PROFIT MAXIMIZATION IN VEGETABLE PRODUCTION IN WESTERN USAMBARA MOUNTAINS IN TANZANIA: *APPLICATION OF GAME THEORY*

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ABSTRACT

Vegetable production is a risky enterprise because of its susceptibility to a number of risks and uncertainties. Such risks and uncertainties include bad climatic conditions, price fluctuations, pests and diseases, land fragmentation, variability of production costs per unit of land and lack of high quality agro-chemicals. The risks and uncertainties make it difficult for farmers to make decisions on the types of vegetables to grow so as to maximize profit. The paper draws on game theory, and has two objectives: to identify categories of farmers on the basis of their risk perceptions, and to find out the types of vegetables each category of farmers grows to maximize profit. Socio-economic surveys were done to collect information on vegetable production where both input and output data were gathered together with average profits. A random sample of 103 farmers who grow vegetables was selected in three villages in Lushoto District, Tanga region-Tazania. The maximax, regret and Laplace criteria showed that the most profitable vegetable was tomato, from which a farmer earned Tsh 871,000/=, -30,000/= and 785,000/= per 0.5 acre, respectively. The results relating to the maximin criterion showed that carrot was the most preferred crop, where a farmer earned an average of Tsh 600,000/= per 0.5 acre. The study concludes that the decisions on what type of vegetable to produce is influenced by a farmer's characteristics and the perception of risks and uncertainties. Pessimistic farmers grow carrots and optimistic ones *grow tomatoes. It is thus recommended that policy makers need to understand vegetable growers' behaviour and perception, and uncertainties when planning to assist them so that they maximize profit.*

Keywords: *Game theory, vegetable production, maximax, maximin, regret and Laplace criteria*

Introduction

Agriculture is one of the risky activities associated with much uncertainties, which put farmers in a dilemma when they have to make decisions on agricultural production (Albici, Belu and Tenovici, 2009; Albici, Teselious and Tenovici, 2010). The risks in agriculture are the result of farmers' imperfect knowledge of the possible outcomes of production (Kahan, 2013a; MMA, 2008a). Owing to having imperfect knowledge, farmers make decisions on production without knowing whether the outcome of their decisions will be positive or negative (MMA, 2008b). The risks in agriculture are likely to increase when production is more commercialised, since the commercialisation of agriculture goes hand in hand with the intensification of production (Alamerie, Ketema and Gelaw, 2014).

The risks in agriculture are caused by natural and anthropogenic forces (Aimin, 2010; Coulibaly, et al., 2011). The natural forces are directly related to the decline of production and, thus, they are referred to as intrinsic variables (NEP, 2015). They include natural events that are beyond farmers' control (Kahan, 2013b). Such events have been put into two broad categories; all extreme weather events such as excessive or insufficient rainfall, temperature variability and gusty winds or storms, and all biological events that affect crop production directly such as diseases and pests (Paulson, 2007). The occurrence of such events is usually unpredictable, which makes agriculture a very risky enterprise (Riabacke, 2006).

Furthermore, there are numerous anthropogenic forces that affect agricultural production. They include, but are not limited to, market-related factors relating to changes in the prices of both inputs and outputs (Putter and Visser, 2007). This because agricultural production takes a long time, from planting to harvesting. During that time, there is likelihood that the prices of agricultural inputs and even the prices of the produce will change (Riabacke, 2006). There are institutional risks related to changes in the policies and regulations affecting agriculture. For instance, changes in government directives on the use of insecticides and pesticides in crop production may cause changes in the prices of farm inputs or outputs (Riabacke, 2006). These factors also include human risks that affect farmers; hence affecting efficiency and productivity. These include the death of a family member or relative, the injury of a farmer or any other health-related problem(s) (Reddy, 2015). There are also financial risks related to farmers' sources of capital. Farmers may obtain capital from financial institutions, which may increase interest rates over time. Finally, agriculture is susceptible to asset risks that involve the damage of the assets used in agricultural production, including the damage of farming tools and machines, burning of the crops, and theft to mention few (Amin and Dahlia, 2015).

