European Journal of Sustainable Development Research
2023, 7(4), em0230
e-ISSN: 2542-4742
https://www.ejosdr.com

MODESTUM

Research Article

OPEN ACCESS

Determinants of adoption of multiple sustainable agriculture practices among mandarin producing farmers in Salyan District of Karnali Province, Nepal

Shishir Dahal [1]*, Bijaya Dangi [1], Raman Kumar Dangi [1], Prakash Bista [1], Aarjal Bhandari [1], Prajwal Adhikari [1], Milan Bhattarai [2]

[1] Institute of Agriculture and Animal Sciences, Tribhuwan University, Tulsipur, Dang, NEPAL
[2] Department of Agriculture Economics and Social Sciences, Institute of Agriculture and Animal Sciences, Tribhuwan University, Katmandu, NEPAL
***Corresponding Author:** ag.dahalshishir@gmail.com

Citation: Dahal, S., Dangi, B., Dangi, R. K., Bista, P., Bhandari, A., Adhikari, P., & Bhattarai, M. (2023). Determinants of adoption of multiple sustainable agriculture practices among mandarin producing farmers in Salyan District of Karnali Province, Nepal. *European Journal of Sustainable Development Research, 7*(4), em0230. https://doi.org/10.29333/ejosdr/13440

ARTICLE INFO

Received: 22 Mar. 2023

Accepted: 30 May 2023

ABSTRACT

Sustainable agriculture practices (SAPs) are eco-friendly farming techniques, which ensure the agricultural production and environmental protection simultaneously. The aim of this study was to identify the potential SAPs being adopted by farmers, their adoptability, and to assess the determinant factors for multiple SAPs adoption. For this, face-to-face interview with 120 mandarin producing farmers, six focus groups, and 11 key informants was conducted in Salyan District of Karnali Province, Nepal. Farms were categorized into four categories on the basis of sustainability score and required inferences on quantitative and qualitative data were made by descriptive statistics and probit regression. Results revealed that majority of the mandarin farms were categorized as fairly low and fairly high categories. Factors such as age, gender, and schooling of household head, access to the Internet, distance of market for farm inputs, and availability of human labor had significantly increased the probability of multiple SAPs adoption at varied level of significance. Farm level policies regarding dissemination of integrated nutrient and pest management tactics, subsidization on eco-friendly farm inputs via cooperatives, trainings, demonstration, and field workshops should be formulated and implemented effectively.

Keywords: sustainable agriculture practices, mandarin, probit, Nepal

INTRODUCTION

Sustainable agriculture is integrated approach of crop and livestock production packages, which ensures the fulfillment of human food and fiber needs, environmental quality, efficient utilization of non-renewable resources, with sustainable economic growth and improved lifestyle of farmers (Reganold et al., 1990). Adoption of sustainable agriculture practices (SAPs) helps to achieve the overarching environmental, social and economic goals (Velten et al., 2015). Sustainable agriculture also supports to achieve sustainable development goals (SDGs) ensuring elimination of poverty and food insecurity (Ehiakpor et al., 2021). The concept includes practices, which are not only environmentally friendly but also non-degrading, resource conserving, socially accepted and technologically appropriate (Food and Agriculture Organization of the United Nations [FAO], 1995). SAPs include intercropping, cover cropping, judicious application of chemical fertilizers, implication of integrated pest and soil management practices and harvesting and safe post-harvest procedures. SAPs are environmentally desirable and are best alternatives against the intensive agriculture practices, which deleteriously hampers the water and soil quality, promotes biodiversity loss and even leads to serious human and animal health issues (Piscart et al., 2009).

Mandarin is major fruit crop grown throughout the mid-hills of Nepal including Salyan. It covers the area of 27,002 hectare with annual production and productivity of 198,406 metric tons and 10.08 metric tons per hectare (Ministry of Agriculture and Livestock Development [MOALD], 2021). Adoption of SAPs during production of mandarin enhances the social, environmental and economical sustainability of the citrus farms (Jordán et al., 2010). Since the fruit orchard requires less tillage operations as compared to regular annual crops, but SAPs are still required to adopt in order maintain the soil quality. Integrated soil and pest management strategies should be adopted in such a way that agrochemicals are either eliminated or used at reduced dosages. Manda et al. (2016) also reported that adoption of SAPs would increase the productivity as compared to non-adopters. However, some of

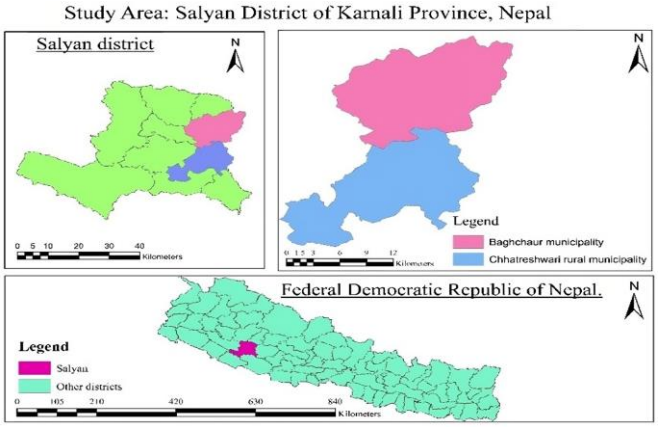

Figure 1. Map of Nepal representing Salyan District & study area (Source: Survey Department, Government of Nepal)

SAPs such as preparation of organic manure, mulching, eco-friendly pest management may not show economic viability and leads to high cost of production (Jordán et al., 2010) but can also be adopted if proper governmental supports are provided. Adoption of SAPs depends on availability of resources, socio-economic and policies of the particular country or province. In case of Salyan, provincial government has already formulated and implemented the policy for transformation of conventional agriculture system into organic system (Baral et al., 2020), which consists of few amendments regarding sustainable agriculture. However, organic agriculture may not ensure the sustainable food supply to growing population.

