11 Risk and uncertainty management in agricultural holding

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Abstract

The goal of the paper is to present improvements in decision-making processes under conditions of risk and uncertainty. The identification of the risk source and uncertainty, which affects the decision-making of farmers, is an important activity on which depends the achievement of better financial effects. Many decisions in the agriculture have the outcomes which are realized through the longer period, after the decision is made. The sources of risk and uncertainty in agriculture are varied, but it can be summarized in five areas of management: production and technology, prices and market, finance, legislation and employees. Risk management in agriculture is engaged in reducing the possibilities of unfavourable outcomes or alleviating its negative effects. Not every decision will be right every time, but decision-making under uncertainty is difficult. The decision can be improved by identification of possible events, assessment of values of its outcomes and variability. Decision tree, matrix profitability and cumulative distribution function can be used in choosing between the risky variants.

Keywords: agricultural holding, risk, uncertainty, management

JEL Classification: D81, Q12, Q14

11.1. Introduction

The agriculture is a risky business. Usually, there is uncertainty about the price, yield and financing conditions. In this paper, some of the procedures for improvement of the decision-making process under conditions of risk and uncertainty are defined, and the techniques are reconsidered, as well as strategies for reducing the risks which are hidden in agricultural production.

The hypothesis is that all necessary information about the input and output prices, yields and other technical data are available and exact, but in practice when it comes to agriculture, it is a rare case [Kahan, 2013].

Many decisions in agriculture have the outcomes, which are being realized for months or years after the original decision had been made. Managers consider that their decisions are the best, and often it turns out that they are not, due to changes, which occur between outcomes and the time when the decisions are made.

The farmers, who are engaged in agriculture, have to make decisions at the beginning of the agri-economic season what crops to sow and to what extent, what should be the level of fertilisers and other inputs, which will be used. The final yield and prices will not be known and secured, but it will be known after several months or even several years, in the case of perennial crops.

The farmer, who has decided to expand the herd of cows by extension and replacement of heifers, must wait for several years before he receives the first income from calves of heifers, which he keeps as a herd for expansion. Unfortunately, the farmers can do little in order to accelerate biological processes in plant and livestock production or to make them more predictable.

When the outcome is more favourable than expected, manager can apply more aggressive deciding or implement decisions to a larger scope. In that situation, financial status is improved and there is no threat to the business. Real risk comes from unexpected outcomes with undesirable results, as lower prices, huge drought or disease. Risk management in agricultural holdings deals mainly with reducing the possibilities of unfavourable outcomes or at least alleviating them.

11.2. The source of risk and uncertainty in agriculture

Risk is a term that is used for description of situation in which the possible outcomes and opportunities are known for each of them. It means that there is more than one possible outcome of a previously made decision [Piggott et al., 2006]. On the other hand, uncertainty characterizes the situation in which the possible outcomes and their probabilities are unknown. The sources of risk and uncertainty in agriculture are varied, but it can be summarized in five areas: production and technology, prices and market, finance, legislation and employment [Aditto et al., 2012; Kay et al., 2012].

Usually, there is a correlation between different forms of risk in agriculture. The risk of yield and the risk of price have a tendency to be in negative correlation [Tangermann, 2001].

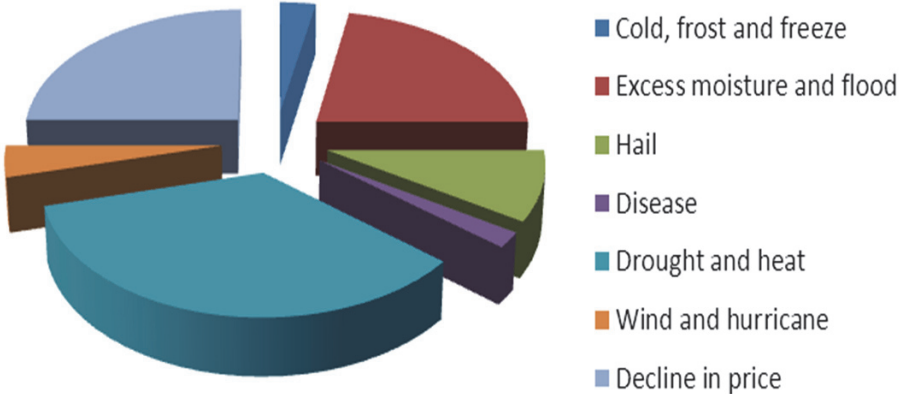## 11.3. Production and technical risk

In the non-agricultural organizations, the use of certain amount of input almost always results in the same quantity and quality of production, with a very small difference. This is not a case with most of processes of agricultural production. Agricultural production, both in terms of quality and quantity, is determined by biological processes, climatic conditions, diseases, insects, weeds, metabolism, genetics and other. These factors cannot be predicted with certainty [Boskovic and Prodanovic, 2016].

