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Determinants of the adoption of different good agricultural practices (GAP) in the command area of PMAMP apple zone in Nepal: The case of Mustang district

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ABSTRACT

The study was carried out to determine the factors affecting the adoption of good agriculture practices (GAP) for apple production in the Prime-Minister Agriculture Modernization Project's (PMAMP) apple zone of Mustang district. Altogether, 100 households from Thasang and Gharapjhong rural Municipalities were chosen for the study by a stratified random sampling technique. Descriptive statistical tools, logistic regression and *t*-test were used to analyze the data which were collected from the semi-structured interview schedule. Out of the ten selected good agriculture practices standards, intercropping practices were adopted by the majority of respondents (83%) while the ring method of irrigation (19%) was found to be the least adopted. The magnitude of logistic regression coefficients of good agriculture practices revealed that occupation was a highly significant ($p < 0.01$) socio-economic variable influencing the adoption of good agriculture practices. Similarly, age, apple cultivated land, economically active population, institutional involvement, and loan for apple cultivation was also found significant ($p < 0.05$) for the adoption of different good agriculture practices. From the independent *t*-test, the productivity of apples was found significantly different between the farmers with and without: recommended nutrient management system, intercropping ($p < 0.05$), recommended pit dimension and irrigation interval ($p < 0.10$). The major problem in apple production were also identified. Based on the findings, increase in apple cultivated land, increase number of apples growing farmers, active role of institution and availability of credit to farmers are suggested to increase the adoption of different GAP in apple. The problems identified in apple production shall be prioritized to boost apple production and marketing. The policy makers and practitioners should prioritize the significant socio-economic characters and determinants in different stages of planning and implementation of program and policies.

1. Introduction

Apple (*Malus domestica*) is one of the high-value agricultural commodities of Nepal [1]. It is one of the major fruit crops of Nepal in terms of the potential growing area, production, and domestic consumption. There is very high demand of apple in Nepal and Mustang is recognized over the country for the quality of apples produced [2]. Furthermore, the implementation of the High-Value Agriculture

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Project (HVAP) in the past, prioritized apple (in Mustang) as one of the seven commodities due to its high impact on the life of rural people of the project areas. The One District One Project (ODOP) program also recognized Mustang as the center for apple production. Similarly, the ten year long (Fiscal Year 2073–2082 B.S.) Prime Minister Agriculture Modernization Program (PMAMP) has named the district as the "Zone of Apple" (Commercial agriculture production and processing center development program).

However, the productivity of apples in Nepal is only 8.20 Mt/ha [3] which is below the average productivity of the world i.e., 18.70 Mt/ha [4]. Besides, farmers are facing various troubles during production. The frost is one of the major risk factors for apple growers. Along with it, disease and pests have been causing serious damage in apples. Most farmers use grafts as the planting materials [5,6,7] which inertly carry the pathogens from the mother plant, and poor orchard management practices pose a great threat due to disease and pest occurrence [8]. In this context, the prodigous application of pesticides leads to residue amounts in the fruit [9,10]. In Nepal, pesticide residue in fruit crops is reported to be about 0.029 kg ai/ha [1]. The conventionally produced temperate fruits, like apples, gives a low yield and is inferior in quality in Nepal [11]. Despite the increasing area under apple cultivation, productivity remains the same because of the lack of adoption of good agricultural practices (GAP) among the farmers, which is a cause for the low profitability of apple sub-sector. To reduce the existing yield gap, farmers must adopt good agricultural practices [1].

Despite the prioritization of apples as major commodities by different projects, the challenges currently being faced by Nepal include the absence of standards for GAP in apple farming. Most of the food safety standards are fixated on end products, whether it is obligatory technical standards or voluntary standards (DFTQC, 2018). Good Agricultural Practices (GAP), as defined by the Food and Agriculture Organization (FAO) [12], are a "collection of principles to apply for on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economic, social and environmental sustainability". The implementation of GAP during on-farm production and post-production processes develops safe agricultural products which is of immense importance for ensuring a safe food supply [13]. Many importing countries as well as domestic buyers especially organized retail are necessisating producers to execute GAP as a pre-requisite for procurement to safeguard the quality and safety of their produce [14]. In addition, implementing GAP also helps advancement of sustainable agriculture and aids in meeting the national and international environment and social development objectives [15]. It has been reported that the implementation of GAP inspires the promotion of optimum use of resources such as pesticides, fertilizers, water, and eco-friendly agriculture [16]. Its social facet would be to safeguard the agricultural workers' health from indecorous use of chemicals and pesticides. It is observed that the second generation of revolution in agriculture is centered on both the government and the agro-processing industry of countries. With a common standard as a basis for South-Asian Assoication for Regional Cooperation (SAARC) Region, adoption of GAP helps to promote regional trade. In this context, the Government of Nepal endorsed the Nepal Good Agricultural Practices (NepalGAP) Directives on October 15th, 2018. The GAP standard in the directive specifies the requirements to be met with respect to good agriculture practices in the farms for the production of fruits and vegetables in the form of five modules. The food safety module and general requirement module are compulsory among the five modules [14]. Each module is conceptualized as a full section incorporating criteria/requirements and their levels of control that should be implemented in a farm (whether a single unit or a group of farms coming under a common group with internal management) [14]. The criteria are categorized into three: "Critical (required to maintain the integrity of the produce, ensures complete food safety)", "Major (mandatory requirements)" and "Minor (may not be essential and depends on produce category)".

In context with our study, the modules with their practices and the criterias follow accordingly– the Food Safety module: includes the use of certified planting materials (six major criteria), fertilizers and soil additives (Plant Nutrient Management and Fertilizer Use - five major, two minor, and two critical criterias), and water (Irrigation/Fertigation – three major, two minor and two critical criterias). The produce quality module includes the irrigation interval while the environment management module includes site history and management (three major and one critical criteria). Our study incorporates the adoption of such practices which fall under different modules having different category of criterias and those which were prioritized by the apple growers of Mustang district.

