ПРИМЕНЕНИЕ ЭКСПЕРТНО-МАТЕМАТИЧЕСКОГО МЕТОДА ДЛЯ ОЦЕНКИ РИСКА ПОТЕРИ УРОЖАЯ В РЕЗУЛЬТАТЕ НЕИСПРАВНОСТИ СЕЛЬСКОХОЗЯЙСТВЕННОЙ ТЕХНИКИ

APPLICATION OF EXPERT-MATHEMATICAL METHOD FOR RISK ASSESSMENT OF PLANT YIELD LOSS OCCURRENCE AS RESULT OF TRACTORS AND AGRICULTURAL MACHINES STOPPAGES CAUSED BY BREAKDOWN

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Оценка риска потери урожая является достаточно сложным процессом, но имеет важное значение при выборе тракторов и сельскохозяйственных машин для хозяйства. Потери урожая зависят от меняющихся производственных условий, поэтому и риск возникновения таких потерь также может быть разным. В статье представлен экспертно-математический метод оценки риска, который все шире применяется при решении сложных экономических и управленческих задач.

Summary: Familiarity with risk of yield loss occurrence as result of tractors and agricultural machines stoppages caused by breakdown has significant importance for process of machine and tractor selection. Based on press review it was demonstrate, that plant yield loss even with same work delay are different, what is result of various character of productions conditions. Because of that also yield loss occurrence risk is differential. Yield loss occurrence risk assessment can be done using expert knowledge with use of expert-mathematical method. In publication presented is way to use expert-mathematical method in risk assessment of yield loss occurrence.

Introduction

Performing agricultural treatment at time demands assurance of high work readiness of tractors and machines. It is connected with machine reliability and efficiency of technical service system. Highly reliable machine is characterized by high price, which has negative influence on exploitation costs and ipso facto cost of treatment. Purchasing cheaper but more unreliable machine will be connected with losses as result of stoppages, which can be longer in situation of inefficient service system. However efficient service system even with frequently breakdown can avoid long stoppages and minimize potential losses. Full assessment of machine usefulness with high or low work readiness can be done based on amount of losses caused by breakdowns. Because of fact that losses can be different even with the same time of stoppage, there is necessary to assess risk of its occurrence. For that purpose expert knowledge can be use.

Plant yield loss issues in the light of literature

Plant yield loss issues because of agricultural treatments delays is theme of many publications as polish as foreign. Most of publications concerns mainly results of sow delay, there is less amount of publications regarding result of harvest delay, while in available sources there is lack of publication regarding results of other treatment delay, including chemical protection treatment and fertilization. Available publications allow saying, that yield loss even with same work delay are differential. As example can be taken germane research carried out in years 1974-1984 concerning influence of winter rape sow delay. Research demonstrates that rape sow 10-14 days delay resulted in 20% average yield reduction, although were years when reduction was only 5% and years with even 38% of yield reduction [Henning, 1985].

Diversity of yield losses are noticed also in case of other cultivations [Kozłowska – Ptaszyńska 1997, Budzyński and others 1999, Wróbel i Kijar 2004, Szempliński and others 2001].

This state is result of such conditions like weather conditions, plant variety resistance for treatment delay and variety and quality of soil. Whether conditions as shows literature has significant influence on plant yield decrease. In Kozłowska - Ptaszyńska (1991) opinion weather conditions in case of spring wheat have more significant influence then cultivation technologies and in Mazurka i Sułek (1997) opinion more than soil conditions. Favorable weather conditions in case of sow result in reduction of yield losses. Piech i Stankowski (1985) expressed the opinion that in case of rye sow delay results decrease of yield occurs only in case of hard winter. Similar conclusions can be made from Kusia i Jończyka (1997) research on results of winter wheat sow 10 days delay. In very unfavorable weather conditions (ground frost) researchers noticed 16% of yield re-

duction, while in less favorable conditions drop down was equal 13%. During other experiments significant yield reduction was not noticed [Zrychta i Noworolnik, 1999].

