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Determinants of Farmers' Crop Choices on Irrigated Agriculture of Halaba and Meskan Districts of Southern Ethiopia

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Abstract
Despite Ethopia's potential to enhance crop production through irrigation, food insecurity has been a defining feature of its poverty for decades. Halaba and Meskan districts are some of the areas with potential for improving crop production through irrigation. However, the potential remains untapped as a result of dependence on rain fed agriculture and farmers' low understanding of irrigation and its proper management. The low utilization of the irrigation potential, has affected farmers' crop choice and their productivity. Crop choice analysis is found to be very important for increasing farm productivity in Ethiopia. However, empirical studies on factors that affect farmers' crop choice are scanty. Hence, this study aims to identify determinants of farmers' crop choice decisions. The study employed Multinomial Logit Model (MNL) to analyze determinants of crop choice. Cross-sectional survey data collected from randomly selected 265 farm households of the total sample households, 136 farming households have access to irrigation. The MNL result shows that male headed households have a higher probability (7.14 %.) of farming cereal crops with vegetables and '*khat*' in combinations. Larger farming families were more likely to choose practicing irrigation for growing cereal crops with vegetables. Costs on fertilizer have significant results (0.07%, -0.04% and -0.03%) in the probability of planting cereals with vegetables, pulse-vegetables and '*khat*' in combinations respectively. Cost incurred on agro-chemicals (herbicide and pesticide) were only significant and negative for cereals-pulse-vegetables choice and vary with 3.9%. Older farmers were more likely to choose cereals combined with vegetables - pulses and with 'khat'. The coefficient on education is positive and significant for cereals with khat. It is suggested that agricultural extension personnel need to focus on the factors that affect farmers' crop choices that entails multiple crop through irrigation turns to high farm productivity and improving food security status of the area.
Keywords: irrigation, crop choice, Multinomial logit model

1. Introduction

Declines in household food production are commonplace for about 60 percent of the rural population in tropical and sub-tropical countries (Bossio, 2005). Therefore, there is a vital need for these countries including Ethiopia to increase agricultural productivity with sustainable management of its natural resource base to satisfy the increasing demand of food. Food production can be increased through use of various inputs like improved seeds, fertilizers, insecticides, pesticides, and irrigation. Hence, whether it comes from rainfall or irrigation, water means life in agriculture (Bossio, 2005). Irrigation water increases agricultural production through both the expansion of cultivable area beyond that possible under rain-fed agriculture and higher crop yields. According to FAO (2007) on average, crop yields per hectare under irrigated agriculture are 2.3 times higher than rain-fed agriculture. However, in Ethiopia in terms of land productivity on irrigated farms, the recent report on Ethiopian economy shown that the average cereals, pulses and oilseeds productivity was lowest at 1.7, 1.3 and 0.3 tons per hectare respectively, while the highest productivity was obtained in sugarcane root crop (8.5 tons), fruits (8 tons) and vegetable (4 tons) per hectare (EEA, 2011).

In Halaba special District of southern Ethiopia, two schemes irrigate 250 ha and supports 375 farm households while in Meskan District, according to MoWR (2008), based different river sources and well about 4397 households were using irrigation. The development of small-scale irrigation schemes with the aim of producing high-value horticultural crops has a number of advantages which helps to reduce the impact of erratic rainfall on household income fluctuations and make use of land multiple times a year (Debello, 2006). The multiple time use of land entails the wider options for crop choice decision and enhancing farm productivity. As cited on (Mailosi, 2011) Pender et.al (2006) found rainfall pattern, temperature, market access, land quality, altitude, income strategy, land management practices and other policy relevant factors such as irrigation, technical assistance, education, and gender and tenure status to influence crop choices on land in East Africa Highlands. These are also attributes to farm productivity and food insecurity of the area. Also Scholten (2006) indicated that crop yields were low because of limited use of improved seeds and agrochemicals, low input use, diseases and weather.

Moreover , smallholders farmers in the study areas lack making decision subject to varying factors on how to allocate resources on arranging alternative crop in view of improving productivity of agriculture thereby addressing food insecurity of the areas though regulation of water distribution, system maintenance, extension advice, input supply and monitoring of schemes are in place. Hence, irrigation can have effect on crop choice decision and crop yield of the farmers. Never the less, documented empirical literature in the study area pertaining factors influencing the determinants of farmers' crop choice analysis under irrigation and non irrigation situation are scanty. To fill this gap, this study identified determinants of farmers' crop choice analysis in the study area. Cross-sectional survey data collected from randomly selected 265 farm households and multinomial logit choice model were used to identify determinants.

