Influence of Biophysical Factors on the Adoption of Soil Conserving Practices among Wheat Farmers in Kazakhstan

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ABSTRACT

The global agricultural sector faces significant challenges, including land degradation and soil fertility depletion, which impact growth and productivity. This study explores the influence of biophysical factors on the adoption of Soil Conserving Practices (SCPs) among 530 wheat farm households in Kazakhstan. Utilizing a multivariate probit model and ordered probit regression, the study assesses the determinants and intensity of SCP adoption, revealing an overall adoption rate of 73%. The findings indicate that most biophysical characteristics are not statistically significant in influencing SCP adoption, with the exception of farm-house distance. Specifically, farm-house distance is significantly and negatively associated with the adoption of minimum tillage and the overall intensity of SCP adoption. As distance increases, the likelihood of adopting minimum tillage decreases, and the probability of adopting multiple SCPs diminishes. Logistical challenges, labor and time constraints, limited access to information and extension services, and infrastructure limitations contribute to this negative association. Additionally, an increase in farm-house distance slightly raises the likelihood of adopting one SCP by approximately 1%, while reducing the likelihood of adopting two SCPs by about 1% and three SCPs by approximately 4.8%. Therefore, this study provides critical insights into how farm-house distance impacts the adoption of SCPs, emphasizing the need for targeted policies and interventions to address logistical and infrastructural barriers. By highlighting the specific challenges faced by distant farm households, the research advocates for tailored support mechanisms to enhance SCP adoption, thereby improving the soil degradation and promoting agricultural sustainability and improving rural livelihoods.

Keywords: soil degradation; wheat production; crop cover; conservation tillage; crop rotation

INTRODUCTION

About 854 million people globally are currently affected by food insecurity and this is largely exacerbated by decline in agronomic production and crops' yields (Lal, 2009; Oldeman, 1998). The decline is a function of soil degradation which has greatly compromised quantity and quality of food production as it is increasing susceptibility to drought stress and elemental imbalance (Bindraban et al., 2012). In an effort to reduce the welfare losses (poverty, increased production cost, food insecurity and low productivity) resulting from soil fertility depletion, attaining sustainable agriculture is pivotal (Gong, Meng, Li, & Zhu, 2013; Lal, 2009). It entails undertaking of resilient agricultural practices that support synergies in not only maintaining the ecosystem but augmenting agricultural productivity. Claimed to be a panacea for the problems of poor agricultural productivity and soil degradation by Giller, Witter, Corbeels, and Tittonell (2009), conservation agriculture (hereafter called CA) is actively promoted by Food and Agricultural

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Organization (FAO), and most governments and non-governmental organizations (NGOs) in developing countries have taken keen interest (Erenstein, Sayre, Wall, Hellin, & Dixon, 2012; Kassam, Friedrich, Shaxson, & Pretty, 2009; Nyanga, 2012; Nyangena & Köhlin, 2009). Arguably, CA is deemed a suitable strategy to assure farmers of welfare gains and environmental sustainability (Kassie et al., 2008). By definition, CA is a farming system capable of preventing losses of arable land and at the same time regenerating degraded lands (Baudron, Mwanza, Triomphe, & Bwalya, 2007; Giller et al., 2009; Kassie et al., 2008).

Since its inception under the banner of CA, these SCPs have become popular and received considerate global support as a pathway to sustainable intensification. Based on literature, four factors explain the general adherence to its principles. First, the belief that continuous no-tilling of the soil with crop residue retention culminates in improvements in "soil health" facilitating higher yields, and attainment of sustainable agriculture (Kassam, Friedrich, Derpsch, & Kienzle, 2015; Kassam et al., 2009). Second, it is the view that disturbing the soil causes soil degradation/erosion and reduces soil carbon (C) stocks and thus is considered unsustainable (Hobbs, Sayre, & Gupta, 2008; Kassam et al., 2015; Lal, 2009). Third, the seemingly mimicking of natural systems in which biomass remains on the soil surface without exposing the soils (Altieri & Nicholls, 2004). Finally, the name given to the practice, CA, has many thinking it means biodiversity-enhancing, a form of low-external-input, and sustainable agriculture as it has widely been endorsed as Climate Smart Agriculture (CSA), contributing to both adaptation and mitigation of climate change (Hobbs & Govaerts, 2010; Pretty & Bharucha, 2014).