Weather conditions influence is felt especially in case of chemical protection treatment delay results, especially fight with fungus diseases. Research made by RZD Chylice-SGGW in years 2002-2004 on winter wheat shows that fungus diseases in various weather conditions generates yield losses 9,1 dt/ha (15,9%) - 13,48 dt/ha (28,1%) [Jaczewska-Kalicka, 2005]. Influence of weather conditions on reduction of plant yield caused by fungus diseases manifest itself mainly by air humidity and in less degree by amount of atmospheric precipitations and air temperature [Jajor i in. 2008].

Weather conditions in aspect of fungus diseases occurrence increases its importance in last few years as result of significant climate changes, which cause, that 30% of plants are infected by fungus diseases, what can causes even 30% yield reduction [Weber 2004, Narkiewicz i in. 2005, Smiley i in. 2005].

Researchers determined also influence of plant variety on result of treatment delay. In case of spring triticale was noticed that less resistance varieties reacted significant reduction of yield on sow delay (even 62% at 20 days of delay), while in case of more resistive varieties even with 20 days of delay yield reduction was not noticed [Mazurek, Nieróbca 2000]. In other researches on results of sow delay of spring triticale with 10 days delay was noticed depending on variety 11-12% decrease while for 20 days delay reduction on level of 24-28% [Nieróbca 2004]. Influence of variety on level of yield loss was noticed also in case of spring wheat. Research of spring wheat sow 10 and 20 days delay results showed, that in case of variety more resistive yield reduction was accordingly: 5 i 28%, while I case of more sensitive variety reduction was on level of 14 i 36% [Mazurek i Sułek 1995].

Results differentiation of sow delay depending on variety was also noticed in case of oats. S14 days sow delay can cause depending on variety 11-21% yield reduction [Mazurek 1993, Budzyński i in. 1999, Wróbel i Kijara 2004].

Mazurek i Podolska (1995) noticed that in case of wheat varieties sensible for sow term with 10 days sow delay yield reduction can be 25% while at 20 days reduction is about 60%. For varieties less sensible in case of 10 days sow delay any changes was noticed but at 20 days delay wheat yield reduction was about 40%.

Differences in level of yield reduction as result of sow delay were noticed also in case of various soil. As example can be used Ralcewicza i Knapkowskiego (2004) research, which sowing winter wheat on soils with different bonitation class with 2 weeks delay, noticed 7-25% yield reduction. Another example are results Szempliński an others (2001) research, which in case of rye sow 14 days delay noticed about 4% yield reduction on better soil and 14% reduction on worse soil. While in other experiments [Kuś, Jończyk 1998] significant drop down were not noticed. Noworolnik research (1991) shows that soil conditions has influence on level of winter barley yield losses. Author demonstrated that winter barley sow 20 days delay caused 5% yield reduction on good wheat complex and on very good rye complex, and 25% reduction on poor rye complex. It is concerning also spring barley where yield reduction as result of sow delay is more felt on poor soils than better one. [Noworolnik 1999]. To others factors having influence on yield losses level belongs variety of preyield. Makowski i Riemann (1988) observing result of rye sow delay noticed that sow of that cereal with 14 days delay in trench cultivation leads to 6% yield reduction while after cereal 17%. Presented news found in literature leads to statement that not always agricultural treatment delays cause significant plant yield reduction. In some cases negative results of work delay can be neutralize be selection of resistive plant variety and good preyield. Additionally in case of favorable weather conditions risk of occurrence big yield losses is definitely lower. It can be encouragement to purchasing cheaper machines even with lower reliability. To verify advanced thesis assessment of yield losses risk occurrence is needed. Because of indicated lack of information completeness regarding yield losses being result of delay, the most useful can be experts assessment method [Maksimov, Nikonov, 2004].