Literature Review

Previous studies carried out by different researchers have emphasized adoption scenario and determinants of improved orchard management practices. For instance, Belbase et al. (2020) have focused on how farmers are familiar with improved orchard management strategies in Gandaki Province of Nepal. Similarly, determinants of adoption of agricultural intensification under different cropping system have assessed by Raut et al. (2011). The field trials on influence of different good agriculture practices were carried out by various researchers including Baral et al. (2021) but adoption determinants such as demographic, socio-economic, and resource accessibility factors were not studied. There are many impediments on adoption of SAPs by resource poor farmers, possible endo and exogenous determining factors should be studied and results should be integrated during policy formulation and implementation. Adoption of SAPs is influenced by dynamic factors, which may varied over the location and may requires different research methodologies to assess them. Such determining factors were not considered by previous researchers, which stretches the research gap for which this study was set to fill.

Objectives of the Study

1. To identify the major SAPs and categorization of farms on the basis of SAPs adoption.
2. To identify the major determining factors of adoption of multiple SAPs among the mandarin producing farmers.
3. To make possible recommendations to the farmers and other stakeholders to increase the adoptability of multiple SAPs.

MATERIALS AND METHODS

Study Site Selection

Salyan District is located in the Western mid-hills of Nepal (**Figure 1**). District is limited developmental infrastructure and dominated by slope land agriculture-based rural economy. Mandarin is major cash crop grown commercially in different regions of the District but Chhatreshwari Rural Municipality (28.3241^0N, 82.2313^0E) and Baghchaur Municipality (28.4511^0N, 82.2851^0E) has higher production and production area due to edaphic and climatic suitability. Thus, these two municipalities were selected purposively for the study.

Data Collection

Both quantitative and qualitative approaches were used to collect the require information. To assess the sampling frame, list of commercial mandarin producing farmers was collected from integrated agriculture and livestock development office (IALDO). Baghchaur Municipality had 780 commercial mandarin growers while Chhatreshwari rural municipality had 468 farmers (IALDO). Out of these sampling frame 61 from Baghchaur and 59 from Chhatreshwari were selected using random selection method making up total sample size of 120. The household heads or their spouse who are involved in production, expenditure and sales were considered to be the decision maker and selected as respondent. Survey was conducted voluntarily, and all of the respondents were agreed to provide information without any justification. Semi-structured questionnaire was prepared and pre-tested in order to find out the farmers' understanding, relevancy and time taken for survey interview before conducting survey and essential corrections were made. Various demographic, socio-economic and knowledge on SAPs were asked to obtain the required information from respondents. Secondary data were collected from various sources such as government reports, research articles, books and websites.

Focus Group Discussion and Key Informant Interviews

Quantitative data was collected from household survey while qualitative information on role of cooperatives, availability of credit providers, attitude of farmers towards adoption of SAPs and their awareness about impacts of intensive farming practices was gathered by interviewing six different focal group in the study site. Furthermore, 11 key informants including agriculture officers, technicians and social mobilizers were interviewed to understand the official process of approaching subsidies and future prospects of government on prioritization of SAPs.

Data Analysis

Collected data was encoded in spreadsheet of MS Excel 2021 on which data cleaning was done to ensure its quality. Required statistical inferences such as frequencies, percentage, mean, and probit regression were done using STATA version 15.

Table 1. Categorization of mandarin farms on basis of SAPs adoption

Categories	Estimation threshold
Category A (low adoption)	SS≤M-SD
Category B (fairly low adoption)	M-SD<B≤Mean
Category C (fairly high adoption)	M<C≤Mean+SD
Category D (high adoption)	M+SD<D≤Max

Note. SS: Sustainability score; SD: Standard deviation; M: Mean; & Max: Maximum

Table 2. Summary statistics of farm categories on basis of SAPs adoption

Farm categories	n	P (%)	CP (%)
Category A (low adoption)	17.00	14.17	14.17
Category B (fairly low adoption)	47.00	39.17	53.33
Category C (fairly high adoption)	38.00	31.67	85.00
Category D (high adoption)	18.00	15.00	100.00
Category A (low adoption)	120.00	100.00	

Note. n: Frequency; P: Percentage; & CP: Cumulative percentage

Table 3. Descriptions and summary statistics of categorical variables

Categorical independent variables		Frequency (n)	Percentage (%)
Gender (=1 if male; 0 otherwise)	Male	100	83.30
	Female	20	16.70
Access to the Internet (=1 if yes; 0 otherwise)	Yes	68	56.70
	No	52	43.30
Access to radio/TV (=1 if yes; 0 otherwise)	Yes	67	55.80
	No	53	44.20
Access to agriculture credit (=1 if yes; 0 otherwise)	Yes	64	53.30
	No	56	46.70
Membership on cooperatives (=1 if yes; 0 otherwise)	Yes	12	10.00
	No	108	90.00
Availability of human labor (=1 if easily available; 0 otherwise)	Yes	92	76.70
	No	28	23.30
Access to forest resources (=1 if yes, 0 otherwise)	Yes	116	96.70
	No	4	3.30
Access to subsidy (=1 if yes, 0 otherwise)	Yes	46	38.30
	No	74	61.70
Land tenure (=1 if private, 0 otherwise)	Yes	97	80.80
	No	23	19.20