The adoption of GAP is critical to recuperating agricultural sustainability [17]. However, there is an extensive accord that their adoption rates have been low in many countries. Therefore, accepting this phenomenon is indispensable to maximize GAP adoption. Many studies have attempted to understand the adoption of such practices. Their findings, as reviewed by Refs. [18,19,20,21,22], collectively suggest that adoption depends on diverse factors like socio-economic, agro-ecological, organizational, informational, and psychological factors, as well as realized attributes [23]. reported that the adoption of GAP in rice is related to household labor constraints, land ownership, and initial expectations regarding the marketing prospects of the GAP-produced rice [24]. reported that the income variable significantly affected the adoption of GAP in Thailand. Similarly [1], reported age to be an important factor in determining awareness about GAP in bananas. Furthermore, a research by Ref. [25] in Thailand reported that the determinants of farmers' perception towards adoption of GAP in rice were gender, education, farmland size, access to credit, income from crop production, contact with extension agents, receiving agricultural information, and receiving training [26]. in their study in Nigeria reported that factors such as the age of household head, gender, education, household size, access to extension services, and household wealth status affect adoption of sustainable agricultural practices. A distinct study by Ref. [27] in Africa, reported that adoption of GAP in long term can help reduce the yield gap, thus signifying the importance of determining the factors affecting GAP.

The knowledge on the significant socio-economic factors affecting the GAP practices will help the policy makers, practitioners and the concerned stakeholders to focus on the respective determinants of GAP during policy making, discussion and program implementation. Furthermore, food safety and food security can be assured if the significant determinants are identified and addressed. However, there is no research on determinants of adoption of GAP in apple fruits in Nepal. Thus, the study was aimed to identify the major factors affecting the adoption of GAP in apple production and also to assess the major problems in apple production in the study area.

2. Materials and methods

2.1. Study site

The research was carried out in the Mustang district, Gandaki Province of Nepal (Fig. 1). The study area included the command areas of the Prime Minister Agriculture Modernization Project (PMAMP), Project Implementation Unit (PIU), Apple Zone i.e., Thasang, and Gharapjhong Rural Municipality. The reason for the selection of these areas is due to the regions (Lower Mustang) being a major domain of apple production in the district [2]. Previously ODOP (One District One Project) program was also implemented in these areas. Due to the consequence of this, the farmers have extended the area under cultivation of apples.

2.2. Sample and sampling technique

A list of apple-growing farmers from each rural municipality was prepared separately, provided by PMAMP PIU, Apple zone, Mustang. It was used as the sampling frame to select the respondent farmers. We included the leading farmers and apple growers in the sampling frame. The apple growers of each area were selected by stratified random sampling method. The interview schedule was done in the top apple-producing wards of Thasang rural municipality (n = 50) and Gharapjhong Rural Municipality (n = 50). Key Informant Interview (KII) and focus group discussions (FGD) was done so as to represent the small farmers, leading farmers, subject matter specialists, and concerned stakeholders.

2.3. Research design and data analysis

Data collection was done through personal interviews. Based on the interview schedule and checklist, questions were asked with the respondents to gain the proposed information. KII and FGD were carried out to triangulate data and information obtained from interview schedule and to obtain additional qualitative information. Primary and secondary data were collected and analyzed. Apple producers were the major sources of primary data. Secondary information was collected from the document of the different organizations/institutions.

Information collected from the field survey was coded and tabulated on Excel. Analysis was done using the Stata Version 16.

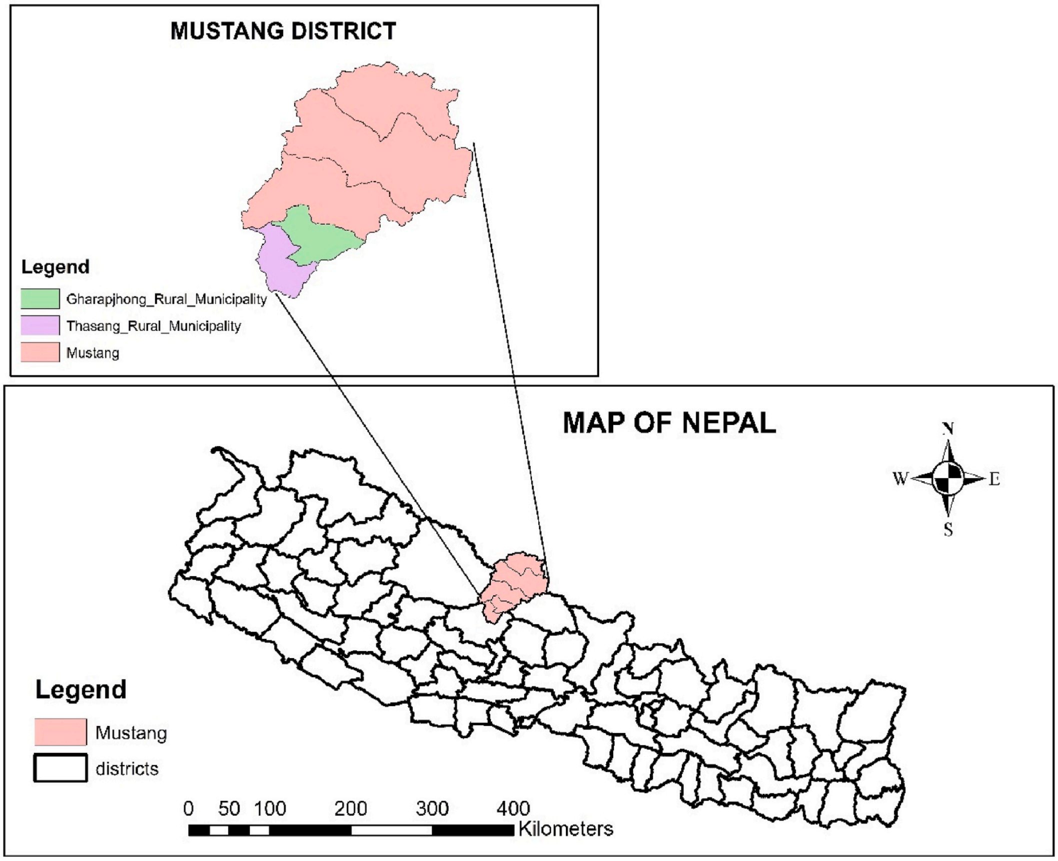

Fig. 1. Map of Nepal showing the study area.