Among the world's leading adopters of SCPs is Kazakhstan and largely attributable to government support measures aimed at addressing soil degradation (Kassam et al., 2015; Kienzler et al., 2012). The belief is that direct-seeded, untilled land does not only produce higher wheat yields than ploughed land but also lowers production costs. In addition, extra income is generated by engaging in crop rotation of wheat with other crops. The other bonus is that residues are left that conserve soil moisture and block the germination of weed seeds. As a result, by 2008 land not ploughed rose from zero to 1.4 million hectares owing to very high adoption rates (Friedrich, Kienzle, & Kassam, 2009). While some farmers in zero-tilled farms use herbicides to control weeds, majority utilize permanent soil cover to suppress weeds. The rational is natural store of weed seed diminishes with zero-tilling and also residues release humic acids which further block weed seed from germinating. A great advantage for Kazakhstan is that retaining crop residue increases the availability of water (Kassam et al., 2012). For instance, since winter snow accounts for 40 percent of Kazakh's precipitation, retaining the stubble of the previous wheat crop traps the snow which melts into the soil when it gets warmer. The resulting benefits are that: (i) erosion is reduced or even eliminated and (ii) more moisture is available along the soil profile. Research in Kazakh has found that zero-tillage along with the use of residues to capture snow, augments yields by 58 percent (Karabayev & Suleimenov, 2009; Wall, Yushenko, Karabayev, Morgounov, & Akramhanov, 2007). However, it is still not clear whether what factors affect SCP adoption given there is hardly a research on the topic in the Kazakh wheat sector (Musafiri et al., 2022).

While tremendous progress has been recorded regarding minimum tillage and crop cover, adoption of diverse crop rotation has been slower yet it would greatly aid farmers to better manage wheat pests and diseases and, increase land productivity (Karabayev & Suleimenov, 2009; Wall et al., 2007). One of the underlining reasons is short summer with a high frequency of dry years during the vegetative period. Mostly, oats, sunflower field peas, lentils, buckwheat, flax and canola are rotated with wheat. However, forage sorghum sown late in May and harvested in August provides fodder for sale or silage, and is also very effective in trapping that precious winter snow when left as post-harvest stubble. Generally, Kazakhstan's wheat growers are already well advanced in the transition to full conservation agriculture but there is dearth of empirical evidence on whether biophysical factors (refer to the physical and biological aspects of the environment that influence the functioning and sustainability of ecosystems) trigger SCP adoption.

To address this knowledge gap, this paper delves into the crucial interplay between biophysical factors and the adoption of SCP among wheat farmers in Kazakhstan. Biophysical factors encompass a spectrum of natural elements, including soil fertility, soil salinity, and the distance from farm to house, which collectively influence agricultural practices and their sustainability (Akter, Mwalupaso, Wang, Jahan, & Geng, 2023; Gardezi & Bronson, 2020). The distance between the farm and the house is particularly noteworthy as it affects the frequency and ease with which farmers can implement and monitor SCPs (Webb, Stokes, & Marshall, 2013). Farms located farther from the farmer's residence may face challenges in regular maintenance and timely application of SCPs, potentially leading to lower adoption rates. By examining these factors, this paper aims to elucidate their role in determining the adoption rates. The insights gleaned from this research not only contribute to the scholarly understanding of sustainable agriculture but also provide practical guidance for policy development and support programs aimed at promoting SCP adoption. Bear in mind that in the realm of sustainable agriculture, the adoption of Soil Conserving Practices (SCP) holds significant promise for enhancing soil health and productivity.

MATERIALS AND METHODS

Description of Study Site and Data

The study was conducted in the Kyzylorda oblast, located in the south of the Kazakhstan. Agriculture in Kazakhstan is essential to the national economy as well as farmers' livelihoods (Vanlauwe et al., 2010). There are various crops grown which also help farmers in obtaining income and enhance household food security.

