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Application of game theory model to selecting management strategies for optimization resources in Agricultural field

Udaykumar S. Kashid[1]

[1] *Research Scholar, Department of Mathematics, J.J.T. University, Jhunjhunu (Rajasthan), INDIA.*

ABSTRACT

In current scenario Agricultural become very risky in India because agricultural production is depending a number of risks such as, soil, weather, climate conditions, pesticides, seeds, price difference, organisms and diseases influx to mention a few of this theory of game theory. The study utilized game theory to determine different crops which maximize net profit of farmers under risks, based on different individuality of the farmers. Using game theory, we decide when two or more than two competitors /farmers compete in a rational. The use of this paper optimizes the resources in both favourable and unfavourable conditions. The main objective is to determine the uppermost expected income of lowest expected outcome earned from studying products in the worst conditions and uppermost output in the lowest time with minimum investments. It can be concluded that the game theory model is a good sign for growers selecting alternative management strategies and applications for optimizing resources more yield production.

Keywords:Game theory, field crops, Maximin and minimax, payoff, zero sum game, mixed strategy

I. INTRODUCTION

In recent years, India ranks worldwide second in Agriculture and allied sector as producer of many cash crops. India farm output plays vital role in increasing GDP (Gross Domestic Product). Agricultural plays an essential role, both for humanity's survival and prosperity. Its close involvement in the processes of Life and its strong interaction with bio-societies reflects its vital significance. Well-being is constrained directly by access to security crops supply.

The objectives of agricultural development are achieved only by possible on the condition that the determinate strategies and formulated a mathematical model of appropriate problems in the agricultural area. This situation largely depends on the cognitive level of planner farmer (player) reaction. In a whole world free of uncertainty and risk, the problems of farmers would be greatly simplified by decision making function[1]. Agriculture is the prime source of food crops production is an engine for economic growth of our country; it creates jobs, supports agricultural businesses and generates more income than staple crops per unit area and per person. The potential benefits of for the developing country and the problems of farmers are numerous. Uncertainty is introduced by price difference, pesticides, seeds, organisms and diseases, technical and technological change, industrial change, climate change and unpredictable human action. A farmer could make plans of strategies for obtaining decided goals and then simply carry out the plans. Horticulture crops can generate higher profits than staple crops, especially when agricultural land is relatively minimized, and labour is maximized. Hence the agriculture problems results are signified the future scope and there is no assurance what happens in the future due to uncertainty and risk, so agricultural structure plans are always accompanied with uncertainty and risk.[1][2]

Farmers /Growers must balance the risks of loss against the potential for profit among alternative management strategies. However, operational research tool as like linear programming determines the maximum profit, according to given information and prerequisite knowledge of the situation, but risk and uncertainty are not taking into consideration. [4]

Game theory is a study of how to mathematically determine the best strategy for given conditions to optimize the outcome. Also, it is the branch of Applied Mathematics concerned with the analysis of strategies for dealing with competitive situations where the outcome of a participant's choice of action depends critically on the actions of other participants. In other words, Game theory is "the study of mathematical models of conflict and cooperation between intelligent rational decision-makers"[5][6]

John von Neumann and Morgenstern published their work "The Theory of Games and Economic Behavior" in 1944. The aim of John von Neumann and Morgenstern was "to find the mathematically complete principles which define the rational behaviour of the participants in a social economy, and to derive from them the general characteristics of that behaviour" [2] In 2012, Alvin E. Roth and Lloyd S. Shapley were awarded the Nobel Prize in Economics "for the theory of stable allocations and the practice of market design" and, in 2014, the Nobel went to game theorist Jean Tirole.

Game theory is technique of operational research for the formal study of decision-making where several players must take a decision that potentially affect the interests of the other players. Game theory is a useful tool used in planning under uncertainties. Growers must balance the risks of loss against the potential for profit among alternative management strategies. Uncertainty and risk perceptions play a key role in the production and investment behaviour of farmer's. The aim of this study is to regulate the crops that will be selected from each category of farmers in good and bad from worst using game theory techniques. In game theory, players want their outcome, which the existing limitations resources on the amount of it, reach the optimum Level. The first and main objective of this study is the resolve of the highest expected income of minimum expected outcome earned from studying products in the worst environments and highest output at the lowest time with minimum investments.

Game theory models, conflict, situation arise and helps to improve the decision process by formulating appropriate strategy [5].

We define some terms associated with the game theory.

a) Strategy: A strategy is a comprehensive plan of action, formulated by a player (an interested and active player in the game), who is well informed of all the alternative strategy available to him and to his adversary (competing player).