Farmers are also put into three categories on the basis of their perception of risks. The first category includes risk-averse farmers, who are afraid of taking risks, and who are more cautious in their farming activities. Such farmers are ready to forgo investing some amount of money in crop production particularly vegetables production to reduce the chances of low income and losses. The second category comprises farmers who are referred to as risk takers. This group has a tendency of opting for the alternatives with some chances of a higher outcome, while ready to accept lower outcome. When it comes to making choices, the risk takers prefer the chance that makes gains rather than defending themselves from significant losses. The last category includes risk-neutral farmers who fall between risk-averse farmers and risk takers (Sima and Marin, 2011).

Farmers' attitude towards risks is the result of various factors. The first is the purpose of production (Giancarlo and David, 2000). Farmers who produce for commercial purposes tend to be more risk takers, while those who produce for subsistence purposes tend to be more risk averse (Raza et al., 2016). Subsistence farmers are driven by their primary purpose of production that is, providing food for their dependants. Thus, they forgo monetary gain (Reddy, 2015). The scale of production is another factor that influences farmers' attitude towards risk (Giancarlo another David, 2000). Another factor that influences farmers' attitude towards risk is the extent of the commitment to the family and responsibilities. Farmers with more family commitments and responsibilities are more risk averse than those with less family commitments and fewer responsibilities. Lastly, past experience may also influence farmers' attitude towards risk. Farmers' good or bad agricultural experiences may influence their present decisions regarding crop production (Bairwa, Kushwana and Suresh, 2013).

Farmers, particularly vegetable growers, are working under high risks owing to the taxability of most vegetables (Evaraast, Putter and Amon, 2011). Besides, vegetable farming is a highly risky business venture, since most vegetables are prone to natural and man-made forces (Singbo, 2012). This makes decision-making regarding the profitability of vegetable farming complex. This makes it necessary to investigate how farmers make decisions on what type of vegetables to grow to maximize profit under good and bad conditions. This study employed game theory to investigate this research problem. Game theory is a probabilistic model employed to analyse and drive rules in making decisions in the context of having two or more individuals competing for some objectives (Sahin et al., 2009). The theory is applied in a situation where outcomes can be determined by the behaviour of all competitors. Game theory is used to analyse participants' relationships and to predict their optimal decisions (Sahin and Miran 2007).

The theory was developed in 1953 and was much used in the field of economics (Oziegbe, 2011). Currently, game theory is used in the social sciences, statistics, mathematics and economics to model conflicts involving two or more rational decision makers (Sahin et al., 2009). Largely, game theory denotes a formal study of decision-making in which numerous players have to make choices that are significantly likely to affect the interests of other players (Turocy and Stengel, 2001). Game theory is a useful tool in planning where uncertainties exist (Rasmusen, 2006). For instance, in agriculture farmers must balance the risks of loss against the potential for them to make some profit (Ozkan and Akcaoz, 2002). There is evidence of the extent to which risk perceptions influence farmers' attitude towards production and investment (Ali and Kapoor, 2008). It is against this background that this paper identifies categories of farmers on the basis of their perception of risks and investigates the types of vegetables grown by each category of farmers during good and bad conditions using game theory.

Several studies have used game theory to examine decision-making in agriculture. For instance, Kassa (2017) studied on the application of decision-making with uncertainty techniques. However, the study investigated only one type of crop (maize) in relation to rainfall as a key determinant in production Karmen and Rozman (2009) did a study on decision-making under conditions of uncertainty in agriculture.. However, the study investigated profit maximization in the production of one crop (oil pumpkin) under several states of nature. The present study examined how vegetable farmers make decisions as to what type of vegetable to grow.

2.0. Methodology

The study was conducted in the Western Usambara Mountains, specifically in Lushoto District, Tanzania. The district was selected because it is one of the major vegetable producers in the country. The district has been a major supplier of vegetables to Dar es Salaam City, Tanga City and the neighbouring towns. However, the vegetable farmers in the study area have not significantly improved their well-being, which is associated with ineffective decision-making regarding the types of vegetables to grow and the production techniques to

The sampling process in this study started by identifying the agro-ecological zones of Lushoto in order to point out the zone with a high volume of vegetable production. Among the five agro ecological zones of Lushoto namely, dry cold, humid cold, dry warm and dry cold, the humid cold zone was identified as the leading zone in vegetable production. Following the identification of the leading agro ecological zone in vegetable production in the study area, all 16 wards located in the zone were purposely selected due to their long term potential for production. From 16 potential vegetable producing wards, three wards were randomly selected to represent other potential vegetable producing wards.

