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APPLICATION OF DECISION MAKING WITH UNCERTAINTY TECHNIQUES: A CASE OF PRODUCTION VOLUME OF MAIZE IN ETHIOPIA

Abstract: *Making of an appropriate decision is a challenge that also determines the success of an organization like Adet Agricultural Research Institute. In this agricultural research institute, production volumes of different maize variety relating to the amount of annual rainfall have been considered as decision strategies or alternatives with their consequences. The decision strategies are based on the amount of annual rainfall. The volume of production of different maize varieties are dependent on the amount of annual rainfall at different locations in Adet Woreda. Hence, the purpose of this study is to analyze and identify optimal strategic decisions for increasing production volume of six variety of maize in Ethiopia – Adet Woreda. The study has applied the five basic techniques for decision making with uncertainty. An eight ye ar production trend of the six variety of maize with different rainfall has been considered in this region to generate different alternatives and finally an optimal strategy has been identified. Accordingly, alternative five (variety PCS.6) is recommended to cultivate in this region, to get maximum production volume annually.*

Keywords:*Decision making with uncertainty, production volume of variety of maize,decision alternatives*

1. Introduction

The Ethiopian agriculture is characterized by extreme dependence on rainfall. The climate is characterized by high rainfall variation (Oram, 1989). Such climate conditions have caused major constraints to agricultural development in Ethiopia. Rainfall being an important climatic element and the study of its variation related to agricultural production like maize production is very important. In agriculture, the production is uncertain both in amount and quality. This uncertainty is due to the fact that uncontrollable elements such as weather conditions or rainfall play a fundamental role in agricultural production such as maize Bert et al., 2005). The amount of seasonal/annual rainfall affects the production volume of variety of maize. Therefore, the problem or the challenge is to determine or decide the variety of maize with the appropriate amount of seasonal/annual rainfall so as to maximize the production volume of maize. One of the approaches or techniques to solve such a

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kind of problem or challenge is decision making under uncertainty (Officer and Anderson, 2001).

In this study, Adet Agricultural Research Institute has been considered as a case study for demonstrating the five techniques of decision making under uncertainty. This research institute has six research departments (crop, livestock, soil and water, forestry and agro-forestry, agricultural mechanization and food science and Agricultural Economics). Due to its importance and wide usage, maize has been selected as a case illustration crop in this study. Maize originated in Central America and was introduced to West Africa in the early 1500s by the Portuguese traders. Today maize is one of the most important food crops worlds wide. It is grown in most parts of the world over a wide range of environmental conditions, ranging between50^0 latitude north and south of equator. It also grows from sea level to over 3000 meters above sea level (Moschini and Hennessy, 2001). It was introduced to Ethiopia during the 1960s to 1970s. In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from low lands to the high lands. It is largely produced in western, central, southern, and eastern parts of the country. In 2012/2013 cropping season 2013044.93 hectares of land was covered with maize with an estimated production not less than 61581175.95 quintals.

Adet Agricultural Research Institute needs to use alternative production strategies to increase the volume of production for different variety of maize with a variety of seasonal/annual rainfall. Different techniques for decision making under uncertainty are applied to optimize the production volume gain per year. This study is to analyze decisions to be made on determining or deciding future production volume of different variety of maize with the given seasonal/annual rainfall in Adet Wereda. This would help the researchers of Adet Agricultural Research Institute to identify an optimal strategy for high volume of production of variety of maize based on the amount of seasonal/annual rainfall in the region. Therefore, the objective of this study is to analyze and identify optimal strategic decisions for increasing production volume of different variety of maize in Adet Woreda.

