The social-economic and institutional conditions that influence the adoption of soil conservation and rehabilitation technologies in Bungoma County, Kenya

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ABSTRACT

In Kenya, soil erosion is one of the major risks to the productivity and sustainability of the environment. In Bungoma County, food security and rural livelihoods are still threatened by declining soil fertility, soil erosion, and unsustainable agricultural activities. This research paper looks into the socio-economic and institutional determinants of the adoption of soil conservation and rehabilitation technologies in Bungoma County. The study was guided by diffusion of innovations theory. The research was based on a descriptive survey design. The target population was 41,109 farm households. Out of this population, a sample population of 381 households was calculated using the formula of determining the sample size by Krejcie and Morgan, which used a 95 per cent confidence level, a 0.05 margin of error, and a 50 per cent proportion of the population in order to be representative. Data were gathered by questionnaire and interview using a descriptive survey design for the farmers. The chi-square test was used to establish the associations between variables, including education level, land area, land ownership type, access to credit, and access to extension services and the adoption of different technologies, which included composting, vermicast, agroforestry, physical measures, and minimum tillage. The results highlight that the level of education, size of land, secure tenure, availability of credit, and extension services play a major role in the adoption of some conservation technologies. The paper concludes that socio-economic empowerment, better access to credit and extension services, and tenure security are the keys to making soil management sustainable. It suggests the need to enhance institutional structures, provide soil conservation training to the farmers, and implement inclusive financial schemes to promote the general acceptance of soil conservation technologies.

Keywords: Conservation, Erosion, Fertility, Soil

I. INTRODUCTION

A significant amount of nutrient depletion, erosion, compaction, and reduced land productivity is a typical symptom of soil degradation, which continues to be one of the most urgent environmental and agricultural issues in sub-Saharan Africa (Lal, 2015). It is compromising food security, reducing the fertility of soil and destroys the viability of the agricultural systems that millions of rural households have depended on. It is further worsened by the fact that the population is growing rapidly, which puts pressure on the available land area, thus making farmers to develop marginal land and reducing fallow time. This has resulted in massive soil erosion, river sedimentation and reduction of crop yields in Kenya especially in the overpopulated areas like the western highlands (Nyangena & Kohlin, 2008). This increase in the agricultural land areas without proper soil conservation practices has led to the disappearance of topsoil and organic matter which have further eroded the natural resource base that is basic in sustainable agriculture.

The crisis is observed in the Bungoma County, which is a major agricultural area. Both large and small household economies rely on smallholder farming as their means of livelihood, but the soil is becoming degraded because of over-cultivation, deforestation, and erosion of vegetative cover (Kimetu *et al.*, 2017). Land degradation has been increased and the soil productivity decreased due to unsustainable activities like continuous monocropping, overgrazing and improper application of organic or inorganic fertilizers. Although several technologies of soil conservation and rehabilitation have been developed such as terracing, agroforestry, contour ploughing and use of cover crops, uptake by the smallholder farmers is low.

It is based on such challenges that a critical insight into socio-economic and institutional dynamics that influence the decision of farmers to use soil conservation technologies is necessary. Education level, size of a farm, availability of credit, extension services and security of land tenure are factors that are critical in influencing the behavior of adoption. The institution support, policy framework, community participation and involvement are important in Bungoma County and other states to sustain management of soil and enhance agricultural production.

1.1 Statement of the Problem

Although there are several government and non-government policies that encourage farmers to conserve soil, soil conservation is still low among farmers in the Bungoma County. Unsustainable farming practices still are being practiced by many farmers, which drain the soil fertility and expose them to the risk of erosions. The socio-economic characteristics including education level, land size, and income level as well as institutional factors including the presence of access to credit and extension services are important in determining adoption behavior (Kassie *et al.,* 2013). Nevertheless, the interplay between these factors in the local setting is not well studied. Lacking empirical understanding of their effect on technology adoption, interventions can continue being ineffective. As such, the paper examined the socio-economic and institutional drivers towards adoption of soil conservation technology in the Bungoma County.

1.2 Research Objectives

i. To determine the effect of the education level on adoption of soil conservation and rehabilitation technologies.
ii. To test the relationship between the size of land and land ownership type and adoption.
iii. To test the hypothesis on the role of access to credit in the adoption of conservation technologies.
iv. To determine the impact of availability of extension services on the level of adoption.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Diffusion of Innovations Theory

The research is based on the Diffusion of Innovations Theory created by Everett Rogers (1962) which is a theoretical framework of spreading new ideas and technologies across a population. The theory proposes that innovation adoption is affected by the perceived attributes of the innovation, channels of communication, time and social systems. The use of technologies happens when the relative advantage, compatibility, ease and benefits are perceived by farmers. These perceptions are influenced by socio-economic factors like education, income, and land ownership (Rogers, 2003). The theory is applicable in soil conservation based on the behavioral change and institutional support through the flow of information to enable a behavior change to sustainable practices. The provision of extension services and access to credit, e.g., is an accelerator that enhances the spread of information across the communities of the farmers.