The process of selecting three wards, involved writing of all 16 wards on pieces of paper, mixed up in a small box and then one piece at a time was picked without replacement. At the end of the process, Lukozi, Baga and Kwai wards were selected. The study uses three wards to represent other producing wards due to a less degree of variability of the elements to be measured. All 16 potential vegetable producing wards share common basic characteristics including both being located in the Western Usambara Mountains which is the selected study area. Both wards are dominated by rural farmers who are involved in vegetable production as a dominant farming system.

After the selection of three wards, the next step was to select the representative study villages. In the selection of study villages, the total number of villages for the selected wards was put into consideration. Lukozi ward had a total number of five villages. Similarly, Kwai Ward had five villages while Baga had three villages. From Lukozi, Kwai and Baga wards three villages namely Lukozi, Kwemakame and Kwesine were selected from each ward respectively. All the selected wards had a total number of 13 villages through which three study villages were randomly selected to represent other study villages. After sampling of study villages, the next step was to determine the sample size. The sample size was obtained using the formula suggested by Israel (2009), which is given below:

$$n = \frac{N}{1+N(e)^2} \quad \text{……………………… …………………..……… Equation 1}$$

Where n = the sample size,

N = the population size, and

e = the acceptable/standard error (the level of precision)

Using the prescribed formula, the total households' population (1,704) of the sampled villages namely Lukozi (614), Kwemakame (563) and Kwesine (527) was obtained from the Village Executive Officers and used to calculate the household sample size. Using a 95 per cent confidence level and a 0.5 per cent level of precision (sampling error), 94 households were obtained as shown below:

$$\text{Therefore, } n = \frac{1{,}704}{1+1{,}704\ (0.1)^2} = \frac{1{,}704}{18.04} = 94.4567275$$

$n =$ 94.4567275 approximately, 94**.**

Israel (2009) notes that many researchers commonly add 10 per cent of the sample size to compensate for the respondents that the researcher is unable to contact or for non-responses. Therefore, this study added nine households to the 94 households and got 103 households.

The calculated sample size was applied to compute the proportion of households in all the villages that was determined by the number of households in each village. The formula used reads as:

$n_h = \frac{N_h}{N} n$ …………………………………………………….……..….. Equation 2

Whereby n_h = proportional sample of each village

N_h = the number of households of each village, and

N = the total number of households in all villages and n is the total sample size of the study population.

The calculated sample size in each village as shown hereunder;

$$\text{Lukozi} = \frac{614}{1{,}704}\,103 = 37$$

$$\text{Kwemakame} = \frac{563}{1{,}704}\,103 = 34$$

$$\text{Kwesine} = \frac{527}{1{,}704}\,103 = 32$$

After calculating the number of households for each village (37, 34 and 32 for Lukozi, Kwemakame and Kwesine respectively), the next step was to determine the specific household heads. Systematic sampling was used to obtain the specific households. The list of households for each village were presented and every sixteenth name in series was picked as the respondent.

Primary data were collected using a questionnaire. Important information on production costs per unit area (0.5 acre), vegetable yields per unit area, vegetable prices during good and bad conditions, and vegetable marketing procedures for each vegetable selected per unit of land were collected. This study used a 0.5 acre as the unit of analysis because of the fragmentation of land in the area where the study was conducted. It was observed that vegetables were grown in the valleys where farmers had small patches of land ranging from 0.5 to 1 acre. Secondary data were obtained from the Horticulture Department at the district's headquarter. Such data included the trend of vegetable production at the district level, the size of cultivated land, the volume of vegetable business and the contribution of vegetable production to farmers' wellbeing. Other secondary data were obtained from research reports and publications on vegetable production.