A strategy can be good or bad. The only requirement is that it should be complete and cover all the possibilities.

b) Pay-off (game) matrix: A pay-off matrix is a tabular representation of the pay-offs of one competitor, which are associated with his strategies in response to the strategies of the other player.

c) Finite game: When the total number of possible strategies in a game is finite, it is called a finite game. In the other situation, the game is an infinite game.

1.1 Objective:

Growers /Farmers will follow any, of any models that which specify a way to operate underneath uncertainty.

1) To examine at the game theoretic criteria to be used as decision models beneath uncertainty by

(a) Demonstrating the categories of drawbacks solution that they recommended and obtained; and

(b) Determining the kind of problem solving for which they are appropriate.2) To find out traditional approaches to decision making under risk and uncertainty.

II SELECTION OF CROPS AS VARIABLE

Growers /Farmers must select crop varieties each production season. Some farmers do not spend much time in making this choice. They plant many varieties which have had satisfactory yields and have displayed other desirable characteristics in past years. The farmer or his neighbours may have had actual experience/prerequisite with the variety or varieties selected. Other farmers consult with research and review experiment station and commercial literature before selecting crops. Research and extension specialists spend considerable time and other resources in evaluating crop varieties and presenting variety data and recommendations to farmers. Usually many varieties are rated as acceptable because their yields, weather, climate conditions, pesticides, seeds, price difference, disease resistance, maturity time, test weight and other characteristics meet certain standards. [7]

2.1 Decision Criteria

Variation/Change in production techniques, developed in new crops, development of new products or inputs, and introduction of other innovations cannot be accurately solved. Such developments may disturb the desirability of alternative options which farmers can make. Price uncertainty is a most important problem of farmers. The static, Mathematical and economic models are heavily on knowledge of prices for making Choices. Thus, the quality of these models is sharply reduced by the existence of worth risk and uncertainty (maximum or minimum). [8] The complicated by reticulated factors that contribute to cost variability.

2.2 The maximin Criteria (principle): Consider Following game as

		Sanjay		
		B1	B2	B3
Abhay	A1	1	5	7
	A2	3	2	-3
	A3	0	4	1

Suppose If Player/farmer Abhay chooses strategy A1, then opponent Player/farmer Sanjay will choose strategy B1 so that the gain of first player/farmer Abhay (or loss of Sanjay) is minimized (to 1). For strategy A2 chosen by Abhay, Sanjay will select the strategy B3. Similarly, for strategy A3 of Abhay, Sanjay will choose the strategy B1. Thus, the minimum pay-offs assured to farmer Abhay are

Strategy	Minimum pay-off
A1	1
A2	-3
A3	0

Among these minimum assured payoffs, Abhay wold try to maximize his payoff. Thus, he would choose the strategy A1 that is the maximin (maximum among minimum) strategy.

Similarly, the opposing Player/farmer Sanjay is playing to minimize his losses. We have the following loss table Corresponding to different strategies selected by him.

Strategy	Maximum pay-off
B1	3
B2	5
B3	7

Then opponent Player/farmer Sanjay will select the strategy B1, which corresponds to the minimum loss among the maximum possible losses, is the minimax strategy of Sanjay.

Thus maximin-minimax principle is that rule based on which one player/farmer(Sanjay) tries to minimize the worst possible losses and the other player/farmer (Abhay) tries to maximize the minimum assured gains. [7]

2.3 Laplace Criterion

The Laplace criterion is based on the hypothesis that the decision maker does not have any knowledge of the "state of nature" that is going to succeed in the period for which he is to decide and, therefore, he should act as though each state of nature was "equally likely" to occur. By this criterion, equal probabilities are assigned to each “state of nature” j in the payoff matrix and then the strategy with the maximum expected payoff is chosen. As there are m possible states of nature in G, the weight assigned to each state of nature (column of P i.e. p_{ij} is the payoff matrix from the viewpoint farmer/player is 1/m or m^{-1}. The Laplace criteria is when the probabilities of many chances of events are square measure unknown, and therefore they should be assumed equal, and the different actions should be judged according to their payoffs averaged over all the states of nature. [9]

Let p_i be the expected payoff to the farmer/player for his i^{th} strategy under Laplace's criterion. Then

$$p_i = \sum_{j=1}^{m} p_{ij}\, m^{-1} = m^{-1} \sum_{j=1}^{m} p_{ij}$$

2.4 Utility Criteria

The utility criterion approach implies that the player/farmer is a risk averter. A risk is someone who preferred a more certain return to an alternative with an equal return, but which is riskier**.**