1.1. Hypothetical approach or scenarios for decision making

In the absence of knowledge about the probability of any state of nature (future) occurring, the decision-maker must arrive at a decision only on the actual conditional payoff values. Scenarios analyses is related with investigating the different alternatives for the option which can performs well with minimum risk (Kurhade and Wankhade, 2015). Currently, scenario assessment is a basic tool used to assess risk and uncertainty about future. Scenario analysis can begin with defining alternative scenarios, its criteria, impacts and risks. Scenario assessments do not forecast what will happen or probability of occurrence they indicate what can happen from different given alternatives (Garg and Singh, 2010). The basic principles which are employed on decision making under uncertainty are considered in this study for determining the probabilities of the situations in the decision process. These principles (scenarios) are applied to analyze and identify an optimal decision from different alternatives for maximizing the production volume of different variety of maize in the given region.

- *Scenario I - Maximax or Minimin:* The maximum principle is the optimist's principle of choice. In Maximax or Minimin criterion the decision-maker should not miss the opportunity to achieve the largest possible profit (maximax) or lowest possible cost (minimin).
- *Scenario II - Maximin or Minimax:* This principle is adopted by

pessimistic decision maker who are conservative in their approach. Using this principle, the minimum pay-offs resulting from adoption of various strategies are considered and among these values the maximum one is selected.

- *Scenario III – Laplace criteria:* it is also called equally likely decision. It is based on the simple philosophy that if we are uncertain about the various events then we may treat them as equally probable. Under this assumption, the expected (mean) value of pay-off for each strategy is determined and the strategy with highest mean value is adopted.
- *Scenario IV – Hurwicz Criterion*: It is also called criterion of realism. The Hurwicz principle of decision-making stipulates that a decision-maker's view may fall somewhere between the extreme pessimism of the maximin principle and the extreme optimism of the maximax principle. This principle provides a mechanism by which different levels of optimism and pessimism may be shown. For this, an index of optimism, α, is defined on scale ranging from 0 to 1. An α = 0 indicates extreme pessimism while α = 1 represents extreme optimism.
- *Scenario V – Savage Criteria:* It is also called criterion of regret. It also know as opportunity loss decision criterion or minimax regret decision because decision maker feels regret after adopting a wrong course of action resulting an opportunity loss of payoff. It is based on the concept of regret and calls for selecting the course of action that minimizes the maximum regret. It is alternatively known as the principle of minimax regret. The regret matrix is derived from the pay- off matrix then the maximum regret value corresponding of each of the strategies is determined and the strategy which minimizes the maximum regret is chosen.

1.2. Overview of decision making under uncertainty

Many organizations face a challenge on making an appropriate decision on the events that will determine their success or failure (Sharma, 2003). While an organization makes a decision, it is necessary to have feasible and viable strategies or alternatives; it requires projecting the consequences associated with different strategies, and also necessary to measure its effectiveness by selecting the most preferred strategy or alternative. Hence, the science of decision analysis is more appropriate to provide a framework for making important decisions (Hillier and Lieberman, 2000). Decision analysis is important whenever there are a set of possible decision alternatives to choose and it allows us to select the best strategy or alternative when there is an uncertainty regarding to the future (Martinez, 2012). Therefore, the basic objective or the goal of decision making with uncertainty is to optimize the resulting payoff using different decision criteria. Nowadays, the decision makers should decide based on the findings from data analysis and decision analysis provides an analytical and systematic approach to the study of decision making.

Decision making is a process of identifying problems and opportunities and choosing the best option among alternative courses of action for resolving them successfully. Mostly, there are three different conditions or situations under which decisions are made: these are decision under certainty, decisions under risk and decisions under uncertainty (Joseph et al., 2010). The scale of certainty can range from complete certainty to complete uncertainty. The difference that ranges between the two extreme points (decision making with certainty and decision making with uncertainty) corresponds to the decision making under risk (probabilistic problems). In the former case, the decision maker has the complete knowledge of the consequence of every decision choice (strategy or alternative) with certainty. It is possible to say that the decision is made under the situation or condition of certainty. In most situations, the solutions are already available from the past experience or incidents and are appropriate for the problem at hand.