Note. Dependent variable: SAPs adoption (=1 if sustainability score ⩾6, otherwise 0)

Estimation of sustainability score

Altogether 18 different commonly practiced SAPs were studied during the field survey. Binary scoring (one if particular SAP is adopted, else zero) for each of SAPs was done. Summation of SAPs was done to estimate the gross sustainability score. Then, the farms were categorized into four different categories on the basis of individual sustainability score (SS), mean and standard deviations (SDs), as shown in **Table 1**.

Probit model

Probit is dichotomous econometric model with binary responses of dependent variables, where inverse standard normal distribution of probability is modeled in linear forms of independent variables (Muthén, 1979). This regression model was used to identify the determinants of high scale potato production in Karnali Province of Nepal:

$$Pr(Y=1)=f(b_0+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+b_7X_7+b_8X_8+b_9X_9+b_{10}X_{10}+b_{11}X_{11}+b_{12}X_{12}+b_{13}X_{13}+b_{14}X_{14}+b_{15}X_{15}+b_{16}X_{16}+b_{17}X_{17},$$

where, Pr(Y=1, if farmer's SS is ⩾6, otherwise 0) is the probability of adoption of at least one third of SAPs, X_1 is age of the household head (years), X_2 gender of household (1 if male otherwise 0), X_3 schooling years of household head (1 if joint otherwise 0), X_4 experience of household head (years), X_5 is access internet (1 if yes otherwise 0), X_6 is conventional mass media i.e., radio and television (1 if yes otherwise 0), X_7 is distance to input market (kilometers), X_8 is total land holdings per household (hectare), X_9 is access to agriculture credit (1 if yes otherwise 0), X_{10} is membership in any cooperatives (1 for yes otherwise 0), X_{11} is access to subsidy (1 if yes otherwise 0), X_{12} land tenure(1 if private otherwise 0), X_{13} is mandarin production (tons per hectare), X_{14} is annual revenue (NRs), X_{15} is access to human labor (1 if easily available otherwise 0), X_{16} is access to forest resources (1 if yes otherwise 0), X_{17} is economically active members (numbers) and b_1, b_2, b_3, ..., b_{17} are regression coefficients.

RESULTS AND DISCUSSION

Summary Statistics of Mandarin Farms

Selected mandarin farms were categorized into four different groups on the basis of SS they gained (**Table 2**). The result shown that, highest numbers of mandarin farms i.e., 47.00 (39.17%) had fairly low adoption of SAPs. Similarly, 38.00 (31.67%) of the farms were categorized in fairly high adoption category. High adoption category included only 18.00 (15.00%) of the mandarin farms with comparatively higher SS. The remaining 17.00 (14.17%) of the farms were ranked in low adoption category with relatively lower SS.

Descriptions and Summary Statistics of Categorical Variables

Some dummy variables were included in regression analysis to determine their influence on SAPs adoption decisions of the mandarin farmers (**Table 3**).

Table 4. Descriptions & summary statistics of continuous variables

Variables	Minimum statistic	Maximum statistic	Mean statistic	Standard error
Age of household head	20.00	93.00	47.73	1.44
Schooling of household head in years	0.00	18.00	5.94	0.46
Experience in years	2.00	40.00	10.31	0.68
Distance of input market in kilometers	0.00	150.00	17.09	2.70
Total land holdings in hectare	0.04	2.64	0.51	0.05
Mandarin production in metric tons	0.06	17.50	3.25	0.29
Annual revenue per household (NRs)	2,520.00	1,225,000.00	224,884.16	23,154.03
Total economically active members	1.00	7.00	3.55	0.13

Results revealed that, most of the households i.e., 100.00 out of 120.00 (83.30%) were male headed and 20.00 (16.70%) by female members. Similarly, only 56.70% of the household had access to internet while rest 43.30% do not have internet facility. Conventional mass media such as radio and television were accessible to only 55.80% while rest of 44.20% of the respondents do not have access to even radio and television. Likewise, 53.30% of the household had taken agriculture loan while 38.30% were benefited by subsidies of cash or kind. Only few i.e., 10.00% of respondents were found to be the member of cooperatives, while 90.00% of them were not the member of any kind of cooperative. About 76.70% of the mandarin farmers responded to have easy access of human labor while 23.30% responded to have difficulty on labor accessibility.

Focal groups also responded that they usually face labor scarcity during intercultural operations and fruit harvesting. Similarly, 96.70% of farmers have access to nearest forest to use required forest resources such as fallen tree leaves while 3.30% of farmers do not have such accessibility. Land ownership pattern was dominated by private land ownership with 80.80% of farmers having their own registered land while 19.20% did not have own land.

