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# Farm level investment and factors affecting adoption of multiple soil and water conservation technologies in semi–arid tropics of India

**Suresh Kumar[1,*], D.R. Singh[1], B. Mondal[2] and Anil Kumar[3]**

[1]*ICAR–Indian Agriculture Research Institute, Pusa Campus, New Delhi–110 012;* [2]*ICAR–National Rice Research Institute, Cuttack–753006, Odisha;* [3]*ICAR–Indian Agricultural Statistics Research Institute, Library Ave, Pusa, New Delhi–110 012.*

*Corresponding author:
*E-mail: skdagri@gmail.com* (*Suresh Kumar*)

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**ABSTRACT**

The study identifies factors affecting adoption of multiple soil and water conservation (SWC) technologies using multivariate probit (MVP) model for data collected from 1239 fields selected by multistage sampling method. The analysis revealed that farmers' share is only 20% in total investment for SWC technologies. The results also showed that field level features, farmer's perception of benefits of SWC technologies, and social capital and extension services are the key determinants of adoption of multiple soil and water technologies – field bund, water harvesting structure (WHS), micro–irrigation (MI), and farm yard manure (FYM) in the semi–arid drought prone areas of Karnataka. Therefore, the identified key determinants need to be targeted for achieving a higher level of adoption of SWC technologies for sustaining the natural resources and thereby livelihood of resource poor farmers of the drought prone areas of the state.

## 1. INTRODUCTION

In India, about 96.40 M ha area, which is about 30% of total geographical area of the country, is witnessing environmental problem of land degradation (SAC, 2016). It is not only posing a threat to agricultural sustainability but also impacting livelihoods of millions of resource poor farmers (Bhattacharyya *et al.,* 2015). For instance, about 13.4 million Mg of crop produce is lost annually due to water erosion alone in India (Sharda and Dogra, 2013). Similarly, TERI (2018) estimated per annum cost of land degradation and land use change to the tune of 2.54% of gross domestic product of India. Within agriculture sector, rainfed agriculture is highly vulnerable to climate change. It accounts for 67% and 44% of net cultivated area and food grains production, respectively and, supports 40% of country's population (Venkateswarlu, 2011). High vulnerability of rainfed areas can be attributed to multiple climatic, biophysical and socio–economic constraints faced by rainfed agriculture, which limits its crop productivity (Mayande and Katyal, 1996; Dar *et al.,* 2007). However, to maintain food security of the country, it is essential that crop production in rainfed areas is increased and sustained because nearly half of its net sown area will remain rainfed even after realizing the irrigation potential (Srinivasa Rao *et al.,* 2015). Among India's states, Karnataka is facing major challenges of soil degradation (Biswas *et al.,* 2019), and climate change and its variability (Krishnakanth and Nagaraja, 2020), posing a threat to agricultural sustainability. Karnataka is the second most drought prone state after Rajasthan (Nagaraja *et al.,* 2011; Goudappa *et al.,* 2012). In Karnataka, out of the various limitations to crop production, moisture stress during crop growth period is one of the most challenging. This is due to preponderance of scanty rainfall with high mean temperature in arid to semiarid areas, leading to moisture stress in most parts of the State. Under such situation, adoption of soil and water conservation (SWC) technologies is of prime importance, since they not only enhance productivity through soil moisture conservation, but also improve soil health, and encourage use of quality inputs, especially improved seeds (Kerr and Sanghi, 1992; Gebrernichael *et al.,* 2005; Rajkumar and Satishkumar, 2014; Wolka *et al.,* 2018). In spite of efforts by the State Government to upscale adoption of conservation technologies, their private or voluntary adoption has been quite low (Reddy *et al.,* 2004; Bhattacharyya *et al.,* 2015). In India, only a few studies (Pender and Kerr, 1998; Sudha and Sekar, 2015) have been undertaken for examining farmers' adoption behaviour with respect to *in–situ* SWC measures. Therefore, there is a need to identify factors affecting adoption of – field bund, micro–irrigation (MI), water harvesting structure (WHS) and farm yard manure

(FYM), that are the most adopted SWC technologies at field level for helping policy planners to achieve greater adoption of these SWC technologies.