The Kyzylorda oblast, in the north – Priaralsky Kara Kum, Aryskuma, has one of the largest deserts of the Old World, and desert plateaus of the suburb of the Kazakh folded country. However, the natural landscape is mainly sandy and clay massifs overgrown with bushes and a saxaul, in a flood plain of the Syrdarya River wood tugayny thickets meet. Absolute maximum and minimum temperature reach to 46 ° and -37 ° respectively. Duration of the vegetative period fluctuates from 190 to 226 days in a year. Generally, the temperature mode of the oblast allows cultivation of wheat, barley, oats, millet, rice, sunflower, mustard, sugar beet, early ripening varieties of a cotton, and also corn (Seitova & Stamkulova, 2017).

Primary data for this study was obtained from a household survey conducted from January to April 2021 in Kazakhstan. Data collection employed three methods: structured questionnaires, focus group discussions (FGDs), and key informant interviews (KII). Triangulation was used to ensure data reliability. The questionnaire was meticulously structured and pre-tested to guarantee uniformity in the information gathered and to align with the study's objectives. To ensure content validity, two experts in Conservation Agriculture (CA) and agricultural economics reviewed the design and nature of the questions to verify that they addressed the study's objectives. Experienced and well-trained enumerators from the Ministry of Agriculture conducted the data collection.

To arrive at the selection of 530 farmers, a multi-staged sampling procedure was employed. Initially, 5 villages were randomly chosen. Within each of these villages, 10 cooperatives were selected. Subsequently, from each cooperative, 10 farmers were randomly selected. Additionally, to address program placement, 30 farmers who were not members of any cooperatives were also randomly selected. This comprehensive approach ensured a representative sample of 530 farmers for the study.

Definition and measurement of key variables

Adoption of SCPs is a key dependent variable in the study. Unlike previous studies (Arslan, McCarthy, Lipper, Asfaw, & Cattaneo, 2014; Haggblade & Tembo, 2003; Lopez-Ridaura et al., 2018; Mazvimavi & Twomlow, 2009), adoption will be measured in twofold. First, any farmer who adopts any of the three practices during the survey year will be considered as an adopter represented by 1 and 0 otherwise. Finally, adoption of each of the respective SCPs will be scrutinized i.e. adopters of crop rotation, crop cover and zero-tillage will be represented by 1 and 0 otherwise. Capturing of SCPs adoption in this manner (in general and specific) is one of the major contributions of this proposed study.

Biophysical factors were captures using three variables -Farm-House (the distance in kilometers between the homested and the farm, Soil fertility a dummy variable capturing self-reported farmers' perception on soil fertility on their farm where 1 represents fertile and 0, otherwise, and finally Soil salinity, a dummy of self-reported perception of soil salinity where 1 represents soil salinity and 0 otherwise. Amadu, McNamara, and Miller (2020) also captured biophysical characteristics in this manner.

Table 1 presents the definition and descriptive statistics of the variables used in this study.

Table 1. Descriptive statistics between adopters and non-adopters

Variables	Description	Non-adopter (N=143	Adoter (N=387)	T stat
Seed	The value of wheat seed used in Kazakh currency	2559.287	2556.504	1.45
Fertilizer	The value of chemical used in Kazakh currency	8660.399	8079.76	2.3
Labor	The value of labor used in Kazakh currency	17783.566	17515.964	1.7
Social network	Household belongs to a social network (1=member)	0.273	0.672	6.3
Gender	The sex of the household head (1=male)	0.811	0.848	
Age	The age of household head in years	51.357	43.7	5.66
Marital	The marital status of the household head (1=married)	0.937	0.925	1.03
Education	Whether household head has attained basic education (1=attained)	0.301	0.568	1.9
Market Distance	The distance to the market in kilometers	2.312	1.893	4.2
Farm-House	The distance from farm to the house in kilometers	0.55	0.532	1.2
Fins Dist	The distance to the nearest financial institution in kilometers	3.371	4.359	4.33
Soil fertility	Self-reported perception on soil fertility (1=fertile)	0.699	0.912	3.45
Soil salinity	Self reported perception on soil salinity (1=saline)	0.615	0.724	1.66
Family size	The number of people in a household	6.629	5.798	1.7
ICT	Possession of ICT in a household (1=possess)	0.196	0.501	5.3
Training	Training attendance on SCPs (1=attended)	0.287	0.654	6.9
Yield	The natural log of wheat yield	7.998	8.087	2.4