2. Research Methodology

2.1. The study Area

The study was carried out in Halaba and Meskan Districts of SNNPR[13] of which Halaba special District is located at70 17' N latitude and 38 ^{0} 06' E longitudes. The total land area of the district is 64,116.25 ha of which 48,337 ha (75%) is considered suitable for agriculture. The total population of the district based on CSA (2008) report is 232,241, (49.7% are female). The altitude of the district ranges from 1554 to 2149 m asl, but most part of the district is found at about 1800 m asl. Rainfall is a major limiting factor in agricultural production in the area. Agro ecologically, most of the District is classified as '*Weina Deg*'[14]. The annual rainfall varies from 857 to 1085 mm, while the annual mean temperature varies from 17^{0}C to 20^{0}C with mean value of 18^{0}C. Bilate River is the source of water for many farming families. The major crops grown including irrigation use are maize, pepper, onion, potato and livestock feeds like rohodes grass, cowpea and others. And Meskan District is located in Gurage zone of the region. The agro ecological zone is characterized with *'Dega*[15]*'* and '*Weynadega*' climatic zone constituting about 18% and 82%, respectively. Its altitude ranges from 1820 to 3500 meters above sea level. The annual rainfall of the district falls in the range of 1400 - 1900 mm. Total population of the district, based on CSA (2008) is 159,884. Out of this the males, 78,393 (49.03%), while the females were 81,491 (50.96%). According to Ministry of Water Resource, only about 60 ha and 440 ha of land have been cultivated under modern and traditional irrigation, respectively (MoWR, 2008). In total, there are about 4397 households who are benefiting from irrigated farm by cultivating mainly tomato, cabbage potato, onion and the likes.

2.2. Sampling Technique

The study focus was on the irrigation water users and non users from Halaba and Meskan districts in SNNPRS, Ethiopia. Size of sample determined based on the size of the population and size of irrigation scheme, to represent the population. The proposed methodology was a multi-stage sampling technique, employed to select sample households. Initially, mean group of kebeles practicing irrigated agriculture was selected purposively. In the subsequent stage sample Kebeles[16] was selected within the irrigated areas depending on type of irrigation systems. Eventually sample of households selected from those already selected one's using random sampling method. The total sample size is determined using formula employed by Israel (1992). To study the impact of irrigation, control areas which are non-irrigated parts of Kebeles were also included in the sample survey. The logic behind this is to compare area under cultivation, cropped area, cropping pattern, cropping intensity, and yield per acre, etc. of irrigation users with that of non-irrigation users. Based on the above computation and considering the population of two districts, the sample size was determined to be 265 farming households. The share of sample for each district is not necessarily determined by the size of population but much focus was on proportions of irrigation users of the areas. Thus, during the survey, in Halaba special district the already assumed water harvesting based irrigation schemes was found to be not functional and hence the sample size was declined.

2.3. Data Collection

Primary data from sample households had been gathered through personal interview. A questionnaire was formulated to obtain information on crop production, prices, income, and size of farm, cropped area, irrigation water use, labor, fertilizer, education, food consumption, and other socio-economic data. In order to gather reliable data required for this study, an interview schedule was designed before sample survey. The interview schedule contained many relevant questions. And it includes questionnaires and interview checklists which were pre-tested in the study area and modified in the light of feedback from the farmers. Irrelevant questions were dropped and other necessary questions were included in the revised version of the interview schedule. For this

[13] Southern Nations ,Nationalities And Peoples Regional State
[14] Mid Attitude level
[15] High Altitude level
[16] The lowest administration division

purpose, training and orientation had been offered for survey enumerators or interviewers. Focus group discussions connected to management of irrigation schemes and secondary data were gathered as part to complement data collected.