Descriptive statistics such as frequencies and percentages were calculated. Logistic regression model was used for analyzing the effect of different variables on different practices under GAP.

Logit regression model was chosen because there is a widespread literature showing that farmer awareness can be analyzed using this model. The dependent variable for this study was the farmer's adoption of different GAP practices (Table 1): with a value of 1 (if the farmer adopts a given GAP) and 0 (for otherwise). The independent variables with their values are shown in Table 1.

This model predicts the logit of the response variable (adoption of GAP) from the independent variable(s). In this process marginal fixed effects were also calculated to determine the probability of different factors (marginal effect) under study to determine the adoption of good agricultural practices. The logistic model was used to analyze the binary or dichotomous response which allows examining how a change in any independent variable changes all the outcome probabilities.

2.4. Statistical analysis

The likelihood of the farmers adopting a GAP practice is predicted by odds ($Y_i = 1$); that is, the ratio of the probability that $Y_i = 1$ to the probability that $Y_i \neq 1$ is shown below in Eq. (I):

$$\text{Odds } Y = P(Y_i = 1) / (1 - P(Y_i = 1)) \tag{I}$$

$$\text{If } Y_i = 1;\ P(Y_i = 1) = P_i$$

$$Y_i = 0;\ P(Y_i = 0) = 1 - P_i$$

Where, $P_i = E(Y_i = 1|X)$ represents the conditional mean of Y given certain values of X.

The logit (Y) is given by the natural log of Odds as shown in Eq. (II) below:

$$\ln[P(Y_i = 1)/(1 - P(Y_i = 1))] = \log \text{Odds} = \text{Logit}(Y) \tag{II}$$

where ln = natural logarithm

The logistic transformation of the probability of the practicing adoption strategies is shown in Eq. (III) below:

$$Li = \text{Logit}(Y_i) = \alpha + \sum_{i=1}^{n} \beta i Xi + \varepsilon_i \tag{III}$$

Where,

Y_i = a binary dependent variable (1, if farmers adopting GAP practices, 0 otherwise),
X_i = vector of explanatory variables used in the model,
β_i = parameters to be estimated (coefficients of independent variables)
α = intercept
ε_i = error term of the model
L_i = Logit and $[P_i/1\text{-}P_i]$ = odd ratios for i = 1, 2, 3, 4 … n farm households

Thus, the binary logistic regression model used in the study was expressed as:

$Y_i = f(\beta_i X_i)$ = f (age of household head, family size, major occupation, ethnicity of respondent household, livestock holding by household, apple cultivated land of household, farming experience, education of household head)

The practices of GAP in our study (Table 1) were selected on the basis of FGD among apple farmers. The selected GAP practices were then further assessed from the GAP Scheme [14]. Although recent advances around the world in apple farming could be observed in case of Nepal, the adoption of these simple GAP practices is still lacking. Application of these GAP practices can help increase the yield in long term [27].

2.5. Ranking of problems

Problem for the production and marketing of apple were ranked with the help of forced ranking technique. The formula given below was used to determine the index for the intensity of problem faced during pre-production, post-production and marketing of apples.

$$I_{imp} = \sum \frac{S_i F_i}{N}$$

Where,
I_{imp} = Index of importance/severity for

i. Diseases
ii. Pests
iii. Production problems

Table 1
List of variables used in the model and their description.

Variables	Variable type	Description of variable	Description of GAP Practices
Dependent variables			
Certified planting materials	Binary	1 = Use of certified planting materials 0 = otherwise	Planting material certified by Government of Nepal/Verified agencies taken as reference
Recommended dose of Farmyard Manure (FYM)	Binary	1 = Recommended dose 0 = Otherwise	Application of FYM @15–25 kg/plant
Recommended pit size	Binary	1 = Recommended pit size 0 = otherwise	3 feet to 1 m size of pit
Farm direction	Binary	1 = South-west direction facing of apple farm 0 = otherwise	South-west facing apple farm is taken as reference
Nutrient management system	Binary	1 = Yes 0 = No	Application of nutrients at different stages as per age of plant
Irrigation method	Binary	1 = Ring method 0 = Others	Ring method of irrigation in apple is taken as reference
Intercropping	Binary	1 = Yes 0 = No	Intercropping practiced in recommended distance as per crop
Plant density	Binary	1 = Recommended rate 0 = No	300 to 500 plants per hectare is taken as reference
Weeding at interval	Binary	1 = Yes 0 = No	Weeding practice two times a year is taken as a reference
Irrigation Interval	Binary	1 = Recommended rate 0 = No	Irrigation in 15 days interval is taken as reference
Independent variables		**Description of variables**	
Age	Continuous	Age of the HH head in years	
Education	Continuous	Years of schooling	
Occupation	Dummy	1 = Agriculture 0 = others	
Economically active population	Continuous	Number of economically active population in the farmers' HH	
Institutional involvement	Dummy	1 = Yes 0 = No	
Loan for apple farming	Dummy	1 = Yes 0 = No	
Livestock Units	Continuous	Number of livestock	
Extension services	Dummy	1 = Yes 0 = No	
Years of experience	Continuous	Experience of apple farmers in years	
Cultivated land	Continuous	Area of apple cultivated land in hectares	

iv. Post production problems
v. Marketing problems
S_i = ith scale value
F_i = Frequency of ith importance/severity given by the respondents
N = total number of respondents

3. Results and discussion

3.1. Socio-economic and demographic characteristics

A total of 100 respondents were interviewed in a scheduled way, in which majority of the respondents (63%) were between the age range of 36–58 years, 85 (85%) were male and 15 (15%) were female. It indicates that male members possess more information and knowledge about the agricultural activities as compared to female in the study area. The overall average family size of study area was 5.55, which was higher than that of national average family size (4.88) in 2011 (CBS, 2011). The study revealed that the majority of the population in study area (71.35%) were economically active population (15–59 years old) which is higher than national percentage of economically active population in agriculture (64.00%) in 2011 [28] and the dependency ratio was observed to be 0.40. The major source of income was found to be agriculture as 55.00% of total population depend on agriculture whereas 45.00% of total population earn their living from non-agricultural sources. Most of the respondents were found to have secondary level of education (32%), followed by illiterate (28%), higher secondary (17%), primary (16%) and university (7%) level of education. In the study area, majority of the respondents were Janajati followed by Dalits, and Brahmin/Chhetri. Out of 100 respondents, 84% were Janajati followed by Dalits (10%) and Brahmin/Chhetri (6%).