On the other hand, there is less information for the decision maker where the situation is uncertain. In this condition, the decision maker will have no or incomplete information and there are many unknowns and possibilities to predict expected results for decision-making strategies (Taghayifard, Khalili and Tavakkoli, 2009). Even it is difficult to assign subjective probabilities to the likely outcomes of strategies. The decision maker himself cannot predict with confidence what the outcomes of his action to be. The decision maker often made an assumption; he/she has no information or intuitive judgment to use as a basis for assigning the probabilities to each state of nature. Therefore, he/she may use their creative approaches and strategies or alternatives to solve the problem based on stochastic probability y functions (Wagner, 1998).

The essential characteristics which are common to all decision analysis models are decision strategies or alternatives, state of nature as well as the payoff value (Hansson, 2005). Of course, there are a finite number of decision alternatives available with the decision-maker at each point in time when adecision is made. The number and type of such alternatives may depend on the previous decisions made and on what has happened subsequent to those decisions (Sharma, 2003).These strategies or alternatives are also called courses of action and are under control and assumed to be known to the decision-maker. Thesemay be described numerically such as, stocking100 units of a particular item or non-numericallysuch as conducting a market survey to know thelikely demand of an item (Jeffrey, 1996). On the other hand, a possible future condition or consequence resulting from the choice of a decision strategy or alternative depends upon certainfactors that are beyond the control of the decision-maker and this is defined as state of nature (in this study the amount of seasonal or annual rainfall in mm^3). For example, if someone is on decision either to carry an umbrella or not, the consequence she/he will be getting wet or not depends on what action took place (Riabacke, 2006). The payoff value is a numerical value that indicates the consequences and results from each possible combination of strategies or alternatives and states of nature.

The decision maker should understand the path for each action through preparation of systematic methods of analyzing the various situations. He/she should gather necessary information to design course of action, identify all events that may occur, take assumptions, describe consequences resulting from the various course of action and determine the probability of an uncertain event occurring (Lopes, 2013). In general a decision involves four steps (Backus et al., 1997): first perception of decision need or opportunity; second formulation of alternative courses of action; third evaluation of the alternatives; and fourth choice of one or more best alternatives. The above five scenarios satisfies those four steps of decision making process. The decision maker would have a chance to see all possibilities from different aspects and select the appropriate strategy. Hence, in this study the analysis of the decision problem or opportunities implies analyzing both the relative production volume of variety of maize and the different seasonal/ annual rainfall amount.

2. Research methodology

When uncertainty exists about the consequences of a particular choice because of stochastic state of nature, the decision problem is said to be risky. External changes like for instance weather conditions that affect the amount of rainfall influences the production volume of crops like maize (Podesta et al., 2002). Hence, the decision maker should see all factors that affect the decision and search the optimal strategy to maximize the production volume. The decision making process involves: identifying and defining of the problem, listing all possible future events, identifying all the courses of action (alternatives or decision choices), expressing the payoffs (P_{ij}) resulting from each pair of course of action, and applying an appropriate decision analysis to select the best strategy or alternative for the given case.

In this research both primary and secondary data are collected. The researcher has conducted a semi-structured interview with the researchers and managers of crop production to collect the information on different varieties of maize production and environmental situations. Secondary data regarding the planned and actual production volume for variety of maize per hectare with different environmental conditions (rainfall in mm) have been collected for the last eight years. Hence, the problems are defined and the possible future events (the amount of rainfall distributions within the given region) which can occur in the context of the decision problem are identified. The course of actions or decision strategies/alternatives are defined and the payoffs (P_{ij}) resulting fromthe course of action (in this case different variety of Maize) and state ofnature (amount of annual rainfall distributions) are expressed to apply an appropriate decision analysis that helped to select the best Maize variety from the given strategies or alternatives.

After collecting the necessary information and data, the appropriate techniques are selected to analyze the data. Decision analysis involves a diversity of techniques to estimate all important information to support the decision maker in selecting appropriate maize variety for specific location with the given amount of rain fall. A model is developed to characterize analysis, and originated a suggested annual amount of annual rainfall in different locations. In this study, the decision making within uncertain condition of annual rainfall amount has considered; it involves strategic or alternative actions (Maize variety) which payoffs depend on the (random) states of nature i.e amount of annual rainfall in mm^3. Specifically, the payoff matrix (Table 1) of a decision problem with *m* strategies or alternative actions (Maize variety) and *n* states of nature (amount of annual rainfall) are represented as follows.

