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Key determinants of adoption of soil and water conservation measures: A review

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ABSTRACT

We synthesized the information on the determinants of soil and water conservation measures to draw the useful insights for policy implications. We found that there are no universally significant factors affecting the adoption of soil and water conservation measures across the regions. Therefore, there is a need for 'location-specific targeted policies' for increasing uptake of soil and water conservation measures. Factors such as 'access to extension services', 'access to credit', 'marketing facilities', 'training' and 'collective actions' were found be having a positive impact on adoption of soil and water conservation measures. Broadly, findings suggest that policy makers should focus on the institutional and economic factors for increasing the use of conservation measures.

Key words: Adoption, Determinants, Soil and water Conservation

Soil degradation is a major environmental problem (Blanco and Lal 2008) and its negative externalities will affect the future generations by reducing the capacity for agricultural production. Soil erosion is a serious problem in India (Biswas *et al.* 2015, Biswas *et al.* 2019), affecting crop production on 147 mha (Bhattacharyya *et al.* 2015). India suffers an estimated annual production loss of 13.4 million tonnes of major cereal, oilseed and pulses (Sharda *et al.* 2010). Investment for soil and water conservation (SWC) measures is crucial for sustaining natural resource (Kumar *et al.* 2014, Kumar *et al.* 2015, Kumar *et al.* 2016) and for increasing resilience due to their synergetic and positive effects (Kato *et al.* 2011). Of the SWC measures at farm level, *in-situ* measures are critical and, probably the first step towards adaptation to climate variability. In spite of well documented benefits of these SWC measures and watershed programmes (Mondal *et al.* 2012, Mondal *et al.* 2013, Mondal and Nalatwadmath 2014, Mondal *et al.* 2018), the extent of voluntary adoption of SWC technologies is very low. Therefore, there is a need of concerted efforts for enhancing the level of adoption of SWC measures. For this, a better understanding adoption process of SWC measures is highly useful. Adoption of SWC measures is determined by a host of factors such as farmers' personal and household specific characteristics, economic and institutional factors, bio-physical characteristics (Shiferaw *et al.* 2009, Adimassu *et al.* 2012, Mondal *et al*. 2013, Kumar *et al.* 2019). For devising an effective programme and policy, and creating an enabling environment, and a better understanding of the key factors, which universally or up to a large extent are responsible for enhancing level of adoption, is essential (Teshome *et al.* 2016). To this end, there is a need to synthesize the information from the extant studies for identifying the key drivers of adoption.

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Review of adoption of soil and water conservation cases

Another challenge is in synthesizing the comparable factors from the studies. Since the studies were conducted in diverse agro-ecological and socio-economic situations (Table 1), therefore, influencing factors varied across these selected studies. Hence, for synthesizing the comparable factors, closely linked variables were merged into another similar factor. For instance, factors like 'access to information' and 'contact with extension agency' are expected to serve the same purpose- providing adequate information and technical know-how relating to different aspect of soil and water conservation. Therefore, both the factors have the same influence on the adoption behavior, and accordingly such variables were merged into a broad factor, namely 'extension services. Thus, all the variables influencing the adoption of SWC measures were merged into broad 16 factors. Then, these 16 factors were categorized into four broad groups, *viz.* household/personal factor (age, education and family size), farm and plot level factor (farm size, tenure, fertility, slope of plot, erosion level and perception of erodibility in the plot, distance of farm/plot from home or road), economic factor (access to credit, number of livestock, assets, off-farm income, marketing facilities) and institutional factor