3.1.1. Farm characteristics of the respondents

The total farm owned by the respondent measured in a certain unit is the land holding of the respondents. It is the sum of lowlands (khet) and uplands (bari). The total area under khet and bari was 974.5 ropani[1] and 112 ropani respectively while average land holding was 9.52 ropani khet and 4.5 ropani bari. Out of 1086.5 ropani area, mean irrigated land was found to be 9.51 ropani (87.57%) and mean unirrigated land was 1.35 ropani (12.42%) in the study area.

3.1.2. Livestock characteristics

Livestock is the integral component of farming system especially in the mid-hills of Nepal. Livestock holding of the study area was calculated in terms of Livestock Standard Unit (LSU) as shown below in Eq. (IV). The formula used to calculate LSU was:

$$\mathrm{LSU} = 1(\text{number of cow / bull / yak}) + 0.4(\text{number of goat}) + 0.4(\text{number of sheep}) + 0.1(\text{number of poultry}) + 1.5(\text{horse}) \quad \text{(IV)}$$

The major livestock reared in the study area were goat/sheep, cow/bull, poultry, yak and horse respectively with average livestock holding of 3.29 LSU.

3.2. Adoption of good agricultural practices

The standard requirements of the good agricultural practices recommended in the GAP standards for fruits and vegetables were taken into consideration for determining the farmers' adoption level. They were certified planting materials, recommended dose of farm yard manure (FYM) in pit, plantation in pit of recommended size, farm direction, weeding frequency, irrigation intercal, nutrient management system, irrigation method, intercropping and plant density.

3.2.1. Use of certified planting materials

Planting materials include seedling used for plantation of apple either from seed source or vegetative propagation (grafting). The planting materials produced in the government farms, Temperate Horticulture Development Center, research stations and private nurseries which have been certified from Nepal Government were used by most of the respondents in the study area. Among the respondents 69% used certified planting materials whereas 31% used uncertified planting materials (Fig. 2).

3.2.2. Direction of farm

Apple show best response in land facing south-west direction (2). The study showed that 55% of the respondents cultivate apple on south-west facing land and 45% of the respondents do not cultivate in south-west facing land (Fig. 2).

3.2.3. Plantation in pit of recommended dimension

The recommended size of pit should be 3 feet to 1 m in size (Acharya, 2015). The study revealed that 74% of the respondent's plant sapling in the pit of recommended dimension whereas 26% of the respondent's plant sapling in the pit of dimension of smaller than the recommended dimension (Fig. 2).

3.2.4. FYM application

The recommended dose of Farmyard Manure during planting is 15 to 25 kg per plant. (MoAD, 2016). The study showed that 63% of the respondents apply FYM within the recommended dose while 37% of the respondents apply other doses than recommended (Fig. 2).

3.2.5. Intercropping

To increase the efficiency of land use and economic returns, intercropping systems are very important for apple cultivation (Gao et al., 2013). Out of 100 respondents, 83% of the respondent's plant short duration crop leaving the canopy area as intercrops while 17% of the respondents do not intercrop (Fig. 2).

3.2.6. Nutrient management system

The proper application of FYM, chemicals, etc. according to the age of plant and as required by the plant falls under nutrient management system. The knowledge about nutrient management was studied and found that 54% of the respondents use nutrient management system whereas 46% of the respondents do not adopt nutrient management system (Fig. 2).

3.2.7. Method of irrigation

The recommended method of irrigation in apple is drip irrigation which is not in practice in Nepal. But to prevent the spread of diseases pipeline and ring method of irrigation is recommended for apple cultivation (3). We categorize respondents on the basis of recommended method. The study revealed that 19% of the respondents use ring method of irrigation whereas 81% of the respondents use other methods (Fig. 2).

3.2.8. Irrigation interval

Irrigation scheduling is done based on the water requirement of the plant. In case of apple irrigation is done at 15 days interval (3). The study revealed that 31% of the respondents irrigated at recommended interval while 69% of the respondents irrigated beyond the

[1] One Hectare equals 20 Ropani.

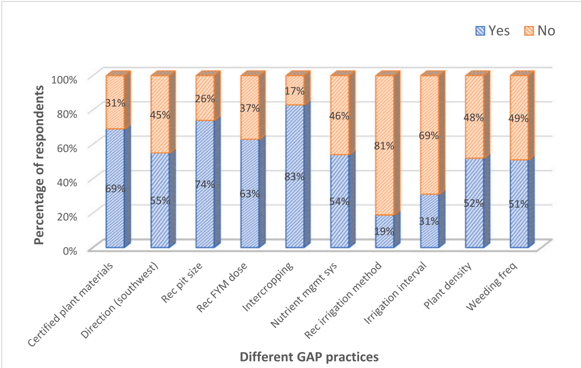

Fig. 2. Adoption level of different GAP practices by respondents.

recommended interval (Fig. 2).

3.2.9. Plant density

Under Ministry of Agriculture Development (MoAD), Asian Food and Agriculture Cooperation Initiative (AFACI) project has recommended number of plants per ropani ranges from 15 to 25 for medium size plant (MoAD, 2016). The study revealed that 52% of the respondent's plant apple within the recommended number per area while 48% of the respondent's plant apple beyond the recommendation number per area (Fig. 2).