3.0. Results and discussion

3.1. Respondents' characteristics and their vegetable fields

A sample of 103 respondents completed the questionnaire. All the respondents were growing vegetables for commercial purposes. About 57 per cent of the respondents owned plots ranging from a 0.25 to 0.5 acre, and 43 per cent owned plots ranging from a 0.5 to 1 acre. It was observed that most of fields were in the valleys because the owners used the flowing streams that remained in the valleys after the rainy season to irrigate their vegetables during the dry season. Most of the surveyed households heads were aged between 30 to 48 years old reaching 64 per cent (see Figure 1). About 87 per cent of the respondents were males. The level of education of the farmers was generally low, as only 21 per cent of the respondents had secondary school education, and 79 per cent had primary school education.

Understanding the respondents' characteristics such as age, sex and the level of education was important in this study; since such attributes have either direct or indirect influence on the decisions they make as to which types of crops to grow to maximize profit. For instance, most of the younger farmers were risk takers, while the older farmers were not. Furthermore, it was revealed that sex determined land ownership and land tenure. Most of the vegetable fields located in the valley belonged to male farmers. Moreover, most of the farmers with secondary school education were risk takers, but most farmers with primary school education were not (Gramzow et al., 2018).

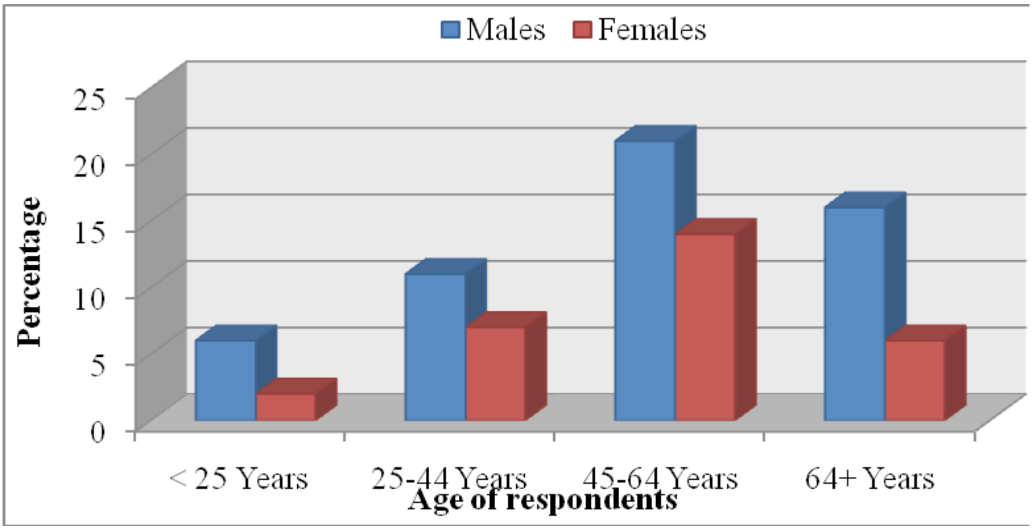

Figure 1: Respondents' age and sex

3.2. Vegetable profits determination under good and bad conditions

The profits made from four the selected vegetables, namely tomato amaranths, sweet paper and carrot, were computed under good and bad conditions. Good conditions represent a successful production season characterised by the presence of enough moisture in the valleys after the rain season.

This results in high yields per unit area averaging 0.5 to 1 tone per 0.5 acre, and high product prices that yield a profit of 25 per cent and above of the production costs. The months when there were good conditions were June, July, August, September, October and November. Meanwhile, bad conditions represent unsuccessful production seasons characterized by unfavourable weather conditions with high and low rainfall. Similarly, this leads to low yields per unit area averaging less than 0.5 tone per 0.5 acre, and low product prices that are less than 25 per cent of the production costs. The months when there are bad conditions include December, January, February, March, April and May.

The survey was conducted between July 2020 and September 2020, when the conditions are good for most of the selected vegetables. In order to get information on vegetable production and marketing with regard to both good and bad conditions, the questions were framed in such a way that they covered both conditions. The respondents' responses were coded and analysed using SPSS version 20 and Microsoft Excel. Data were presented using tables, charts, graphs and descriptions.