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Empirical strategy

To achieve the study's objectives, a multivariate probit model was used to evaluate the influence of biophysical factors on the adoption of three soil-conserving practices (SCPs). Additionally, an ordered probit model was employed to examine the influence of biophysical factors on the intensity of adoption.

A multivariate probit model (MVP)

Generally, the decision to adopt a SCP by a household is discrete in nature, and in this case multiple SCPs may be adopted. One possible occurrence is that the adoption of a SCP may be influenced by decisions to adopt other SCPs. Thus, models that assume the independence of the error conditions of the different CSA practices are inappropriate and may generate bias estimates. Therefore, the multivariate probit model (where it is possible to adopt several SCPs) was applied as adoption decisions of this sort (CSAP) are inherently multivariate. The advantage of this approach is that it helps to identify possible complementarities (positive correlation) and substitutability (negative correlation) between the 3 SC practices. The specification of the model takes the following form:

$$Y_{ipk}^{*} = X_{ip}'\beta_k + \varepsilon_{ip}, \text{ where } Y_{ipk}^{*} = \begin{cases} 1 \; if \; Y_{ipk}^{*} > 0 \\ 0 \; otherwise \end{cases} \text{ for each CSAP choice} \qquad (5)$$

Where Y_{ipk}^{*} is a latent unobservable variable of the ith farm household (i= 1,……., N) facing a adoption decision of the available SCPs (k= MT, CR, and CC) on plot p (p=1,....., p) based on household, farm plot and location characteristics (X_{ip}'), β_k are parameters to be estimated, and ε_{ip} is the error term.

With a zero conditional mean and a variance normalized to the unity (for identification of the parameters), the error terms jointly follow a multivariate normal distribution (MVN) where (u_R; u_M; u_S;) $\xrightarrow{\text{MVN}}$(0, Ω) with the matrix Ω given as follows:

$$\Omega = \begin{bmatrix} 1 & \rho RM & RS \\ \rho RM & 1 & \rho MS \\ \rho RS & \rho MS & 1 \end{bmatrix} \qquad (6)$$

Where is the coefficient of the pairwise correlation of error terms of three SCPs.

The correlations of the error terms are critical in justifying the use of multivariate probit over univariate probit for each SC practice in that when the correlations in the off-diagonal elements in the covariance matrix become non-zero, the former must be applied.

Ordered probit model (OPM)

The introduction of SCP by farmers on their plot isn't done as a complete package, thus it is difficult to measure SCPs as a package to assess the degree of adoption (Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2013; Teklewold, Kassie, & Shiferaw, 2013). The number of SCPs adopted by a household was instead used as a dependent variable. We categorized adoption intensity into 3 parts – one, two and three practices. Since there are three SCPs under consideration, the outcome variable ranges from 1 to 3. Hence, an ordered Probit model was employed and is specified as follows:

$$Y^{*} = X'\beta + \varepsilon \qquad (7)$$

Where, ε is the error term which follows a normal distribution with zero mean and unit variance, X' is a vector of determinants of adopting different number of SCPs, β are parameters to be estimated and Y* is denotes a latent unobserved variable given by:

$Y = 0$ if $Y^* \leq 0$

$= 1$ if $0 < Y^* \leq \alpha_1$

$= 2$ if $\alpha_1 < Y^* \leq \alpha_2$:

$= J$ if $\alpha_{J-1} \leq Y^*$

Where, values of Y are observed, and α are unknown parameters to be calculated.