Climate change (extreme events such as hurricanes, tsunamis, extreme temperatures) for now present small risk for agricultural production, they have small influence on the variability of the yields of agricultural crops, respectively, and only in some areas [Anton et al., 2012].

Contamination of organic production by genetically modified organisms and other contaminants present significant risk in production, which disproportionately increases at the global level [Hanson et al., 2004].

Figure 1 shows different causes of relative significance of losses of insured arable crops. Almost all realized losses are associated with the weather.

Figure 1. The causes of insured crop losses

- Cold, frost and freeze
- Excess moisture and flood
- Hail
- Disease
- Drought and heat
- Wind and hurricane
- Decline in price

Source: U.S. Department of Agriculture, Risk Management Agency [2008].

The producers of livestock also have to face risks. Cold, wet weather in the spring or dry weather during the summer can cause the catastrophic losses in some types of production. Incidence of diseases can force producers to liquidate the whole herd [Kay et al. 2012].

The second source of producing risk is new technology[1], which presents that the way of production changes [Chavas and Shi, 2015]. Risk is reduced to expected performance, expenses and other issues that must be considered before introducing new technology [Boskovic and Prodanovic, 2016]. However, failure to adopt new technology can mean that producer will miss extra profit and become uncompetitive [Aditto et al., 2012].

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[1] Genetically modified types of maize have built resilience to European moth, thus the risk of loss of yield is reduced. The risk shows the quality of the grain and the acceptance by the market [Chavas and Shi, 2015].

The new sorts or hybrids can have high profit potential. However, if the conditions of productions significantly deviate from those in which they are tested (drought, insects) for the market, they can be unreliable and risky [Boskovic and Prodanovic, 2016].

11.4. The price and market risk

The price variability is a source of uncertainty for agricultural producers. The product prices vary from year to year, from day to day, and they are unknown for individual producer [Broll et al., 2013]. The governments have impact on the prices and producing decisions of farmers through agricultural policy. The demand affects the prices and is a result of the customers' habits, incomes, export policy, living standards and the price of competitive products. Some price movements follow seasonal or cyclical trends, which can be predicted, but even these trends manifest high instability. The customers impose quality standards or quantitative restrictions, which are difficult to be met for the producers and thus present a market risk [Kahan, 2013].

The prices of raw materials have a tendency to be less changeable from output prices, but still enter in the zone of uncertainty. Several times during last decades, oil scarcity caused a sudden increase in the cost of energy, fertilizers, pesticides, etc. Likewise, livestock producers, who buy animals or / and food, are under uncertainty due to changes in the price of raw materials [Tangermann, 2011].

11.5. Financial risk

Financial risk arises with lending money to finance the production. This risk is caused by the possibility of change in interest rates, the willingness of lenders to continue lending, unpredictable changes in market values of credit, as well as business capability to generate cash flows, necessary for reducing debt [Kuzman et al., 2007].

Production, marketing and financial risks exist and they are interrelated. The ability to repay the debt depends on the level of production and the price obtained for productions. Financing the production and storage of goods depends on the ability to borrow the necessary capital. Therefore, all three types of risk should be considered together, especially when the plan of risk management in agricultural holding is developed.

11.6. Legal risk

Increased awareness of food safety influences the choice of the mode of production. The conversion of conventional into organic production requires meeting certain rules that are defined by the Law on organic production. The farmers should be aware of the period of weaning from the use of pesticides, anti-

biotics, as well as rules about locating the manufacturing plant and handling fertilizer. Non-respect for the rules can bring expensive penalties and lawsuits, which increases the costs of business. The losses occur when the milk must be dumped because of high level of harmful residues or when the animals must be culled.

The farmers also should be the subject of legal action or invited to responsibility for accidents caused by machinery or livestock or for the law-breaking in the field of health, safety or treatments of engaged workers. Managers should be informed about the current rules and regulations [Kahan, 2013].