3.2.10. Frequency of weeding

More than two times weeding is beneficial as it prevents the insect to hide on the bushes (2). The study revealed that 51% of the respondents practiced weeding more than two times while 49% of the respondents practiced less than two times (Fig. 2).

3.3. Factors determining adoption of GAP in apple production

The influence of socio-economic factor on GAP variables were determined through logistic regression analysis using STATA software. Various factors as socio-demographic and extension related factors affect the adoption of GAP. The study analyzed the effects of such independent variables on the adoption of GAP. Before, performing the regression, diagnostic tests were carried out to check the multicollinearity problem in the independent variables. None of the independent variables was found to have a significant correlation, suggesting no problem of multicollinearity. For regression analysis using the Logit model, different independent variables were used among which some were observed to be statistically significant. Factors with a p-value below 0.05 were sought to be statistically significant.

3.3.1. Use of certified propagation materials

A healthy planting material should be free from diseases and insects/pest. Good quality propagation materials should be used from reliable sources (Government office/registered private nurseries/tissue culture laboratories) [13]. The results shown in Table 2 revealed that the use of certified planting materials was not significantly affected by socio-economic variables but through marginal effect after logistic found education to be significant with use of certified planting materials at 10% level of significance. The marginal effect showed that, with one year of additional increase in schooling, the respondents are 21.5% less likely to use a certified planting material.

Similar results have been reported by Ref. [29] who reported a negative influence of formal education towards adopting genetically

Table 2
Influence of socio-economic variables on the use of certified planting materials.

Use of certified propagation materials	Odds Ratio	Std. Err.	Z	p>|z|	dy/dx	p>|z|
Age	1.008	0.031	0.28	0.781	0.001	0.781
Education	0.271	0.250	−1.41	0.158	−0.215	0.077*
Occupation	1.982	1.340	1.01	0.311	0.143	0.339
Economically active population	0.855	0.130	−1.02	0.309	−0.030	0.308
Institutional involvement	1.785	1.368	0.76	0.450	0.118	0.469
Loan for apple	0.603	0.533	−0.57	0.568	−0.105	0.591
Technical service	0.553	0.375	−0.87	0.383	−0.120	0.401
LSU	1.002	0.092	0.24	0.810	0.000	0.810
Log likelihood	−36.52					
Prob > Chi^2	0.3147					

Note: * indicates significant at 10% level.

modified crops. Similarly [25], also reported education to have significant effect on adoption of GAP in Thailand.

3.3.2. Direction of farm

The direction of farm also determines the production of apple as apple shows best response in land facing south-west direction [30]. From the study (Table 3), it was found that direction of farm was significant with LSU from logistic analysis and through marginal effect after logistic at 10% level of significance. With increase in number of livestock by one unit, the farmers are 0.4% more likely to choose the south-west direction of farm.

With the increase in number of livestock, the chosing of the south-west direction could be to acclimatize the cold weather by the animals in the district.

3.3.3. Dimension of pit

The pit should be prepared 15 to 30 days before planting. The recommended size of pit for fruit cultivation should be 1 m cube in size so that the roots have enough space for growth and nutrient uptake [30]. The results (Table 4) revealed that the use of recommended dimension of pit was found to be significant with age, institutional involvement and apple cultivated land at 10% level of significance through logistic analysis but through marginal effect after logistic found only age and apple cultivated land to be significant with use of recommended pit dimension at 5% and 10% level of significance respectively. With the increase in age of farmers by one year, the farmers are 1.1% more likely to grow apples in recommended dimension of pit.

Similar results were reported by Ref. [26] who revealed age as a significant determinant of sustainable agricultural practices. Older farmers are assumed to have gained knowledge and experience over time and are better able to evaluate technology information than younger farmers [31,32]. Similarly, with increase in cultivated land of apple by 1 unit, farmers are 2% more likely to grow apples in recommended dimension of pit. Farmers with large farm size are likely to adopt a new technology as they can afford to devote part of their land to try new technology unlike those with less farm size [33].

3.3.4. Recommended dose of FYM during planting

The results from both logistic analysis and marginal effect after logistic (Table 5), showed institutional involvement and apple cultivated land to be significant with FYM during planting. Similar result was reported by Ref. [34]. With the institutional involvement, the farmers are more likely to use recommended dose of FYM by 35.1%.

Involvement in an institution enhances social capital allowing trust, idea and information exchange [32]. Farmers within an institution learn from each other the benefits and usage of a new technology [33]. suggests that social network effects are important for individual decisions, and that, in the particular context of agricultural innovations, farmers share information and learn from each other. Studying the effect of community-based organization in adoption of corm-paired banana technology in Uganda [35], found that farmers who participated more in community-based organizations were likely to engage in social learning about the technology hence raising their likelihood to adopt the technologies. Similarly, with increase in cultivated land of farmers by 1 unit, farmers are more likely to use recommended dose of FYM by 1.8%. This could be due to the availability of excess of land out of which some may be devoted for the use of technology.

3.3.5. Intercropping

Intercropping has great importance from economic point of view as well as to conserve soil [36]. Intercropping with legumes help to add nutrient to the soil [36]. From the study (Table 6) it was found that economically active population have significant effect on intercropping at 5% level of significance from both logistic and marginal effect after logistic analysis. On increment of economically active members by a number, farmers are more likely to adopt the intercropping by 4.2%.

A similar finding was reported by Ref. [26], who found the household size to be a significant determinant of adoption of agricultural practices. Since intercropping requires a greater number of labor (family labor also), with the increase in economically active members in the family, more active family labor could be used for the purpose of intercropping practices [32].

Table 3
Influence of socio-economic variables on choosing direction of farm.