Table 1: Vegetables production and marketing conditions influencing farmers' decision-making.

State of nature	Production/marketing conditions
	Securing reliable markets
	Increase in prices
	Good weather conditions
Good conditions	Absence of pests and diseases
	Unpredictable markets
	Decrease in prices
	Bad weather conditions
Bad conditions	Prevalence of pests and diseases

Source: Modified from Sahin et al. (2009)

The profit from each vegetable was determined from both conditions. It was determined by deducting all production costs from the total sales, as the following equation shows.

$$P = Ts - (Pc = L + S + F + Pe \& I)$$

Where P = net profit

Ts = total sales

Pc = production costs

L = labour costs, S = seed costs, F= fertilizer costs, Pe = pesticide costs I = insecticide costs

After calculating the profits made from each selected vegetable in each growing season, the profits were grouped into each growing conditions. The average profits for each growing conditions were calculated by adding all the profits made under particular conditions, and divide the total by the number of months found in particular growing conditions. The average profits made from every vegetable were used to produce a payoffs matrix, from which the most paying vegetables were identified using each criterion of game theory, as demonstrated in the results and discussion section.

3.3. Game theory decision making criteria for profit maximization in vegetable production

Examining the decisions made as to which profitable types of vegetables to grow under good and bad conditions, the study employed four criteria of game theory, namely Maximax, Maximin, Regrets and Laplace while considering the farmers' characteristics. The Maximax criterion was used to identify the farmers who grow crops which enable them to maximize profit. These optimistic vegetable farmers assume the best of all possible alternatives (Sahin at al., 2009). The Maximin criterion was used to identify farmers who expect the worst to happen. They look at the worst that could happen under each action, and then choose the action with the largest reward. They also assume that the outcome of any decision made will be worst, and then they take action with the best worst case scenario (Sahin at al., 2009).

On the other hand, regret criterion takes into account that the regret of an outcome is the difference between the value of that outcome and the maximum value of all the possible outcomes; in the light of the particular chance event that actually occurred (Ozkan and Akcaoz, 2001). The farmers in this category choose the alternative that minimizes the regret they may have. Laplace criterion approach implies that when the probabilities of several chances of events are unknown to the farmers, they should be assumed equal, and different actions should be judged according to their payoffs averaged over all the states of nature.

3.4. Application of game theory to farmers' selection of vegetable types for profit maximization

As mentioned earlier, this study employed the four criteria of game theory to identify the types of vegetables e farmers grow to maximize profit. The characteristics of farmers reflected the four used criteria of game theory. Such characteristics include optimists, pessimists, regrets and prudent farmers which are represented by maximax, maximin, regret and Laplace criteria respectively. The findings show that 37 per cent of the farmers were falling under maximax, 29 per cent under maximin criterion, while 18 and 16 per cent of the surveyed farmers fell under regret and Laplace criteria respectively (Figure 2).

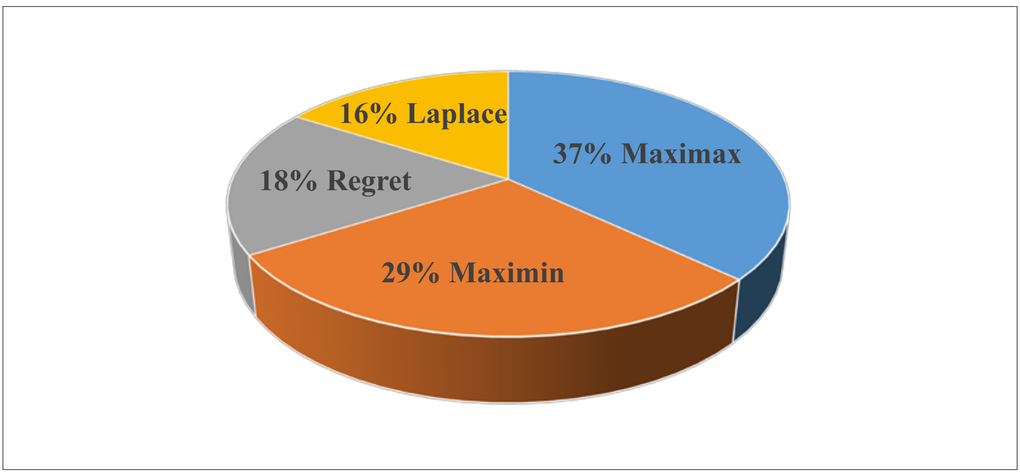

Figure 2: Percentage of vegetable farmers with their respective criteria

In the present study, the game is described as:

G = (V, T, P) whereby

V = (v_1, v_2,.v_i,.., v_n) the commercial grown vegetables among the surveyed farmers.

