0.16	-0.009**	0.05	0.003	0.13
Household size	-0.014	0.16	0.017	0.16	-0.003	0.72
Caste of the household	0.065	0.23	-0.020	0.73	-0.045*	0.09
Market access variables						
Road connectivity of the plot	0.018	0.69	0.002	0.96	-0.020	0.40
Plot distance to dwelling	-0.005	0.67	0.004	0.80	0.002	0.72
Plot distance to market	0.001	0.59	0.000	0.96	-0.001	0.19
Village-level characteristics						
Village under IWMP	-0.326***	0.00	0.174***	0.00	0.152***	0.00

Notes: ***, **, * denote significant at 1%, 5%, and 10% respectively.