Eventually, marginal effects of each outcome are expressed as follows (Greene, 2003):

$\Pr(Y = 0|x) = \Phi(-x'\beta)$

$\Pr(Y=1|x) = \Phi(\alpha_1 - x'\beta) - \Phi(x'\beta)$

$\Pr(Y=2|x) = \Phi(\alpha_2 - x'\beta) - \Phi(\alpha_1 - x'\beta)$

:

$\Pr(Y = J|x = 1 - \Phi(\alpha_{J-1} - x'\beta)$.

EMPIRICAL RESULTS AND DISCUSSION

Intensity of SCP Adoption

The study finds that the adoption rate of Soil Conserving Practices (SCPs) stands at 73% (Figure 1). Specifically, about 50% of farm households adopt one practice, while 17% adopt two practices, and 6% adopt all three practices under consideration. Despite these figures, none of the identified categories have adoption rates exceeding 50%, indicating that there are limiting factors influencing adoption.

The highest adoption rate observed is 26% for farmers adopting only crop rotation. This suggests that farmers understand the benefits of crop rotation in improving soil quality, food access, and income augmentation. Conversely, minimum tillage, a practice that is less labor-intensive and can reduce costs while improving yields, has a lower adoption rate. Only a small percentage of farmers engage in minimum tillage due to several factors as noted during focus group discussions:

Complexity and Knowledge Gap: Minimum tillage requires technical knowledge and skills that not all farmers possess. It involves adapting equipment and machinery, which can be costly and unfamiliar to farmers without adequate training or extension services.

Initial Costs and Investment: Transitioning to minimum tillage involves upfront investments in equipment and materials. Farmers with limited financial resources may find these costs prohibitive, especially if they are uncertain about the long-term benefits.

Risk Aversion: Farmers may be reluctant to adopt practices that they perceive as risky or unproven. Minimum tillage can initially lead to lower yields or require adjustments in pest and disease management, which can deter risk-averse farmers.

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Perceived Benefits: While minimum tillage can reduce labor costs and improve soil health over time, some farmers may not perceive the immediate benefits compared to their current practices. Lack of information about long-term benefits may also discourage adoption.

Labor and Time Constraints: Farmers facing labor shortages or time constraints, especially during peak agricultural seasons, may find it challenging to implement minimum tillage, which requires more planning and management compared to conventional tillage.

Policy and Market Support: The absence of supportive policies, market incentives, or subsidies for SCP adoption, including minimum tillage, may limit widespread adoption. Farmers are more likely to adopt new practices if there are financial or regulatory incentives to do so.

Social and Cultural Factors: Traditional farming practices and community norms can influence agricultural decisions. Some farmers may continue to use conventional tillage due to cultural inertia or a preference for familiar practices within their community.

Addressing these barriers to minimum tillage adoption requires targeted interventions. Providing access to affordable equipment, technical training, and extension services can improve farmers' knowledge and confidence in adopting minimum tillage. Moreover, creating financial incentives and supportive policies can encourage farmers to overcome initial investment barriers and perceive the long-term benefits of sustainable soil management practices. By addressing these factors, agricultural policy and support programs can promote broader adoption of Soil Conserving Practices, ultimately enhancing soil health and agricultural sustainability in Kazakhstan.