Table 1 Studies on adoption of soil and water conservation (SWC) measures

Study	Location	SWC measures	Model	Sample size
Birhanu and Meseret (2013)	North Western Ethiopia	Soil/stone bund	Logit	162
Teshome *et al.* (2016)	North-Western Ethiopia	Soil bunds	Ordered probit	298
Lapar and Pandey (1999)	Philippine	Contour hedgerow	Probit	130
Pender and Kerr (1998)	Semi-arid India	Soil and water conservation	Tobit	120
Liu and Huang (2013)	Southwest China	Contour cultivation	Probit	100
Liu and Huang (2013)	Southwest China	Contour cultivation	Poisson regression	100
Sileshi *et al.* (2019)	Ethiopia	Stone bund, soil bund and bench terracing	Multivariate probit	408
Mugonola *et al.* (2013)	South western Uganda	Multiple	Logit	271
Mekuriaw *et al.* (2018)	Ethiopian highlands	Terrace	Logit	269
Posthumus (2005)	Peruvian Andes	Bench terraces	Probit	176
Posthumus (2005)	Peruvian Andes/	Bench terraces	Probit	188
Jara Raojas *et al.* (2012)	Central Chile	Water conservation practices	Poisson, Multinomial Logit	319
Pilarova *et al,* (2018)	Republic of Moldova	Minimum tillage, crop rotation and mulch	Binary and ordered probit	234
Turinawe *et al.* (2014)	South Western Uganda	Multiple	Tobit	273
Nyangena (2008)	Rural Kenya	SWC investment	Probit	556
Anley *et al.* (2007)	Western Ethiopia	Multiple	Tobit	101
Amsalua and Graaff (2007)	Ethiopia	Stone terraces	Bivariate probit	147
Kabubo-Mariara *et al.* (2009)	Kenya	Multiple	Probit and Tobit	457
Asafu-Adjaye (2008)	Fiji	Multiple	Ordered probit	610
Deressa *et al.* (2009)	Ethiopia	Soil conservation	Multinomial logit	830
Baidu-Forson (1999)	Niger	Earthen mounds	Tobit	114
Kpadonou *et al.* (2017)	West African Sahel	Multiple	Multivariate and ordered probit	500
Bizoza and De Graaff (2012).	Rwanda	Bench terraces	Probit	301
Teshome *et al.* (2016)	North-Western Ethiopia	stone and soil bunds	Ordered probit	298
Alufah *et al*. (2012)	Kenya	Soil and water conservation	Logit	120
Mango *et al*. (2017).	Southern Africa	Soil and water conservation	Logit	312
Bekele and Drake (2003)	Eastern Ethiopia	Soil and water conservation	Multinomial logit	145
Wolka *et al.* (2018)	Southwest Ethiopia	Stone bunds, *Fanya juu* and soil bunds	Chi-square analysis	201
Kessler (2006)	Bolivia	SWC investments	Factor analysis	60
Mena (2016)	Ethiopia	Soil bund, grass strip and *fanya juu*	Logit	103
Mengistu and Assefa (2019)	Southwest Ethiopia	Soil bund, grass strip cultivation	Multivariate and ordered probit	304
Asfaw and Neka (2017)	Ethiopia	Soil and water conservation	Logit	112
Meseret (2014)	Ethiopia	Soil and water conservation	Logit	149
Singha (2019)	India	Soil and water conservation	Standard probit	432
Gessesse *et al.* (2016)	Central Ethiopia	Tree-planting	Logit	121
Mogesa and Taye (2017)	North-Western Ethiopia	SWC measures	Logit	338
Batiwaritu and Mvena (2009)	Ethiopia	Soil bund	Logit	120
Sudhaa and Sekar (2015)	South India	Soil and water conservation	Multinomial logit	330
Mutuku *et al.* (2016)	Kenya	Soil and water conservation	Tobit and logit	124
Bodnar and Graaff (2003)	Southern Mali	Soil and water conservation	Descriptive	298
Karidjo *et al.* (2018)	Niger	Soil and water conservation	Logit	149

Contd.

Table 1 (*Concluded*)

Study	Location	SWC measures	Model	Sample size
Biratu and Asmamaw (2016)	Ethiopia	Participation conservation	Descriptive	101
Tenge *et al.* (2004)	Tanzania	Soil and water conservation	Cluster and factor	104
Tesfaye *et al.* (2014)	Ethiopia	Land management practices	Binary logistic	498
Willy and Holm-Müller (2013)	Kenya	Soil conservation practice	Ordered and Probit	307
Teklewold and Köhlin (2011)	Ethiopia	Stone terrace and soil bund	Multinomial logit	143
Sidibe (2005)	Burkina Faso	Zai and stone strip	Probit regression	230
Mbaga-Semgalawe and Folmer (2000)	Tanzania	Soil conservation measures	Poisson regression	300
Kazianga and Masters. (2002).	Burkina Faso	Field bunds and micro catchment	Tobit regression	258

(contact/access to extension services, membership to any organization and training).

Summarizing the results, following the vote count method, variables having significantly positive and negative influence on the adoption of soil and water conservation measures were counted (Table 2).