Descriptions and Summary Statistics of Continuous Variables

Continuous variables influencing the adoption decision of multiple SAPs were studied (**Table 4**). The mean age of household head was 47.73 years, which ranges from 20.00 years to 93.00 years in the study area. The average years of schooling of household head was 5.94 years with minimum of 0.00 years to maximum 18.00 years. The experience of farmers on mandarin production also had huge variations. The mean years of experience was 10.31 years, which ranged from 2.00 to 40.00 years. Similarly, the distance of market for farm input supply was 17.09 kilometers from their farms.

Likewise, average land holdings of the household were 0.51 hectare, which ranges from 0.06 to 2.64 hectare per household. Since the land holdings of household is widely distributed, the productivity of their farms was also varied in the same way. The mean productivity of farm was 3.25 metric tons per hectare and found to distributed between 0.06 to 17.50 metric tons per hectare. The average annual revenue from mandarin production was NRs 224,884.16 per household ranging from NRs 2,520.00 to NRs 1,225,000.00 per household. Average number of economically active members was 3.55 per household (min. 1.00 and max. 7.00).

Adoption of Sustainable Agriculture Practices

Sustainable soil and water management practices

Soil and water are the scare farm resources and easily get degraded during crop production. These are crucial for food, feed and fiber supply and maintains the terrestrial and aquatic ecosystems (Jie et al., 2002). Among the various soil and water management practices, application of organic manure, judicious use of chemical fertilizers, implementation of conservation tillage, cultivation of cover crop, mulching, soil chemical analysis and localized irrigation methods were taken as the indicators to study if farmers adopt sustainable soil and water management practices in the study area (**Figure 2**).

About 98.33% the farmers of the study area were found to apply organic manure at least once a year. Addition of organic manure helps soil biological, physical and chemical properties to improve and enhance its sustainability for crop production (Komatsuzaki & Ohta, 2007). In contrast, only few i.e., 8.30% of the farmers were applying chemical fertilizers in judicious way while remaining 91.67% were unaware about proper application methods, application doses and time. This may disrupt the soil properties, damages the soil micro-biome, causes water and soil pollution and even phytotoxicity. Conservation tillage, which is another major technique to be adopted to extend the sustainability of soil, ensures the productivity of soil by reducing loss of arable land, maintains permanent soil cover, promote plant diversity and makes agriculture more climate resilient (El-Beltagi et al., 2022). It was adopted by 78.33% of the farmers.

Mandarin orchards need frequent tillage either to incorporate manures or to control weeds, but frequent manipulation of soil enhances the erosion. Rest 21.67% of farmers were found to prefer to manipulate soil as maximum as possible. Similarly, 42.50% of farmers were cultivating cover crops such as cowpea, soybeans and black gram at least once a year. Integration of such large foliage nitrogen fixing crops in the orchard reduces the splash erosion by rain drops, reduces the water velocity during rainfall, enhances the infiltration, supplies additional nitrogen and organic matter to the soil (Komatsuzaki & Ohta, 2007) and control the orchard weeds. Mulching is the agronomical practice of leaving non-soil material on the soil surface with the aim of conserving soil and water (Jordán et al., 2010). Mulching either organic or synthetic was done by 19.17% of the mandarin farmers while remaining 80.83% were never cover their orchard with none of the mulching materials.