Use of experts assessment method for management and economic enterprises

Nowadays experts assessment methods become more widely used. They are irreplaceable in case of complicated and complex problems. [Internet1]. One of most widespread method using experts assessment is Delphi method, developed by Rand Corporation in order to use experts assessment for prediction of military technologies development and planning [Linstone i Turoff 1975, Orlov, 2002, Griffin, 2005]. This is questionnaire method and decreases danger of coping declarations or assessments of others experts. In this process we can count on that some experts personal prejudices will be neutralized by others experts from same group opinions [Chong, Brown,

2001]. Beginnings of Delphi method are military usage. In 1944 year Delphi method was used for assessment of future military technologies. Two years later it was used by Douglas Aircraft Company for assessment of intercontinental military war actions in within RAND project. In years 1950-60 Delphi method was improving by Olafa Helmer'a and Normana Dalkey'a z RAND Corporation and sponsored by US Air Force [Internet8, Internet9].

Lterature (Stabryła, 2000) list example of Delphi method usage such questions answering: when wide domination in space will take place, what management model will dominate in time of common globalization, what new niche will appear in service market etc. this method can be successfully used for forecasting technological breakthroughs in Boeing company, new products market potential in General Motors and future market conditions for US government [Griffin, 2005].

Other example is usage of Delphi method in forecasting future of agro tourist farm [Internet8] and political-sociological research like in Czech Republic research regarding people migration [Internet10].

Delphi method is very popular. In last years about 40 thousands research were carried out with usage of that method. Average cost of that research was equal about 5 thousands USD, but some of them cost even 130 thousands USD [Orlov, 2004].

Delphi method as research technique, which is successfully used in foresight enterprises around the world was included to research offer of Pentor Research International counts in Poland in marketing researches [Internet12]. In internet (Internet 5) is available characteristic of Arundel project implemented by European Commission within which was prepared forecast of energetic branch future with use of Delphi method including estimation long term trends of energetic technologies development, its potential and social effects of used technology in 30-years perspective. Collected within project allow formulate probable future structure of Europe energetic system and determine necessary tasks leading to assure long-term competitive energetic system and improve live quality in Europe [Internet5]. Delphi method is characterize by independence of experts opinion, anonymity of judgments, multistep procedure, agreement and addition of qualified people opinions [Internet3]. It has special application in situations of incomplete information [Rowe, Wright 1999, Martino 1972] and risk analyzes [Internet11]. Average difference between results of Delphi method and traditional methods is 10-15%, while Basu and Schroeder (1977) forecasting market transactions in period of two years noticed 2-3% discrepancy from real values [Internet8]. Full description of that method can be found in literature [Radzikowska i in. 2000, Stabryła 2000, Orlov 2002, Trajniov i Trajniov 2003, Tinjakova, 2006, Afonichkin i Mihalenko 2009] as also in internet [Internet1, Internet2]. Delphi method can be also useful in risk assessment especially in case of missing statistical data [Maksimov, Nikonov, 2004]. Can be also used in calculation of subjective probability for strategic company security needs [Stabryła, 2000].

Procedure of carrying out research in Delphi method

Delphi method consists in sending questionnaire to experts, in which they will express their opinion about analyzed issue. Research procedure in first place requests to formulate the problem, which will be analyzed and next preparation of questionnaires. Following, second step is making a list of experts, which will be included to research. Experts selection is quite significant factor. Experts should have knowledge adequate to analyzed issue, should be characterized by creative thinking, should have ability to assess identifying risk, and also free from personal prejudices to analyzed issues [Internet4]. Therefore experts are not random selected, but on purpose taking in advance their knowledge and experience of theme being under consideration. Experts group should consist of from 25 to 100 people. Group can be bigger but it makes difficult final steps, within which questionnaires results are prepared. Less than 25 people causes that results are representative [Internet7]. Most frequently minimum experts amount is calculated in mathematical way [Izdebski, 2003]. In some types of research can be formulate two or even few experts groups for example practicians and theoreticians [Izdebski, 2003].

Actual research begins from third step, from sending questionnaires to experts. First questionnaire with questions should contain additional information, so called cover letter, in which research organizers presents research purpose and goals and rules of cooperation (expert cannot be surprise by another questionnaires, because is possible that he will not answer) [Internet7]. After receiving filled up questionnaires analysis is carry out and results processing using statistical method [Tinjakova, 2006].

