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Review on Decision-making under Risk and Uncertainty in Agriculture

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ABSTRACT

One of the most celebrated and feared concepts in the world today are risk which is the product of uncertainty. Many studies said, risk and uncertainty are often used interchangeably as they are the same thing, but it is not true. While risk can be measured and estimated but uncertainty cannot. Uncertainty regarding complete unawareness of the future and there is no amount of technical adjustment or mathematically delicacy that can change our basic ignorance of the future. However, risk and uncertainty cannot be separated because where there is uncertainty, there is risk. The probability of risk can be measured precisely, while that of the uncertainty can only be measured through the subjective likelihood depending on the marginal utility of an individual. Probably, no single model is the best at farm level, but the use of, MOTAD with compromise programming, marginal utility of money and Linear programming (LP) technique seems to offer a more powerful analytical instrument for agricultural systems modeling with respect to risk, uncertainty and decision-making, respectively.

Keywords: Risk, uncertainty, linear programming, MOTAD, decision-making

In agriculture production system, a cropping pattern or allocation of land to different type of crops varies with farmer's perspective of his land holding. For each farmer, profit becomes an objective function which he wishes to maximize. These problems of allocation of land for different crops, maximization of production of crops, maximization of profit, minimization of cost of production are addressed in agricultural management system. But with changing scenario of complex real life problem, several objectives need to be associated in the agricultural planning and management. Thus, some alternative methods were needed to handle this complex problem of decision-making, as the maximization of crop production cannot guarantee the maximization of profit. In the agriculture sector, profit or loss also depend on fluctuating demand, supply and pricing of a particular crop with minimization of cost of cultivation needed for that crop. Thus, the maximization of profit turns out to be a multi-objective decision-making problem.

Agricultural production is biological in nature and heavily depends on agro-climatic conditions and is carried out mostly in small sized holdings. Recurrent and speedy choices are to be taken up in agricultural production. Therefore, the farmer has to make decisions in extremely unstable and insecure circumstances (Nieuwoudt, 1972).

Historically, risk and uncertainty behavior of decision makers have been studied quite well with respect to individual agricultural producers. Most farmers adopt risk-reducing strategies involving such elements as flexibility, liquidity, diversification and are cautious in adopting new techniques and levels of input use that yield less than maximum expected returns.

Any situation in which decision maker is challenged with a choice between alternatives actions constitutes a decision problem. Most economic theory has been developed for analysis of decisions under conditions of certainty where in the precise outcomes of all actions are assumed know. However, most "real world" decisions were taken in the face of risk or uncertainty. That is, precisely what outcome will occur as a result of taking a particular action is not known to the decision maker (Anderson, *et al.*, 1997).

Risk and uncertainty in agriculture

The terms 'risk' and 'uncertainty' can be defined in various ways. One common distinction is to suggest that risk is imperfect knowledge where the probabilities of the possible outcomes are known and uncertainty exists when these probabilities are not known. Ahuja (2010) defines risk as a situation which the outcome of a decision is uncertain but the probability of each possible outcome is known and can be estimated. The analysis of decision-making and choice involving risk requires that the individual knows all the possible outcomes and also have some idea of the probability of occurrence of each possible outcome. For example, in tossing a coin there is equal chance of getting either head or tail. But this is not a useful distinction, since cases where probabilities are objectively 'known' are the exception rather than the rule in decision-making. Instead, in line with common usage, we define uncertainty as imperfect knowledge and risk as uncertain consequences, particularly possible exposure to unfavourable consequences. Risk is therefore not value-free, usually indicating an aversion for some of the possible consequences. For these decisions, risk may be judged to be significant. In farming, many farm management decisions can be taken with no need to take explicit account of the risks involved. But some risky farm decisions will warrant giving more attention to the choice among the available alternatives.

Types and sources of risk in agriculture

Because agriculture is often carried out in the field and always entails the management of inherently variable living plants and animals, it is especially exposed to risk. *Production risks* come from the unpredictable nature of the weather and uncertainty about the performance of crops or livestock, for example, through the incidence of pests and diseases, or from many other unpredictable factors.