Factors affecting adoption of SWC measures

We identified some of variables which are having the comparatively higher positive influence on adoption of soil and water conservation measures (Table 2). These factors are: education (50.0%); tenure security (44.4%); perception of level erosion (42.9%); farm size (41.9%); higher slope of the plot (69.6%); access to credit (40.0%); marketing facilities (50.0%); access to extension services (67.7%); and membership of organization and participation (70.6%). Therefore, it can be stated that these are the key factors for enhancing the adoption of soil and water conservation measures. In the next section of paper, all the factors have been discussed in detail as to how these factors influence the adoption of soil and water conservation measures.

Personal and household specific factors

Age: In case of the age, we found that in around 70 per cent of the cases, it had a non-significant effect on the determination of adoption of soil and water conservation measures. However, some researchers reported that age has a positive impact on the adoption of soil and water conservation measures (Bekele and Drake 2003, Amsalu and De Graaff 2007, Mango *et al.* 2017). For this, it was argued that older farmers have relatively higher experience, and might accumulated more physical and social capital (Kassie *et al.* 2013), leading to a greater rate of adoption of soil and water conservation measures. Contrarily, in some

Table 2 Relative influence of factors on adoption of soil and water conservation measures (per cent)

Factors	Variables	SN	SP	NS	N
Personal and Household Characteristics	Age of decision makers	24.4	6.7	68.9	45
	Education level of farmers	7.1	50.0	42.9	30
	Family size	9.1	21.2	69.7	42
	Perception and level of soil erosion	0.0	42.9	57.1	21
Plot and Farm Level Characteristics	Farm size/ total area cultivated	23.3	41.9	34.9	43
	Tenure security	0.0	44.4	55.6	27
	Low fertility of plot/farm	29.4	17.6	52.9	17
	Slope of plot	13.0	69.6	17.4	23
Economic Characteristics	Farm assets	0.0	27.3	72.7	11
	Access to credit facilities	5.0	40.0	55.0	20
	Number of livestock units	24.0	16.0	60.0	25
	Income from off farm activities	25.0	16.7	58.3	24
Institutional characteristics	Access to or contact with extension services	0.0	67.6	32.4	34
	Membership of an organization and participation in conservation programmes: Social capital	5.9	70.6	23.5	17
	Availability of marketing facilities	20.0	50.0	30.0	10
	Training of farmers for SWC measures	0.0	50.0	50.0	8

Source: Authors calculation from studies given in Table 1, Notes: SP, SN, NS, N indicate the significantly positive, significantly negative, non-significant and number of studies/cases considered.

other studies, it was reported that age had significantly negative effect on adoption. They opined that the benefits of soil and water conservation cannot be realized within a short time period; therefore, older farmers refrain from making conservation investments. Furthermore, younger farmers may have longer planning horizons and, hence, have higher likelihood to invest in sustainable land management practices (Tiwari *et al.* 2008).

Education: It has been observed that education is associated with relatively better access to information, ability to comprehend and evaluate the conservation measures in terms of economic viability and technical feasibility (Mango *et al.* 2017). Education was reported to have a positive influence on adoption of conservation technologies (Amsalu and De Graaff 2007, Mango *et al*. 2017). However, some researchers noted that education had a negative effect on the adoption. They argued that argued that education might offer opportunities for alternative livelihood options in off-farm activities.

Family size: Establishment and maintenance of SWC measures is labor intensive activities. Therefore, the availability of farm labor affects adoption level. Family size and economically active family members were observed to have a positive influence on investment in soil and water conservation measures (Pender and Gebremedhin 2007). Furthermore, it is also believed that with an increase in family size, the probability is higher that the farm will be used by the future generations, motivating for maintaining the fertility and soil health. However, Bekele and Drake (2003) found that family size had a significantly negative relationship with the adoption of SWC measures.

Perception of soil erosion

Farmers recognizing soil erosion at their farm have higher probability of adoption (Willy and Holm-Müller 2013). However, farmers' perception of the erosion problem per se is often not sufficient to take the decision to adopt SWC measures since eventual adoption is governed by other factors, particularly the financial constraints. Perceived productivity gain/expected benefit from the use of technologies are also an important factor determining adoption. Moreover, financially viable SWC measures not only encourage adoption but also serve as an important factor for continued use of SWC measures (Teshome *et al.* 2016).