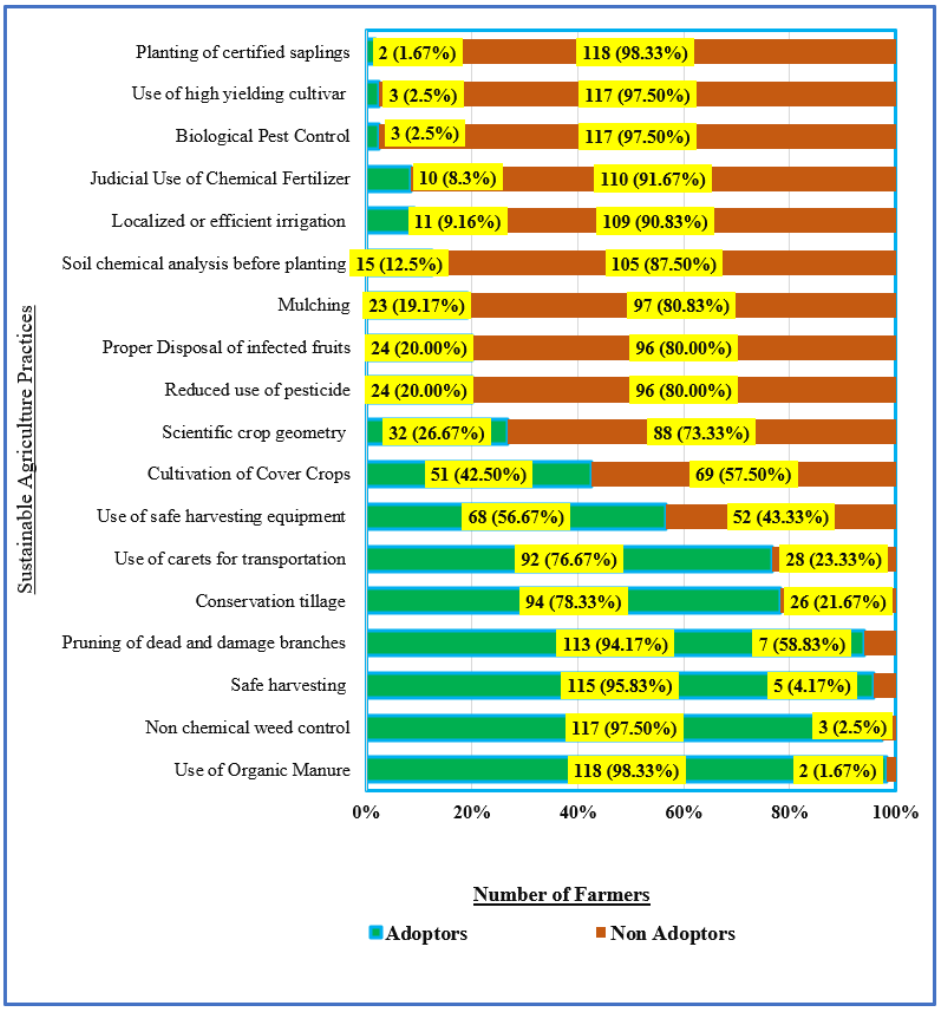

Figure 2. Commonly adopted sustainable agriculture practices among mandarin farmers in Salyan, Nepal (Source: Field survey, 2023)

Organic mulching is done by using agricultural wastes such as crop stubbles, straw, chaffs or fallen tree leaves, which improves the soil condition by adding up organic matter (Prosdocimi et al., 2016) whereas synthetic mulching can be done by synthetically manufactured plastic materials, which controls weed, conserve the soil but do not add up any organic matter to the soil (El-Beltagi et al., 2022). Laboratory analysis of soil chemical properties is must important to find out the pH and nutrient availability in the soil hence soil nutrient management becomes easier. Merely 12.50% of the mandarin farmers had tested their soil before plantation of saplings while 87.50% have never done any kind of soil chemical analysis. Also, only 9.16% of the total mandarin farmers were using localized irrigation techniques either via drip irrigation or point irrigation method by placing the water pipe near the tree trunk while 90.83 % of the farmers either used flooding via water channel or used sprinkles. Efficient use of water lowers the cost of production, enhances the crop production and ensure the sustainable food security (Russo et al., 2014).

Sustainable agronomic and orchard management practices

Planting materials such as seeds, seedlings or saplings should be of reliable and certified to ensure the desirable plant growth and production. Very few i.e., 1.67% of the farmers responded that they had planted good quality, disease free and certified planting materials while remaining 98.33% farmers used uncertified planting materials either locally exchanged or farm produced. Focus group discussion and key information interviewee also confirmed that most of the farmers even do not know the cultivar of mandarin they planted. Similarly, merely 2.50% of the farmers had planted high yielding cultivars while 97.50% planted locally available cultivar without considering the productivity of the cultivar. Scientific crop geometry of at least 6×6 meters was found to be maintained by 26.67% of the mandarin growing farmers while rest 73.33% of the farmers planted with their own generalization. Pruning of dead and damaged branches is utmost important to reduce the disease spreading in the orchard (Krajewski & Krajewski, 2011). About 94.17% of the farmers were found to prune such unwanted branches at least once a year while rest 5.83% never did so. Similarly, 97.50% of the farmers were found to prefer to control weed by non-chemical methods such as manual weeding or adopting mulching practices while 2.50% used herbicides to control orchard weeds. Tillage, manual or mechanical weeding are the applicable alternative of hazardous herbicides (Mia et al., 2020). As told by key informants, only few i.e., 20.00% of the farmers were disposing the fallen and infected fruits properly while 80.00% of them were unaware about proper disposal techniques and used to leave the infected fruits in the

Table 5. Factors affecting adoption of multiple sustainable agriculture practices using probit regression model

Explanatory variables	Coefficient	Standard error	z value	p value	dy/dx
Age of household head (years)	0.0183	0.0019	1.050	0.295	0.002
Gender of household head	1.5350**	0.0748	2.110	0.035	0.174
Schooling of household head (years)	0.1163	0.0095	1.350	0.176	0.013
Experience in years	-0.0475	0.0033	-1.550	0.122	-0.005
Access to internet	1.8754***	0.0732	2.540	0.010	0.213
Access to radio/television	-0.3044	0.0526	-0.650	0.516	-0.035
Distance to input market	0.0798**	0.0041	2.030	0.043	0.009
Total land holdings (hectare)	1.3799*	0.0885	1.670	0.096	0.157
Access to agriculture credit	1.0990	0.0889	1.370	0.172	0.125
Membership on cooperatives	-0.5101	0.0884	-0.650	0.518	-0.058
Access to subsidy	-0.8205	0.1027	-0.900	0.370	-0.093
Land tenure	-0.1541	0.0926	-0.190	0.850	-0.018
Mandarin production (metric tons)	-0.1759	0.0235	-0.840	0.402	-0.020
Annual revenue (NRs)	0.0000	0.0000	-0.150	0.882	0.000
Availability of human labor	2.0318***	0.1271	3.040	0.002	0.231
Access to forest resources	0.1978	1.1270	0.180	0.860	0.022
Economically active members (numbers)	-0.0678	0.0214	-0.360	0.720	-0.008
Constant	-3.2481*	1.8800	-1.730	0.084	

Note: ***, **, & * represents significance at p<0.01, p<0.05, 6 p<0.1, respectively; Numbers of observations=120; Log likelihood=-24.770; LR Chi-square=48.370***; Prob>Chi-square=0.0001; & Pseudo R-square (R2)=0.4940

orchards. Proper disposal of infected fruits is necessary to reduce the disease and pest infestation in the orchard.