2.2 Empirical Review

2.2.1 Effect of Education Level on the Adoption of Soil Conservation and Rehabilitation Technologies

Education is important in influencing awareness, perception and decision making by the farmers towards agricultural innovations. Feder et al. (1985) hold the view that education improves capacity of farmers to obtain, process and use information pertaining to new technology that augments chances of adoption. Educated farmers tend to be more in the position to know the advantages and expenses and long-term effects of soil conservation and rehabilitation technologies (Schoonhoven & Runhaar, 2018).

Empirical evidence in the sub-Saharan Africa has continually revealed that there is positive relation between education and the adoption of technology. As an example, Mwangi and Kariuki (2015) discovered the level of literacy played a significant role in determining the extent to which farmers in Kenya adopted soil and water conservation practices because educated farmers are more likely to interact with the extension officers and use better methods of soil conservation, including terracing, agro forestry and contour ploughing. In the same study, Tenge *et al.* (2004) found that the more formal education one had, the more he or she could adopt the soil conservation measures in Tanzania because of better knowledge on the process of land degradation.

Nevertheless, the correlation of the two education and adoption is not always linear. According to some researchers like Bekele and Drake (2003) some studies have indicated that though in formal education, the rate of awareness is incremental, the effect reduces when farmers are overly dependent on the indigenous knowledge systems and conservation technologies are labour-intensive. Therefore, learning should be followed by a specific training, examples, and programs of participation extension to reinforce adoption judgments.

2.2.2 Relationship between Land Size, Land ownership and adoptions

The area of land and ownership system plays a major role in the willingness and the ability of the farmers to invest in long term conservation practices. Place and Hazell (1993) argue that secure land tenure encourages farmers to use soil conservation practices as they know that they will reap the rewards in the future. Conversely, farmers in leased or communal land mostly shun long-term investments because of the uncertainties on the re-entrance of land.

According to the studies of Kassie *et al.*, (2010) and Pender and Kerr (1998) in Ethiopia and India respectively, the farmers with larger and privately owned plots are more likely to embrace conservation technologies like terraces, grass strips, and organic soil management. The size of bigger landholdings enables flexibility in setting aside some of the land to experiment and the risks of the initial loss of productivity when implementing conservation structures are eliminated.

On the other hand, the smallholders might not be able to conserve their lands because they have limited land and labour hence could not easily afford to leave productive land to conservation work. Shiferaw and Holden (1998) contend that tenure insecurity and soil fragmentation inhibit investments in soil rehabilitation because farmers consider this intervention as expensive and time-consuming before fruits can be realized. Thus, the tenure security and the land size remain central to the insight of adoption behaviour, among the rural farmers.

2.2.3 Role of Access to Credit in the Adoption of Conservation Technologies

Access to credit is one of the main factors that determine the adoption of technology since it helps in relaxation of the issue of liquidity which in most times disallows farmers to invest in conservation efforts. Feder *et al.*, (1990) argue that credit availability promotes farmers to buy inputs, engage labor, as well as embrace technologies that demand initial capital investment. Technologies like terracing, planting trees, and contour farming are some of the technological methods of soil conservation requiring upfront expenses which poor households do not have access to unless they are subsidized.

The published empirical data on Kenya, Uganda, and Ethiopia show that access to credit plays a significant role in predicting the adoption of conservation technologies. Indicatively, Nkonya *et al.*, (2008) discovered that farmers who had access to formal institutions of credit had an increased chance of investing in the practice of soil fertility improvement and water harvesting structures. On the same note, Mugwe *et al.*, (2009) established that involvement in the microfinance programs increased the capacity of farmers to use integrated soil fertility management technologies in central Kenya.

Nevertheless, the availability of credit is not certain to lead to adoption. Place *et al.* (2007) suggest that the attitude of farmers, their perception of risk and trust in financial institution are some of the factors that affect the use of credit. Additionally, it can deter uptake due to high rates of interest, collateral requirements and inadequate rural banking infrastructure particularly among smallholder farmers. Thus, the availability of cheap and flexible credit facilities continues to be key in enhancing quickening the acclimatization of soil conservation technology.

2.2.4 Effect of Extension Services on the Level of Adoption

Extension services are significant in eliminating knowledge gaps between researchers and farmers. The Diffusion of Innovations Theory used by Rogers (2003) supports the idea, that, with successful communication via extension systems, the spread of and the integration of new technologies is faster. The agricultural extension officers are intermediaries who offer technical advice, demonstrations and constant follow up to sustainability to make sure that the conservation practices are appropriately implemented.