III CROPS MATERIAL AND STRATEGY

Decision-making/Game theory was used in analyses gross product price knowledge obtained within the production. Gross production price/value was calculated by multiplying crop yield and prices received by farmers depend upon their financial cost and outcomes. The gross production values of crops are different from each other and fluctuated from year to year. In this study, gross product value data, including price and yield of major products and the crop classification. Games are usually classified according to two criteria:

The net product of the theory of game and the number of participants within the game (theory of games). The first criterion makes it attainable to differentiate between the zero-sum games (equal value) and non-zero-sum games (Non equal value). The second criteria is that the number of participants/farmers should be finite. Farmers are working in a circumstance combined with risk, certainty and uncertainty. Uncertainty of future worth price and crop yield can cause uncertainty in income as well as the objective of the farmer. Thus, all the entering of risk in agricultural planning, processing is essential. Therefore, all the risks, certainties and uncertainty facing a farmer can be summarized in the form of a combination of natural production and farmer in front of nature are considered as actors in two-person zero-sum game or non-zero game that largely nature may be ineffective Decision of a farmer in finalized in his farm financial monetary programs randomly. [10][11] During this state of game theory, there are different decision-making criteria to help obtain a farm program. -Game theory depends on to hypothesize the behavior of participants or farmers/players and may make possible to attain in these situations. The first player fears the second player can with conflicting interests recognize his chosen strategy; accordingly, prediction of his behavior for his behavior would be easy. If the first player has 'm' strategy and second player have 'n' strategy, the possible outcomes of game can be shown by the following benefit matrix. Operation research techniques on game theory continues to deliver into rather complicated types of competitive circumstances. However, the main goal during this paper is on the modest case, called two-person, zero-sum games. As the name implies, these games involve only two players or farmers. They are denoted to as zero-sum games because one player wins whatever the other one loses, so that the sum of their net result is zero.

3.1) Two -Farmer Zero sum game

If Two Farmers/players have two coins covered with their hands. Simultaneously and independently, they select a "head" or a "tail" by uncovering the coins in their hands. [12] If the selections match, player 2 (Udita) will give her a coin to player 1 (Archana) and if the selections mismatch, player 1 (Archana) will give his coin to player 2 (Udita). Then the pay-off matrix of the game would be

		Udita	
		Head	Tail
Archana	Head	(1, -1)	(-1 ,1)
	Tail	(-1 ,1)	(1, -1)

In any case, the sum of the pay-offs of the two players/farmers is zero.

3.1.1 Saddle point: A saddle point of a game (if it exists) is that point in the payoff matrix (of player A) where the maximum gain of A is equal to the minimax loss of player B. In such a case, the saddle point is the value of the game.

If we consider pay-offs of both players/farmers, Archana and Udita as

		Udita	
		High	Low
Archana	High	-3	-1
	Low	2	0

Thus, the minimum pay-offs assured to farmer Archana are

Strategy	Minimum pay-off
High	-1
Low	0

Among these minimum assured payoffs, Archana would try to maximize her payoff. Thus, she would choose the strategy Low that is the maximin (maximum among minimum) strategy.

Similarly, the opposing Player/farmer Udita is playing to minimize her losses. We have the following loss table corresponding to different strategies selected by her.

Strategy	Maximum pay-off
High	2
Low	0

Then opponent Player/farmer Udita will select the strategy Low, which corresponds to the minimum loss among the maximum possible losses, is the minimax strategy of Udita.

Hence saddle point of game is to select Low strategy by both farmers.

3.1.2 Stable (equilibrium) solution: If a saddle point exists in a game, the corresponding pair of strategies is a stable (equilibrium) solution.

3.2 Pure strategy: When a player knows with certainty the strategy that he is going to use, the strategy is called a pure strategy. In fact, a pure strategy is a strategy used by the player in the game.

3.3 Game of mixed strategies

When a game does not exist a saddle point, then game theory recommends each player or farmer to assign a probability distribution over the set of strategies. In such type of game, minimax value is not equal to maximin value, so the game does not have a saddle point. In such games the fact persists that on having knowledge about the opponent's strategies; each player can improve his position. Then, in such situations, to arrive at a solution, it is necessary that none of the players should have any advance information about the opponent's strategies. So, in place of having some criterion about choosing a single strategy to be used, a probability distribution is used to choose among various possible (and acceptable) strategies.[13] Since both the players are rational players so they are choosing their strategies in such a manner as to maximize their outcomes.