Direction of farm	Odds Ratio	Std. Err.	Z	p>|z|	dy/dx	p>|z|
Age	0.990	0.034	−0.29	0.776	−0.002	0.775
Education	0.867	0.666	−0.18	0.854	−0.033	0.854
Occupation	2.375	1.710	1.20	0.230	0.187	0.182
Economically active	0.938	0.133	−0.44	0.657	−0.014	0.657
Year of experience	1.036	0.040	0.93	0.353	0.008	0.353
Institutional involvement	0.870	0.617	−0.20	0.845	−0.032	0.846
Loan for apple	1.480	1.297	0.45	0.654	0.094	0.660
Technical service	0.674	0.455	−0.58	0.560	−0.090	0.550
LSU	0.982	0.010	−1.64	0.100*	−0.004	0.095*
Apple cultivated land	1.066	0.043	1.58	0.114	0.015	0.113
Log likelihood	−40.88					
Prob > Chi^2	0.4760					

Note: * indicates significant at 10% level.

Table 4
Influence of socio-economic variables on the use of recommended dimension of pit.

Dimension of pit	Odds Ratio	Std. Err.	Z	p>|z|	dy/dx	p>|z|
Age	1.071	0.038	1.90	0.057*	0.011	0.047**
Education	2.495	2.137	1.07	0.286	0.173	0.319
Institutional involvement	3.309	2.403	1.65	0.099*	0.230	0.124
Loan for apple	2.086	2.102	0.73	0.465	0.107	0.386
Technical service	1.247	0.909	0.30	0.761	0.036	0.755
LSU	1.003	0.012	0.31	0.753	0.000	0.753
Apple cultivated land	1.13	0.079	1.74	0.082*	0.020	0.050**
Log likelihood	−34.05					
Prob > Chi^2	0.086					

Note: * and ** indicates significant at 10% and 5% level respectively.

Table 5
Influence of socio-economic variables on the use of FYM during planting.

FYM during planting	Odds Ratio	Std. Err.	Z	p>|z|	dy/dx	p>|z|
Education	0.492	0.371	−0.94	0.347	−0.163	0.317
Occupation	0.448	0.315	−1.14	0.254	−0.181	0.213
Economically active populations	1.049	0.150	0.34	0.736	0.011	0.736
Year of experience	0.987	0.031	−0.41	0.254	−0.003	0.685
Institutional involvement	4.339	3.333	1.91	0.056*	0.351	0.038**
Loan for apple	2.430	2.314	0.93	0.351	0.196	0.288
Technical service	0.348	0.241	−1.52	0.129	−0.255	0.118
LSU	1.003	0.009	0.37	0.712	0.000	0.712
Apple cultivated land	1.081	0.049	1.71	0.088*	0.018	0.086*
Log likelihood	−39.63					
Prob > Chi^2	0.14					

Note: * and ** indicates significant at 10% and 5% level respectively.

Table 6
Influence of socio-economic variables on the use of intercropping.

Intercropping	Odds Ratio	Std. Err.	Z	p>|z|	dy/dx	p>|z|
Age	1.038	0.027	1.43	0.152	0.004	0.144
Education	1.335	1.045	0.37	0.711	0.035	0.724
Occupation	2.132	1.436	1.12	0.261	0.105	0.327
Economically active population	1.437	0.252	2.06	0.039**	0.042	0.024**
Loan for apple	1.009	0.762	0.01	0.990	0.001	0.990
Technical service	2.487	1.877	1.21	0.227	0.095	0.166
Apple cultivated land	1.005	0.042	0.14	0.890	0.0006	0.890
Log likelihood	−40.65					
Prob > Chi^2	0.196					

Note: ** indicates significant at 5% level.

3.3.6. Nutrient management system

Use of fertilizers, manure, etc according to age of plants is crucial for fruits production. The study revealed that education has significant effect on nutrient management system at 10% level of significance from logistic analysis but from marginal effect after logistic, education and institutional involvement have shown significant effect on nutrient management (Table 7). With additional

Table 7
Influence of socio-economic variables on the use of nutrient management system.

Nutrient management according to age of plant	Odds Ratio	Std. Err.	Z	p>|z|	dy/dx	p>|z|
age	1.023	0.025	0.92	0.359	0.005	0.359
Education	2.853	1.728	1.73	0.083*	0.245	0.057*
Year of experience	0.975	0.029	−0.82	0.410	−0.006	0.410
Institutional involvement	0.430	0.224	−1.61	0.107	−0.207	0.097*
Loan for apple	1.610	0.946	0.81	0.418	0.118	0.414
Technical service	1.608	0.818	0.93	0.350	0.118	0.348
Apple cultivated land	0.988	0.029	−0.40	0.689	−0.002	0.689
Log likelihood	−65.26					
Prob > Chi^2	0.383					

Note: * indicates significant at 10% level.

increment in the year of education, the farmers are 24.5% more likely to adopt the nutrient management while, the involvement of farmers is institution showed 20.7% less likely to adopt the nutrient management system.

Similar results have been reported by Ref. [5] who reported that education and involvement in extension related institution have a positive impact on nutrient management system in Chinese rice. Furthermore [1] reported education to have significant effect on adoption of GAP in banana cultivation in Nepal, while [25] reported both education and involvement in extension had significant effect on adoption of GAP in Thailnad. This is because higher education influences respondents' attitudes and thoughts making them more open, rational and able to analyze the benefits of the new technology [37]. This eases the introduction of a new innovation which ultimately affects the adoption process [38].

3.3.7. Method of irrigation

In order to provide adequate moisture, irrigation should be applied to the plant. Mostly drip irrigation has of great importance as low quantity of water can fulfill the entire requirement of plant but in Nepal ring method and irrigation through pipeline is commonly used. From the study it was found that socioeconomic factors have no significant effect on adoption of irrigation method.

3.3.8. Irrigation interval

Frequent irrigation at 15 days interval is recommended for fruit cultivation (3). The study found that age, occupation, economically active population, experience showed significant effect on irrigation interval at 10% level of significance from logistic analysis while from marginal effect after logistic, occupation showed significant at 1% level of significance (Table 8). With an additional increment in age by a year, farmers are 1.4% less likely to adopt appropriate irrigation interval. Similarly, if the occupation of the respondent is agriculture, the farmers are 6.1% more likely to adopt recommended irrigation interval. With the increment in number of economically active population by a number, the farmers are 5.8% more likely to adopt proper irrigation interval. Similarly, increment in the experience by a year tends to increase the likeliness to adopt the irrigation interval by 1.4%.