Research has demonstrated that the rate and quality of extension contact have a substantial effect on the adoption rates in Kenya (Mutsotso *et al.*, 2014) and Uganda (Place *et al.*, 2003). The farmers that engage frequently with the extension agents have a higher propensity to implement soil conservation practices like contour bunds, agroforestry, and composting. Furthermore, the participatory extension methods that help farmers to take part in making decisions boost ownership and sustainability of conservation programs (Anderson & Feder, 2007).

However, institutional inefficiency and insufficient manpower in the extension departments is a thorn in the flesh of developing countries. According to Mwangi *et al.*, (2021), the efficiency of extension programs is in most cases diminished by lack of resources and lack of coordination between government and non-governmental organizations. These systems can be improved with the help of training, digitalization, and multi-stakeholder partnerships to promote the spread and uptake of soil conservation tech in a more significant way.

III. METHODOLOGY

3.1 Research Design and Approach

The research was based on a descriptive survey design, which aims at examining the socio-economic and institutional conditions that determine the use of soil conservation and rehabilitation technologies. This method enables quantitative study of the relationships between the variables and gives information on the behavioral patterns in the farming community.

3.2 Target Population

This study targeted 41,109 farm households in Bungoma County, which is the sum total of households that practice farming activities as per Kenya National Bureau of Statistics data in 2019. These households were used as the unit of analysis as they are directly involved in production in the agricultural sector, and they are the decision-makers when it comes to soil conservation and rehabilitation technologies. The population has a wide range of socio-economic and institutional nature, in terms of education levels, land size, ownership, access to credit and extension services. The target population facilitated the study to produce a holistic understanding of the factors of adoption of soil conservation practices.

3.3 Sampling Strategy and Sample Size

The sampling plan adopted in the study was stratified random sampling where the farmers in various wards in the Bungoma County were adequately represented. The stratification was done depending on the differences in agro-ecological zones and level of farming which were used to capture the different experiences in soil conservation and rehabilitation practices. The simple random sampling was used to select households within every stratum to maximize bias and increase the validity of the result. The total population was then used to get a sample size through using the formula developed by Krejcie and Morgan (1970), and the sample size established was 381 farm households out of the total population of 41,109. Such sample was thought to be adequate to have 95 confidence level and 5% margin of error.

3.4 Data Collection

Structured questionnaires and semi-structured interviews were used as the main methods of collecting primary data. The instruments were used to gather demographic data, characteristics of the farm, institutional support accessibility, and adoption of soil conservation technologies. Agricultural reports and policy documents were used to get secondary data.

3.5 Data Analysis

The SPSS software was used in the analysis of data. Socio-economic characteristics were summarised using descriptive statistics and chi-square tests were used to test the relationships between independent variables (education, land size, land ownership, credit access and extension services) and adoption of conservation technologies (composting, vermicast, agro forestry, physical measures and minimum tillage).

3.6 Ethical Considerations

Ethical permission was obtained by the appropriate authorities. The participants had been briefed on the aim of the study as well as their rights to confidentiality, voluntary participation and to discontinue the study at any point. Reporting did not reveal any identifiable information.

IV. FINDINGS & DISCUSSION

4.1 Response Rate

There are a number of socio-economic and institutional factors influencing the implementation of soil conservation and rehabilitation technologies in Bungoma County. These are the education level, which will affect farmers knowledge and readiness to use the better practices; land size that defines the magnitude and ability to use the technology and the land ownership type, which will impact the investment choices and long-term dedication to sustainable land management of the farmers. Moreover, credit access allows farmers to invest in resource-intensive technologies and credit access to extension services allows farmers to increase awareness, technical skills and conservation innovations implementation abilities. The subsequent subsections show the findings of the chi-square analysis to determine the impact of each of these factors on technology adoption.

4.1.1 Effect of the Education Level on Adoption of Soil Conservation and Rehabilitation Technologies

Table1 presents the results of the Chi-square test showing the relationship between farmers' education levels and their adoption of various soil conservation and rehabilitation technologies in Bungoma County. The results illustrate how education influences the uptake of specific technologies such as composting, vermicast, physical measures, agroforestry, and minimum tillage.

Table 1

Chi-Square Test Showing the Relationship Between Farmers' Education Levels and Their Adoption of Various Soil Conservation and Rehabilitation Technologies in Bungoma County

Level of Education	Test values		
	Chi-Square Value	**df**	**P-value**
Compost Acreage	5.167[a]	8	0.740
Vermicast Acreage	13.936[a]	8	0.083
Physical measure Acreage	9.260[a]	4	0.055
Agroforestry Along SWCs Acreage	11.097[a]	4	0.025
Minimum tillage Acreage	20.597[a]	8	0.008

The results of the analysis indicate the existence of different levels of statistical significance between the education level and adoption of soil conservation and rehabilitation technologies in the Bungoma County. The level of education plays an important role in the adoption of minimum tillage ($p = 0.008$) and agro forestry along the soil and water conservation structures (SWCs) ($p = 0.025$). These results indicate that the increased education leads to the improvement of awareness and understanding of the long-term advantages of these methods, and, therefore, their usage increases.