Table 1. The payoff matrix for a decision problem

Course of actions	State of natures				
	s_1	s_2	s_3	....	s_n
a_1	$P(a_1, s_1)$	$P(a_1, s_2)$	$P(a_1, s_3)$	……	$P(a_1, s_n)$
a_2	$P(a_2, s_1)$	$P(a_2, s_2)$	$P(a_2, s_3)$	……	$P(a_1, s_n)$
a_3	$P(a_3, s_1)$	$P(a_3, s_2)$	$P(a_3, s_3)$	……	$P(a_1, s_n)$
. . .	. . .	. . .	. . .	. . .	. . .
a_m	$P(a_m, s_1)$	$P(a_m, s_2)$	$P(a_m, s_3)$	……	$P(a_m, s_n)$

The element $a_i$represents the strategies or alternatives (six Maize varieties) 'i'and the element S_j represents amount of annual rainfall in mm^3 'j'. The outcome associated with different maize variety a_i and amount of annual rainfall in mm^3S_j is $P(a_j, S_j)$. The decision making with uncertain condition is that the probability distribution associated with the amount of annual rainfall in mm^3S_j, $j = 1, 2,3, 4, 5, ... , n$, is either difficult to determine or unknown situation. Because of these situations, the decision maker would lead to the consideration of the five basic criteria for analyzing the decision problems in uncertain conditions.

As stated earlier, in order to analyses this situations commonly used decisions making models under uncertainty were used. These are: Maxi max or Mini min, Maxi min or Mini max, equally likely, Criterion of realism and Criterion of regret. Those techniques are used to compare different decision alternatives in the case study of production volume of different maize variety in the given region (Adet Woreda). In the maximum of maximum or minimum of minimum criterion (maximax or minimin criterion), it is necessary to locate the maximum or minimum payoff values corresponding to each strategy and select the best strategy with anticipated payoff value. In the maximax technique or approach, the maximum production volume with sufficient annual rain fall amount has been considered as one alternative. It is a pessimistic approach. On the other hand, when maximin or minimax technique or approach is applied, the minimum production volume of maize variety with insufficient rainfall amount has been considered. It is a pessimistic approach. In equally likely criterion, the production volume of different maize varieties are mutually exclusive and collectively exhaustive, so the probability of each of these units must be one (number of states of nature). Hence, it is necessary to assign equal probability value to each situation by using the formula (1÷ number of states of nature). Then, Compute the expected (or average) amount of payoff for each strategy by adding all the amounts or payoffs and dividing by the number of possible states of nature or by applying the formula: (Probability of state of nature j) x (Payoff value for thecombination of alternative i and state of nature j) and select best expected payoff value to select best strategy (Kitaw, 2009).

On the other hand, Hurwicz criterion has tried to balance or compromise the two extreme approaches (Optimistic and pessimistic). Hurwicz who suggested this criterion, introduced the idea of a coefficient of optimism (denoted by α) to measure the decision-maker's degree of optimism. This coefficient lays between 0 and 1, where 0 represents a complete pessimistic attitude about the future and 1 a complete optimistic attitude about the future. Thus, if α is the coefficient of optimism, then $(1 - \alpha)$ will represent the coefficient of pessimism. The working methods of this technique are: first decide the coefficient of optimism α (alpha) and then coefficient of pessimism $(1 - \alpha)$ (Wen and Iwamura 2008). Secondly, for each strategy select the largest and the lowest amount or payoff value and multiply these with α and $(1 - \alpha)$ values respectively. Then, finally calculate the weighted average by using the formula and select a strategy with best anticipated weighted average amount or payoff value. Accordingly, in the production volume of maize variety and the amount of annual rainfall would be optimized by applying the criterion of realism. Finally, in criterion of regret, the decision maker would have an opportunity to revise his decision after adopting a wrong course of action. The working methods in this technique are: develop an opportunity loss (or regret) matrix from the given amount or payoff matrix (find best payoff corresponding to each situations of annual rainfall and subtract all other entries - payoff values in that row from this value), for each strategy identify the worst or maximum regret value, then select the strategy (alternative) with the smallest anticipated opportunity-loss value.