Sustainable pest control practices

Biological pest control was not in the preference of mandarin farmers in the study area. Merely 2.50% of them were implementing biological pest control techniques such as biopesticides, use of traps, parasites or parasitoids. Remaining 97.50% of them were adopting chemical pest control measures, this might be due to lack of cost efficient and effective biological pest control alternative.

Similarly, 20.00% of the farmers were found to switch to chemical pest control at last option or prefer to reduce the use of pesticides as much as they can while rest 80.00% of them were using pesticides as their first option or never tried biological pest control measure. Rational use of pesticides under the principle of integrated pest management should be adopted to create sustainability in farming system (Ekström & Ekbom, 2011).

Sustainable harvesting and post-harvest practices

Harvesting techniques also determines the sustainability of fruit orchards. About 56.67% of the farmers were using safe harvesting equipment such as secateurs or cutting knives to detach the fruit from mother plant. Unusual twisting and forcibly pulling of fruits may damage the branches and reduces the fruit quality. However, 43.33% of farmers never used such safe harvesting equipment. Similarly, 95.83% of them were harvesting fruits safely either keeping them in safe bag or basket while 4.17% of farmers never used such safe holding materials and prefer to harvest either shaking the tree or throwing the fruits from the tree and collecting them again.

Furthermore, 76.67% of farmers were using safe carets for transportation while 23.33% of them were transporting fruits either in bamboo basket or sacks. Manual harvesting requires less initial cost but may require huge operational cost while mechanical harvesting is efficient, requires large initial investment but needs special orchard management such as balance hedge row, height of tree and so on (Sanders, 2005).

Determinants of Adoption of Sustainable Agriculture Practices

Adoption of SAPs depends on various demographic and socio-economic attributes. Thus, probit model was used to assess the factors determining the adoption intensity of SAPs among the citrus growing farmers in Salyan district of Karnali province, Nepal (**Table 5**).

Among the various factors included in the regression model, gender of the household head, access to internet, distance of market for farm inputs, total land holdings of the household and availability of human labor force were major factors, which had significantly enhanced the probability of farmers' adoption of multiple SAPs whereas farmer's experience, access to radio and television, membership on cooperatives, access to subsidy, land tenure, production of mandarin and economically active members had negative influence on SAPs adoption probability. When the age of the household head increases with one year, the probability of adopting more SAPs would increase by 0.20%, however this increment was statistically non-significant.

The result supported the findings of (Oyetunde-Usman et al., 2021) who found that the age of household head significantly increases the numbers of SAPs adopted by the farmers. This may be due to accumulation of experience farming activities. If the household head is male, then the probability of adopting SAPs would increase with 17.40%, which was found statistically significant at 5% level of significance, which might be due to unequitable resources and inputs access between male and female household heads. This was in line with the researchers (Oyetunde-Usman et al., 2021) who found that, female headed households are less likely to adopt more sustainable practices in Nigeria. Similarly, years of schooling of household head when increases by 1.00 year, the probability of adopting more SAPs would increase by 1.30% but found statistically non-significant.

Similar finding was reported by (D'souza et al., 1993) in the United States, where education was found to significantly increase the adoption probability of multiple sustainable agriculture would decrease by 0.50%. Increased experience with new technologies might be fruitful but repetition of traditional farming knowledge over the rarely improves the sustainability of the farms. Alwedyan and Taani (2020) also found that, probability of adopting multiple SAPs would decrease with increasing farming experience.

Farmers' access to internet had shown positive relation with adoption of SAPs. Farmer with access to internet, was found to increase the probability of SAPs adoption by 21.30% and was statistically significant at 1% level of significance. On the other hand, if the farmer has access to conventional mass media, the probability of adopting SAPs would decrease by 3.50%, however the decrement was found statistically non-significant. The distance that farmers travel to purchase farm inputs surprisingly had negative influence on adoption probability of SAPs. It was found that, when the distance of input market increases the adoption probability also increases by 0.90% and found to be statistically significant at 5% level of significance. This might be due to the fact that local retailers cannot supply required quantity of inputs at reasonable price, farmers need to travel more distances to bigger market. However, result was in contrast with (Oyetunde-Usman et al., 2021). Likewise, total land holding of household when increased by one hectare, the probability of adopting more numbers of SAPs would significantly increase by 15.70%. Since the agriculture credit is useful to maintain the regular input supply in the farm and motivates farmers to adopt multiple SAPs in their farms, its accessibility had shown positive influence on adoption probabilities. If the farmer has access to agriculture credit, the probability of adopting more numbers of SAPs would increase by 12.50%, however this increment was statistically non-significant. Similar results were found by researchers (Ehiakpor et al., 2021) in Ghana. In contrast, if the farmer has membership of cooperatives, then the probability of adopting SAPs would reduce by 0.58% but was found statistically non-significant. Focal group discussion and key information interviewee revealed that most of the agricultural cooperatives in the district supply agrochemical including fertilizers and pesticides at cheaper rate, hazardous uses may happen resulting into reduced sustainability of the farms. Interestingly, the annual revenue of household had neutral effects on probability of SAPs adoption. When the annual revenue increase, the probability of adoption of SAPs would not change but was statistically non-significant. Availability of human labor on time during various orchard management operations had positively influenced the adoption of multiple SAPs. When the farmer had adequate labor supply in the market the adoption will increase by almost by 23.10%, which was statistically significant at 1% level of significance. If the farmer has access to forest resources, the probability of adopting more numbers of SAPs would also increase by 0.22%, however, this increment was found statistically non-significant. Farmers use forest leaflitters as organic mulching materials, which covers the soil surface, reduce erosion, adds organic matter to the soil and promotes in non-chemical weed control, accessibility to forest resources helps farmers to adopt multiple SAPs. And total numbers of economically active members in household had influenced negatively on adoption probability of SAPs. When numbers of economically active members increase, adoption probability of SAPs would decrease by 0.80%, but was statistically non-significant. Access to subsidies also was negatively influencing adoption probability of SAPs. When farmer has access to subsidy either in cash or kind, probability of adopting more numbers of SAPs decreases by 0.93%. This might be due to the fact that subsidized inputs such as agrochemicals are distributed to the farmers or they prefer to use less labor-intensive inputs such as fertilizers in their farm if cash is provided, which was supported by key informant interviewees. Similarly, when farmer owns his land, the probability of adoption of SAPs would decrease by 0.18%. Also, annual production of mandarin also had negative influence on adoption of SAPs. When annual mandarin production increases with 1.00 ton per hectare, probability of adopting more SAP would decrease by 0.20%, which might be due to higher efficiency of fertilizers and pesticides, but production may not continue for long term.