## 2. MATERIALS AND METHODS

A combination of purposive and multistage sampling technique was followed to select the final sampling units *i.e.* farmer. North–central part of Karnataka, which is highly drought prone, was selected purposively for this study. Four agro–climatic zones (ACZ) namely, central dry, northern dry, north–eastern dry and northern transitions were again selected purposively to represent the drought prone area of the State. From each ACZ, one district was then randomly selected. However, from the northern dry zone two districts were selected randomly to ensure sampling proportionate to its area since its geographical area is almost double to that of other selected dry zones. Later, from each selected district, two sub–watersheds were randomly selected. Then, from each selected sub–watershed, a minimum of 20 farmers were randomly selected from the list of all farmers of the sub–watershed listed in its detail project report (DPR) for watershed development project planning. Adjacent to each selected site, control farmers (non–adopters, which are located out–side the watershed areas) in equal numbers were also selected. Thus, a total of 593 farmers having 1239 fields / plots were selected for the study. Selected farmers were classified into three categories namely, marginal (<1 ha), small (1–2 ha) and medium (>2 ha).

### Multivariate Probit (MVP) Model

Generally, farmers adopt a mix of technologies to deal with a multitude of agricultural production constraints; therefore, the adoption decision is inherently multivariate. Attempting univariate modeling would exclude useful economic information about interdependent and simultaneous adoption decisions (Dorfman, 1996). In one–equation model, it is assumed that information about a farmer's up–take of one SWC technology does not change the probability of taking up of another technology. However, the MVP model approach simultaneously models the influence of a set of explanatory variables on each of the different SWC measures, while allowing for potential correlation between unobserved disturbances, as well as relationship between adoptions of different practices (Belderbos *et al.,* 2004). The correlation may be due to complementary (positive correlation) or substitutability (negative correlation) relationship between different conservation measures (Belderbos *et al.,* 2004). Failure to capture unobserved factors and interrelationships among adoption decisions regarding different practices will lead to bias and inefficient estimates (Greene, 2008). As the adoption of specific technologies is not independent of other technologies on the same farm, following Marenya and Barrett (2007), we employed a MVP model that accounts for error term correlation. If such correlation exists, estimates of simple probit models would be biased and inefficient.

Our MVP model consists of four binary choice equations, *viz.,* field bund, FYM, WHS, and MI, which are the most common technologies adopted by the farmers at individual field level as per the pre–data collection discussion with farmers and field functionaries working for watershed management in drought prone areas of the state. We therefore have four dependent binary variables $Y_{ij}^*$ for household $ii$ and field / plot $jj$ for technology $k$:

$$Y_{ijk} = \begin{cases} 1, if\ Y_{ijk}^* > 0 \\ 0, otherwise \end{cases} \qquad ...(1)$$

$$Y_{ijk}^* = X_{ijk}' \beta_k + \mu_{ijk} \qquad ...(2)$$

Where, $Y_{ijk}^*$ is a latent variable that captures the degree to which a farmer $i$ views technology $k$ as beneficial for him. This latent variable is assumed to be a linear combination of observed field and household characteristics, $X_{ijk}'$ and unobserved characteristics captured by the stochastic error term, $\mu_{ijk}$ (eq. 2). The vector of parameters to be estimated is denoted by $\beta_k$. Given the latent nature of $Y_{ijk}^*$, estimation is based on observable binary variables $Y_{ijk}$, which indicates whether or not a farmer used a particular technology in the reference year.

The error terms $\mu_{ijk}$ (k = 1, 2 . . . 6) are distributed multivariate normal each with mean 0 and a variance–covariance matrix $V$, where $V$ has '1' on the leading diagonal, and correlations

$p_{jk} = p_{kj} p_{jk} = p_{jk}$ as off–diagonal elements:

$$V = \begin{cases} 1 & \rho_{12}\ \rho_{13} \cdots \cdots \rho_{1k} \\ \rho_{21}\ 1 & \rho_{23} \cdots \cdots \rho_{2k} \\ \rho_{j2}\ \rho_{j2} & \rho_{j3} \cdots \cdots 1 \end{cases} \qquad ...(3)$$

Off–diagonal elements are of interest in the covariance matrix, which represent the unobserved correlation between the stochastic components of the different types of conservation technologies.