Farm and plot level characteristics

Farm size: A number of authors have recognized that farm size has mixed effects on the adoption of soil and water conservation practices. Many researchers (Bekele and Drake 2003, Amsalu and De Graaff 2007, Mango *et al.* 2017) noted that farm size had a positive influence on the adoption of conservation measures. Firstly, this is due to fact that large farms have higher risk of production losses due to lack of proper conservation practices, therefore, to avoid the such losses, farmers invest in soil and water conservation measures (Mango *et al.* 2017). Moreover, lager farmers also have greater wealth and capital, which indicates their relatively sound capacity to invest in SWC measures. Secondly, large farmers also have relatively lesser space constraints. Therefore, they can easily spare land for construction of bunds and terraces. In some studies, instead of farm size, plot size was taken into consideration considering its relevance for certain SWC measures. A positive influence of plot size was found on the adoption of soil and water conservation measures (Kassie *et al.* 2012, Liu and Huang 2013).

Tenure security

A farm/plot is assumed as tenure secure, if it is owned by the farmer or he/she is certain about the continued use in future. Tenure security affects the investment decision relating to soil and water conservation through assurance (farmers are assure that they are going to get long terms benefits of soil and water conservations), realizability (the benefits of investments in conservation efforts can be realized in exchange or sale of land) and collateralization (serve as collateral for accessing credit facilities and some other benefits) effects. Many studies reported a positive effect of tenure security on the adoption of soil conservation practices (Nyangena 2008, Kassie *et al.* 2013, Teklewold *et al.* 2013, Teshome *et al.* 2016). For this, it was argued that ownership is an assurance for future use and therefore provides incentives for investment in conservation efforts for harnessing long-term benefits. It is, therefore, expected that tenure insecurity is negative association with conservation measures (Teklewold and Köhlin 2011) due to restricted planning horizons as tenants are not going to realize the benefits of their conservation efforts. Furthermore, it was reported that share-renters have relatively more incentive to adopt SWC measures than cash-renters as landlords also tend to participate more actively in the management of natural resources on farms which are rented under share leases (Soule *et al.* 2000).

Level of fertility and slope

An inverse relationship between fertility and adoption of soil conservation measures (Amsalu and de Graaff 2007, Kassie *et al.* 2012, Tesfaye *et al.* 2014) was observed. However, Bekele and Drake (2003) argued that soil fertility is expected to have a direct and positive effect on adoption. He observed that, in the eastern highlands of Ethiopia, farmers tend to construct and maintain soil and stone bunds on more fertile plots to reduce run-off and soil loss. Because on such plots the marginal benefit of conservation in terms of avoided productivity loss was higher (Turinawe *et al.* 2015). The higher slope of a plot, one of the major determinants of erosion potential, was reported to have a positive effect on adoption (Amsalu and De Graaff 2007, Kassie *et al.* 2012) as compared to plots with gentle slope.

Economic factors

Off-farm income: Off-farm income influences the technology uptake through the labor force effect and income effects (Huang *et al.* 2019.) It was found that increased availability of opportunities for off-farm employment had a negative effect on the soil and water conservation investments (Pender and Gebremedhin 2007, Amsalua and Graaff 2007). Off-farm income's negative effect is through the labour force effect. It means that off-farm employment opportunities cause labor shortages restricting the farmer's ability to construct soil conservation structures. Moreover, such farmers may be less concerned about improving land quality due to their orientation towards off-farm income opportunities, thereby reduces their dependence on the agriculture income (Teklewold and Köhlin 2011).

Access to credit

It was observed that formal credit markets do not function well in agricultural societies due to high information, monitoring and transaction costs, lack of collateral and moral hazard problems. Additionally, in degraded areas, most the farmers are resource poor. Under such conditions, a positive relationship between the level of adoption and the availability of credit (Yirga 2007) was reported as an easy access to credit helps overcoming the problem of cash constraints and thereby allows farmers to buy purchased inputs such as fertilizer, improved crop varieties, and irrigation facilities.

Livestock

Ownership of cattle also has a positive impact on the soil conservation effort (Willy and Holm-Müller 2013). Farmers are likely to implement soil conservation practices that have win–win benefits, for instance, Napier grass and filter grass strips which provide fodder to complement those measures which generate long term benefits of soil erosion control. However, Adimassu *et al.* (2016) argued that the effects of livestock holding on farmers' investments are inconsistent. This is because there are some farmers whose livelihoods depend on livestock production and do not want to invest in land improvement activities.