To express this mathematically, consider a game, being played by two players/farmers Udita and Tanya that have no saddle point. Let player Udita has m strategies available to her and the player Tanya has n strategies available to her. Defined as

p_i = Probability (player Udita uses i^{th} strategy), i=1,2,3….m

q_j = Probability (player Tanya uses j^{th} strategy), j=1,2,3…. n

For player Udita, the pure strategies are i=1,2,3….m and the mixed strategies are $p_1, p_2, p_3 \ldots\ldots p_m$

3.4 Expected pay-off of the player: A measure of performance of mixed strategies:

Although no completely satisfactory measure of practical is available for evaluating mixed strategies or the pure strategy, a very useful one is the expected payoff. By applying the probability distribution.

Let g_{ij} be the pay-off to player Udita when the player Tanya uses the strategy j and she uses the strategy i, i = 1,2… m and j = 1,2…n. Then the expected pay-off of the player Udita is defined as

$$E(U) = \sum_{i=1}^{m} \sum_{j=1}^{n} g_{ij}\ p_i\ q_j$$

3.5 Calculus approach to solve a 2X2 mixed strategy game:

In this Calculus approach method of 2X2 mixed strategy game, the expected value of the game for a player is maximized and the probability (mixed strategy) corresponding to which this maximum value exists, is obtained.

Consider the following 2X2 mixed strategy game.[2]

Let the pay-off matrix of two players/farmers A and U is given as follows:

		Udita (U)	
		y	(1-y)
Archana (A)	x	3	7
	(1-x)	5	2

Player Archana (A) selects her strategies with probabilities x and (1-x) respectively, and the player Udita (U) chooses her strategies with probabilities y and (1-y) respectively. Find the solution to the game

To find the optimal mixed strategy for this game, we must optimize expected gain to any one player. Suppose we want to maximize the expected gain to player A. We assign probabilities x and (1-x) to A of choosing strategy A_1 and A_2 respectively. Similarly, probabilities y and (1-y) are allotted to player U for choosing strategies U_1 and U_2 respectively. [14][15] Then expected gain to player A is given by

$$E(A) = \sum_{i=1}^{m} \sum_{j=1}^{n} g_{ij} p_i q_j$$

E(A)= 3 (x) (y) +7 (x) (1-y) + 5 (1-x) (y)+ 2 (1-x) (1-y) …………….(1)

This expected gain is to be maximized for player A. for that, we differentiate the expression partially with respect to x and y at zero by maxima and Minima principal. We have

$$\frac{\partial E(A)}{\partial x} = 3y + 7(1-y) - 5y - 2(1-y) = 0$$

$$-7y + 5 = 0$$

$$y = \frac{5}{7} = 0.7143 \ldots\ldots\ldots\ldots\ldots(2)$$

$$(1-y) = 1 - \frac{5}{7} = \frac{2}{7} = 0.2857 \ldots\ldots\ldots(3)$$

Similarly,

$$\frac{\partial E(A)}{\partial y} = 3x - 7x + 5(1-x) - 2(1-x) = 0$$

$$-7x + 3 = 0$$

$$x = \frac{3}{7} = 0.4286 \ldots\ldots\ldots\ldots\ldots(4)$$

$$(1-x) = 1 - \frac{3}{7} = \frac{4}{7} = 0.5714 \ldots\ldots\ldots(5)$$

Put equation (2), (3), (4), (5) in equation (1)

Hence, The Expected value of the game is

$$E(A) = 3(0.4286)(0.7143) + 7(0.4286)(0.2857) + 5(0.5714)(0.7143) + 2(0.5714)(0.2857)$$

$$E(A) = 4.7551$$

IV CONCLUSION

The game theory (but mostly pretty simple) has been applied to agricultural situations involving the market behaviour of farmers, climatic uncertainty, the adoption of innovations, bargaining, pesticides, seeds, price difference, organisms and diseases and firm-household relationships. Game theory is concerned with competitive situations. Farm planning problems conceive the farmer playing a game against nature.

Decision criteria used in the study are minimax, maximin, utility, two person zero sum game, mixed strategy game and Laplace criteria. This is since optimistic farmers are not risk averse while maximin the situation. Agricultural applications of game theory can serve as prototypes for possible applications in other fields.

The use of the game theory model in agriculture is to optimizes the resources in both favourable and unfavourable conditions. The main objective of this paper by using game theory is to determine the uppermost expected income of lowest expected outcome earned from studying products in the worst conditions and uppermost output in the lowest time with minimum investments.

Game theory can be useful for project management, construction of major dams at minimum cost, optimum allocation of supply and collection points for fertilizer/seeds and agriculture outputs and optimum mix of fertilizers for better yield.

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