CONCLUSIONS AND RECOMMENDATIONS

Various SAPs adoptable in the mandarin farms were identified and their adoption scenario and determinants were assessed through this study. Adoption determining factors including demographic, socio-economic and resource accessibility were estimated, which covered up the reduceable research gaps of previous researchers. The results revealed that majority of the farms were fairly low (39.17%) and fairly high (31.67%) category of SAPs adoptions then followed by high adoption (15.00%) and low adoption (14.17%) category. Poor adoptions of sustainable soil and water management, pest control, agronomic and orchard management and post-harvest handling practices were due to lack of technical knowhow, limited resources and limitation of efficient sustainable alternatives. Gender of the household head, access to internet, distance of market for farm inputs, total land holdings of the household and availability of human labor force were the major determinants of adoption of SAPs in the district. Male household heads were most likely to adopt multiple SAPs as compared to female. If farmer has access to internet and availability of human labor is easy, then the probability of adoption of SAPs would significantly increase by 21.30% and 23.10% respectively. In contrary, membership of cooperatives and access to subsidy were influencing negatively on adoption of SAPs.

Farm level policies seemed to be formulated and should be pushed through fast route for their implementation. Roles of agriculture cooperatives should be regulated towards extension of SAPs and eco-friendly inputs supply instead of focusing on chemical fertilizers and pesticides supplying. Similarly, mode of subsidies such as agrochemicals including fertilizers and pesticides should be replaced by environmentally friendly nutrient sources like vermicompost, quality manures and sustainable pest management measures including IPM tactics should be focused. Notwithstanding, government should focus on improving extension services with trainings, demonstration and field workshop to enhance the farmers knowledge about SAPs.

Limitation of the Study

The present research is based on primary data collected during field survey since secondary source information was rarely available. The technical suitability of SAPs needs to be studied scientifically before recommendation. The adoptability of any farming practices is influenced by dynamic sorts of endo and exogenous factors, which may differ over the locations. However, the study can be useful for program planning, policy formulation and implementation.

Author contributions: SD: designed survey, prepared questionnaires, conducted field survey, analyzed data, & wrote paper; **BD, RKD, PB, AB, & PA:** helped during survey design, data collection, & data input; & **MB:** supervised during survey design & analysis. They all agree with the results and conclusions.

Funding: No funding source is reported for this study.

Declaration of interest: No conflict of interest is declared by the authors.

Ethical statement: The authors stated that the study did not require approval from the institutional ethics committee. Highest ethical practices were followed during the study.

Data sharing statement: Data supporting the findings and conclusions are available upon request from corresponding author.

REFERENCES

Alwedyan, S., & Taani, A. (2020). Citrus farmers adoption of sustainable agriculture practices and its determinants in the Jordan Valley: The case of Northern Ghor. *Journal of Sustainable Development, 14*(1), 36-51. https://doi.org/10.5539/jsd.v14n1p36

Baral, P., Paudel, R., Kharal, S., & Khadka, A. (2020). Organic agriculture in Nepal: Policies and practices. *Journal of Institute of Agriculture and Animal Sciences, 36*(1), 279-289. https://doi.org/10.3126/jiaas.v36i1.48430

Baral, R., Kafle, P. B., Panday, D., Shrestha, J., & Min, D. (2021). Adoption of good agricultural practices to increase yield and profit of ginger farming in Nepal. *Journal of Horticultural Research, 29*(1), 55-66. https://doi.org/10.2478/johr-2021-0009

Belbase S., Tiwari A., Baral S., Banjade S., & Pandey D. (2020). Study of improved mandarin (citrus reticulata blanco) orchard management practices in mid hills of Gandaki Province, Nepal. *Malasiyan Journal of Sustainable Agriculture, 4*(2) 49-53. https://doi.org/10.26480/mjsa.02.2020.49.53