T = (t_1, t_2,., t_j,.. t_m) are the average profits for commercial grown vegetables, and

P = pij the payoff matrix from the average profits for the commercial grown vegetables

As i = 1, 2,…n and j = 1, 2,…m, P is an n × m matrix.

The average profits for the selected vegetables were used as a payoff matrix as stipulated hereunder.

$$P = \begin{array}{c} \\ v_1 \\ v_2 \\ v_3 \\ v_4 \end{array} \begin{pmatrix} t_1 & t_2 \\ 550{,}000 & 1{,}000{,}000 \\ 200{,}000 & 350{,}000 \\ 250{,}000 & 400{,}000 \\ 600{,}000 & 950{,}000 \end{pmatrix}$$

Maximax criterion as tool for profit maximization among optimistic vegetable farmers

Based on maximax criterion, the results revealed that farmers who made decisions regarding to vegetable production for profit maximization were optimistic about production, and market conditions of vegetables. These optimistic farmers opted for tomato production as shown in the following payoff matrix.

As Ci regarded as expected payoffs to the farmer in his ith selected vegetable, thus;

$$C_i = (r)\ (\max_{ij} p_{ij}) + (1-r)\ (\min p_{ij})$$

If max Ci = Ci, the farmer will choose i*th vegetable type.*

In this case r = 0.7 and 1-r 0.3

$$P = \begin{array}{c} v_1 \\ v_2 \\ v_3 \\ v_4 \end{array}\begin{array}{c}\begin{array}{cc} t_1 & t_2 \end{array} \\ \begin{pmatrix} 570{,}000 & 1{,}000{,}000 \\ 200{,}000 & 350{,}000 \\ 250{,}000 & 400{,}000 \\ 600{,}000 & 950{,}000 \end{pmatrix}\end{array} \quad \begin{array}{l} C_i \\ (0.7)\ (1{,}000{,}000) + (0.3)\ (570{,}000) = 871{,}000 \\ (0.7)\ (350{,}000) + (0.3)\ (200{,}000) = 305{,}000 \\ (0.7)\ (400{,}000) + (0.3)\ (250{,}000) = 355{,}000 \\ (0.7)\ (950{,}000) + (0.3)\ (600{,}000) = 845{,}000 \end{array}$$

Therefore, max Ci = Ci = C1 = 871,000 → v_1 is ideal under maximax criterion for r i = 0.7.

As revealed by the findings, tomato had the highest payoff of Tshs 871,000/= per 0.5 acre. Optimist farmers opted for tomato production, a situation which is connected to the fact that tomatoes are demanded throughout the year for domestic uses on daily basis, as well as commercially in cafeterias and hotels and small food venders. Tomatoes are important, and in fact necessary requirement in the preparation of most dishes. They are also the basic raw materials used in the production of their preserved alternatives.

Additionally, the selection of tomatoes by optimist farmers was associated by the relatively long harvesting period ranging from five to nine weeks. The risk associated with tomato production is connected with their sensitivity to climatic aspects especially humidity. Tomatoes is presumed to be highly sensitive to soil and environmental moisture due to the fact that moisture is known to affect levels of nematodes and fungi infections. Tomatoes are bulky and perishable with serious implications for transport, shelf life and storability. In Tanzania, and the Western Usambara in particular, there is added risk of post-harvest losses experienced during the high production season as a result of breach in the value chain resulting from low level of processing and value addition. Difficulty in obtaining good quality farm inputs together with high levels of costs of these essentials lead to increased levels of risk faced in the production of tomato.