2.4. Analytical Methods

This study has used the Multi Nominal Logit (MNL) model to analyze the crop choice of small holder farmers involving multiple unordered discrete variables based on the specification of (Green, 2003). Conceptually, it is assumed that the owner of an irrigated field optimizes the expected gain, therefore he or she chooses the crop that best benefit or most profitable for his/her given attributes. If a farmer has J alternatives, indexed j=1, 2 …J., The expected benefit/profit of crop j for individual i is denoted as Π_{ij}. Π_{ij} can be written as a deterministic component plus a random component: $V_{ij} + \varepsilon_{ij}$, where V_{ij} is a function of characteristics specific to individual i and ε_{ij} is a random error. Further, we assume that V_{ij} takes the form $\beta_j X_i$, where β_{ij} is a vector of parameters associated with the j-th crop choice and X_i is a vector of explanatory variables. The farmer chooses crop j if and only if $\Pi_{ij} > \Pi_{ik}$, for all other k≠j. Let Yi be a random variable that indicates the choice made, and then the probability of individual i choosing crop j is :

$$\text{Prob}(Y_i=j)=\text{Prob}(\Pi_{ij} >\Pi_{ik})$$
$$=\text{Prob}(V_{ij} +\varepsilon_{ij}>V_{ik}+\varepsilon_{ik})$$
$$=\text{Prob}(\varepsilon_{ik}-\varepsilon_{ij}<V_{ij} -V_{ik}) \quad (1)$$

If the error terms are independent and identically distributed with Weibull distribution, $F(\varepsilon_{ij} = exp(-e^{\varepsilon_{ij}})$, then

$$\text{Prob}(Y_i =j)=\frac{e^{\beta_j' X_i}}{1+\sum_{j=1}^{j} e^{\beta_j' X_i}} \quad (2)$$

According to Green (2003), the estimated equations provide a set of probabilities for the J +1 choice for a decision maker with characteristics X_i. if Bj*== β j + q for any vector q, then recomputing the probabilities defined below using Bj* instead of β j produces the identical set of probabilities because all the terms involving q dropped out that is to remove indeterminacy in the model. A convenient normalization that solves the problem is $\beta_0 = 0$. This arises because the probabilities sum to one, so only J parameter vectors are needed to determine the J + 1 probabilities. Therefore, the probabilities of the multinomial model are specified as:

$$Prob(Y_i = j/X_i) = \frac{e^{\beta_j' X_i}}{1+\sum_{j=1}^{j} e^{\beta_j' X_i}} \text{ for j= 0, 1,….,J, } \beta_0=0 \quad (3)$$

By using this model, estimation was made that how the independent variables affect the probability of choosing a crops/or set of crops. In this case it is useful that the odds ratio, P_j / P_k, does not depend on the other choices, which follows from the independence of disturbances in the original model. From a behavioral viewpoint, this fact is not very attractive. The log-likelihood can be derived by defining, for each individual, $d_{ij} = 1$ if alternative j is chosen by individual farmer i, and 0 if not, for the J − 1 possible outcomes. Then, for each i, one and only one of the d_{ij}'s is 1. The log-likelihood is a generalization of that for the binomial probit or logit model which is specified as:

$$\ln L = \sum_{i=1}^{n} \sum_{j=0}^{j} d_{ij} \ln prob(Y_i = j) \quad (4)$$

Where lnL is log likely hood function and d choice indicator. The derivatives have the characteristically simple form,

$$\frac{\partial \ln L}{\partial \beta_j} = \sum (d_{ij} - P_{ij}) x_i, for\ j = 1,...J \quad (5)$$

The exact second derivatives matrix has J ^{2}K × K blocks, where (j = l) equals 1 if j equals l and 0 if not. Since the Hessian does not involve d_{ij}, these are the expected values, and Newton's method is equivalent to the method of scoring. It is worth noting that the number of parameters in this model proliferates with the number of choices, which is unfortunate because the typical cross section sometimes involves a fairly large number of regressers. The coefficients in this model are difficult to interpret. It is tempting to associate β_j with the jth outcome, but that would be misleading. By differentiating equation (10), we find that the marginal effects of the characteristics on the probabilities are:

$$\delta_j = \frac{\partial P_j}{\partial x_i} = P_j \left[\beta_j - \sum_{k=0}^{J} P_k \beta_k\right] = P_j \left[\beta_j - \overline{\beta}\right] \quad (6)$$

Therefore, every sub vector of β enters every marginal effect, both through the probabilities and through the weighted average that appears in δ_j. These values can be computed from the parameter estimates. As a lead up to the analyses of the logit model results, the dependent variable has been identified the crop chosen on each