In the contrary, there is less or no significant relationship between education and adoption of vermicast ($p = 0.083$), physical measures ($p = 0.055$), and composting ($p = 0.740$). Implementation of these technologies might be based on practice, community knowledge-exchange or demonstrations by farmers rather than schooling. All in all, the issue of education seems to be major in promoting the application of knowledge-intensive conservation technologies like minimum tillage and agroforestry. Increasing the rate of adoption of these technologies and bettering the long-term outcomes of soil management could thus be achieved by increasing the education of farmers in training and awareness initiatives.

The results indicate that education levels are strongly correlated with the adoption of some soil conservation technologies with minimum tillage ($p=0.008$) and agro forestry in structures of soil water conservation (SWCs) ($p=0.025$) showing significant correlation. These findings indicate that the levels of higher education have a significant positive role in the awareness and knowledge of the benefits of such practices by farmers. Learned farmers would have a higher perception of the benefits of sustainable practice in the long run and they would have the technical skills to adopt complicated strategies such as minimum tillage and agroforestry. These results are consistent with those of Kabubo-Mariara (2007), who also pointed out the importance of education in the process of adopting the modern technologies in agriculture.

Through education, farmers can gain access to and get processed information on new conservation methods, translate technical guidelines, and learn the larger scope of the soil health management. As an example, agro forestry involves a subtle skills in the selection, spatial planning, and management of tree species that can be effectively provided to educated people. Likewise, minimum tillage entails certain equipment and procedures that might be not familiar to lowly educated farmers.

On the other hand, the use of technologies, like composting ($p=0.740$) and physical measures ($p=0.055$) have less close relationships with education levels. This means that these practices are more accessible and they can be embraced regardless of formal education. An example of composting is the fact that in many cases, composting is based on the time-tested approaches towards organic waste disposal, which have been used over years. Likewise, physical interventions, such as terracing, can be prescribed by community standards or group work, and therefore are not dependent on technical know-how. These observations are echoed by Rambo *et al.* (2017) who observe that the idea that practices of conservation culturally embedded do not necessarily presuppose formal education to be implemented.

The results emphasize the need to use custom intervention. Although education-based programs can help advance the introduction of knowledge-intensive technologies, culturally aware strategies should take the first priority in practices based on the use of traditional knowledge. This duality means that there is fair access and that more measures are adopted in terms of conservation.

4.1.2 Relationship between the Size of Land and Land Ownership Type and Adoption

Table 2 summarizes the Chi-square test results assessing the relationship between farm size (in acres) and the adoption of different soil conservation technologies. The table highlights whether the scale of landholding affects the likelihood of adopting specific conservation practices among farmers.

Table 2

Chi-Square Test Results Assessing the Relationship Between Farm Size (in Acres) and the Adoption of Different Soil Conservation Technologies

Land size in Acres	Test values		
	Chi-square value	**df**	**P-value**
Compost Acreage	5.861[a]	6	0.439
Vermicast Acreage	26.268[a]	6	<.001
Physical measure Acreage	6.205[a]	3	0.102
Agroforestry Along SWCs Acreage	5.476[a]	3	0.140
Minimum tillage Acreage	8.546[a]	6	0.201

The findings indicate that, there was a significant positive correlation between land size and vermicast adoption, which is statistically significant ($p < 0.001$). The larger landholdings seem to promote the use of vermicast by farmers probably due to the fact that the technology can be scaled and it is economical when it is applied on a large land area. Other technologies like composting ($p = 0.439$), physical measures ($p = 0.102$), agroforestry and SWCs ($p = 0.140$) and minimum tillage ($p = 0.201$) are not significantly related to land size. This implies that the practices can be applied in both small and large farms. Factors like availability of resources, labour and technical support may be more influential in determining their adoption than acreage. The results highlight the fact that even though bigger land areas may act as a motivator in the use of some technologies such as vermicast, most of the soil conservation strategies are flexible with either small-scale or large-scale farming systems.

The discussion highlights the importance of land size as a critical factor affecting the adoption of particular soil conservation technology especially vermicast technology ($p<0.001$). Vericulumn farmers endowed with bigger land area will tend to embrace vermiform casting since it is scalable and economical. On larger farms, it is easier to be more flexible in allocating parts of the farms to experimental practices and reduce the possible risk of extreme consequences of initial adoption. This observation is consistent with that of Kassie *et al.* (2013) who noted that farmers with large parcels of land usually have the room to experiment and invest in new farming technologies. Vermicast is also a by-product of earthworms and has been shown to increase the quality of soil and its ability to retain water which is particularly appealing to bigger operations that need to find sustainable and high yield solutions.