This assumption means that eq. 2 generates a MVP model that jointly represents decisions to adopt a particular SWC measure. This specification with non–zero off–diagonal elements allows for correlation across the error terms of several latent equations, which represent unobserved characteristics that affect the choice of alternative conservation measures. By this, when analyzing the determinants of adoption, we take into account the influence of non–observable household characteristics on adoption decisions. For instance, there may be a correlation between farm–invariant characteristics (*e.g.* managerial ability) and the decision to adopt a technology (Teklewold and Köhlin, 2011). A pooled MVP model is reliable under the assumption that unobserved heterogeneity is uncorrelated with observed independent covariates. We have multiple field observations; we estimated eq. 2 with Mundlak (1978) approach to control unobserved heterogeneity, which is by adding the means of field–varying explanatory variables as additional covariates in the model. Therefore, we used pseudo–fixed effects specification, which enables consistent parameter estimation. In order to do so, the right side of our pseudo–fixed effect regression equation includes the mean value of the field–varying explanatory variables (Mundlak, 1978) as given in eq. 4.

$$\psi_h = \bar{x}\alpha + \eta_h, \eta_h \sim (0, \sigma_\eta^2) \quad ...(4)$$

Where, $x$ is the mean of the field–varying explanatory variables (such as average soil fertility, slope, type of soil *etc.*) within each household (cluster mean), α is the corresponding vector coefficient, and $\eta$ is a random error unrelated to $x_s$. The vector $\alpha$ will be equal to 0 if the observed explanatory variables are uncorrelated with the random effects. We conducted F–test against the null hypothesis that the vector α are jointly equal to zero; the test results rejected the null hypothesis (chi2(6) = 53.5, Prob > chi2 = 0.0000) and justified the relevance of fixed effects (Wooldridge, 2002).

## 3. RESULTS AND DISCUSSION

### Descriptive Statistics of Selected Variables

Descriptive statistics of factors which expectedly influence adoption of SWC technologies are presented in Table 1. In case of household characteristics, 81% of fields / plots were owned by male headed households and 48% of farmers also earned income from off–farm source. Average age and level of education (schooling years) of household

**Table: 1**
**Summary of descriptive statistics of the sample fields / plots**

| Group | Variables | Definition / units | Mean / No. |
|---|---|---|---|
| Household level characteristics | Male head of household | If male = 1; otherwise = 0 | 1002 (80.9) |
| | Age of decision maker | Year | 50.8 (13.5) |
| | Education level of head | Schooling in years | 4.9 (4.8) |
| | Family size | Number | 5.0 (2.3) |
| | Land dependency ratio | Land holding per person (ha) | 0.6 (0.7) |
| | Off farm income | If yes = 1; otherwise = 0 | 592 (47.8) |
| | Farm asset index | Index (0 to 1) | 0.11 (0.1) |
| | Livestock | Number | 3.4 (2.2) |
| | Access to credit | If crop loan availed = 1, otherwise = 0 | 813 (65.6) |
| Farm and field level features | Size of landholding | ha | 2.17 (2.1) |
| | Average size of field | ha | 0.73 (0.6) |
| | Own tenurial status of field | If own field = 1; otherwise = 0 | 861 (69.5) |
| | High slope of the field | If high = 1; otherwise = 0 | 768 (62.0) |
| | Red soils | If red = 1; otherwise = 0 | 281 (22.7) |
| | Black soils | If black = 1; otherwise = 0 | 602 (48.6) |
| | High level of soil erosion | If high = 1; otherwise = 0 | 463 (37.4) |
| | Moderate level of soil erosion | If moderate = 1; otherwise = 0 | 289 (23.3) |
| | Good level of soil fertility | If good = 1; otherwise = 0 | 403 (32.5) |
| | Medium level of soil fertility | If medium = 1; otherwise = 0 | 590 (47.6) |
| | Adoption of improved variety | If improved = 1; otherwise = 0 | 733 (59.2) |
| Social capital and capacity building | Interaction with neighbours and friends | Sometimes = 1 | 447 (36.1) |
| | | Occasional = 2 | 355 (28.7) |
| | | Very frequent = 3 | 436 (35.2) |
| | Usefulness of interaction | Not useful = 1 | 120 (9.7) |
| | | Moderately useful = 2 | 568 (45.8) |
| | | Very useful = 3 | 551 (44.5) |
| | Training attended | If yes = 1; otherwise = 0 | 692 (55.9) |
| | Exposure visits | Visit to model watersheds (No.) | 1.1 (0.8) |
| | Access to extension services | Visit to KVK / RSK (No.) | 2.7 (1.6) |
| Perception relating o benefits of SWC measures | Reduction in runoff | 1 to 5 scale | 3.2 (1.4) |
| | Reduction in soil loss | 1 to 5 scale | 3.6 (1.3) |
| | Improvement in soil fertility | 1 to 5 scale | 3.4 (1.4) |
| | Improvement in soil moisture | 1 to 5 scale | 3.3 (1.3) |
| | Augmentation of groundwater | 1 to 5 scale | 3.5 (1.3) |
| | Risk perception | Crop failed in 10 years (No.) | 3.4 (0.7) |
| District dummies | Tumkuru | If yes = 1; otherwise = 0 | 213 |
| | Bidar | If yes = 1; otherwise = 0 | 329 |
| | Gadag | If yes = 1; otherwise = 0 | 319 |
| | Total sample fields | Number | 1239 |