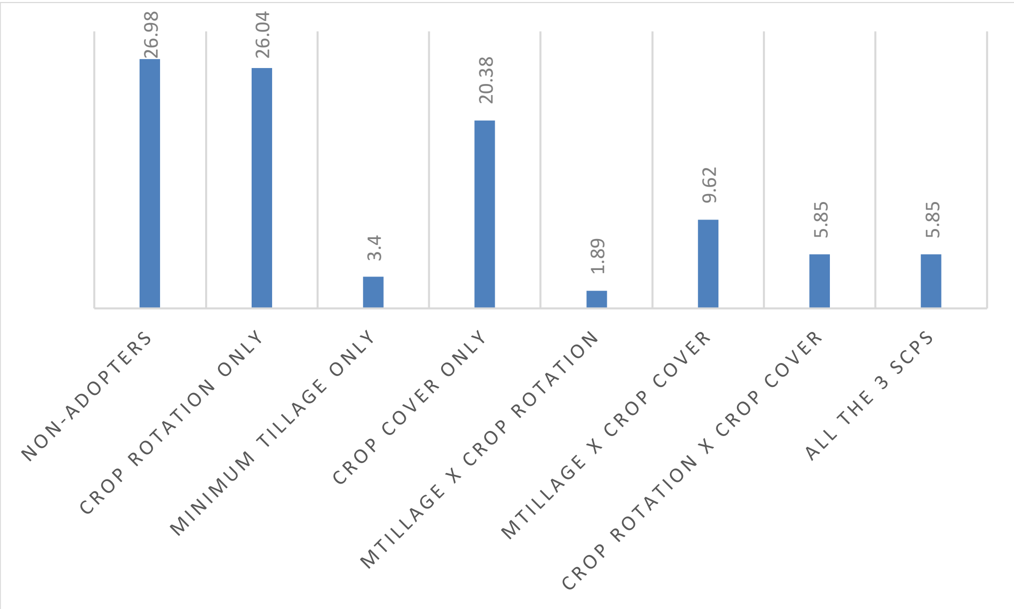

Figure 1 Nature and Extent of SCP Adoption

The association of farm-house distance on SCPs adoption

Table 2 presents the findings from the multivariate probit regression analysis, which examines the influence of biophysical characteristics on the adoption of Soil Conserving Practices (SCPs). The results indicate that biophysical characteristics are generally not statistically significant in influencing SCP adoption, with the exception of one factor: Farm to House Distance: The distance between the farm and the house is negatively associated with the adoption of minimum tillage. Specifically, as the distance increases, households are less

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likely to adopt minimum tillage practices.

The following are the possible explanations as informed by key informants:

Proximity and Management: Farmers who live closer to their farms may find it easier to manage and implement changes in farming practices, such as minimum tillage. They may have more regular access to their fields, making it convenient to monitor and maintain the required equipment and practices.

Labor and Time Constraints: Longer distances between the farm and house may increase the perceived time and labor required to implement minimum tillage. Farmers who live farther away may face greater logistical challenges in commuting to their fields, which can deter them from adopting practices that require additional time and effort.

Access to Information and Extension Services: Farmers living closer to urban or extension service centers may have better access to information, training, and support for adopting new agricultural practices. Conversely, those living farther away may have limited access to these resources, which can hinder their ability to adopt practices like minimum tillage.

Infrastructure and Equipment: Infrastructure limitations, such as poor road conditions or lack of storage facilities near the field, can also affect the adoption of minimum tillage. Farmers who live farther away may face challenges in transporting equipment or storing machinery, which are essential for implementing minimum tillage effectively.

Finally, while most biophysical characteristics examined in the study did not show significant effects on SCP adoption, the negative association between farm-to-house distance and minimum tillage adoption highlights the importance of considering logistical and practical constraints in promoting sustainable agricultural practices. Addressing these factors through targeted education, infrastructure development, and policy support can potentially increase the adoption rates of SCPs, thereby improving soil health and agricultural sustainability.

On the other hand, we find that farmers' membership in a social network is likely to influence the adoption of all three Soil Conserving Practices (SCPs), while the age of the farmer negatively influences the adoption of all three SCPs. This is consistent with reality, as social networks often serve as hubs for information exchange. However, as farmers age, their propensity to adopt new practices tends to decrease. Interestingly, training on soil conservation is likely to improve the adoption of all three SCPs, while education and access to credit are likely to facilitate the adoption of minimum tillage.

