VOL. 7, NO. 5, MAY 2012 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science


www.arpnjournals.com

APPLICATION OF GAME THEORY TO HORTICULTURAL CROPS IN SOUTH-WEST NIGERIA

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ABSTRACT

Agricultural production is susceptible to a number of risks such as climatic condition, price variation, pest and diseases infestation to mention a few. The study utilized game theory to determine vegetables and fruits which maximize net profit of farmers under risks, based on different characteristics of the farmers. Data on vegetables production (input and output) were collected from a random sample of 60 farmers cultivating each of the selected vegetables and fruits (50 farmers) from Oyo and Ondo state. The games were constructed based on the net profit obtained from each of the vegetables and fruits. Maximax, Maximin, Regret, Utility and Laplace criteria of game theory were used in the analysis. The Maximax and Laplace criteria showed that the best vegetable and fruit to cultivate by farmers were Tomato (Net profit of ₦ 526,000/ha) and Pineapple (Net profit of ₦ 1398,200/ha). The results of the Maximim and Utility criteria indicated that *Amaranthus* (net profit of ₦ 272,920) and Pineapple (Net profit of ₦ 1398,200/ha) were the best options. With regret criteria, Pepper (net profit of ₦ 490,000/ha) and Plantain (net profit of ₦ 1348,625.8/ha) were the best options for the farmers. It is recommended for optimistic farmers to produce Tomato and Pineapple while *Amaranthus* is recommended for pessimistic farmers.

Keywords: horticultural crops, game theory, agricultural production, decision criteria.

INTRODUCTION

Agriculture is the principal source of food and livelihood in Nigeria (Philip *et al.*, 2008). Agricultural production in Nigeria contributes more than 30% of the total annual GDP, employs about 70% of the labour force, accounts for over 70% of the non-oil exports and, provided over 80% of the food needs of the country (Adegboye, 2004, Philip *et al*., 2008). Agriculture in Nigeria is a small holder occupation supporting 90 percent of total food production (Olayemi, 1982).

Horticulture is a sub sector of the agricultural sector. Horticultural crop production is an engine for economic growth; it creates jobs, supports agri-businesses and generates more income than staple crops per unit area and per person (GHI, 2007). The potential benefits of horticulture for the developing world are numerous. Horticultural crops generate more jobs per hectare, on-farm and off-farm, than staple based agricultural enterprises (Ali *et al*., 2002). Horticulture crops can generate higher profits than staple crops, especially when land is relatively scarce and labor is abundant (Cock and Voss, 2004; Gabre-Madhin and Hagglade, 2003; Minot and Ngigi, 2004; Subramanian *et al*., 2000). Over two billion people suffer from micronutrient deficiencies through poor diets (UN/SCN, 2004). Fruits and vegetables are the most appealing and affordable sources of these micronutrients. Diet improvement increases a person's productivity, reduces health care related costs and therefore raises the productivity and incomes of the poor (GHI, 2007). Many vegetables and fruits are rich in beneficial phytonutrients including lycopene, beta-carotene and other antioxidant compounds that can reduce the risk of chronic disease by protecting against free-radical mediated damage (Southon, 2000).

Agricultural production is inherently risky, which put farmers at risk of not being able to meet even their basic subsistence needs (Hurley, 2010). Agricultural production depend on some biotic and abiotic processes that are not completely understood (Hurley, 2010). It has been reported by Sahin, *et al.* (2007) that price fluctuations, marketing structures and legal arrangements are the major external factors, which are not under controls of farmers.

Game theory is a mathematical method for analyzing calculated circumstances such as in games where a person success is based upon the choices of others (Wiki, 2011). A game can also be described as a formal description of a strategic situation. Game theory is the formal study of decision-making where several players must make choices that potentially affect the interests of the other players (Turocy and Stengel, 2001). Game theory is a useful tool used in planning under uncertainties (Rasmusen, 2006). Growers must balance the risks of loss against the potential for profit among alternative management strategies (Ozkan and Akcaoz, 2001). Risk perceptions play a key role in the production and investment behaviour of farmers (Ali and Kapoor, 2008). The aim of this study is to determine the crops that will be selected by each category of farmers in good and bad conditions using game theory techniques.