Conversely, the technology that has been adopted like composting ($p=0.439$) and agro forestry ($p=0.140$) do not have significant correlation with land size. This absence of correlation indicates the flexibility and suitability of these practices to different farm sizes. An example is composting, which is the conversion of organic waste into fertilizer containing high levels of nutrients, which can be effectively used on small plots or scaled up to large enterprises. Agro forestry, on the same note, incorporates trees in the growth of crops or livestock, whereby the advantages include soil stabilization as well as increase of biodiversity, irrespective of the scale of the farm.

These practices are flexible in nature, which highlights the possibility of inclusive implementation in various farming scenarios. Marketing conservation accessible and scalable technologies would make sure that smallholder farmer and large-scale farmers can achieve gains through conservation practices. The policies adopted to focus on smallholder farmers, who are usually constrained in the resources and finances, might focus on the distribution of affordable and efficient technologies such as vermicast technology. Pretty *et al.* (2011) argue that subsidies, training, and availability of inputs are important in helping smallholders to embrace sustainable practices. The policy and development practitioners can promote the adoption of soil conservation practices in large numbers by adjusting the interventions to reflect variations in the land size thus promoting sustainable agricultural development in Bungoma County.

Type of Land Ownership: Table 3 presents the statistical relationship between types of land ownership and the adoption of soil conservation and rehabilitation technologies. It shows how tenure security and ownership arrangements influence farmers' investment in sustainable soil management practices.

Table 3
Statistical Relationship Between Types of Land Ownership and the Adoption of Soil Conservation and Rehabilitation Technologies

Type of land ownership	Test values		
	Chi-square value	df	P-value
Compost Acreage	8.453[a]	2	0.015
Vermicast Acreage	3.564[a]	2	0.168
Physical measure Acreage	9.113[a]	1	0.003
Agroforestry Along SWCs Acreage	0.953[a]	1	0.329
Minimum tillage Acreage	12.401[a]	2	0.002

The findings suggest that the kind of land ownership has a significant effect on the adoption of composting ($p = 0.015$), physical measures ($p = 0.003$), and minimum tillage application ($p = 0.002$). The chances of farmers adopting such practices are higher where farmers have secure or formal land tenure as they have long-term benefits and thus worth investing their labor and financial resources. On the other hand, there are no significant differences between the ownership type and vermicast ($p = 0.168$) and agroforestry along SWCs ($p = 0.329$), which indicates that those technologies can be applied despite poor ownership security.

These results emphasize the fact that tenure security encourages an investment in sustainable practices, especially those that are associated with an increased initial cost or long-term maintenance. Enhancement of land tenure policies would thus promote the broader use of conservation oriented farming systems.

As indicated in the analysis, the nature of land ownership has a very strong effect on the adoption of some of soil conservation technologies, especially composting ($p=0.015$), physical measures ($p=0.003$), and minimum tillage ($p=0.002$). Secure land tenure gives the farmers the assurance of investing in practices that have long term payoffs. As an example, through composting, the soil becomes fertile in the long run, whereas physical controls such as terracing and building bunds lessen erosions in steep farms and finally, minimum tillage helps in maintaining soil structure that will be cultivated later. The findings are supported by Place *et al.* (2003), who underline that secure ownership of land is a determining factor in conservation investments in the whole of Sub-Saharan Africa. Land owners are farmers, and they view land as a long-term asset and hence they have been encouraged to practice in a manner that enhances the health of the soil and productivity in agriculture.

On the other hand, land ownership does not seem to have such an impact on such technologies as vermicast ($p=0.168$) and agroforestry ($p=0.329$). This implies that such practices are rather motivated by short-term gains or community-based projects rather than tenure security. One example is Vermicast that is an instant boost to soil fertility and crop yields, and it is likely to be tempting, irrespective of who is the owner. In the same way, multifunctional advantages of agro forestry like availability of fuel-wood, fodder and amelioration of soils may attract farmers who have different tenure agreements.

This difference shows the need to adjust the soil conservation strategies to the existing land tenure systems. In the regions with weak land tenure, using other technologies such as vermicast and agroforestry, which have short payoffs and do not require ownership may be an effective approach. Resource management programs at the community level as suggested by Food and Agriculture Organization [FAO] (2011) can also be critical in promoting the practice of such practices in shared or communal pieces of land.

Through the focus on tenure-related challenges and the use of flexibility of some of the practices, the policy makers will be able to develop inclusive strategies that promote sustainable production of soils in varying land ownership arrangements. The method guarantees that every farmer irrespective of the tenure will be in a position to participate and gain in conservation moves, which will create a sustainable agricultural season in Bungoma County

4.1.3 Role of Access to Credit in the Adoption of Conservation Technologies

Table 4 displays the Chi-square results examining the influence of access to credit on farmers' adoption of soil conservation technologies. It identifies which conservation practices are most affected by the availability of financial resources.