To present numerical rating of the degree of compliance according to literature concordance factor is used, which is defined according to the formula:

$$\Theta = \frac{S}{\frac{1}{12}N_E^2 \cdot (b^3 - b) - N_E \sum_{i=1}^{N_E} \cdot T_i}$$

Where: S — sum of squared deviations of the actual value of rank, N_e — number of experts, b — number of factors evaluated, T_i — rate similar rank

In order to find out that the compliance experts, is not accidental is used χ-square test szukaj [Tinjakova, 2006]

$$\chi^2 = \frac{S}{\frac{1}{12}N_E \cdot b \cdot (b+1) - \frac{1}{b-1}\sum_{i=1}^{N_3} T_i}$$

Compliance judgments of experts within local priorities assessment is determined by the coefficient of variance calculated according to formula [Tinjakova, 2006]:

$$Vj = \frac{g_j}{m} \cdot 100 \quad [\%]$$

where g_j –Standard deviation, m_j – mean (the value of the local priority)

In the case of non-compliance expert opinions, to the experts whose opinions differ in relation to others, is sent another survey with information about the results obtained previously. In this way, professionals are motivated to take a position with regard to the opinion of other experts, without giving their identities. Experts can either remain at their initial beliefs, or under the influence of motivated opinions of others, support the majority assessment [Internet7].

It is commonly believed that the result of expertise can be considered only on basis of full compliance expert opinions. However, in a situation where instead of one consistent groups of experts, two or more groups with different views can be excreted, does not mean that the purpose of the research has not been achieved [Internet1]. On the contrary, studies show that the objective has been achieved and they have shown that there is no compliance on the matter of opinion. Striving at all costs to gain compliance expert opinions can lead to conscious experts informed selection ignoring all points of view. Thus, ignoring the opinion of experts-dissidents is not recommended [Internet1].

Risk assessment of yield losses due to plant downtime due to breakdown with use of expertise

The risk of yield losses of plants occurs during of the tractor or machine breakdown. This risk is greater in a situation when the tractor or machine stoppage time is significant what can cause work delay beyond the acceptable agricultural term. The period of tractor or machine stoppage depends on the efficiency of the service system. This however depends on the structure and functioning of the service system.

As the service system has to understood set of all elements that affect the maintenance of tractor and machinery ready for work. In the case of tractors and machinery with not advance construction without electronics elements and control system, which can be repaired without help by elements being a part of maintenance system by operator if he has the mechanic skills eventually by friendly mechanic, mechanic workshop carrying out repair automotive technology, which can make repairs tractors and machinery components such as engines and spare parts stores for tractors and machinery, which in Polish conditions exist even in short distances from the farm. Of course, part of the system are also the manufacturer's maintenance service.

An example of such a system is the maintenance of tractor-known Polish producer Ursus, mostly models 2812 and 3512 (with an engine power 28 and 35 kW), whose design is largely allows you to repair itself, a nearby repair shops are able to make complex repairs and Spare parts can be purchased even in the few shops located at a distance of 15-20 km from the farm.

In the case of the removal system failure usually occurs relatively quickly at the risk of a significant delay in the work beyond the date agricultural is not too large.

Another structure has a system of maintenance of tractors and high-tech machines in case of emergency where the operator in most accidents is forced to use the manufacturer's service departments. In this system components to maintain the tractor and the machine ready for work are mainly specialized repair teams, authorized repair shops and warehouses of spare parts, which are mainly located in the premises of the dealers of machinery and tractors. But they may be at considerable distances from the farm.

Removal of the tractor or the failure of advanced machinery will require in most cases, the arrival of the team and the service is in accordance with the law may arrive after 24-48 hours of notification of failure. In Polish conditions, high-tech tractors and construction machinery but rather imported from abroad and therefore in circumstances where the service does not possess the necessary parts together, there is sometimes need to download them from abroad. Despite the declaration of servicemen, the collection of spare parts from abroad should not last longer than 48 hours to show their own observations of how this period may be much longer.