3.5. Maximin criterion as a tool for the profit maximization among pessimist vegetable farmers

According to the maximin approach, the farmer tries to choose the best of the worst. Basing on this approach, farmers are regarded as pessimistic. This means that farmers select the combination of activities which will maximize their minimum income. This strategy gives the farmer maximum security. Basing on this approach, it was revealed that the highest payoff was obtained from carrot at Tshs 600,000/= per 0.5 acre. In this criterion, the farmer takes a minimum profit for each vegetable type and chooses the type which provides him or her the maximum payoffs of those minimum profits as shown hereunder.

Let min pij = li.

j

If max li = li*, then the farmer choose his i*th vegetable type under maximin

i

criterion.

$$
\begin{array}{cccc}
 & t_1 & t_2 & l\text{i (Row minimum)} \\
v_1 & 570{,}000 & 1{,}000{,}000 & 570{,}000 \\
P = v_2 & 200{,}000 & 350{,}000 & 200{,}000 \\
v_3 & 250{,}000 & 400{,}000 & 250{,}000 \\
v_4 & 600{,}000 & 950{,}000 & 600{,}000
\end{array}
$$

As revealed by the findings, max li = li* = v_4 = 600,000 → v_4 optimal under maximin criterion.

Carrots are bound to be attractive due to the low levels of risks involved in the production. Opting for carrots production, farmers were assured with maximum returns regardless of adverse production and marketing conditions. Relatively, long shelf life of carrots protecting growers from heavy losses. Also the nature of carrots being root vegetable makes it less vulnerable to diseases and pests. The most critical climatic factor is moisture, which is supplemented by traditional irrigation along the valley bottoms.

3.6. Regret criterion as tool for profit maximization among least regret vegetable farmers

This criterion aimed at minimizing the possible regrets of producers (Shin, et al, 2008b). It claims that in order to minimize risk, the least regret farmers will always choose the alternative with the least regret in production. The study revealed that farmers making decision using regret criterion opted for tomatoes and carrots, both with minimum regrets with payoffs of -50,000/= Tshs per 0.5 acre. The payoff matrix using regret criterion revels that tomatoes and carrots had minimum regrets as shown hereunder.

In the first column: - t_1v_1, t_1v_2, t_1v_3 t_1v_4 – t_1v_4 such that:

$$t_1v_1 - t_1v_4 = 570{,}000 - 600{,}000 = -30{,}000$$
$$t_1v_2 - t_1v_4 = 200{,}000 - 600{,}000 = -400{,}000$$
$$t_1v_3 - t_1v_4 = 250{,}000 - 600{,}000 = -350{,}000$$
$$t_1v_4 - t_1v_4 = 600{,}000 - 600{,}000 = 0$$

In the second column: - t_2v_1, t_2v_2, t_3v_3 t_4v_4 – t_2v_1 such that:

$$t_2v_1 - t_2v_1 = 1{,}000{,}000 - 1{,}000{,}000 = 0$$
$$t_2v_2 - t_2v_1 = 350{,}000 - 1{,}000{,}000 = -650{,}000$$
$$t_3v_3 - t_2v_1 = 400{,}000 - 1{,}000{,}000 = -600{,}000$$
$$t_4v_4 - t_2v_1 = 950{,}000 - 1{,}000{,}000 = -50{,}000$$

From above two sets of equations, the regret matrix is created to find the vegetable type with the minimum regret as shown below.

$$\begin{array}{ccc} & t_1 & t_2 & li^{r}(\text{row minimum}) \\ & v_1 & -30{,}000 & 0 & -30 \\ P = & v_2 & -400{,}000 & -650{,}000 & -400{,}000 \\ & v_3 & -350{,}000 & -600{,}000 & -350{,}000 \\ & v_4 & 0 & -50{,}000 & -50{,}000 \end{array}$$

Therefore, max $l_i^r = l_i^{*r} = l_i^r\ 0 \rightarrow v_1$ optimal vegetable (tomato) under regret criterion with least regret of -30 payoff.