Price risks is also a standard attribute of farming activities. Because of the biological production lags mentioned above, production decisions have to be made far in advance of realizing the final product, so that the market price for the output is typically not known at the time these decisions have to be made. Price uncertainty is all the more relevant because of the inherent volatility of agricultural markets. Such volatility may be due to demand fluctuations, which are particularly important when a sizable portion of output is destined for the export market. Production uncertainty as discussed earlier, also contributes to price uncertainty because price needs to adjust to clear the market. In this process some typical features of agricultural markets are responsible for generating considerable price volatility, even for moderate production shocks (Giancarlo and David, 1999).

Governments are another source of risk for farmers. Changes in the rules that affect farm production can have far-reaching implications for profitability. For example, a change in the laws governing the disposal of animal manure may have significant impacts; so too numerous changes in income-tax provisions, or in the availability of various incentive payments. Risks of these kinds may be called *institutional risks*.

The people who operate the farm may themselves be a source of risk for the profitability and sustainability of the farm business. Major life crises, such as the death of the owner or the divorce of a couple owning a farm in partnership, may threaten the existence of the business. Prolonged illness of one of the principals may cause serious losses to production or substantially increased costs. And carelessness by the farmer or farm workers, in handling livestock or using machinery for example, may similarly lead to significant losses or injuries. Such risks may be called *human or personal risks*.

The aggregate effect of production, market, institutional and personal risks comprise business risks. Business risks are the risks facing the firm independently of the way in which it is financed. Such risks comprise the aggregate effect of all the uncertainty influencing the profitability of the firm. *Business risks* affect measures of farm business performance such as the net cash flow generated or the net income earned.

Technological risk associated with the evolution of production techniques that may make quasi-fixed past investments obsolete, emerges as a marked feature of agricultural production. Technological improvement necessarily implies that the same level of input can now produce larger quantity of produce. The upward shift in the production function signifies that more output can be produced at each level of input after technological progress. This effect would-be due to the delayed operation of the law of diminishing marginal returns. Thus, improvement of knowledge or technological progress, which is a continuous phenomenon, may render some techniques less efficient and finally obsolete. In the Fig. 1 for the same input level X_0, the yield is increased from Y_0 to Y_1 due to technological improvement from T_0 to T_1.

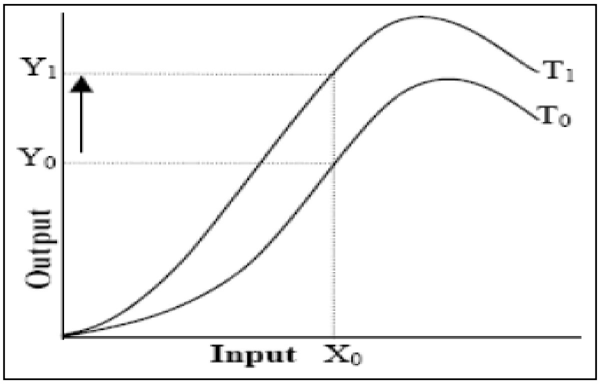

Fig. 1: Improvement in technology increases the yield

Risk management and decision analysis

Many descriptions of the process of risk management view risk as rather like a disease that has to be treated. Decision-making involves setting your goals and objectives, identifying the problem, determining your alternatives, evaluating these alternatives, selecting an alternative, implementing that alternative, and bearing responsibility for the outcome. Decision-making in a risky environment also involves attitudes toward risk, ability to bear risk, and formation of expectations about the future. The decision-making process is complex, and farmers differ both in how they make decisions and in the decisions they make. Instead of treating risk management as something that is separate from general management of an organization, we see a need to account for risk as an integral part of all management decision-making. We take this view because just about every decision has its consequences in the future and we can never be certain about what the future may bring. So most if not all management decisions create some risk exposure. Making risk management a separate process ignores this reality. Moreover, economics teaches that profit is the reward for risk taking – no risk means no gain. So what is needed is a process to balance risk against possible rewards. Separating out the treatment of risk may ambiguous the need to get the balance right.