Each of the maintenance systems at the onset of failure can act inefficiently by which downtime can result in delayed implementation of the treatment beyond the period allowed agro technical and thereby cause a loss of yield.

Risk of inefficient response system maintenance will vary depending on its structure and functioning of which would depend on the manufacturer (Offer tractors and machinery, distribution of service points and supply of spare parts).

Hence, several scenarios can be distinguished functioning of the maintenance of tractors and machinery. Sample Scenarios for tractors are shown in Table 1

Table 1 Scenarios available in Poland, systems maintenance

Numer scenariusza	Scenariusz
1	Great potential for repairing a tractor on their own, good access to spare parts and workshop services (eg, resulting from a large number of points in the supply of parts and workshop)
2	Great potential for repairing a tractor on its own, worse access to spare parts and workshop services (eg, due to the need to download parts from overseas).
3	Limited possibilities of repairing a tractor on their own, need to summon the crew of the failure of service, easy access to the service and spare parts
4	Limited possibilities of repairing a tractor on their own, need to call the service team of failures, poorer access to service and spare parts (eg a significant distance from the headquarters site, the need to download the service of spare parts from abroad)
5	Significantly reduced the possibility of repairing a tractor on their own, need to call the service team of most accidents, good access to the service and spare parts
6	Significantly reduced the possibility of repairing a tractor on their own, need to call the service team of most accidents, poorer access to good service and spare parts (eg a significant distance from the headquarters site, the need to download the service of spare parts from abroad)

Each of the scenarios is characterized by a greater or lesser risk that downtime due to failures will delay the work beyond the maximum time limit agro technical.

That risk assessment can be made using the knowledge of experts. The proposed test procedure will be the task of the expert analysis of different scenarios and then an expert for a particular scenario, the maintenance of the system will assess the opportunities posed implementation work in the cultivation period. Scores reflect the opinion of his chances of assessing percentage from 0 to 100%.

Assessment of individual experts will be subjected to statistical treatment in accordance with the principles presented above, the method of Delphi.

Based on these assessments can be held for a particular scenario, the operation of the maintenance level of risk of loss of yield.

The role of experts is expected farmers, farm owners, while owners of agricultural tractors. Selection of farmers as the experts, is predicated on the fact that they have practical experience. At the same time, farmers bear the financial consequences of negative events such as the farm yield losses, so have the practical knowledge to assess the impact of these losses and their causes. For the test procedure, prospective farmers are having a minimum of 5 years of professional work on the farm.

Along with the knowledge of the risk of yield losses due to a malfunction of the tractor is desirable also know the size of the risk of these losses. This is connected with the fact that the size of yield losses in production are affected by what has been presented in the publication of the review of the literature. Hence, yield losses due to a malfunction of the tractor or machine can reach high levels (maximum losses), average and low (minimal loss). They will result from the conditions of

production, which can be very detrimental (cause maximum loss of yield), average and very good (cause minimal loss of yield).

In the case of very bad production conditions, all important factors that determine yield are negative in nature, such as corn is grown in poor soils, while the tractor or machine downtime adverse weather conditions and plant variety is very resistant to the effects of delays. In the case of a favorable production conditions, all important factors that determine yield are positive in nature, such as corn is grown on good soils, during downtime causes of the accidents are good weather conditions and plant variety is resistant to the effects of delays. In terms of the average production of the essential factors determining yield is positive in nature while some have negative consequences such as weather conditions are detrimental to the plants but the variety is resistant to the effects of delay of work.

Risk assessment of minimum, maximum and average yield losses must take into account the fact that the risk of adverse or favorable conditions of production is different in the periods of various agronomic treatments. At the same time inappropriate timing of the execution of each of the agronomic treatments have varying impact on the size of yield losses.

The procedure of risk assessment, the total loss of yield will be implemented as proposed in the literature [Maksimov, Nikonov, 2004].