*Figures in parentheses indicate percentage* head was 51 years and 4.9 years, respectively. The average size of family, size of landholding, land dependency ratio and livestock ownership were 5 numbers, 2.17 ha, 0.6 ha and 3.4 numbers, respectively. Farm asset index, an index of the farm implements ownership, was found to be low (0.11) on sample farms. However, access to credit was good and nearly two–thirds of farmers had availed crop loan.

In case of farm and field level characteristics, the average size of field was 0.73 ha and 70% of fields were cultivated by owners. One–third and nearly a half of the farmers perceived fertility of their fields to be good and of medium level, respectively. 37% and 23% of farmers opined soil erosion on their fields to be of high and moderate level, respectively. The high slope of their fields and cultivation of improved varieties were perceived by 62% and 59% of farmers, respectively. This is due to demonstration of improved crop varieties in watershed areas, especially at the time of implementing watershed activities, by project implementing agencies. In social capital and capacity building, 35%, 29%, and 36% of farmers interacted very frequently, occasionally and sometimes with friends and neighbours regarding SWC technologies, and most of the farmers perceived that interaction was useful. Access to extension services through visit to KVK / RSK and exposure visits to model watersheds were 2.7 and 1.1 numbers $yr^{-1}$ alongwith a high variation among the sampled farmers. It can be attributed to implementing agencies conducting training programmes for farmers in project areas for ensuring effective adoption of SWC technologies and exposure visits to convince them by exposure to the potential benefits of watershed technologies in real field conditions. Farmers' perception on benefits of SWC measures on scale of 1 to 5 were found to be between 3.2 to 3.6 for reduction of runoff and soil loss, improvement in soil fertility and moisture, and augmentation of groundwater, however, the variability in the perception among the respondents was high. The risk perception in terms of crop failure in last 10 years was high (3.4 times) in the selected farmers. For capturing location effects, dummy variables were used for the selected districts.

## Farm Level Investment for SWC Technologies

The study area is rainfed and prone to frequent droughts. Therefore, the adoption of SWC technologies, namely; field bund, WHS and MI, are important for increasing yield and reducing risk of crop failure in such areas. Considering the importance of these measures, the Government has implemented various schemes in study area from time to time through watershed development projects and provided financial assistance and technical guidance to the farmers. Farm level investment in SWC technologies is given in Table 2. Adoption of field bund on selected farms was about 53% in the study area. Farm category–wise results shows that about 47%, 51%, and 60% of the marginal, small and large farmers, respectively adopted the field bund. Overall average investment on field bund was about ₹ 7,645 $field^{-1}$ and ₹ 23,684 $farm^{-1}$; it was ₹ 6,470 and ₹ 10,352 on marginal farms and ₹ 8,590 and ₹ 4,309 on large farms, respectively because of increase in the size of field as well as farm. The farmers' contribution in field bund was only 10%, and major part of investment was funded by the Government.

In case of WHS, nearly one–fourth of the farmers adopted it with an average investment of about ₹ 70,403 $structure^{-1}$. Similarly, the farmers' share in investment in