Obviously, some decisions are more risky than others and those for which the range of possible consequences is narrow, with little or no chance of a really bad result, can be handled easily with a bit of common sense. But there are also other decisions for which the range of possible consequence is wide, perhaps with a non-trivial chance of bad outcomes. For these decisions much more careful consideration will certainly be warranted. However, dealing with such risky choice is not easy – there may be many options to choose between and the consequences of each may depend on many uncertain factors. Decision analysis may be defined as the philosophy, theory, methods and practices necessary to systematically address important risky decisions. Decision analysis includes methods and tools for identifying, representing and assessing important aspects of a risky decision, leading to a recommended course of action consistent with careful consideration of the possible consequences of the alternative choices, the associated probabilities of those consequences and the relative preference for possible outcomes. In other words, it is a prescriptive theory of choice.

REVIEW OF LITERATURE

Risk in agriculture

Camm (1962), analysed alternative plans for 100 acres farm using quadratic programming technique that illustrated the degree of risk likely to occur from price and yield variation. The alternative crop plans were obtained for the different levels of returns which promised to cover fixed costs and were suggested for consideration by farmers. Results showed that, the fluctuations in yield and prices of products were considered to represent the greatest variation in gross margin, the averages, variance and covariance's of gross margins from a sample of farms.

Shahid (1998), studied on risk efficient resource allocation in agricultural systems of Pakistan: a farm level analysis can ensure optimal utilization of available farm resources for a given level of risk. In common, farm-planning models make a large set of farm plans. Farmers can choose the plan that outfits their production environment and is matching with attitude towards risk. It uses compromise-programming techniques together with risk planning methods over risk-programming models for developing the best compromise farm plans. Compromise farm plans furnish useful evidence on resource sharing and risk. It can also be utilized for assessing environmental costs in agriculture with little adaptation. But ecological problems where-some limitations are required to be placed on the use of some inputs with known ecological externalities.

Frank and Ragnar (1999), emphasized that firm behavior under risk with the help of panel data set of Norwegian salmon farms, showed that the structure of production risk plays an important role in production decisions of risk-averse producers, both with respect to optimal input levels and to adoption of new technologies. Farms are heterogeneous with respect to production risk. In other words, farms employing the same input levels have different levels of output risk. Inputs are found to be risk-controlling instruments .Since production risk is an inherent feature of the production process in most primary industries.

Mukherjee (2010), explores the relationship between crop diversification and risks in India. Herfindhal's index has been used to investigate crop diversification level across major states in the study period. The study indicated that compute yield risk and price risk of each states using markowitz's mean variance theory and map it with the crop diversification for the corresponding states. It is seen that while the relationship is optimistic in the case of crop diversification and yield risk, there is no relationship between crop diversification and price risk. Accounting for the existence of uncertainty and the attitude towards risk would help in better comprehension of the cropping decision.

Otaha and Imo (2012), noted that investment decisions are based principally on the attributes of these three classes of decision makers *i.e.*, the risk averter has diminishing marginal utility of money whose subjective probabilities is greater than his objective probability, while risk lover has increasing marginal utility of money with his objective probability more than his subjective probability and risk neutral has constant marginal utility of money with his objective probability equal to his subjective probabilities. It also observes that corruption and unfavourable macroeconomic environment in Nigeria compared to other countries are the major determinants of low investment in Nigeria.

A study conducted by JitkaJanova (2014), in the Czech Republic revealed that crop plan optimization under risk on a farm level developed is covering both the randomness of parameters entering the problem and the complex crop succession requirements. In the crop plan model presented, the harvests randomness is considered and in addition to the common agribusiness restrictions, also the crop succession requirements are incorporated via the linear constraints. The results obtained from the model for a provided the areas of arable land cropped by the particular crop plants. These areas fulfill the fundamental crop rotation rules while performing the expected profit at a sufficiently high level as shown by the Monte Carlo simulation. The model does not determine the pattern of the land, hence the farmer himself/herself has to decide where the crops will be and a good level of profit can be expected.