11.7. Personal risk

The manager and employee are the most important resources of organization, including the agricultural holding. The risk of accidental injury or illness is real, because the agriculture is traditionally a dangerous occupation. The key employee may be retired, may change jobs or move out of the rural areas. If there is no adequate replacement in the field of engagement of employee that has left, production can suffer significant losses [Kahan, 2013].

Family quarrel or divorces can change the value of property, reduce funding and also bring business into the loss zone.

11.8. Risk management in agriculture

Good risk management does not mean elimination of all risks, but limitation of risks to the level that the managers are prepared and capable to cope with.

Financial reserves play a major role in determining the ability of taking the risk. Farms with huge amount of capital can have higher losses, before they become insolvent. High value of debt, in relation to assets, is alleviated by high scope of production. These farms are also more exposed to financial risks, such as the increase of interest rates [Kay et al., 2012].

Holdings with high fixed costs of living, education, health care are less able to overcome the risks and they should not be overexposed to them. The farmers, who have more than their property in the form of cash or goods, have non-agricultural employment or can address their friends for help in case of financial difficulties, they have greater ability to take the risks. Some of farmers reject to take the risk, although they do not have the debt and have strong cash flow.

Most farmers tend to avoid risk. They are ready to take some risks, but only when they expect return on investment with increase in a long term. Financial obligations and previous financial experience are the most important factors, which influence readiness of producers to take certain amount of risk [Broll et al., 2013].

When the managers are not confident in the future, they often use some kind of average or "expected" values for the yields, expenses or prices. There is no guar-

antee that this value will be real outcome, but decisions must be based on the best available information, experience and judgment of individual [Kay et al., 2012].

In the Table, six possible ranges of wheat yield is shown, together with the assessed probabilities yield. Using probabilistic method, yield of 4-6 t/ha will be selected. During planning, it will be good to use the average point or 5 t/ha. Probabilistic method is especially useful when there is a small number of possible outcomes which are considered. This method can be used during evaluation of future costs and prices, with appropriate modifications.

Table 1. The expected value of wheat yield

Possible wheat yield (t/ha)	Probability (%)
0-2	5
2-3	15
3-4	20
4-6	40
6-8	15
> 8	5
$\sum$	100

Source: own calculation.

Manager, who must select between two or more varieties, should consider the variability of possible outcomes, beside the expected values. For instance, if the two alternatives have the same expected value, most managers will select the one whose potential outcome has lower variability [Kahan, 2013].

11.9. The cumulative distribution function

Many risky events in agriculture have almost unlimited number of possible outcomes. Useful technique for huge number of possible outcomes is cumulative distribution function (CDF). CDF is a graph of values for events with possibility that the real outcome will be equal or lower than the value of each. The outcome with the lowest possible value has the cumulative possibility of almost zero, and the maximum possible value has the cumulative possibility 100% [Kay et al., 2012]. The steps in creating the CDF are the following:

- Make a list of all possible values for events' outcome and assess their possibilities, e.g., data for the yield can be used as a set of possible values. If it is assumed that each of 10 variants have the equal opportunities to be repeated, it presents 10% of total possible outcomes or distribution.
- Make the list of possible values from the lowest to the highest, as it is shown in the next Table.

- Allocation of cumulative possibility to the lowest value is equal to the half of the span during presentation. Every remark presents one segment or it moves from total of distribution, so it can be assumed that observation falls in the middle range. For instance, the lowest yield presents the first 10% of distribution, thus the cumulative possibility of 5% can be assigned.
- Calculate the cumulative possibility (possibility of obtaining that value or minus one) for each of other values by adding the possibility, presented fewer values until the values of own probability. In example, remained observed yields would have cumulative possibilities 15%, 25%, etc. [Kay et al., 2012; Ferris, 2006].
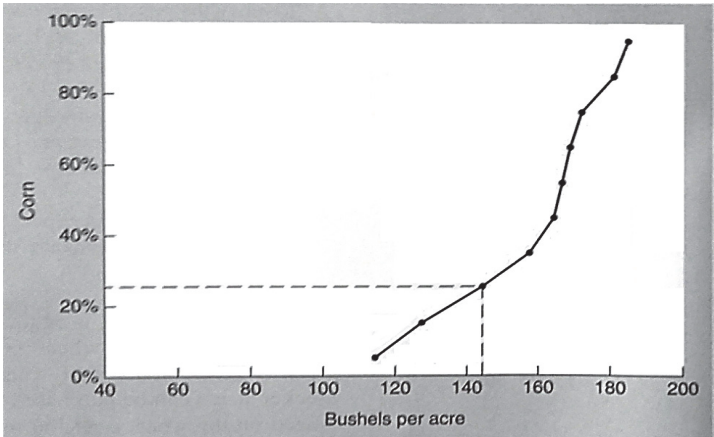
Table 2. The cumulative probability of distribution for maize