The analyses were made on annual production volume of average of eight years for each type of maize variety and evaluate each alternative then to decide the best strategy depending on the situation.

3. Analysis of decision making with uncertainty in production volume of maize

In this study, decision making with uncertainty has been selected to identify and select best strategies or alternatives from the given options based on the values and preferences of the decision maker. In this research, the case area named Adet Woreda has been considered to apply the decision making under uncertainty. In this area, Adet agricultural research center has been doing the research activities especially on different crops such as Maize. The research has focused on the volume of maize variety production with different annual rainfall amount in the selected region or area. Climate variability is one of the main sources of uncertainty and risk in many agricultural systems in Ethiopia. Indeed, agriculture has been described as the most weather-dependent of human activities and most production decisions directly or indirectly involve a consideration of this factor. Because farmers usually do not know what climate to expect in the following growing season, they have evolved conservative cropping strategies that not only may fail to capitalize fully on beneficial conditions but also frequently buffer poorly against negative effects.Decisions involved in maize production were divided into three major groups and their timing. The first group included decisions related to the assignment of land among various possible farm activities (i.e., crops), including maize. The second group involved decisions about maize production technology (hybrid selection, planting date, crop density, fertilizer amount and timing, weed and pest control strategies). Finally, a third group of decisions was linked to marketing strategies for the crop. Decisions that were influenced by expected or realized climate conditions were considered as entry points for climate information.

In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from low lands to the high lands. It is largely produced in western, central, southern, and eastern parts of the country. In 2012/2013 cropping season 2013044.93 hectares of land was covered with maize with an estimated production not less than 61581175.95 quintals. Maize is produced mainly for food, especially in major maize producing regions particularly for low income groups; it is also used as staple food. It is also consumed roasted or boiled as vegetables at green stage. In addition, it is used to prepare local alcoholic drinks known as ‘’tela’’.

Making a decision implies that there are alternative choices to be considered, and in such case Adet crop research center want not only to generate as many of the strategies or alternatives as possible but also to choose the one to be best fits to the researcher goals, objectives, and desires. Decision making with uncertainty as considered in risk situation, involves production volume of different maize variety which the amount of payoffs depend on the (random) amount of annual rainfall in mm^3. The decision is based on the previous trends and data as well as the current situations of the issue. The decision maker does not have complete knowledge about the issue. As stated above, there are five techniques that can be used to compare different strategic alternatives and select an optimal one. Hence, the decision maker needs to see all possible ways before deciding an optimal strategy. Therefore, the researcher has been investigated all possible ways using the five techniques that would be very useful for the decision maker (Adet crop research center). An eight year production trend of the six variety of maize (BH546, PAC781, BH547, Galaxy, CPS.6 and CPS.10) with different rainfall has been collected from this research center and used to generate different alternatives. The summary of these alternatives are tabulated and an optimal strategy has been identified as follows.

The Table 2 shows the variety of maize and its correspondence rain fall with its production volume for eight years on average. It is the average value of eight years for the six variety of maize.

Table 2. Average production volume of variety of maize and its correspondence rainfall

	Annual rain fall in mm^3					
Variety of Maize	<= 500	500- 600	600- 800	800- 1000	1000- 1200	>= 1200
BH546	55	70	65	55	50	40
PAC781	50	62	66	57	45	42
BH547	42	70	78	71	55	51
Galaxy	50	70	64	53	40	38
CPS.6	25	38	60	75	90	85
CPS.10	68	72	56	49	40	30

The following assumptions are considered for the analysis of the data.