Uncertainty in agriculture

Bowden *et al*. (1985) explained the research paradigm for system agriculture. According to them, agriculture was a complicated human activity involving uncertainty and change. There was a need for system thinking considering agriculture with a sense of its complex wholesomeness and to take active and feasible action. According to them, Farming System Research was primarily concerned with the adoption of existing agricultural research to provide technology, relevant to farm resources.

Srinivasraju *et al*. (2000) studied on optimum cropping pattern for Sri ram sagar project with an objective of maximization of net benefits. Uncertainty in the inflows arising out in the uncertainty in the rainfall is tackled through chance stochastic programming. Inflows at 4 levels of dependability *viz.*, 75%, 80%, 85% and 90% were considered in this study to obtain various possible optimal cropping patterns and optimal operating policies. Results indicated that for 90% dependability level, paddy (summer) and paddy (winter) occupied 62,930 ha and 14,700 ha area, respectively. The acreage of groundnut (summer), groundnut (summer rainfed) and groundnut (winter) were 1500 ha, 93,260 ha and 15810 ha respectively. The acreages of chillies and sugarcane were 3100 ha and 4100 ha respectively. Total irrigated area was 1, 81,590 ha (101.96% irrigation Intensity) whereas total cropped area is 2, 74,860 ha (153% Cropping intensity). The optimum cropping pattern yield net benefits of ₹ 1,672 million.

Hasan and Murat (2005), explained the reasons for variability and the difference between risk and uncertainty in wheat production in Turkey. Annual data belonging to yield and price of wheat cover the period of 1981-2000. The level of uncertainty in yield, price and gross income was examined for wheat via using coefficient of variation and coefficient of random variation. Results show that farmers are faced vagueness in agricultural production due to some factors (climate changes, price policy changes, etc), which are not under the control of farmers. To reduce risk and variability, agricultural insurance, product diversification, contract farming and future markets can be the solutions.

Rajkumar (2007) while studying the economics of redgram based cropping systems in Bidar district of Karnataka. CS-I (redgram + jowar), CS-II (redgram + blackgram), CS-III (redgram + soybean), CS-IV (redgram + greengram) and CS-V (redgram sole) were the five important redgram based cropping systems followed in the study area. Results showed that the majority of farmers faced exogenous factors problems of high wages, scarcity of own fund, price instability and absence of market information which lead to uncertainty of income to the farmers.

A study on optimum allocation of agricultural land to the vegetable crops under uncertain profits using fuzzy multi-objective linear programming-revealed that optimum cropping patterns using Linear Programming (LP) technique in case of fixed prices (profits) of crops. But instability in prices is high for vegetable crops due to their costly cultivation with high risk of profitability even though enhanced profits over food crops. The study makes an effort to compute the volatility in profits of vegetable crops using max-min approach of fuzzy programming. Results showed that, a proper land utilization and proper cropping pattern is needed at farmers' level itself. The farmer must grow the vegetable crops in a way that it should be picked and be marketed in whole period to find at least best weighted return as a assured profit of ₹ 10.89 lakhs in spite of fluctuating prices (Lavanya Kumari *et al*., 2014).

Decision-making and Risk programming

Binswanger *et al*. (1980) elicited the risk preferences of a sample of Indian farmers. They used several elicitation techniques, one of which included gambling questions with real monetary pay-offs. These methods measured farmers' levels of risk aversion, which were then used in regression analyses of farmers' adoption decisions. Statistical significance tests showed mixed results, and their findings were inconclusive with regards to risk aversion.

Berbel (1993) proposed a multi-criteria approach or dealing with risk when modelling an agricultural system through the simultaneous use of risk and game-theoretic programming. The use of multi-criteria techniques enables the decision maker to study the trade-offs and conflicts between profitability (expected returns) and risk (measured either by Partial Absolute Deviation (PAD) or minimum gain). Results suggests that, in practice, solutions generated by risk and game-theoretic programming are quite similar.