Similar results were reported by Ref. [39] who reported that experience has positive association with adoption of irrigation related technology. With the increase in age, the farmers realize the importance of irrigation and also if the occupation of people is agriculture, they are more concerned with the irrigation interval. The household with greater number of economically active population have the capacity to relax the labor constraints required during introduction of new technology [32].

3.3.9. Plant density

The study revealed that plant density was found insignificant with the socio-economic variables from logistic regression analysis and marginal effect after logistic.

3.3.10. Frequency of weeding

The results showed that, age, institutional involvement and credit for apple were significant at 10% level of significance from both logistic and marginal effect after logistic analysis (Table 9). With the increment in age of the respondent by a year, the farmers are 1.4% more likely to adopt weeding at recommended frequency. Similarly, the farmers with loan for apple cultivation are 39% more likely to adopt weeding at recommended frequency. In contrast, the participation of the respondent in an institution showed 29.5% less likeliness to adopt weeding at recommended frequency.

It is believed that access to credit/loan promotes the adoption of technologies through relaxation of the liquidity constraint as well as through the boosting of household's-risk bearing ability [40,41]. This is because with an option of borrowing, a household can do away with risk reducing but inefficient income diversification strategies and concentrate on more risky but efficient investments [41]. The less likeliness to adopt frequent weeding with participation in institution could be due to learning externalities within social networks increased the profitability of adoption, but also farmers appeared to be free-riding on their neighbors' experimentation with the new technology (here, frequency of weeding) [42].

Table 8
Influence of socio-economic variables on the use of recommended irrigation interval.

Irrigation interval	Odds Ratio	Std. Err.	Z	p>|z|	dy/dx	p>|z|
Age	0.925	0.038	−1.85	0.064*	−0.014	0.058*
Education	0.538	0.416	−0.80	0.424	−0.121	0.449
Occupation	5.768	5.390	1.88	0.061*	0.244	0.008***
Economically active	1.372	0.228	1.90	0.057*	0.058	0.056*
Years of experience	1.084	0.051	1.72	0.086*	0.014	0.077*
Institutional involvement	1.391	1.084	0.42	0.671	0.058	0.659
Loan for apple	1.331	1.192	0.32	0.749	0.055	0.760
Technical service	0.585	0.418	−0.75	0.453	−0.093	0.427
LSU	1.000	0.009	0.04	0.967	0.000	0.967
Log likelihood	−44.63					
Prob > Chi^2	0.852					

Note: * and *** indicates significant at 10% and 1% level respectively.

Table 9
Influence of socio-economic variables on the frequency of weeding.

Frequency of weeding	Odds Ratio	Std. Err.	Z	p>|z|	dy/dx	p>|z|
Age	1.061	0.036	1.74	0.082*	0.014	0.082*
Education	2.415	1.837	1.16	0.246	0.209	0.215
Occupation	0.792	0.532	−0.35	0.729	−0.057	0.729
Economically active	0.856	0.127	−1.04	0.298	−0.038	0.297
Years of experience	0.975	0.036	−0.67	0.504	−0.006	0.504
Institutional	0.294	0.210	−1.71	0.087*	−0.295	0.066*
Loan for apple	5.529	4.884	1.94	0.053*	0.390	0.016**
Technical service	0.803	0.532	−0.33	0.741	−0.054	0.740
LSU	1.014	0.010	1.43	0.154	0.003	0.155
Apple cultivated land	1.013	0.039	0.35	0.728	0.003	0.728
Log likelihood	−40.5					
Prob > Chi^2	0.385					

Note: * and ** indicates significant at 10% and 5% level significantly.

3.4. *Effect of GAP on apple productivity*

The effect of GAP on apple productivity was analyzed through independent *t*-test analysis (Table 10).

3.4.1. *Independent t-test analysis of apple productivity with GAP standards*

The study revealed that the productivity of farmers who adopt recommended pit dimension was found higher (379.80 kg/ropani) than farmers who didn't adopt the recommended pit dimension (246.20 kg/ropani). The difference was found to be significant at 10% level of significance. Furthermore, the average productivity of apple in farmer's field who applied nutrient according to age of plants was higher (418.74 kg/ropani) than farmers who didn't apply nutrient according to age (258.58 kg/ropani). The difference was found significant at 5% level of significance. It was also found that the average productivity of farmers who adopted proper intercropping was found to be greater (374.72 kg/ropani) than those who didn't adopt intercropping (200.29 kg/ropani). The difference was found to be significant at 10% level of significance. The farmers who adopted the recommended irrigation interval had higher apple productivity (441 kg/ropani) compared to non adopters (302 kg/ropani) and the difference was significant at 10% level of significance. The use of GAP can play a significant role in reduction of yield gap in plants has been reported by Ref. [27] which is very similar with our study. Similarly [43], also reported increased yield upon adoption of GAP in potato which they reported to be due to decrease in soil erosion and [44] reported increased productivity in oil palms due to adoption of GAP. The increased yield observed in GAP adopters in our study could be attributed to practice of orchard management as per the recommended dose/size/rate, etc. which created a favorable environment for optimal growth and yield of fruits in apples.

3.5. *Major problems of apple production in study area*

3.5.1. *Major diseases*

The ranking of major disease which infest apple is shown in Table 11 below. The study revealed that papery bark was the major problem of the study area and ranked as I whereas powdery mildew is ranked II, root rot is ranked III, collar rot is ranked IV and apple scab is found to be minimum problematic as compared to other diseases.

3.5.2. *Major insects*

The ranking of major insects' infestation in apple production is shown in Table 12 below. The study revealed that wooly aphid was

Table 10
Independent *t*-test analysis of apple productivity with GAP standards.