Institutional factors

Membership and participation: Social Capital: It was observed that overlooking farmers' participation and their indigenous knowledge particularly in the planning stages of SWC programmes are identified as the main reason for failure of conservation progarmmes. Participation of local people/stakeholders through their collective action in the design and implementation of the SWC programmes, determines the success of natural resource management progarmmes (Shiferaw *et al.* 2009). Evidently, in India, it was observed that progarmmes implemented by the non-governmental organizations (NGO) were more successful than that of implemented by the government mainly due to more active and effective participation of local people ensured by the NGO (Mondal *et al.* 2016, Biswas *et al.* 2017). Therefore, planning and implementation of interventions on a participatory basis were relatively more successful (Shiferaw *et al.* 2008). Participation facilitates sharing of resources and information and also helps in creating awareness related to detrimental effects of soil erosion. For instance, participation and social networks enables farmer-to-farmer exchange of planting materials, information and labor, and thereby helps in overcoming the constraints (financial and labour) especially in the areas where there is inadequate information and imperfect markets (Kassie *et al.* 2013, Wang and Lu 2015). Further, membership of farmers' association indicates the intensity of contacts which enhances the possibility of collective learning (Adegbola and Gardebroek 2007), selection of appropriate soil conservation practices and accessing innovations for local conditions (Willy and Holm-Müller 2013). Social networks reduce transaction costs and consequently affect the adoption decision positively (Rijn *et al.* 2012). Social capital/network plays a vital role in the adoption of agricultural innovations (Nyangena 2008) by influencing cooperative behaviour, preferences, transaction costs, and information sharing. As there is a strong physical interdependency between adjacent farms with respect to hydrology and soil erosion (Beekman and Bulte 2012, Teshome *et al.* 2016), cooperation with adjacent farms is important for the continued adoption of SWC measures by ensuring proper maintenance of conservation structures which are of common interest and inter-linked, and are crucial for sustaining programmes at watershed scale.

Access to information

It was observed that access to information/advisories had a positive impact on adoption of soil and water conservation measures (Bekele and Drake 2003, Adegbola and Gardebroek 2007, Nyangena and Juma 2014, Mango *et al.* 2017). It enables famers to develop a better understanding related to potential consequences of soil erosion. Extension services also make farmers more conscious of their vital soil resources, and thereby encouraging them to use judiciously for sustaining natural resources for future generations (Mugonola *et al.* 2013).

Training

Natural resource management technologies are knowledge-intensive; therefore, technical assistance is an important determinant of their adoption. Lack of technical support negatively affects the adoption of conservation measures (Bekele and Drake 2003, Dessie *et al.* 2012). Human capital in terms of education and job skills is a critical factor in sustainable development. A positive relationship on technology adoption vis-à-vis farmers' training was observed by Sidibe (2005) who reported that the likelihood of adopting *zaı* and stone strips is higher in case of a trained farmer than that of an untrained one.

Market facilities

Many researchers demonstrated the positive effect of better market access on adoption soil and water conservation measures. Access to market often facilitates commercialization of crop production system, and serves as a driving force for sustainable intensification of agriculture

(Shiferaw *et al.* 2009). Therefore, improved market access could be considered as a remedy against soil degradation (Nkonya *et al.* 2016) as it offers incentives to improve their land quality (Teklewold and Köhlin 2011). Generally, access to market is assessed by the distance to input and output markets, which reflects the transaction costs associated with buying inputs and selling produce. Additionally, apart from deciding the access to the market, distances also indirectly affect the availability of new technologies, information and credit institutions (Kassie *et al.* 2013).

Conclusion

This study summarized the influence of 16 factors assessed from 49 studies related to physical structures of soil and water conservation. It can be suggested that there are no universally significant factors affecting the adoption of soil and water conservation measures, therefore, it appears that there is lack of general consensus among researchers as to which factor is to be targeted for enhancing adoption. Hence, there is a need for 'location-specific targeted policies' for increasing uptake of soil and water conservation measures. In other words, it can be stated that 'one-size-fits-all approach' is not a prudent approach for encouraging adoption of soil and water conservation measures. Yet, from the review, a number of insights can be drawn for designing resource management policies by identifying key factors which can be effective in enhancing the rate and intensity of adoption of SWC measures. In conclusion, it can be stated that the factors which, in most of cases, have a positive influence on the adoption of conservation measures should be considered while formulating the soil and water conservation plans and schemes. These factors are: extension services, access to credit, availability of marketing facilities, training and collective actions. Therefore, these factors can be used as a starting point for planning of soil and water conservation progarmmes/polices, particularly when the location specific information is lacking, and in the view of resource and time constraints.

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