Table 2: Influence of Biophysical Characteristics on SCP Adoption

Explanatory Variables	Crop Rotation		Minimum Tillage		Crop Cover	
	Coef	S.E	Coef	S.E	Coef	S.E
Biophysical						
Farm-House	-0.141	0.099	-0.152*	0.092	-0.171	0.110
Soil fertility	0.283	0.198	0.077	0.185	0.204	0.195
Soil salinity	0.084	0.131	0.112	0.132	0.066	0.129
Control						
Social network	0.367***	0.127	0.366***	0.129	0.264**	0.127
Gender	0.059	0.156	0.050	0.161	0.143	0.154
Age	-0.027***	0.008	-0.016**	0.008	-0.026***	0.008

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Marital	0.191	0.240	-0.036	0.249	0.204	0.235
Education	0.028	0.129	0.243*	0.133	0.133	0.125
Market Distance	-0.014	0.067	-0.056	0.070	0.023	0.066
Fins Distance	0.100**	0.042	0.114***	0.045	0.057	0.041
Family size	-0.054	0.045	-0.080*	0.045	-0.055	0.044
ICT	0.018	0.123	0.356***	0.129	-0.070	0.122
Training	0.219*	0.123	0.318***	0.128	0.309***	0.122
Yield	0.182	0.122	0.171	0.122	0.106	0.118
Constant	-1.278	1.146	-0.902	1.151	-0.722	1.111
Combinations						
rho21	0.326***	0.067				
rho31	0.730***	0.039				
rho32	0.355***	0.066				
Model Diagnostics						
N	530					
Log likelihood	-862.28					

Notes. *, **, and *** indicate statistical significance levels at 10%, 5%, and 1%

Farm-house distance and adoption intensity

Table 3 presents the influence of biophysical characteristics on the intensity of Soil Conserving Practices (SCPs) adoption, estimated using ordered probit regression. The results reveal that only the distance between the farm and the house is statistically significant. Specifically, an increase in the distance between the farm and the house is likely to increase the likelihood of adopting one SCP by approximately 1%, while reducing the likelihood of adopting two SCPs by 1% and three SCPs by 4.8%.

The significant impact of farm-to-house distance on the intensity of SCP adoption can be explained by several factors:

Logistical Challenges: Greater distances between the farm and the house may impose logistical challenges for farmers, making it difficult to manage and implement multiple SCPs effectively. This increased distance can result in higher travel times and transportation costs, which can deter farmers from adopting more than one SCP.

Time and Labor Constraints: Implementing multiple SCPs typically requires more time and labor. Farmers who live farther from their farms may face additional time constraints and labor demands, making it less feasible to adopt and manage several SCPs simultaneously.

Accessibility to Resources and Support: Proximity to the farm often means better access to resources, information, and extension services. Farmers living closer to their fields may find it easier to access the necessary support and materials needed to implement multiple SCPs. Conversely, those living farther away may have limited access to these resources, hindering the adoption of multiple practices.

Monitoring and Maintenance: The effectiveness of SCPs often relies on regular monitoring and maintenance. Farmers living farther from their fields may find it challenging to conduct the frequent checks and upkeep required, leading them to adopt fewer SCPs that are less demanding in terms of oversight.

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Table 3: Influence of Biophysical Characteristics on the Intensity of SCP Adoption

Explanatory variable	1 SC Practice		2 SC practices		3 SC practice	
	Marginal	SE	Marginal	SE	Marginal	SE
Biophysical						
Farm-House	0.010**	0.005	-0.010**	0.005	-0.048**	0.022
Soil fertility	-0.013	0.009	0.014	0.009	0.066	0.044
Soil salinity	-0.005	0.006	0.005	0.006	0.024	0.030
Control						
Social network	-0.021***	0.007	0.022***	0.007	0.105***	0.029
Gender_01	-0.006	0.007	0.006	0.008	0.028	0.037
Age	0.001***	0.000	-0.001**	0.000	-0.007***	0.002
Marital	-0.010	0.011	0.010	0.012	0.050	0.056
Education	-0.009	0.006	0.009	0.006	0.045	0.030
Market Distance	0.002	0.003	-0.002	0.003	-0.008	0.016
FinsDist	-0.006***	0.002	0.006***	0.002	0.030***	0.010
Family size	0.004*	0.002	-0.004*	0.002	-0.019*	0.010
ICT	-0.007	0.006	0.007	0.006	0.032	0.029
Training	-0.019***	0.006	0.019***	0.006	0.093**	0.029
Yield	-0.009	0.006	0.009	0.006	0.046	0.028
Model diagnostics						
N	530		530		530	