- All maize type planting date, crop density, fertilizer amount and timing, weed and pest control strategies to be similar.
- Seed rate to be constant 25 kg per hectare
- Constant sales price for each maize variety

3.1. Computation with Laplace criterion technique or criterion of rationality

From the theoretical point of view, the Laplace criterion is based on the principle of insufficient reason. Since, the probability distributions for the given situations are not known; it is difficult to accept that the probabilities associated with the states of nature are different. The strategies or alternatives in these situations are thus lead to be evaluated using the optimistic assumption that all states (annual rainfall amount) are equally likely to occur. This also called an equal probabilities criterion or criterion of rationality; since the probability of states of nature (in this case the amount of annual rainfall in mm^3) is not known it is assumed that all varieties of annual rainfall occur with equal probability, i.e. assign as an equal probability.

The computation procedures in this method are summarized as:

- Determine expected value for each alternative; if n denotes the number of events and p's denote the payoffs, then expected value is given by $1/n(p_1+p_2+p_3+\ldots+p_n)$
- Choose the alternative that yields the maximum value of p.

Since n = 6, then the expected value (EV) for maize variety of BH546, PAC781, BH547, Galaxy, CPS.6, CPS.10 are computed respectively as follows.

$$\text{(EV) BH546} = \frac{1}{6}(55+70+65+55+50+40) = 55.83$$

$$\text{(EV) PAC781} = \frac{1}{6}(50+62+66+57+45+42) = 53.67$$

$$\text{(EV) BH547} = \frac{(42+70+78+71+55+51)}{6} = 61.17$$

$$\text{(EV) Galaxy} = \frac{1}{6}(50+70+64+53+40+38) = 52.5$$

$$\text{(EV) CPS.6} = \frac{1}{6}(25+38+60+75+90+85) = 62.17$$
$$\text{(EV) CPS.10} = \frac{1}{6}(68+72+56+49+40+30) = 52.5$$

From the above computed values 62.17 is the maximum expected value. Thus, according to Laplace criterion, the Adet crop research center will choose an alternative of Maize variety of CPS.6 if the center feels that this technique is more applicable.

3.2. Computation with maxi max criterion or criterion of optimism

From theoretical point of view, the Maxi max criterion (Table 3) is considered as an optimistic approach. In this technique, the decision maker will select the most maximum value among the maximums of production strategies.It suggests that the decision maker examine the maximum payoffs of strategies or alternatives and choose the strategy whose outcome is the best (maximum value). The computation procedure in this method are summarizing as:

- Locate the maximum payoff values corresponding to each alternative (or course of action or strategy), then;
- Select an alternative with maximum payoff value.

Table 3. Commutation using Maxi max criterion or criterion of optimism

Variety(in quintal)	State of natures(rain fall in mm^3)						Maximumrow
	<= 500	500- 600	600- 800	800-1000	1000-1200	>= 1200	
BH546	55	70	65	55	50	40	70
PAC781	50	62	66	57	45	42	66
BH547	42	70	78	71	55	51	78
Galaxy	50	70	64	53	40	38	70
CPS.6	25	38	60	75	90	85	90
CPS.10	68	72	56	49	40	30	68
The maximum of maximum value							*90*

Thus, the maximum of maximum value is 90 that correspond to the alternative maize variety of CPS.6. Hence, if Adet crop research center follows an optimistic approach, this alternative could be applied.

3.3. Computation with maxi min criterion or criterion of pessimism

In a similar way the Maxi min criterion (Table 4) is considered as a pessimistic approach. The decision maker (Adet crop research center) examines only the minimum payoffs of strategies and chooses the strategy whose outcome is the least bad.This approach may be justified because the minimum payoffs may have a higher probability of occurrence or the lowest payoff may lead to an extremely unfavorable outcome. The computation procedure in this method are summarizing as:

- Locate the minimum payoff values corresponding to each alternative (or course of action or strategy), then;
- Select an alternative with maximum payoff value.