Maize (bushels/acre)	Cumulative distribution (%)
115	5
128	15
145	25
158	35
165	45
167	55
169	65
172	75
181	85
185	95

Source: Kay et al. [2012].

Each of the value pair connects the points, as it is shown in the Figure 2.

Figure 2. Cumulative function of distribution for maize

Source: Kay et al. [2012].

Cumulative function of distribution allows the depiction of all possible results for the certain event. At the top of the graph, the difference between the possible outcomes is smaller. The upper parts of the graph are the steeper than the lower parts, which indicates that the dependence on yield of the good weather is not as important as the negative reaction to the poor growing conditions.

11.10. Making decisions under conditions of risk

Making decisions under conditions of risk requires careful consideration of various strategies and possible outcomes. The process can be divided into several steps [Kay et al., 2012; Backus et al., 1997]:

- Identification of the cases that could be the source of the risk;
- Identification of the possible outcomes of events, such as weather or prices and their probabilities;
- Consideration of alternative strategies;
- Determination of the consequences or results of each possible outcome for each strategy;
- Assessment of the risk and expected yield for each strategy and evaluation of relations between them.

For instance, wheat is sown in autumn. Traders avoid to purchase and sell wheat in autumn and in winter in order to sell it at well-known prices from the contract, in spring. The main resource of farmer risk is the weather factor that affects the price. Let us assume that there are possible outcomes for this event due to good, average or poor weather with probabilities of 20%, 50% and 30%. Probability can be evaluated by studying the past weather events, as well as the recent forecasts.

If we avoid too much and buy too little at a favourable time, the opportunity for additional profit will be missed. If we too much buy and weather conditions are poor, there will not be enough fruit, extra food must be bought, and profit will be reduced or a loss will occur [Backus et al., 1997].

The farmer considers three alternative actions: purchase of 300, 400 or 500 beef cattle. Three weather outcomes are possible for each strategy, which creates nine potential combinations of results which should be considered.

When the elements of the problem are defined, it is useful to organize the information and to select some method of action [Kahan, 2013]. There are two ways to do it: a decision tree or matrix profitability.
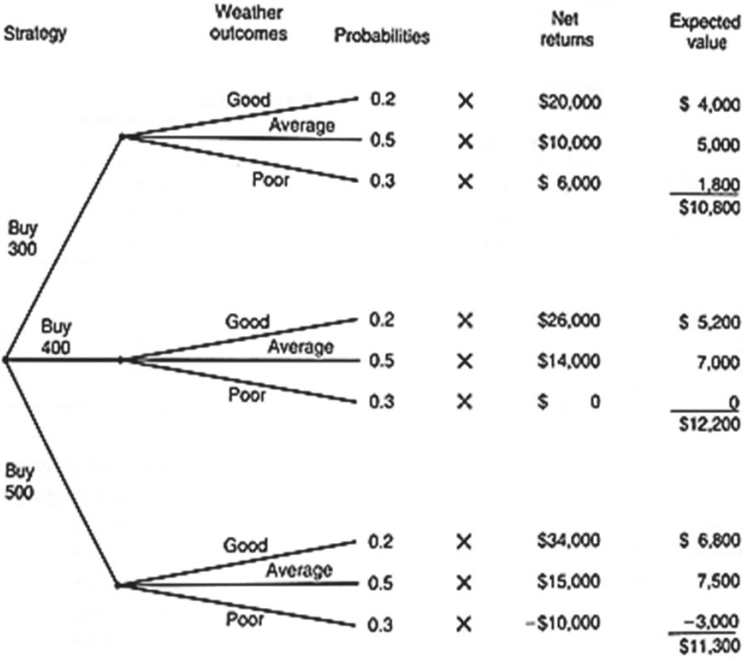
11.11. Decision tree

Decision tree is a diagram which depicts several strategies, potential outcomes of events and their results [Lu et al., 2011].