The aggregate size of the risk of yield losses would be calculated as the sum of products of the impact of the implementation of the various treatments out of term the size of yield losses and risks of various favorable or unfavorable conditions of production as shown in the following dependencies developed on the basis of literature [Maksimov, Nikonov, 2004].

$$R = \sum_{j=1}^{N} R_j \cdot g_j \qquad \sum_{i=1}^{N} g_j = 1$$

where: R — risk and losses of this magnitude, Rj — numerical evaluation of the risk of a j-th production conditions in the J-term performance of this surgery agro technical gj — the impact of the implementation out of term j-th treatment agro technical the size of yield losses

The use of expert knowledge will consist in the fact that the first experts using their experience will assess the risk of particular conditions of production (very great, average and bad) in different periods of exercise agro technical. Treating the participation of all types of conditions is 100% will determine the percentage cover specific conditions in a given period of performing agro technical. (Table 2)

Table 2 Distribution of the risk occurrence in production

	Warunki produkcyjne			
	bardzo korzystne	przeciętne	bardzo niekorzystne	SUMA
Okres prac przygotowujących glebę do siewu	R11	R21	R31	100
Okres siewu zbóż	R12	R22	R32	100
Okres występowania chorób i szkodników	R13	R23	R33	100
Okres występowania chwastów	R14	R24	R34	100
Okres nawożenia pogłównego	R15	R25	R35	100
Okres zbioru	R16	R26	R36	100

where: R — risk and losses of this magnitude, Rj — numerical evaluation of the risk of a j-th production conditions in the J-term performance of this surgery agro technical Subsequently, the experts will carry out an impact assessment out of term work on the size of yield losses. In this case, the sum of the individual evaluations should be 100 %.

Tab.3 Out of term performance impact on the volume loss treatments

Rodzaj zabiegu	Ocena
Inappropriate timing of the implementation of procedures to prepare the soil for sowing	G1
Inappropriate timing of the execution of sowing / planting	G2
Inappropriate timing of the implementation procedures of chemical protection against weeds	G3
Inappropriate timing of the implementation procedures of chemical protection against diseases and pests	G4
Inappropriate timing of the implementation of top dressing fertilizer treatments	G5
Inappropriate timing of the execution set	G6
	100

Based on the assessments used will be calculated the risk of yield losses.

Minimum risk of yield losses will be calculated from this relationship: R_{minstr} = R11*G1+R12*G2+R13*G3+R14*G4+R15*G5+R16*G6

The risk of the average yield losses will be calculated from this dependence:

R_{przstr} = R21*G1+R22*G2+R23*G3+R24*G4+R25*G5+R26*G6

By contrast, the maximum risk of yield losses will be calculated from this relationship: R_{maxstr} = R31*G1+R32*G2+R33*G3+R34*G4+R35*G5+R36*G6

Of course, the sum of individual risks should be $1R_{minstr} + R_{przstr} + R_{maxstr} = 1$

The role of the experts involved in assessing the risk of loss are also envisaged farmers, farm owners with long-term (minimum of 5 years) experience in production.

Summary

Risk assessment of yield losses due stoppage caused by break down is difficult but important issue decision-making process regarding the choice of a machine or tractor. Knowing the risk of losses and their value can fully evaluate the effects of failures in decision-making method used to facilitate decision-making such as decision tree. Expert knowledge, especially based on practical experience is a valuable tool to assess risk. Hence the widespread use of methods of evaluation experts in management and business enterprises.

Риск получения потерь урожая вследствие применения простых тракторов и машин и их аварий оказывает существенное значение при выборе трактора и машины. На основании обзора литературы показали, что потери урожая даже при опоздании работ, дифференцируются, что они вытекают из изменчивого характера производственных условий. Риск получения потерь урожая также дифференцируется. Оценку риска получения потерь урожая можно получить, используя знание экспертов и применения экспертно-математического метода. В публикации представили способ использования экспертно-математического метода в оценке риска получения потерь урожая.

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