**Table: 2**
**Farm level investment in SWC technologies**

| Particulars | Marginal | Small | Medium | All |
|---|---|---|---|---|
| Field bund | | | | |
| Adoption of field bund (%) | 47.4 | 51.1 | 60.2 | 52.8 |
| Investment on field bund $field^{-1}$ | 6470 | 7966 | 8590 | 7645 |
| Investment on field bund $farm^{-1}$ | 10352 | 17525 | 43809 | 23684 |
| Farmers' share in investment in bund (%) | 10.00 | 10.00 | 10.00 | 10.00 |
| Water harvesting structure | | | | |
| Adoption of WHs (%) | 20.1 | 20.7 | 27.6 | 22.8 |
| Investment on per WHS | 65571 | 68308 | 75674 | 70403 |
| Investment on WHS $farm^{-1}$ | 13177 | 14170 | 20849 | 16028 |
| Farmers' share in investment on WHS (%) | 15.50 | 23.10 | 32.60 | 31.90 |
| Micro-irrigation | | | | |
| Adoption of the MI (%) | 21.1 | 20.7 | 23.0 | 21.6 |
| Investment on MI $unit^{-1}$ | 25693 | 32329 | 43802 | 34082 |
| Investment on MI $farm^{-1}$ | 5409 | 6707 | 10057 | 7357 |
| Farmers' share in MI (%) | 12.50 | 17.60 | 26.70 | 24.79 |
| SWC technologies | | | | |
| Investment on SWC $farm^{-1}$ | 23664 | 31410 | 60353 | 39322 |
| Farmers' share in SWC technologies (%) | 13.17 | 16.75 | 18.53 | 19.61 |

*WHS: water harvesting structure; MI: micro–irrigation*

WHS showed an increasing trend with farm size; it was 15%, 23%, and 33% on marginal, small and large farms, respectively. However, per hectare investment was very low on large farms (₹ 4,854) in comparison to small (₹ 9,701) and marginal farms (₹ 17,832), most likely due to economy of scale.

The adoption of MI like drip and sprinkler irrigation technologies promotes efficient utilization of scarce irrigation water. However, the overall adoption of MI was about on 22% of selected farms. The investment on MI was about ₹ 34,000 unit$^{-1}$ and ₹ 7357 farm$^{-1}$. However, per farm investment on MI was only ₹ 5409 on marginal farms, and it increased to ₹ 10057 on large farms. Further, per unit investment was ₹ 25693 and ₹ 32329 and ₹ 43802 on marginal, small and large farms, respectively. Similarly, farmers' share in investment on MI showed an increasing trend with farm size and it was 12%, 18% and 27% on marginal, small and large farms, respectively. However, per hectare investment on MI was very low on large farms (₹ 2,337) in comparison to small (₹ 4,592) and marginal farms (₹ 7,320), most likely due to economy of scale.

The total farm level investment in SWC technologies was about ₹ 39,000 farm$^{-1}$. The comparison across different categories of farms revealed that investment per farm showed an increasing trend with increase in farm size whereas a reverse trend was observed in investment per unit of land as expected. Per farm investment was ₹ 23,664 on marginal farms and increased to ₹ 31,410 on small and ₹ 60,353 on large farms. Similarly, the farmers' share in farm level investment in SWC technologies showed an increasing trend with farm size, and it was 13%, 17%, and 19% on marginal, small and large farms, respectively. On the other hand, per hectare investment was lower on large farms (₹ 13,867) and highest on marginal farms (₹ 34,220). Overall, it can be stated that the share of farmers is about 20% in the total investment for SWC technologies. This implies that about 80% is being shared by public investment.

## Complementarity or Trade–Off Among Adoption of Multiple SWC Technologies

Adoption of one technology may influence the adoption of another technology, implying that there could be complementarities or trade–off among adoptions of multiple SWC technologies. It can be seen from Table 3 that there was a positive correlation (0.584, $p < 0.05$) between the adoption of WHS and field bund. This is due fact that in soil bund adopted fields (areas wherein watershed progarmmes were implemented), the utilization of farm pond is also higher since the excess water from the treated areas can be channelized to farm pond or other WHSs. Similarly, there was a significantly higher positive correlation (0.75, $p < 0.001$) between the MI and WHSs. Because, it is highly recommended that harvested water should be used judiciously with the help of MI system in drought prone areas. It can be concluded that there is a complementary relationship among the adoptions of multiple SWC technologies.