Table 4
Chi-Square Results Examining the Influence of Access to Credit on Farmers' Adoption of Soil Conservation Technologies

Access to credit	Test values		
	Chi-Square value	df	P-value
Compost Acreage	19.971[a]	10	0.030
Vermicast Acreage	7.178[a]	10	0.709
Physical measure Acreage	12.158[a]	5	0.033
Agroforestry Along SWCs Acreage	4.694[a]	5	0.454
Minimum tillage Acreage	100.564[a]	10	<.001

The access to credit has a substantial impact on the use of composting ($p = 0.030$), physical measures ($p = 0.033$), and the use of minimum tillage ($p < 0.001$). Farmers who have financial means are in better position to acquire equipment, inputs or even labour required in these practices. Minimum tillage that has the most significant association, frequently implicates the procurement of specialized equipment or machinery which supports the idea of credit in enabling adoption. On the other hand, vermicast ($p = 0.709$) and agro forestry along SWCs ($p = 0.454$) do not have a significant relationship with credit access, which means that, the practices are not capital intensive and can be applied in low capital investment. These findings indicate the importance of credit as an enabler to the uptake of costly technologies. An increase in affordable credit services via cooperatives, microfinance institutions and agricultural banks would thus increase adoption of sustainable soil management practices.

The availability of credit is also very important in determining the adoption of capital-intensive technologies in soil conservation. The research indicates that there are strong correlations between the availability of credit and the adoption of minimum tillage ($p=0.001$), composting ($p=0.030$) and physical measures ($p=0.033$). Such practices may demand huge financial requirements on initial investment in tools, equipment, or inputs which may be a challenge to the financially constrained farmers. The barriers can be overcome through credit access which allows farmers to adopt and maintain such technologies. The findings are also supported by Deressa *et al.* (2009) who underscore the role of financial resources in increasing the adoption of agricultural innovations.

Minimum tillage such as that of the example requires specialized equipment that might not be affordable to smallholder farmers unless they are given financial aid. On the same note composting takes laborious operations and in certain instances, organic waste management facilities. Terracing and bund building are especially resource-consuming measures that not only demand materials but also a great amount of labor which further stresses the role of credit in enabling such measures to be made possible.

On the other hand, the two practices vermicast ($p=0.709$) and agro forestry ($p=0.454$) are not significantly related to access to credit. Such activities are relatively cheap and commonly based on the easily accessible resources, including organic waste to create vermicast or tree seedlings to practice agro forestry. Their low financial needs allow them to be available to a larger number of farmers, irrespective of their access to credit. This observation highlights the need to encourage such low-cost technologies in the regions with low financial capabilities.

Policymakers ought to come up with specific credit schemes targeting soil conservation technologies in order to increase capital-intensive use. These programs might entail low interest loans or grants to buy the necessary equipment and input. Besides, the inclusion of subsidies or community-based assistance on high cost practices might be incorporated to close the financial gap to the smallholder farmers. At the same time, by encouraging low-cost technologies such as vermicast and agro forestry using training and resources sharing schemes it is possible to secure widespread implementations in a variety of financial situations. This two-fold strategy would enhance conservation of the soil and resolving barriers of finances leading to sustainable agriculture within Bungoma County.

4.1.4 Availability of extension services on the level of adoption

Table 5 presents the statistical association between farmers' access to extension services and the level of adoption of soil conservation and rehabilitation technologies. It highlights the extent to which information, training, and technical support affect the uptake of these practices.

Table 5
Statistical Association Between Farmers' Access to Extension Services and the Level of Adoption of Soil Conservation and Rehabilitation Technologies

Access to extension services	Test values		
	Chi-Square Value	df	P-value
Compost Acreage	6.874[a]	8	0.552
Vermicast Acreage	15.328[a]	8	0.055
Physical measure Acreage	8.493[a]	4	0.076
Agroforestry Along SWCs Acreage	10.142[a]	4	0.039
Minimum tillage Acreage	18.762[a]	8	0.012

Extractive service access demonstrates some statistically significant correlations with minimum tillage (p = 0.012) agroforestry on SWCs (p = 0.039). These findings represent that information transmission, training, and technical assistance by the agents of extension is essential in the adoption of knowledge intensive and skill intensive technology. There are higher chances that farmers who are contacted on a regular basis by extension will effectively put into practice such practices. The Vermicast (p = 0.055) is almost statistically significant indicating that the extension support is not independent of its uptake but other variables like the input can also act. Weaker associations were found in composting (p = 0.552) and physical measures (p = 0.076) as they are relatively easy techniques that may be passed through traditional knowledge and farmer-to-farmer learning.