GAP Standards	Productivity (kg/ropani[a])		Mean difference	Standard Error		t-Value	p-Value
	Non adopter	Adopter		Non-adopter	Adopter		
Use of certified	337.58	348.42	−10.84	63.13	53.78	−0.11	0.45
Direction of farm	300.11	400.01	−99.89	36.94	80.96	−1.19	0.11
Pit dimension	246.20	379.80	−133.59	44.63	53.81	−1.40*	0.08
FYM at planting	303.53	369.45	−65.92	54.59	58.15	−0.76	0.22
Nutrient management	258.58	418.74	−160.16	40.83	67.89	−1.93**	0.027
Irrigation method	354.51	330.29	24.21	61.52	48.00	0.28	0.38
Irrigation interval	301.93	441.06	−139.13	30.18	116.36	−1.55*	0.06
Intercropping	200.29	374.72	−174.42	41.49	49.06	−1.58**	0.05
Plant density	378.43	314.27	64.15	76.46	38.78	0.76	0.22
Frequency of weeding	351.28	339.09	12.19	72.26	44.25	0.145	0.44

Note: * and ** indicates significant at 10% and 5% respectively.
[a] One Hectare equals 20 Ropani.

Table 11
Major diseases of apple in study area.

Problem	Index	Rank
Apple scab	0.419608	V
Collar rot	0.513725	IV
Root rot	0.533333	III
Powdery mildew	0.678431	II
Papery bark	0.85098	I

the major problem of the study area and ranked as I whereas zygaena moth is ranked II, tent caterpillar is ranked III, Sanjose scale is ranked IV and apple borer is found to be minimum problematic as compared to other insects.

3.5.3. Production problems

The ranking of major production problems is shown in Table 13 below. The study revealed that lack of knowledge about improved production technique was the major problem of the study area. Lack of production materials was found to be the second major problem. Infestation of diseases and insects is ranked III and lack of subsidy in production materials is ranked as IV. Low production of apple was the least of the problems faced by the apple growers.

3.5.4. Post production problems

The details of post-production problems faced by apple growers are presented in Table 14 below. The results showed that, lack of packaging and grading was the major postproduction problem of the farmers in the study area. The second major problems were lack of knowledge of post-production technology followed by greater loss in transportation. Apple being perishable product, storage problem was also the next major problem for farmers, due to which they were compelled to sell their produce at any price. Similarly, post-harvest insect damage was also the major postproduction problems in the study area.

3.5.5. Marketing problems

The details of marketing problems faced by apple growers are presented in Table 15 below. The results showed that, lack of market information was the major marketing problem of the farmers in the study area. The second major problem was lack of organized market followed by low seasonal price and poor transportation. Similarly, lack of certification was also the major problems in the study area.

4. Conclusion and policy recommendations

4.1. Conclusion

Good agricultural practices are the key for a sound health followed by the economic value gained by the products. Fruit crops are highly income creating if orchards are managed properly. Farmers should adopt and implement GAPs in farming in order to enhance the quality of products and decrease the effect from non-tariff barrier while cultivating the fruits in an environment-friendly manner. The findings from the above study revealed that socio-economic characters like age, economically active members, education, occupation, institutional involvement, years of experience, livestock unit, apple cultivated land, availability of loan for apples showed significance with respect to adoption of different GAPs. Thus, these determinants shall be prioritized for promoting the adoption of GAP among apple farmers in the command area of Apple Zone. The major plant protection problems like papery bark disease and wooly aphid insects should be prioritized by the farmers. In case of production, post production and marketing; the government and concerned projects shall focus to improve knowledge on cultivation technique, training on packaging and grading, and provision of market information. Further studies on technical efficiency, allocative efficiency and economic efficiency of farmers adopting GAP and not-adopting GAP can be recommended.

4.2. Policy recommendation

To assure the greater adoption of GAP, government should motivate growers by promoting use of certified planting materials and training the ways to manage farm and methods of farming (eg. direction of farm, irrigation interval, planting density, intercropping, weeding frequency, etc.). Government's role is crucial in the development of irrigation systems and water storage dams for agriculture. Moreover, introduction of agricultural zoning in agricultural policies is another alternative to drive the success of a GAP program. Farming in the appropriate area or zoning will impact the farmers significantly to be able to produce according to the potential of the area. In addition, it should support farmers to be in group/participate in institution in order to easily disseminate the knowledge on GAP. Another strategy to successfully raise GAP adoption among the apple growers is through the increase in agricultural land, raise awareness about GAP, increase number of farmers in apple cultivation, and access to credit for the farmers. GAP helps in controlling abuses of natural resources, and having regional GAP is one important aspect of securing field to fork health through participation of local communities.

Table 12
Major insects of apple in study area.

Insect Problem	Index	Rank
Wooly aphid	0.830986	I
Zygaena moth	0.746479	II
Tent caterpillar	0.684507	III
Sanjose scale	0.357746	IV
Apple borer	0.371831	V

Table 13
Production problems of apple in the study area.

Problem in production	Index	Rank
Lack of production materials	0.742	II
Lack of knowledge about improved production technique	0.806	I
Infestation of disease and pest	0.632	III
Lack of subsidy in production material	0.492	IV
Low production	0.328	V

Table 14
Post-production problems of apple in the study area.

Post production problems	Index	Rank
Lack of packaging and grading	0.86	I
Lack of knowledge	0.7	II
Greater loss in transportation	0.60	III
Lack of storage facilities	0.45	IV
Postharvest insect and damage	0.38	V

Table 15
Marketing problem of apple in study area.

Problem marketing	Index	Ranking
Lack of market information	0.83	I
Lack of organized market	0.75	II
Low seasonal price	0.72	III
Poor transportation	0.47	IV
No certification	0.23	V

Declarations

Author contribution statement

Janarjan Adhikari: Conceived and designed the experiments, Performed the experiments, Contributed materials, analysis tools or data, and Wrote the paper.

Rabin Thapa: Performed the experiments, Analyzed and interpreted the data and Wrote the paper.

Data availability statement

The data that has been used is confidential.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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