Notes. *, **, and *** indicate statistical significance levels at 10%, 5%, and 1%

CONCLUSION AND POLICY RECOMMENDATIONS

This paper examines the impact of biophysical factors on the adoption of Soil Conserving Practices (SCPs) among farmers in Kazakhstan, with a primary focus on the distance between farm and house. The analysis reveals that farm-house distance is significantly and negatively associated with the adoption of minimum tillage and the overall intensity of SCP adoption. Specifically, as the distance increases, the likelihood of adopting minimum tillage decreases, and the probability of adopting multiple SCPs diminishes. This negative association is attributed to logistical challenges, labor and time constraints, limited access to information and extension services, and infrastructure limitations faced by farmers with distant farms.

In addition to farm-house distance, the analysis highlights the importance of social networks, training on soil conservation, and access to credit in facilitating SCP adoption. Membership in social networks significantly boosts the adoption of all SCPs, while training on soil conservation enhances the adoption of these practices. Older farmers are less likely to adopt SCPs, reflecting a preference for traditional farming methods.

Based on these findings, several policy recommendations are proposed. Improving infrastructure, particularly roads and storage facilities, can reduce logistical challenges and facilitate easier access to fields. Enhancing extension services and providing targeted training programs can bridge the knowledge gap and equip farmers with the necessary skills for adopting SCPs, particularly minimum tillage. Providing financial incentives, subsidies, and access to credit can help farmers overcome initial investment barriers and perceive the long-term benefits of SCPs. Encouraging the formation and strengthening of social networks can enhance information exchange and community support for adopting SCPs. Implementing supportive policies and market incentives can promote the adoption of SCPs and sustainable agricultural practices.

The study is not without limitations. First, it focuses on farmers in Kazakhstan, which may limit the generalizability of the findings to other regions with different biophysical and socio-economic conditions. Second, the data used may have limitations in terms of accuracy and completeness, affecting the robustness of the findings, especially since it was collected during the Covid-19 pandemic. The measurement of biophysical factors and their influence on SCP adoption may also be subject to biases and inaccuracies.

Nevertheless, our findings suggest that targeted interventions, such as improving infrastructure, providing support services, and promoting social networks, can effectively increase SCP adoption rates, thereby enhancing soil health and agricultural sustainability. To corroborate our findings, future research should address the limitations of this study and explore broader geographic scopes to compare the influence of biophysical factors on SCP adoption in different regions. Longitudinal studies should be implemented to assess the long-term impacts of SCP adoption on soil health and agricultural sustainability. More detailed and precise measurements of biophysical factors are needed to better understand their influence on SCP adoption. Evaluating the effectiveness of policy interventions and support programs can also inform more effective strategies for promoting sustainable agricultural practices. By addressing these areas, future research can provide deeper insights into the factors influencing SCP adoption and inform more effective strategies for promoting sustainable agricultural practices.

Ethical Statement: This study received ethical approval from the local authority and adhered to the ethical standards set forth by the Declaration of Helsinki and other relevant guidelines. No sensitive information that could harm individuals or communities was disclosed. Data were aggregated and anonymized to ensure no individual or group could be identified, maintaining strict confidentiality and privacy for all participants. Personal data were anonymized, securely stored, and access was restricted to authorized personnel only. Informed consent was obtained from all participants, who were fully informed about the nature, purpose, and potential risks and benefits of the research. They were given the opportunity to ask questions and withdraw from the study at any time without repercussions. This research was conducted with the highest standards of integrity and in accordance with the ethical guidelines of Professor Geng, Nanjing Agricultural University, and other relevant ethical bodies. All data collected and analyzed were obtained transparently, responsibly, and accurately.

Data Availability: The methods and procedures used in this research are described in sufficient detail to allow for replication. The raw data and analysis scripts are available upon request to promote transparency and reproducibility.

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