Figure 3 shows the decision tree for the previous example. It is about three potential strategies depending on weather forecasts, results for each of them, the probabilities for each outcome and assessed net returns for each of nine possible variants. For instance, if 300 beef cattle is bought, net returns is $20,000 with nice weather, $10,000 with average weather forecast, and just $6,000 with poor weather conditions [Kay et al., 2012].

On the basis of the decision tree, it can be expected that the farmer will opt for strategy "Buy 400", because it has the highest expected value, $12,000. However, this strategy predicts possibility of losing profit, in poor weather conditions.

Figure 3. Decision tree for management of heifers purchase

Source: Kay et al. [2012].

11.12. Matrix profitability

Matrix profitability contains the same information as the decision tree, but it is organized in the form of Table. The upper part of Table depicts outcomes of each strategy for each of potential weather outcomes. Expected values, both minimum and maximum values and the range of results, are shown in the lower part of the Table.

Table 3. Matrix profitability for management of heifers purchase

Items	Value of probability	Net return for each purchase strategy		
Weather outcomes	Probability	Buy 300	Buy 400	Buy 500
Good	0.2	20,000	26,000	34,000
Average	0.5	10,000	14,000	15,000
Poor	0.3	6,000	0	-10,000
Expected value		10,800	12,200	11,300
Minimum value		6,000	0	-10,000
Maximum value		20,000	26,000	34,000
Range		14,000	26,000	44,000

Source: Kay et al. [2012].

11.13. The rules of decision-making under conditions of risk

When the farmers face with the decision which includes risk, they can use different rules of strategy selection. Appropriate rule will depend on the decision maker with an attitude to risk, on financial status, demands of liquidity and other. Some of the rules of decision-making under conditions of risk include [Kay et al., 2012; Kahan, 2013]:

- The most likely outcome identifies the outcomes which are the most likely to occur and the strategy with the best consequences for that outcome is selected. In the previous Table, average weather forecast has the greatest probability (0.5), and "Buy 500" strategy has the greatest net benefit for that ($15.000).
- The maximum expected value suggests selecting strategy with the highest expected profit.
- Comparison of risk and yield. Each strategy, which has lower expected return and higher risk than other strategies, should be rejected.
- Security at the first place. This rule is concentrated on the worst possible outcome for each strategy and ignores other possible outcomes. Decision maker assumes that there are no serious problems for good expected results, while the real concerns are the unfavourable outcomes. The strategy, which is selected with the best possible result, and has the worst outcome, will be rejected. This rule is adequate for holdings in a bad financial situation, which would not survive any bad year.
- Probability of neither gain nor loss. Knowing the probability that some strategy will result with financial loss, can help decision maker.

11.14. Strategies for risk management

Various strategies of risk management are at the disposition of the farmers, whether it is about reducing the level of risk or mitigating the negative consequences of realized risk. Some strategies for risk management include one risk, and other incorporate more risks and are effective [Huirne et al., 2007; Piggott et al., 2005].

Including and understanding the effects of risk on the agricultural holding will allow the producers to develop appropriate strategies, which can help them to cope with negative consequences of realized risks or to resist the risks [Aditto et al., 2012].

Learning about how to combine the tools for risk management is useful for forming the management strategy, to achieve better results [Piggott et al., 2006].

The following strategies can be used in order to reduce risk [Backus et al., 1997; Kay et al., 2012; Baue and Bushe, 2003]:

- The stability of the enterprise. Modern technology can control the effects of weather on the production, and the government's programmes can control the prices or amounts of goods which can be sold.

- Investing in multiple production lines. If the profit of one product is small, the profit of production and the sale of another product can prevent the decline of total profit below the acceptable level. Diversification of the yield can improve the stability of the family holdings. The intention should be minimizing the surface of risky crops and maximizing the surface of less risky crops [Nguyen et al., 2007].

- The insurance contract is concluded with and insurance association with aim to cover the losses. Without the insurance or financial reserves, natural disasters can cause huge financial losses, which will prevent continuation of business. The farmers can insure the property, crops and the planned gross income. Some farmers purchase newer machines in order to prevent the risks against failures. The EU has a programme of subsidies and *ex-post* aid for covering the damages, which are not insured [Diaz-Caneja et al., 2009; Tangermann, 2011].