Visagie *et al.* (2004) analysed optimising an integrated crop-livestock farm using risk programming. This study attempts to identify the optimal mix of crops and the number of animals the farm needs to keep in the presence of crop production risk for a range of risk levels. A mixed integer linear programming model was advanced to model the decision environment faced by an integrated crop-livestock farmer. The deviation of income from the expected value was used as a measure of risk. Results of the model under different constraints shows that, in general, strategies that depend on crop rotation principles are preferred to strategies that follow mono-crop production practices. Mono-crop systems (wheat and medics) failed to enter to the optimal solution in all the risk levels specified. For profit maximisation and risk minimisation integrated crop-livestock environment diversification is the best option.

The farmers operate under extreme risk situations of flood and drought in Nigeria. Risks in Wetlands Farming was estimated by using Minimization of Total Absolute Deviation (MOTAD) model. Model indicates that with the existing plan, the farmer is going to get a gross income of ₹ 28624 where as in profit maximising plan, it was ₹ 33744. In case of risk efficient plan, it was around ₹ 13762, ₹ 15668, ₹ 19912 and ₹ 28063 respectively. The mean absolute deviation is least (₹ 7049) in case of plan 3 which is most risk efficient plan (Gabriel and Umoh, 2008)

Sachinkumar (2012) studied the risk efficient farming systems in the farming systems in northern transitional zone of Karnataka. Minimization of total absolute deviation (motad) model as suggested by Hazell (1971) was used. The MOTAD model can incorporate the risk element associated with net returns of the farming system. The absolute mean deviation of the net returns was considered to signify the risk involved through the farming systems. Results depicted that the optimum plan suggested complete replacement of soybean with groundnut (1.70 ha) in irrigated land and chickpea and cotton with jowar (1.09 ha) in day land. The dairy enterprise was unaffected. The risk efficiency forces the farmers to allocate more area to soybean (1.72 ha) in irrigated land and cotton (0.63 ha) and jowar (0.46 ha) in day land with 2.16 dairy animals per farm.

Agarana *et al*. (2014) observed that most banks fail as a result of mismanagement of credit risk. The management of credit risk as it affects loan portfolio management and proactive strategy to seek out relative value opportunities are considered. An operational research procedure, linear programming, is applied to the management of loan portfolio of banks. Results obtained by using simplex method showed that, how to avoid possible occurrence of non-performing loans, bad and doubtful debts in banks when some percentage of the loans they give out are not secured. Reducing the unsecured short term loan to 2%, that is the class of loan which originally was to be greater or equal to 70% was reduced to less than 2%, gives optimal solution greater that when this class of loan was ≥ 0.2%. A sensitivity analysis is carried out by altering the percentages of the unsecured loans and showed that, reduction in the percentage of unsecured loan improves the banks objectives marginally especially when the loan is of a longer term.

Decision-making in agriculture: a linear programming methodology aimed at to determine the optimum allocation of land of five food crops by using agriculture data, with respect to various input factors viz. daily wages of labour and machine charges for the period 2004-2011 and solved by standard simplex algorithm. It is observed that the total land used is found to be 2752.56 acres which is greater than 2409 acres than the land available for cultivation in the first season. The maximum profit achieved is ₹ 1376 (Sofi *et al.,* 2016).

CONCLUSION AND POLICY RECOMMENDATIONS

It is profusely clear that considerations of uncertainty and risk cannot be escaped when addressing most of the agricultural economics problems. The economic analysis are multi-layered and widespread, with issues that extend from the pure theory of rational behaviour to the practicality of developing risk-management advice. There are several mathematical programming techniques available for modeling of specific agricultural systems problems. Probably, no single model is the best at farm level, but the use of, MOTAD with compromise programming, marginal utility of money and Linear Programming (LP) technique seems to offer a more powerful analytical instrument for agricultural systems modeling with respect to risk, uncertainty and decision-making, respectively. Linear Programming (LP) technique is pertinent in optimization of resource allocation and achieving efficiency in achieving increased agriculture production of food crops (rice, wheat, maize, pulses and other crops). Decision-making in agriculture, a linear programming approach aimed at to determine the optimum land allocation of food crops with respect to various factors and constraints. In addition to the information that MOTAD offers (risk-efficient set of farm plans and trade-off among objectives), compromise MOTAD furnishes the farmer with very useful information on the compromise sets of farm plans.

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