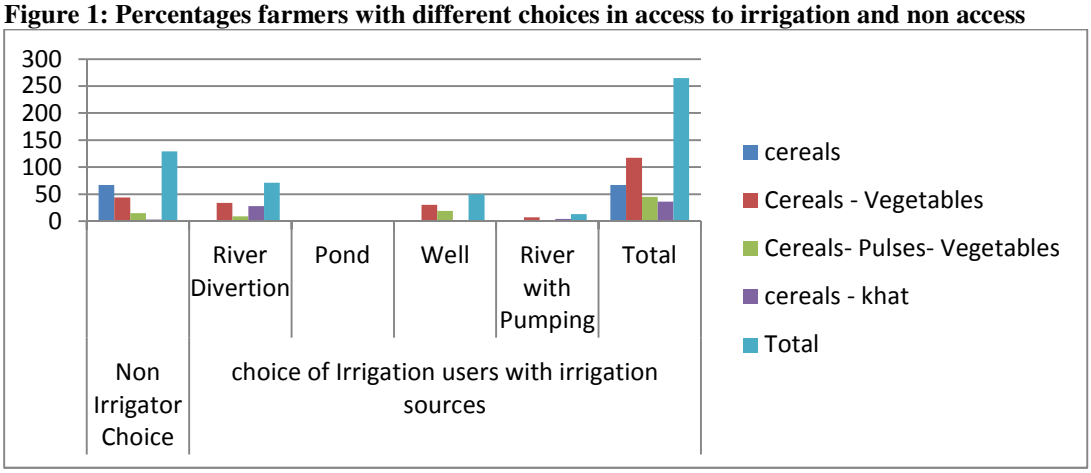
sample irrigated and non irrigated site. In this analysis, the reported type of crop was coded as: 1, 2, 3 and other depending up on the number of category. In line with some of important explanatory variables included in the model to determine the crop choice are output and input prices, training/education, access to market, seasonal variation, type of irrigation system and nature of the farming system as influenced by the interplay of various biophysical and socioeconomic variables, resource endowment, social capital and social psychological factors.

3. Results and Discussion

3.1. Descriptive Results

The crop choice trends of the sample households distributed between non irrigation and irrigation users from different sources is presented in Figure 1. Farmers who grew only cereals were totally non irrigation users. Whereas the combination of cereals with vegetables were very common for both cases which constituted about 43% of the total sample households. Vegetables for non irrigation users were to indicate about pepper and Ethiopian cabbage (grown commonly through intercropping). But the use of other variety of vegetables like tomato, head cabbage, onions were very common for irrigation users as it is indicated in many other studies. Farmers who choose to grow combination cereals with '*khat*'[17] were 38 households of which 35 were irrigation users. This indicates that choice 'khat' was one of important selection next to vegetable for irrigation users.

Figure 1: Percentages farmers with different choices in access to irrigation and non access



Own computation survey (2013/2014)

Like other parts of the country, there are two crop seasons in Districts. In both irrigated and non irrigated farms major crops grown during '*belg*'[18] *were* maize, haricot bean, sorghum grown on 38%, 3.3%, and 4.8% land area respectively. On the other hand, on irrigated farms, onion, Irish potato, tomato, head cabbage and beet were main crops. In the '*meher*'[19] season, wheat, barley, field pea, faba bean and pepper are the main crops. And 13% of the farm area was cultivated to wheat, 10.4%, of '*teff*' and only little (0.16%) is allocated for barley cultivation.

3.2. Econometric Estimation Results

Table 1 presents multi nominal logit model by which the chi-square value shows that likely hood ratio statistics are highly significant suggesting the model has strong explanatory power with significant variables after checked for hetroscedasticity indicated by robust standard deviation labels. The model also took in to account the characteristics 'universal' logit model as it avoids the independence of irrelevant alternatives (IIA) property while maintaining the multinomial logit form by making each ratio of probabilities a function of the attributes of all the alternatives. It is difficult, however, to give an economic interpretation of this model other than 'a flexible approximation to a general functional form' (Hausman & McFadden, 1984). Thus the MNL result shows male headed household had a higher probability of practicing cereal with vegetables and *'khat'* combinations by 7.14% and 1.09% at 1% and 5% level of significance respectively. So male headed households were more likely to undertake productions on irrigation since majority of 'khat' growers were included in irrigation users' category. This indicates that they have better access to resources and information's for easily adopting new technology.