- Sharing the yields by lease. Landlord pays part of the expenses and obtains part of crops or livestock in exchange for rent. In that way, risk of poor production, low sales prices or high costs of input is divided. Also, variable rent level can be agreed.

- Due to the risk and uncertainty about the price and yield, some farmers do all jobs for the owner of land in exchange for a fixed amount (e.g. utility fattening). The owner of land takes the whole risk on himself.

- Long-term contract with the suppliers of input decreases the risk of production below the capacity. The Loan Contract labour (for fruit and vegetables harvest) will provide maximum use of capacity.

Several strategies can be used to decrease prices variability (market risk) or to adjust the satisfying price in advance, when the products are ready for sale:

- Expanding the sale. Instead the placement of all products at once, many farmers do that several times during the year. In that way, the sale at the lowest price is avoided and the sale of all goods at the highest prices is disabled [Nguyen et al., 2007].
- The Purchase Agreement before the sowing / planting guarantees to the producer placement of the product, as the future prices. Usually, the Purchase Agreement does not allow the sale at a higher price, if the same in the meantime increases [Broll et al., 2013].
- The investment for reducing the risk is possible before the sowing, during the vegetation or while the products are stored. This strategy can be used to lock the price of input which should be bought in the future [Backus et al., 1997].
- Option of the sale determines the minimum price in exchange for the payment of certain reimbursement, but still provides the sale of goods at a higher price, if it is possible [Tangermann, 2011].
- Market investments are present in some countries due to minimizing the risk on the basis of the price change [Kimura, 2010].
- Some strategies allow changes in the decisions, if there is a change in price or the weather conditions are changing [Nguyen et al., 2007], e.g. planting of annual instead of perennial crops. Renting the certain property, as land or mechanization instead of purchase, is one of examples of maintenance flexibility management.

For the maintenance of liquidity and purchasing power, reducing the financial risk respectively, the following strategies are useful:

- Fixing the interest rate.
- Self-Liquidating Loans are those which can repay the damage. The loans for the purchase of food for cattle and other production inputs are the example.
- Liquid reserves (cash or other resources which will be easily converted to cash) will help the farm in case of realization of risk.
- The credit reserves. Many farmers do not borrow the credit to its final limit. This unused part of the credit means that additional resources can be obtained in case of an unfavourable event.

- Equity capital or net value of the job provides the purchasing power and larger part of liquidity [Kuzman et al., 2007; Backus et al., 1997].

Appropriate legal and institutional framework can empower the ability of farmer to adopt the approaches of collective risk management [Tangermann 2011]. Strategy for legal risks management can be:

- Agricultural holdings can be organized through different legal forms. Some of them, such as limited liability companies and cooperatives, offer more protection from legal obligation than others.
- The insurance of responsibility protects from the claims by third parties for injury or property damage, and for which the insured or employee can be responsible. The demands of responsibility on the farm can occur when the livestock wanders on the road and causes an accident, or when someone gets hurt on the farm [Kay et al., 2012].

The risks, related to the employees, can be minimized through the health insurance, life insurance, safety precautions, backup management, etc. The key persons should know managerial activities in order to be included in case when the top manager is not able to continue the jobs.

Other strategies of risk management in the agriculture are in use, which includes more possible risks, and it can cover:

- work as usual, which means that there is no special strategy for risk management;
- crop insurance;
- diversification of crops and activities;
- reclaiming the risk by paying in cash [Bauer and Bushe, 2003].

11.15. Conclusions

The agriculture is a risky work where the outcomes of decisions are unknown or variable. The decisions must be thought-over, using the updated information and available techniques.

Risk management in agriculture is engaged in decreasing the possibilities of unfavourable outcomes or alleviating their negative effects. Not every decision will be right each time, but deciding under conditions of uncertainties difficult. The decision can be improved by identification of possible events, evaluation of value of their outcomes and variability.

The decision tree, matrix profitability and cumulative distribution function can be used in choosing between risky variants. Some farmers take into account just expected yields, some of them the variability of the outcome and some only look at results of negative outcomes.

Risk on agricultural holdings can be reduced or controlled by multiple techniques. The farmers decrease the extent of possible outcomes, guarantee minimum results in exchange for fixed expanse, and provide greater flexibility in making decisions. There are those who take greater risk, which can provide high level of profit in favourable situations, but it implies ability and experience.

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