**Table: 3**
**Correlation coefficients among the adoption of SWC technologies**

| SWC technologies | Field bund | Water harvesting | Micro-irrigation | Farm yard manure |
|---|---|---|---|---|
| Field bund | 1.0 | | | |
| Water harvesting | 0.584** (0.06) | 1.0 | | |
| Micro-irrigation | 0.016 (0.055) | 0.75*** (0.02) | 1.0 | |
| Farm yard manure | 0.235*** (0.069) | -0.036 (0.060) | 0.020 (0.054) | 1.0 |

*Notes: ***, ** and * represent level of significance 1%, 5%, and 10%, respectively. Figures in parentheses are standard errors.*

## Determinants for Adoption of Field Bund

Considering the high correlation among adoption of SWC technologies and binary choice of either adoption or non–adoption, fitting of MVP model is the most suitable approach. Overall, Wald chi–square statistics showed good fit of the model (Table 4).

Among the household level characteristics, household size, off farm income, farm assets index and number of livestock owned had a significant positive bearing on the probability of adoption of field bund. On the other hand, the coefficient of age of the decision makers was negatively significant. This implies that younger farmers are more willing to adopt field bund. This result is in line with earlier studies (Ersado *et al.,* 2004; Shiferaw and Holden, 2000). Higher probability of adoption of younger farmers can be attributed to the fact that, generally, benefits of SWC cannot be realized within a short time period, therefore, older farmers do not have much incentive for investing in conservation efforts (Mbaga–Semgalawe and Folmer, 2000). In the study area, we noticed that younger farmers were more educated, had more access to the required information and technologies, and also had a better understanding of negative consequences of soil erosion and land degradation, resulting in a higher probability of adoption. Furthermore, we observed that younger farmers wanted to pursue market–oriented farming and were also aware about the importance of sustaining natural resources. Among farm and field level physical features, it can be seen that most of these features *viz.,* size of landholding, tenure (ownership of the field), slope of the field, type of soil and higher level of erosion were found to have a positive significant effect on adoption of field bund. Positive effect of tenure can be attributed to confirmed future ownership of the same land providing incentive to him for investing in conservation measures on the land (Gebremedhin and Swinton, 2003) and harnessing its long–term benefits. Many studies reported a positive