The concluding findings demonstrate the need to reinforce agricultural extension systems in order to facilitate the impartation of experience and technical skills. Extended coverage of the extension might make a significant impact on the use of sustainable soil conservation and rehabilitation technologies. Availability of extension services is one of the critical issues in the usage of knowledge-intensive soil conservation technologies. The analysis reveals that there are significant corporeal associations amid extension services and adoption of minimum tillage (p=0.012) and agro forestry (p=0.039). These practices cannot be executed without special knowledge and the extension agents are crucial in offering the required training and technical guidance. Muriithi *et al.* (2018) note that the extension services are used to address the knowledge gaps, thereby providing the farmers with the skills and knowledge to adopt and maintain new and sustainable agricultural practices.

An example of this is minimum tillage whereby the soil disturbances are accurately controlled to maximize the productivity and conservation process, which may be complicated to the farmers unless instructed by the experts. In a similar manner, agro forestry requires information regarding tree species, planting, and how to integrate into the current mechanisms of production. These processes are made easy by the extension services with the use of demonstrations, workshops and one on one interaction so that farmers get to know and be in a position to practically use these techniques.

On the other hand, there is less connection between the use of technologies, such as composting (p=0.552) and physical measures (p=0.076) and extension services. These practices are usually based on folk practices and community-based networks that can be used in place of formal education. In these practices, farmers who have a rich cultural or communal background did not feel that extension services are necessary in matters of implementation. Nevertheless, this consistency in the reliance on the traditional methods might inhibit the optimization and scaling of such practices particularly in regions that do not have a powerful community setup.

In order to increase the rate of adoption of advanced conservation practices, there is a need to intensify the extension services in the underserved regions. The expansion of the coverage and the ability of the extension programs should be given the following priority by the policy makers in order to make sure that the programs can be customized to meet local needs and knowledge gaps. These may involve the use of mobile departments, provision of online learning resources, and the use of bonuses to motivate extension workers in the community in order to improve accessibility. Besides, incorporation of traditional practices into extension programs may generate a holistic model that may streamline innovative techniques with cultural aptitude that will promote wider embrace of varied soil conservation technologies. In so doing, the extension services will provide a base towards sustainable agriculture in Bungoma County.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This research determines that the implementation of the use of soil conservation and rehabilitation technologies in Bungoma County depends on the socio-economic and institutional factors. Knowledge on sustainable practices improves the appreciation and knowledge of the farmers on the same as well as land size and ownership provides incentive to invest in long term measures. Credit also allows capital intensive technologies to be adopted and extension services transfer the technical knowledge needed to execute the same. Findings show that to achieve sustainable soil management, the approach along with it should be holistic to cover not only technical but also social and institutional obstacles.

5.2 Recommendations

The County Department of Agriculture and NGOs must also redouble their efforts in training farmers via field demonstrations and community workshops in order to get them to adopt conservations on soil. Training farmers will improve their knowledge and skills concerning conservation techniques like terracing and agroforestry hence promoting sustainability. On ownership and size of the land, the national and county governments should through the ministry of lands hasten land titling, and boundary conflicts be resolved to obtain tenure. The secure ownership enables the farmers to invest in permanent soil conservation measures. Financial institutions and county revolving funds must develop low-interest and flexible loans to be used specifically to fund investments on soil conservation. The local government can offer the guarantee so that smallholders can access the inputs and machinery required to have sustainable agriculture. With regard to extension services, the Ministry of Agriculture needs to hire additional field officers, improve logistics, and launch mobile-based advisory services in order to address the remote farmers. Enhanced expansion chains guarantees the availability of technical advice and encouragement to embrace the best practices in time. These measures all combined, education-based on actions, land security, credit access, and extension systems will stand farmers empowered, lessen soil degradation, and increase agricultural productivity at Bungoma County.

REFERENCES

Anderson, J. R., & Feder, G. (2007). Agricultural extension. In R. Evenson & P. Pingali (Eds.), *Handbook of agricultural economics* (Vol. 3, pp. 2343–2378). Elsevier. https://doi.org/10.1016/S1574-0072(06)03044-1

Bekele, W., & Drake, L. (2003). Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: A case study of the Hunde-Lafto area. *Ecological Economics, 46*(3), 437–451. https://doi.org/10.1016/S0921-8009(03)00166-6

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change, 19*(2), 248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change, 33*(2), 255–298. https://doi.org/10.1086/451461

Feder, G., Lau, L. J., Lin, J. Y., & Luo, X. (1990). The relationship between credit and productivity in Chinese agriculture: A microeconomic model of disequilibrium. *American Journal of Agricultural Economics, 72*(5), 1151–1157. https://doi.org/10.2307/1242526

Food and Agriculture Organization (FAO). (2011). *The state of the world's land and water resources for food and agriculture: Managing systems at risk*. Food and Agriculture Organization of the United Nations.