METHODOLOGY

Study area

This study was conducted in Oyo and Ondo state of Nigeria. Ondo state occupies an area of 15,500 km^2 with a population of 3, 441, 024 according to population census of 2006. It is located on latitude 7^o10^1N and longitude 5^o05^1E (Ondo State Wikipedia, 2010). There are 18 local government areas in Ondo state. Oyo State is an inland state in South-Western Nigeria (8°00′N 4°00′E/8°N 4°E). According to population census of 2006 results, it has population of 5, 591, 589 and the state consists of thirty three Local Government Areas (Oyo State Wikipedia, 2010).

Data collection

Data on vegetables production were collected from a random sample of 60 farmers cultivating each of the vegetables from Oyo state while data on fruit production was also collected from random samples of 50 farmers cultivating each of the fruits in Ondo state, Nigeria. In Oyo state, Iseyin Local Government and Ibarapa central Local Government were purposively selected because most of the farmers cultivate horticultural crops and about 70 percent of the populace is farmers. For Ondo State Ile Oluji and Owo local government were randomly selected.

For vegetables, the highest and the lowest gross profit of Pepper, Watermelon, Amaranthus, Celosia, Corchorus, Telfairia, Okra and Tomato were calculated under good and bad condition were determined. Also, the gross profit of selected fruits (sweet orange, plantain and pineapple) was also calculated under good and bad conditions. Following Sahin *et al.*, (2009) approach, unsuccessful production period represented a bad situation where negative climatic conditions, low yields and low product prices were predominant. On the contrary, the successful production period represented a good situation where positive climatic conditions, high yields and high product prices were predominant.

Decision criteria

There are several well-known approaches to decision making under uncertainty, although none is really satisfactory. Maximax, Maximin, Regrets, Utility and Laplace were determined as the major criteria of game theory considering that these criteria would explain the primary producers' characteristics (Miran, 2005).

Maximax (Optimist)

The maximax criterion indicates that the decision-maker should choose the alternative which maximizes the maximum value of the outcome. This optimistic approach implies that the decision-maker should assume the best of all possible worlds (Business Dictionary, 2011).

Maximin (Pessimist)

This pessimistic approach implies that the decision-maker should expect the worst to happen. The maximin person looks at the worst that could happen under each action and then choose the action with the largest payoff. They assume that the worst that can happen will, and then they take the action with the best worst case scenario.

Regret criterion

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. The decision-maker should choose the alternative that minimizes the maximum regret he could suffer.

Utility criterion

The utility criterion approach implies that the farmer is a risk averter. A risk averter is someone who prefers a more certain return to an alternative with an equal return but which is more risky.

Laplace criterion

This is when the probabilities of several chance of events are unknown, they should be assumed equal, and the different actions should be judged according to their payoffs averaged over all the states of nature.

Table-1. Strategies of players which represent production and marketing conditions.

Strategies	Characteristics marketing conditions
Good Conditions	Successful marketing
	Increases in product prices
	Good climatic conditions
	Pest and diseases free
Bad Conditions	Unsuccessful marketing
	Decreases in product price
	Bad climatic conditions
	Pest and diseases infestation

RESULTS AND DISCUSSIONS

Maximax criterion

Based on maximax criteria, the player is optimistic about production, weather and pricing conditions. An optimist farmer will therefore cultivate tomato and pineapple on his farm. Tomato had the highest profit of ₦ 526,000 per hectare in good condition. This was followed by pepper having the profit of ₦ 490,000/ha. For fruit production, an optimistic farmer will select pineapple with net profit of ₦ 1398,200/ha under good condition (Table-2).

Optimists preferring tomato production may be connected with the fact that tomato is demanded throughout the year. They are required by every household on daily basis. Tomato is important and in fact indispensable requirement in preparation of most dishes. They are also the basic raw materials use in production of their processed/canned alternatives. The risk associated with tomato husbandry has to do with their sensitivity to climatic factors especially moisture. Tomato is reputed to be highly sensitive to soil and environmental moisture due to the fact that moisture is known to affect levels of nematodes and fungi infestations. Tomatoes are bulky and perishable with serious implications for transport, shelf life and storability. In Nigeria, there is added risk of peculiar glut experienced during the peak period of production as a result of breach in the value chain resulting from low levels of processing and value addition. Difficulty in procurement of inputs and labours coupled with high levels of costs of these essentials lead to increased levels of risk encountered in production of tomato.