Table 4. Commutation using Maxi min criterion or criterion of pessimism

Variety(in quintal)	State of natures(rain fall in mm^3)						Minimum row
	<= 500	500- 600	600- 800	800- 1000	1000- 1200	>= 1200	
BH546	55	70	65	55	50	40	40
PAC781	50	62	66	57	45	42	42
BH547	42	70	78	71	55	51	42
Galaxy	50	70	64	53	40	38	40
CPS.6	25	38	60	75	90	85	25
CPS.10	68	72	56	49	40	30	40
The maximum of minimum value							42

Thus, the maximum of minimum value is 42 that correspond to the alternative maize variety of PAC781 and BHs47. Hence, if Adet crop research center follows a pessimistic approach, these alternatives could be applied.

3.4. Computation with Hurwitz criterion or criterion of realism

It is one of criterions used to select the minimum and the maximum payoff to each given action. The Hurwitz criterion (Table 5) attempts to compromise the two extremes posed by the optimist and pessimist criteria. Instead of inclining to total optimism or pessimism, Hurwitz considers a measure of both by assigning a certain percentage weight to optimism and the balance to pessimism. However, this approach attempts to strike a balance between the Maxi max and Maxi min criteria. It suggests that the minimum and maximum of each strategy should be averaged using α and 1- α as weights α represents the index of pessimism and the alternative with the highest average selected. The index α reflects the decision maker's attitude towards risk taking. The computation procedure in this method are summarizing as:

- Choose an appropriate, α so that (1-α) represents degree of pessimism.
- Determine the maximum as well as the of each alternative and obtain: H= α*maximum+ (1- α)*minimum, for each alternative.
- Choose the alternative that yields the maximum value of H.
- After discussion with managers and researchers in Adet crop researcher center and through the detail investigation of the average ratio of their plan and their actual output is found to be 100:70 respectively. Hence, the researcher has estimated α value equal to 0.7 which reflects the real situation of the issue.

Table 5. Computation using Hurwitz criterion or criterion of realism

Variety(in quintal)	State of natures(rain fall in mm^3)						Maximumrow	Minimum row	Hurwiz value
	<= 500	500- 600	600- 800	800- 1000	1000- 1200	>= 1200			
BH546	55	70	65	55	50	40	70	40	61
PAC781	50	62	66	57	45	42	66	42	58.8
BH547	42	70	78	71	55	51	78	42	67.2
Galaxy	50	70	64	53	40	38	70	40	61
CPS.6	25	38	60	75	90	85	90	25	70.5
CPS.10	68	72	56	49	40	30	68	40	59.6

The Hurwiz value (HV) for maize variety of BH546, PAC781, BH547, Galaxy, CPS.6, CPS.10 are computed respectively as follows:

HV of (BH546) = 0.7*70 + 0.3*40 = 61

HV of (PAC781) = 0.7*66+ 0.3*42 = 58.8

HV of (BH547) = 0.7*78+ 0.3*42 = 67.2

HV of (galaxy) = 0.7*70+ 0.3*40 = 61

HV of (CPS.6) = 0.7*90+ 0.3*25 =70.5

HV of (CPS.10) = 0.7*68+ 0.3*40 = 59.6

Thus, according to the Hurwitz criterion, the maximum value is 70.5 that correspond to the alternative maize variety of CPS.6 and the research center could prefer this approach to compromise between the two extremes (optimistic and Pessimistic approaches).

3.5. Computation with mini max criterion or minimum regret criterion

Mini max criterion or criterion of regret examines the regret, opportunity loss resulting when a particular situation occurs and the payoff of the selected alternative is smaller than the payoff that could have been attained with that particular situation. The computation procedure in this method are summarizing as:

- Determine the amount of regret corresponding to each alternative for each state of nature. The regret for j^{th}event corresponding to i^{th} alternative is given by:
  i^{th} regret=(maximum payoff - i^{th}payoff) for j^{th} event
- Determine the maximum regret amount for each alternative.
- Choose the alternative which corresponds to the minimum of the maximum regrets.