D'souza, G., Cyphers, D., & Phipps, T. (1993). Factors affecting the adoption of sustainable agricultural practices. *Agricultural and Resource Economics Review, 22*(2), 159-165. https://doi.org/10.1017/s1068280500004743

Ehiakpor, D. S., Danso-Abbeam, G., & Mubashiru, Y. (2021). Adoption of interrelated sustainable agricultural practices among smallholder farmers in Ghana. *Land Use Policy, 101*, 105142. https://doi.org/10.1016/j.landusepol.2020.105142

Ekström, G., & Ekbom, B. (2011). Pest control in agro-ecosystems: An ecological approach. *Critical Reviews in Plant Sciences, 30*(1–2), 74-94. https://doi.org/10.1080/07352689.2011.554354

El-Beltagi, H. S., Basit, A., Mohamed, H. I., Ali, I., Ullah, S., Kamel, E. A. R., Shalaby, T. A., Ramadan, K. M. A., Alkhateeb, A. A., & Ghazzawy, H. S. (2022). Mulching as a sustainable water and soil saving practice in agriculture: A review. *Agronomy, 12*(8), 1-31. https://doi.org/10.3390/agronomy12081881

FAO. (1995). Sustainable agriculture and rural development–An atlas of food and agriculture. *Food and Agriculture Organization of the United Nations*. www.foa.org

Jie, C., Chen, J.-Z., Tan, M.-Z., & Gong, Z.-T. (2002). Soil degradation: A global problem endangering sustainable development. *Journal of Geographical Sciences, 12*(2), 243-252. https://doi.org/10.1007/BF02837480

Jordán, A., Zavala, L. M., & Gil, J. (2010). Effects of mulching on soil physical properties and runoff under semi-arid conditions in southern Spain. *Catena, 81*(1), 77-85. https://doi.org/10.1016/j.catena.2010.01.007

Komatsuzaki, M., & Ohta, H. (2007). Soil management practices for sustainable agro-ecosystems. *Sustainability Science, 2*(1), 103-120. https://doi.org/10.1007/s11625-006-0014-5

Krajewski, A. J., & Krajewski, S. A. (2011). Canopy management of sweet orange, grapefruit, lemon, lime and mandarin trees in the tropics: Principles, practices and commercial experiences. *Acta Horticulturae, 894*, 65-76. https://doi.org/10.17660/ActaHortic.2011.894.5

Manda, J., Alene, A. D., Gardebroek, C., Kassie, M., & Tembo, G. (2016). Adoption and impacts of sustainable agricultural practices on maize yields and incomes: Evidence from rural Zambia. *Journal of Agricultural Economics, 67*(1), 130-153. https://doi.org/10.1111/1477-9552.12127

Mia, M. J., Massetani, F., Murri, G., & Neri, D. (2020). Sustainable alternatives to chemicals for weed control in the orchard–A review. *Horticultural Science, 47*(1), 1-12. https://doi.org/10.17221/29/2019-HORTSCI

MOALD. (2021). Statistical information on Nepalese agriculture. *Ministry of Agriculture and Livestock Development*. https://moald.gov.np/publication-types/agriculture-statistics/

Muthén, B. (1979). A structural probit model with latent variables. *Journal of the American Statistical Association. 74*(368), 807-811. https://doi.org/10.1080/01621459.1979.10481034

Oyetunde-Usman, Z., Olagunju, K. O., & Ogunpaimo, O. R. (2021). Determinants of adoption of multiple sustainable agricultural practices among smallholder farmers in Nigeria. *International Soil and Water Conservation Research, 9*(2), 241-248. https://doi.org/10.1016/j.iswcr.2020.10.007

Piscart C., Genoel R., Doledec S., Chauvet E., & Marmonier P. (2009). Effects of intense agriculture practices on heterotrophic processes in streams. *Environmental Pollution, 157*(3), 1011-1018. https://doi.org/10.1016/j.envpol.2008.10.010

Prosdocimi, M., Tarolli, P., & Cerdà, A. (2016). Mulching practices for reducing soil water erosion: A review. *Earth Science Reviews, 161*, 191-203. https://doi.org/10.1016/j.earscirev.2016.08.006

Raut, N., Sitaula, K. B., Vatn, A., & Paudel, S. G. (2011). Determinants of adoption and extent of agricultural intensification in the central mid-hills of Nepal. *Journal of Sustainable Development, 4*(4), 47-60. https://doi.org/10.5539/jsd.v4n4p47

Reganold, J. P., Papendick, R. I., & Parr, J. F. (1990). Sustainable agriculture. *Scientific American, 262*(6), 112-121. https://doi.org/10.1038/scientificamerican0690-112

Russo, T., Alfredo, K., & Fisher, J. (2014). Sustainable water management in urban, agricultural, and natural systems. *Water, 6*(12), 3934- 3956. https://doi.org/10.3390/w6123934

Sanders, K. F. (2005). Orange harvesting systems review. *Biosystems Engineering, 90*(2), 115-125. https://doi.org/10.1016/j.biosystemseng.2004.10.006

Velten, S., Leventon, J., Jager, N., & Newig, J. (2015). What is sustainable agriculture? A systematic review. *Sustainability, 7*(6), 7833-7865. https://doi.org/10.3390/su7067833