**Table: 4**
**Multivariate probit regression coefficients of factors affecting adoption of SWC technologies**

| Variables | Field bund | | Water harvesting | | Micro-irrigation | | Manure | |
|---|---|---|---|---|---|---|---|---|
| | Coefficient | RSE[#] | Coefficient | RSE | Coefficient | RSE | Coefficient | RSE |
| Household characteristics | | | | | | | | |
| Male headed household | 0.198 | 0.184 | -0.101 | 0.114 | 0.083 | 0.097 | 0.250** | 0.121 |
| Age of decision maker | -0.014*** | 0.005 | -0.005 | 0.003 | -0.006** | 0.003 | -0.002 | 0.003 |
| Education level | -0.011 | 0.015 | 0.101** | 0.011 | 0.020** | 0.009 | -0.011 | 0.011 |
| Household size | 0.068** | 0.030 | -0.004 | 0.024 | 0.004 | 0.018 | -0.001 | 0.024 |
| Off farm income | 0.272* | 0.143 | 0.209* | 0.111 | 0.054** | 0.083 | -0.019 | 0.106 |
| Farm assets index | 0.640** | 0.054 | 0.012 | 0.035 | -0.006 | 0.028 | -0.014 | 0.039 |
| Livestock ownership | 0.067** | 0.030 | 0.033* | 0.018 | 0.058*** | 0.017 | 0.008* | 0.021 |
| Farm and field level features | | | | | | | | |
| Size of landholding | 0.102** | 0.051 | 0.170*** | 0.033 | 0.229*** | 0.031 | -0.036 | 0.036 |
| Status of field ownership | 0.058* | 0.149 | 0.520*** | 0.116 | 0.287*** | 0.100 | 0.043* | 0.105 |
| High slope of field | 0.044** | 0.029 | 0.088 | 0.110 | 0.135 | 0.094 | -0.212** | 0.108 |
| Red soils in field | 0.852*** | 0.164 | 0.052 | 0.138 | -0.031 | 0.116 | -0.138 | 0.137 |
| Black soils in field | 0.886*** | 0.156 | -0.132 | 0.131 | -0.033 | 0.102 | -0.237* | 0.121 |
| High level of soil erosion | 1.079*** | 0.141 | -0.037 | 0.111 | 0.256*** | 0.090 | 0.265** | 0.104 |
| Moderate level of soil erosion | -0.426*** | 0.153 | -0.018 | 0.123 | 0.115 | 0.108 | 0.084 | 0.129 |
| Good level of soil fertility | -0.935*** | 0.187 | -0.119 | 0.148 | 0.216* | 0.127 | 0.087 | 0.149 |
| Medium level of soil fertility | -0.624*** | 0.132 | -0.073 | 0.117 | 0.149 | 0.097 | 0.039 | 0.118 |
| Social capital and capacity building | | | | | | | | |
| Interaction with neighbours and friends | 0.066 | 0.086 | 0.236*** | 0.070 | 0.178*** | 0.054 | -0.001 | 0.067 |
| Usefulness of interaction | -0.002 | 0.103 | 0.171** | 0.077 | -0.010 | 0.064 | -0.026 | 0.075 |
| Undertaking training in SWC | 0.677*** | 0.163 | 0.318** | 0.128 | 0.144 | 0.101 | 3.058*** | 0.217 |
| Exposure visits to model watersheds | 0.171** | 0.039 | 0.031 | 0.103 | 0.057 | 0.079 | 0.029 | 0.099 |
| Access to extension services | 0.210* | 0.044 | 0.003 | 0.029 | 0.001 | 0.022 | -0.032 | 0.028 |
| Perception on benefits of SWC measures | | | | | | | | |
| Reduction in runoff | -0.007 | 0.052 | -0.003 | 0.037 | -0.056** | 0.029 | -0.007 | 0.035 |
| Reduction in soil loss | 0.130* | 0.010 | 0.053 | 0.037 | -0.022 | 0.030 | 0.008 | 0.038 |
| Improvement in soil fertility | 0.540** | 0.019 | 0.066* | 0.037 | 0.033 | 0.027 | -0.061 | 0.037 |
| Improvement in soil moisture | 0.086* | 0.050 | -0.016 | 0.037 | 0.027 | 0.030 | 0.063 | 0.038 |
| Augmentation of groundwater | 0.025 | 0.048 | 0.087** | 0.036 | 0.049* | 0.029 | 0.052 | 0.038 |
| Perception of crop failure risk | 0.170*** | 0.046 | 0.001* | 0.035 | 0.040* | 0.030 | 0.015 | 0.036 |
| Regional dummy (Base category: Koppal) | | | | | | | | |
| Tumkuru | 0.545** | 0.254 | -0.334* | 0.182 | -0.835*** | 0.146 | -1.747*** | 0.196 |
| Gadag | -0.547** | 0.237 | -0.438** | 0.178 | -0.109 | 0.128 | -1.639*** | 0.188 |
| Bidar | -0.072 | 0.384 | -0.436 | 0.296 | -0.778*** | 0.219 | -1.039*** | 0.347 |

Joint significance of mean of field varying covariates chi-square (12) = 222.14, Prob> chi2 = 0.0000
Sample size = 1209 Wald chi-square (140) = 1540.25, Prob> chi2 = 0.0000

*Notes: [#]RSE is the Robust Standard Error adjusted for clustering on–farm households to allow for correlation within group. ***, ** and * represent level of significance 1%, 5%, and 10%, respectively.*

effect of future security of land ownership on adoption of soil conservation practices (Shiferaw and Holden, 2000; Nyangena, 2008; Teshome *et al.,* 2013). As anticipated, both field slope as well as soil erosion level were associated with a high probability for adoption of field bund. These results are in conformity with earlier studies, in which it was reported that the likelihood of adoption was higher if a cultivator was able to recognize the negative effects of soil degradation on crop yields (Baidu–Forson, 1999; Ervin and Ervin, 1982; Hopkins *et al.,* 1999; Shiferaw and Holden, 2000; Willy and Holm–Müller, 2013). Contrarily, other field level physical features, namely moderate level of erosion and high and moderate level of fertility of fields were associated negatively with taking–up of field bund. Among factors relating to social capital and extension services, training, exposure visits and access to extension services had a positive relationship with up–take of field bund, which is in line with our prior anticipation, as social capital facilitates exchange of views and experiences, and also facilitates sharing of resources, which are essential for community–based SWC efforts / programs. Similar to our results, a positive role of social capital in adoption of agricultural technologies was reported (Grootaert *et al.,* 2004; Nyangena, 2008; Prokopy *et al.,* 2008; Teklewold and