Table 6. Computation using mini max criterion or minimum regret criterion

Variety(in quintal)	State of natures(rain fall in mm^3)						Maximumrow
	<= 500	500-600	600-800	800-1000	1000-1200	>= 1200	
BH546	13	2	13	20	40	45	45
PAC781	18	10	12	18	45	43	45
BH547	26	2	0	4	35	34	35
Galaxy	18	2	14	22	50	47	50
CPS.6	43	34	18	0	0	0	43
CPS.10	0	0	22	26	50	50	50
The minimum of maximum value							35

Thus, according to criterion of regret technique, the regret value is 35 that correspond to the alternative maize variety of BH547. Hence, the research center minimizes its regret to 35 by selecting this maize variety.

4. Summary of findings

So far, the six variety of maize production volume with different rainfall value has been computed and analyzed using the five techniques or models of the decision making process (Maxi max or Mini min, Maxi min or Mini max, equally likely, Criterion of realism and Criterion of regret) in an uncertain situations. In this research, the different techniques or models have shown the best alternatives to maximize the production volume of maize in this region. The aggregate values (quintals per hectare) are also computed using each techniques or models. The summarized results of alternative decision making models that could be exercised by the research center to increase the production volume of variety of maize are shown on table 7. If the research center applies Laplace criterion, the aggregate value of quintal per hectare would be 62.17 for CPS.6 maize variety. As it is displayed on table 7, the decision models of Laplace criterion, Maxi max criterion and Hurwicz criterion have resulted with CPS.6 maize variety. On the other hand, Maxi min criterion and regret criterion have resulted with BH547 maize variety.

Table 7. Summarized results of alternative decision making models

S.N	Decision analysis models	Selected alternatives	Aggregate value (Quintal per hectare)
1	Laplace criterion	CPS.6	62.17
2	Maxi max criterion	CPS.6	90
3	Maxi min criterion	PAC781, BH547	42 each
4	Hurwicz criterion	CPS.6	70.5
	Regret criterion	BH547	35

Therefore, to select the best strategy for maize variety production in Adet Woreda agricultural research center, it is necessary to consider the aggregate value obtained in each maize variety production strategies.

- Volume of production for maize variety BH546 = 0
- Volume of production for maize variety PAC781= 42
- Volume of production for maize variety BH547= 42+35=77
- Volume of production for maize variety Galaxy = 0
- Volume of production for maize variety CPS.6 = 62.17+ 90 + 70.5= 222. 67
- Volume of production for maize variety CPS.10 = 0

From the above aggregate values, the most profitable production volume of maize variety is CPS.6 and the researcher has proposed this type of maize to be selected by Adet crop research center to increase the production volume.

5. Conclusions

Decision making under uncertainty is a big challenge for the decision maker. In this situation, Probability is an instrument used to measure the likelihood of occurrence for an Event. The limitation in this study is that the decision maker needs to have best experience and knowledge on the issue to select the optimal strategy from the given alternatives. In decisions under uncertainty, the decision makers have to select one of stated alternative course of action with the extended information about their outcomes, costs, and earn financial results. This paper has explored the decision making process under uncertainty of rain fall variation with annul production volume of variety of maize in Adet Wereda. The study has applied the five basic techniques or principles ((Maxi max or Mini min, Maxi min or Mini max, Laplace criterion, Hurwicz criterion and Savage Criterion) for decision making with uncertainty. An eight year production trend of the six variety of maize (BH546, PAC781, BH547, Galaxy, CPS.6, and CPS.10) with different amount of rainfall has been considered in this region to generate different alternatives.The decision making models under uncertainty were used and compared in the case study of production volume of maize variety. The analyses were made on annual production volume of average of eight years for each type of maize variety. Each alternative has been evaluated. The aggregate results show that alternative five (PCS.6) is recommended to cultivate in that area, where the research center should produce the PCS.6 type of maize to get maximum production volume annually. The analysis implied that BH546, Galaxy and PCS.10 have not recommended for that area and further study is necessary to identify and use them on other areas.

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