Pineapple is a crop of choice for an optimist farmer because it is a prime fruit whose distinct taste and flavour is relished by foreign and indigenous elites in high brow neighborhoods throughout the country. It is in critical demand by fruit processing industries and produce exporters. The risks associated with pineapple production are directly linked to scarce planting materials and tillage requirement. Pineapple husbandry may be particularly cumbersome due to challenges of tillering and flowering dormancy which may affect yield and profit levels if left in hands of uninitiated labour. Pineapple fruits are bulky and highly perishable creating a critical harvesting, transport, handling and marketing challenges.

Maximin criterion

According to the maximin strategy the player, in this case the farmer tries to choose the best of the worst. The farmer is regarded as a pessimist based on this criterion. This means that the farmer selects the combination of activities which will maximize his minimum income. This strategy gives the farmer maximum security. According to this criterion, the highest net profit under bad condition is obtained from amaranthus production at ₦ 120,000/ha. Similarly for fruits, the best of the worst is from pineapple production with a net profit of ₦ 700,000/ha (Table-2).

Amaranthus are certainly bound to be attractive to pessimist due to the low levels of risks involved in their husbandry and production. Low levels of capital are involved protecting growers from heavy losses. The gestation period is fairly short resulting in low levels of labour requirement and interest on capital. The most critical climatic factor is moisture which is redeemable through irrigation. The least sophisticated irrigation technology is always sufficient in production of amaranthus.

Regret criterion

The minimization of the possible regrets of producer was aimed with this criterion (Sahin, *et al*., 2008b). In order to minimize risk, the farmer will choose the alternative with least regret in his production. In this study, the next best alternative is Pepper. From the results of the analysis, the regret of the producer was estimated at ₦ 36,000/ha. The next best alternative in fruit production is plantain with a net profit of ₦ 195,950/ha (Table-2).

Utility criterion

This criterion assumes that the producer is risk averter. To determine the utility values, the lowest value of strategies was determined and subtracted from all the results of related strategy (Sahin, *et al*., 2008b). For risk averter farmers would prefer to produce amaranthus with net profit of ₦ 110,000/ha. In the same vein for fruits, risk averter farmers will choose pineapple with net profit of ₦ 550,000/ha (Table-2).

Laplace criterion

According to Laplace criterion, when the probabilities of conditions are not known, the probabilities of the good and bad conditions are equal. Good and bad conditions were given equal weights. The farmer is regarded as being prudent. The weighted value of each strategy was found by multiplying both of two conditions with 0.5 and then added together (Sahin, *et al*., 2008b). From the result of the analysis, the highest weighted value was ₦ 273,000/ha. This value was obtained for tomato production. Further, for fruit production, the highest weighted value was obtained from pineapple with a value of ₦ 1,049, 100/ha.

Table-2. Game theory results for farmers.

Producers characteristics	**Criterion**	**Net profit ₦ /ha for vegetable**	**Net profit ₦/ha for fruits**	**Preferred products** (vegetables and fruits)
Optimistic	Maximax	526, 000	1398, 200	Tomato, pineapple
Pessimistic	Maximin	120, 000	700, 000	Amaranthus, pineapple
The least regrets	Regret	36, 000	195, 950	Pepper, plantain
Risk averter	Utility	110, 000	550, 000	Amaranthus, pineapple
Prudent	Laplace	273, 000	1049, 100	Tomato

CONCLUSIONS

Decision making will be influenced by farmers' characteristics. Decision criteria used in the study are maximax, maximin, regret, utility and laplace criteria. Optimistic farmer will chose tomato while pessimistic will cultivate amaranthus on the farm. This is due to the fact that optimistic farmers are not risk averse while pessimistic farmers are risk averse in nature.

ACKNOWLEDGEMENTS

Special thanks to Dr. Ahmed Sahin, Assistant professor, Department of Agricultural Economics, Faculty of Agriculture, Kahramanmaras Sutcu Imam University, Turkey for his assistance in the course of this study. Our appreciation also goes to Mr. Wasiu Adeoye for his guidance and assistance in the study.

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