Köhlin, 2011; Adimassu *et al.,* 2012; Jara–Rojas *et al.,* 2012; Willy and Holm–Müller, 2013; Wossen *et al.,* 2013). Training also had a positive effect on adoption, and this finding is in line with earlier studies (Anley *et al.,* 2007; Chesterman *et al.,* 2019). Extension services had a positive effect, as anticipated, on decision to adopt SWC practices. Similar findings were also reported by many researchers (Bekele and Drake, 2003; Mbaga–Semgalawe and Folmer, 2000; Shiferaw and Holden, 2000; Mango *et al.,* 2017). These studies suggested that access to an effective extension service helps not only to realize the detrimental effects of land degradation but also sensitize about availability of suitable technologies. Turning to perception of benefits of SWC, it can be seen that most of the variables, namely reduction in soil loss, improvement in soil fertility and moisture had positive effects on the adoption of field bund. Furthermore, risk perception (perceived chances of crop failure) was also positively associated with up–take of field bund. Understandably, expected benefits of technologies are critical for increasing adoption rates (Baidu–Forson, 1999; Mbaga–Semgalawe and Folmer, 2000; Shiferaw and Holden, 2000). Similarly, we also found that farmers having higher perceived benefits of SWC practices were taking up and using conservation measures.

**Determinants for Adoption of WHSs**

In case of WHSs, among the personal and household features, level of education and off–farm income had favourable effects on taking up of WHSs. Since most farmers of the region are resource poor, therefore, off–farm income enables them to invest in SWC technologies. Similar results were also reported in previous studies (Mbaga–Semgalawe and Folmer, 2000; Tiwari *et al.,* 2008). Among farm and field level characteristics, farm size and confirmed future ownership of the same land had a positive bearing on the up–take of WHSs. This is due to the fact that large farmers can afford to allocate land for making dug–out pond or farm pond. Furthermore, these structures require sizable amount of investment, and give benefits for a long period of time. Therefore, farmers prefer to construct such structures on their own farms. Social capital and training factors were also associated with adoption of rain water harvesting structures. Risk perception and perception related to benefits of SWC measures also had a favourable bearing on up–take of WHSs. It has been observed that farmers who perceive the risk of crop failure try to minimize such chances by adopting WHSs so as to provide supplemental irrigation at the time of critical stages of crop growth.

**Determinants for Adoption of MI**

In case of MI system, it was observed that age, education, off–farm income and number of livestock units are positively associated with its adoption. Similar results were also obtained by Madhava and Surendran (2016). Among farm and field level features, factors such as size of landholding, security of future land ownership, high level of erosion as well as fertility were found to be enhancing MI system adoption for judicious use of bore–well or farm pond water.

**Determinants for Adoption of FYM**

FYM application is also an important SWC measure which enhances soil fertility, moisture retention etc. FYM application was done more by families having a male as the family head. Number of livestock units owned also influenced its application. Among farm and field level features, confirmed future ownership of the same land, prevalence of black soil type in a field, and high level of soil erosion favourably impacted application of FYM.

Undertaking of training also had a positive association with likelihood of adoption of the manure application. However, neither any of the perceived benefits of SWC measures nor perception of crop failure risk were found to be associated with the manure application. In comparison to Koppal district, probability of farmers adopting manure was significantly higher in Tumkuru, Gadag and Bidar districts.

## 4. CONCLUSIONS

The main aim of the study was to examine farm level investment for SWC measures, and also to identify the factors affecting the adoption of multiple SWC technologies–field bund, MI, WHS and FYM in semi–arid and drought prone areas of the Karnataka state. Keeping in view correlation among SWC technologies adoption, we used the MVP model. For the study, primary data from 1239 fields / plots were collected of 593 farmers. About 80% of total investment for SWC technologies is being shared by the Government. Among the household level characteristics, age, education level, off–farm income and livestock ownership were found to have a favourable effect on adoption of these SWC technologies. Similarly, most of the field level features like size of landholding, confirmed future ownership of the same land, high field slope, type of soils and high level of erosion were observed to have a positive and significant impact on adoption of these multiple SWC technologies. Further, we also found that perception of farmers relating to benefits of soil and water technologies and risk of crop failure had a positive bearing on the adoption. Therefore, there is need to bring out a desirable change in the perception of the farmers through awareness programmes. Most importantly, social networking, and training in SWC had a positive effect. Therefore, there is a need of strengthening them. Strengthening of extension services for the farmers can have a positive impact on adoption. These variables should be considered while formulating a programme and scheme for scaling–up of SWC measures.

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