[17] Stimulant plant (Catha edulis)
[18] Refers to the period from March to May
[19] Refers to the period from June to September

Table 1 Econometric result determinants of Farmers crop choice

Variables	Cereals -Vegetables	Cereals-Pulses-Vegetables	Cereals - '*Khat'*
Cropyearhead	0.0637 (0.0321)**	0.0268(0.0369)	0.0604(0.0492)
Distmkt	-0.0212(0.0677)	0.066(-0.0779)	0.247(0.0988)**
Distext	-0.134(0.183)	0.123(0.221)	-0.884(0.307)***
Agehead	-0.0194(0.0321)	-0.0743(0.0416)*	-0.0655(0.0575)
Famlysize	0.151(0.132)	0.294 (0.152)*	0.231(-0.161)
Educhead	0.183(0.115)	0.214(0.139)	0.253(0.149)*
Hhincome	-0.297(0.255)	0.237(0.327)	0.153(0.37)
Cropvalue	-0.591(0.333)*	-0.518(0.423)	-1.247(0.516)**
Landcropped	-0.415(0.583)	1.327(0.638)**	2.045(0.685)***
TLU	-0.134(0.167)	-0.308(0.197)	0.227(0.211)
Costseed1	-0.0123(0.0219)	0.0303(0.0289)	0.0706(0.032)**
Costfertilizer	-0.00869(0.0199)	-0.017(0.0223)	-0.0425(0.0258)*
Costlabour	0.0106(0.0124)	0.0222(0.0152)	0.0146(0.019)
Costchem	-0.0324(0.0207)	-0.0389(0.0227)*	-0.046(0.0282)
Costirr	0.0204(0.0072)***	0.0102(0.00786)	0.014(0.0101)
Accessirr	17.95(0.478)***	17.78(0.605)***	21.89(1.075)***
Totalproduction	0.643(0.45)	-0.245(0.533)	-2.723(0.652)***
Constant	2.082(4.548)	1.601(6.148)	24.12(8.077)***
Observations	265	265	265
R-squared			

Notes Titles: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Cropping experience of household is significant for those farmers deciding on selecting cereal - vegetable combination hence with increase year of experience on cropping the probability incorporating other crops like vegetable is more likely greater. Access to irrigation was significant for 3 choices. This indicates that those farmers incorporate vegetables and *'khat'* in crop choices was most likely those engaged in irrigation use. Family size was only significant for pulse involved cropping system selections that is in cereal- vegetables combinations. Thus, larger farm families were more likely to choose pulse with cereal with vegetables combination for irrigation user cases. Pulses like haricot bean and field pea were the supplementary role to fill food consumption gaps. In contrast S. Niggol Seoa *et al.*(2008), larger farm families are less likely to choose maize and soybeans (cereal-pulse combinations) in South American farms. These crops are easily mechanized and so may be selected by farmers with smaller families.

From crop production inputs, expenditures on fertilizer, seed were significant and negative, which represents yield increasing inputs will result decrease in the probability of planting cereals with vegetables, with 'khat' and with pulse-vegetables combination. For instance, a unit increases in cost of fertilizer of the household head results in decrease in 4%. Other significant factor costs were total expenditures realized on agro-chemicals (both herbicide and pesticide only significant for cereals-pulse - vegetables, where it is significant and negative at 10% with variation of 3.9% , that indicate the elasticity choices for 1 birr additional cost on agro-chemicals results in decreasing the choice of cereals - pulses - vegetables by 3.9% compare to other choices.

Cost on irrigation is significant at 10% for 3 crop choices characterized with Irrigation use however the elasticity of selecting cereals with 'khat' was increasing while other choices were nearly equivalent to with 1 birr increase in cost of irrigation 'khat' to cereal crop will increase; here the consideration was only for variable cost of irrigation. Market distance was found to be positive and significant for cereals combined with both pulses and vegetable chooser farmers where as negative for those who were combining cereal with vegetable only. Older farmers were more likely to choose cereals combined with vegetables and pulses and 'khat'. The coefficient on education was positive and significant for cereal with 'khat' crop choice as shown in the Tab1e 4.12. And that implies that lower educated farmers tend to grow cereals and vegetables. In different ways, Martins Odendo *et al*. (2009) found out that education level of the household head had a positive and significant effect on leguminous crops.