Kabubo-Mariara, J. (2007). Land conservation and tenure security in Kenya: Boserup's hypothesis revisited. *Ecological Economics, 64*(1), 25–35. https://doi.org/10.1016/j.ecolecon.2007.06.004

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological Forecasting and Social Change, 80*(3), 525–540. https://doi.org/10.1016/j.techfore.2012.08.007

Kassie, M., Pender, J., Yesuf, M., Kohlin, G., Bluffstone, R. A., & Mulugeta, E. (2010). Estimating returns to soil conservation adoption in the northern Ethiopian highlands. *Agricultural Economics, 41*(2), 173–187. https://doi.org/10.1111/j.1574-0862.2010.00438.x

Kimetu, J. M., Lehmann, J., Ngoze, S. O., Mugendi, D. N., Kinyangi, J. M., Riha, S., Verchot, L., Recha, J. W., & Pell, A. N. (2017). Reversibility of soil productivity decline with organic matter of differing quality along a degradation gradient. *Ecosystems, 11*(5), 726–739. https://doi.org/10.1007/s10021-008-9154-z

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement, 30*(3), 607–610. https://doi.org/10.1177/001316447003000308

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability, 7*(5), 5875–5895. https://doi.org/10.3390/su7055875

Mugwe, J., Mugendi, D., Mucheru-Muna, M., Merckx, R., & Vanlauwe, B. (2009). Determinants of the decision to adopt integrated soil fertility management practices by smallholder farmers in the Central Highlands of Kenya. *Experimental Agriculture, 45*(1), 61–75. https://doi.org/10.1017/S0014479708007072

Muriithi, B. W., Bett, H. K., & Ogada, M. J. (2018). Extent and determinants of adoption of improved maize varieties in Embu County, Kenya. *International Journal of Agricultural Extension, 6*(1), 41–51.

Mutsotso, B., Wambua, S., & Mbuvi, J. (2014). Agricultural extension in Kenya: The case of the system of extension. *International Journal of Agricultural Extension, 2*(1), 89–97.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development*, *6*(5), 208–216.

Mwangi, W., Wambugu, S., & Muriithi, B. (2021). Effectiveness of extension services in promoting adoption of climate-smart agriculture practices among smallholder farmers in Kenya. *African Journal of Agricultural Research, 17*(3), 412–423. https://doi.org/10.5897/AJAR2021.15541

Nkonya, E., Pender, J., Jagger, P., Sserunkuuma, D., Kaizzi, C., & Ssali, H. (2008). *Strategies for sustainable land management and poverty reduction in Uganda* (Research Report 133). International Food Policy Research Institute.

Nyangena, W., & Köhlin, G. (2008). Estimating returns to soil and water conservation investments: An application to crop yield in Kenya. *Environment for Development Discussion Paper Series, EfD DP 08-32*.

Pender, J., & Kerr, J. M. (1998). Determinants of farmers' indigenous soil and water conservation investments in semi-arid India. *Agricultural Economics, 19*(1–2), 113–125.

Place, A., Jackson, B., & Smith, C. (2007). *Adoption of new technologies in education*. Academic Press.

Place, F., & Hazell, P. (1993). Productivity effects of indigenous land tenure systems in sub-Saharan Africa. *American Journal of Agricultural Economics*, *75*(1), 10–19. https://doi.org/10.2307/1242969

Place, F., Barrett, C. B., Freeman, H. A., Ramisch, J. J., & Vanlauwe, B. (2003). Prospects for integrated soil fertility management using organic and inorganic inputs: Evidence from smallholder African agricultural systems. *Food Policy, 28*(4), 365–378. https://doi.org/10.1016/j.foodpol.2003.08.009

Pretty, J., Toulmin, C., & Williams, S. (2011). Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability, 9*(1), 5–24. https://doi.org/10.3763/ijas.2010.0583

Rambo, C. M., Ong'ayo, H. A., & Owuor, C. O. (2017). Influence of farmers' education level on adoption of agricultural technologies in Kenya: A case of Nyando Sub-County, Kisumu County. *African Journal of Agricultural Research*, *12*(9), 700–709. https://doi.org/10.5897/AJAR2016.11826

Rogers, E. M. (1962). *Diffusion of innovations*. Free Press.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Schoonhoven, Y., & Runhaar, H. (2018). Conditions for the adoption of agro-ecological farming practices: A holistic framework illustrated with the case of almond farming in Andalusia. *International Journal of Agricultural Sustainability*, *16*(4–5), 442–454. https://doi.org/10.1080/14735903.2018.1537664

Shiferaw, B., & Holden, S. (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.

Tenge, A. J., De Graaff, J., & Hella, J. P. (2004). Social and economic factors affecting the adoption of soil and water conservation in West Usambara Highlands, Tanzania. *Land Degradation & Development*, *15*(2), 99–114. https://doi.org/10.1002/ldr.606