3.7. Laplace criterion as tool for profit maximization among prudent vegetable farmers

According to Laplace criterion, when the probabilities of conditions are not known, the probabilities of getting profit and loss are equal. Chances to get profit and loss were given equal weights in this study, and with this situation, the farmer is regarded as being prudent. The weighed value of each vegetable was found by adding the profits of both conditions, divided by two to obtain the average profit for each vegetable as shown hereunder:

Let k_t be the expected profit to the farmer for his or her ith vegetable type under Laplace's criterion.

Then if max $k_i = k_i^*$ thus the farmer opted his her i*th vegetable type.

i

$$\begin{array}{cc|l} & \begin{array}{ccc} & t_1 & t_2 \end{array} & k_i \quad \textit{(Expected payoff of row i)} \\ P = & \begin{pmatrix} v_1 & 570,000 & 1,000,000 \\ v_2 & 200,000 & 350,000 \\ v_3 & 250,000 & 400,000 \\ v_4 & 600,000 & 950,000 \end{pmatrix} & \begin{array}{l} \dfrac{570,000 + 1,000,000}{2} = \dfrac{1,570,000}{2} = 785,000 \\ \dfrac{200,000 + 350,000}{2} = \dfrac{550,000}{2} = 275,000 \\ \dfrac{250,000 + 400,000}{2} = \dfrac{650,000}{2} = 325,000 \\ \dfrac{600,000 + 950,000}{2} = \dfrac{1,550,000}{2} = 775,000 \end{array} \end{array}$$

Therefore, max ki = ki* $k_1 \rightarrow v_1$ is optimal under Laplace's criterion.

From the results of the analysis, the highest weighted value was Tshs 785,000/= per 0.5 acre. This value was obtained from tomato production. Thus, farmers who made decision using Laplace criterion opted to cultivate tomatoes.

Table 2: Types of vegetables opted by each category of farmers for each decision making criteria.

Farmers' characteristics	Model approach (Criteria)	Average profit per 0.5 acre (Tsh)	Opted vegetable type
Optimists	Maximax	871,000/=	Tomato
Pessimists	Maximin	600,000/=	Carrots
Least regrets	Regret	-30,000/=	Tomato
Prudent	Laplace	785,000/=	Tomato

During field survey, it was further observed that the production conditions for most selected vegetables were generally impressive. The survey was conducted between July 2020 and September 2020, which was the season for good condition for most of the selected vegetables. Also, it was reported that production risks were not very much threatening the farmers in the last five consecutive years. However, the farmers pointed out that non- production risk, particularly market related risks were more affecting vegetable farming. They also pointed out that, the market related risks such as absence of reliable markets, shortage of storage facilities, inadequate transport facilities and the presence of unrestful middlemen were the major risks affecting the profit in vegetable farming.

4.0. Conclusion and Recommendations

This study intended to determine the types of vegetables that would be selected by each category of farmers for profit maximization using game theory criterion. The used criterion were maximax, maximin, regret and Laplace. The results revealed that the optimists' least regrets and prudent farmers represented by maximax regret and Laplace criterion respectively opted for tomato cultivation. One the other hand, pessimist farmers represented by maximin preferred to cultivate carrots. Therefore, decision making concerning vegetable production in the Western Usambara Mountains was largely influenced by farmers' characteristics and perceptions of the associated risks and uncertaint

It is recommended that agricultural policy makers, horticulture in particular, should understand vegetable farmers' behaviours and perceptions toward risks and uncertainties when planning to assist them for profitable vegetable production. Understanding farmers' perceptions towards risks in vegetable production would help to identify the type of vegetables which can generate more profit than the other under prevailing conditions. This should go hand in hand with encouraging farmers to change their attitude towards risks, and thus diversify types of vegetables they grow. This will help to reduce overcrowding of similar type of vegetables in the markets, especially during bumper harvest seasons; a situation that is associated with the decline of profits.

Either, the study suggests areas of further study including farmers' perceptions on climatic related risks on vegetable pro farmers' perceptions of non-climatic risks on vegetable production, and the opportunities and challenges in utilizing external overseas vegetables markets. Also the study calls upon the need to investigate the rate at which indigenous vegetables are replaced by exotic vegetable types. Such studies will help both farmers and other vegetable stakeholders to gain more insights on vegetable production and marketing.

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