Total output was significant at 10% and negative for two crop choices except the cereal vegetables selections however the elasticity of selecting cereals with *'khat'* and with vegetable - pulse combination was decreasing by3.6% and 17.3% respectively while cereal with vegetables increasing at 20.8%. Choices were nearly equivalent to with one kg addition in output, this can indicate that the crop supply decrease with above given amount so here the consideration is only for variable. Total crop value is significant at 10% and negative for cereal- pulse-vegetable selection however the elasticity of selecting cereals with 'khat' is positive at 2.8% as indicated on the table 2. This can indicate that with 1 birr increase in the crop value increases with this amount.

Here the consideration is only for variable irrigation use. Negative crop value indicates that the household rely more likely on food production than cash crop production. And the cereal 'khat' growers more likely relied on production for food than for cash. Differentiating equation (1) with respect to the explanatory variables provides marginal effects of the explanatory variables. The marginal effects, or marginal probabilities, are functions of the probability itself. They measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from the mean (Green 2003).

Table 2 Marginal effects after mlogit

Variable	y= CV=.890	y= CK=.01041362	y= CVP=.09937649	
	dy/dx	dy/dx	dy/dx	
Agehead	0.35%	-0.06%	-0.28%	
Sexhead	7.14%	1.09%	-8.23%	
Famsize	-1.54%	-0.06%	1.60%	
Educhead	-0.33%	0.07%	0.27%	
Cropyearhead	0.38%	0.00%	-0.38%	
Distmarket	-0.60%	0.29%	0.30%	
Distextension	-2.97%	-0.72%	3.69%	
TLU	-0.29%	-1.65%	1.94%	
Costseed	-1.79%	0.28%	1.51%	
Totalland	10.06%	-0.17%	-9.89%	
Totaloutput	20.83%	-3.56%	-17.27%	
Cropvalue	-0.53%	-2.27%	2.80%	
Costlabor	-3.56%	-0.02%	3.57%	
Costirrigation	-0.69%	0.57%	0.12%	
Costherbcid	-0.36%	0.07%	0.29%	
Croppedland	-34.12%	6.46%	27.66%	
Costfrtilizer	0.07%	-0.04%	-0.03%	

4. Conclusion

The finding shows that use of irrigation serves as one of the means to expand choice of crops for enhancing crop productivity and ensuring household food security. The survey result shows most of the male headed households were found to be producing high value crops like cereals with vegetables and *'khat'*. Education was also positive and significant for cereal –*'khat'* choice. It is a fact that the more household heads get educated, the higher will be the probability of educating family members and acquainting them with modern agricultural technologies. However, it was observed that women in the study area have been constrained by several factors and their level of literacy to understand and adequately use irrigation for appropriate crop choice decision. Thus, relevant and timely trainings should be provided to rural extension agents so that they can educate rural households on technical skills, awareness on the benefits, short and long-term effects of irrigation. Land cropped was significant and positive for choice of cereals with pulses – vegetables and with *'khat'* which was 12% and 20% respectively. But the probability of selecting cereals with *'khat'* combination was greater. The farmers' concern for '*Khat'* is very high in the study area because it is a high value crop. Using irrigation for 'khat' increases the rate at which' khat' is harvested and the amount income generated. The increase in the generation of income enhances the farmers' capacity to ensure food security at the household level. Yet, growing *khat'* may lead to more addiction and that may have negative physical, economical and social effects in the long run. So government should design a mechanism to minimize the negative social effects without compromising its economic benefits.

Though pesticide and herbicides have role of enhancing crop productivity in the study area, they were found to be scarce and expensive. In addition to this, some farmers who use these chemicals on tomato farms apply very high and abnormal amount because of their preference to listen to other farmers instead of professionals. Therefore, the government, cooperatives and non government organizations have to make sure that the farmers who apply unacceptable amount of chemicals understand the ill effects of such a practice on human health and the environment.

Although vegetables are considered as high value crops in current market, it could not adequately serve to get farm gains as much as possible. From survey result, in Halaba special district harvesting time of irrigation crops mainly head cabbage was observed mismatch of market seasons. And in Meskan district, post harvesting management of tomato crop was found to be poor and demonstrated by so much wastages and discards of defectives tomatoes. Therefore, government intervention for improving existing value chain management for minimizing unnecessary wastages in crop production and ensuring efficient use of irrigation schemes to enhance

farm productivity and food security of the area. So in general the results of this study can be used for the development of a decision support tool government extension services to advise farmers on their crop choice for increasing farm productivity and possibilities to improve food security status of the area.

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