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OPTYMISATION OF THE DECISION-MAKING PROCESS RELEVANT TO THE CHOICE OF AGRICULTURAL MACHINES USING THE AHP METHOD

Summary

The aim of the study was to evaluate the usefulness of the analytic hierarchy process (AHP) for the ranking of a finite set of agricultural machines from the point of view of their quality and purchase costs. The experiments comprised three after-harvest cultivators of similar operational-economic parameters. Relative values of the assessed machines as well as of weights of their criteria were determined by means of a pair comparison method. The results of the performed comparisons made it possible to calculate a complex index (global priority) for each machine in the form of a decimal fraction from 0-1 interval. Values of these indices provide the basis for the ordering of the set of machines and indicating the optimal machine with the highest significance. In the course of experiments, Expert Choice computer software was employed which is intended for aiding decisions prepared in accordance with the AHP method.

OPTYMALIZACJA PROCESU DECYZYJNEGO DOBORU MASZYN ROLNICZYCH METODĄ AHP

Streszczenie

Celem pracy była ocena przydatności metody analizy hierarchicznej procesu AHP do rangowania skończonego zbioru maszyn rolniczych, ze względu na ich jakość i koszty zakupu. Badaniami objęto trzy kultywatory do uprawy pożniwnej o zbliżonych parametrach eksploatacyjno-ekonomicznych. Określenie relatywnej wartości przyjętych do oceny maszyn i wag ich kryteriów, odbywa się za pomocą metody porównywania parami. Wyniki porównań pozwalają na obliczenie wskaźnika kompleksowego (priorytetu globalnego) dla każdej maszyny w postaci ułamka dziesiętnego z przedziału 0-1. Wartości tych wskaźników stanowią podstawę uporządkowania zbioru maszyn i wskazanie optymalnej maszyny, o najwyższej istotności. W pracy skorzystano z programu komputerowego Expert Choice, który jest przeznaczony do wspomagania decyzji przygotowanych według metody AHP.

1. Introduction

Product quality, including quality of agricultural machines, should be considered from the point of view of complex phenomena, i.e. such phenomena that cannot be expressed by means of a single trait or measured directly. In order to perform a reliable quality assessment, it is indispensable to take into consideration a number of factors of which some are of measurable nature, whereas others can only be presented in a descriptive form. A decision-maker, on the basis of a subjective evaluation of several or several dozen different criteria, can determine the complex quality of a given product. In order to assure objective assessment of individual criteria and their weights, a reliable method is necessary and here the method of analytic hierarchy process (AHP), which is included in the group of intelligent systems assisting the decision making process, can be useful.

The AHP method elaborated by Saaty [3] finds application in assisting multiple-criterion decision-making processes in each field of human activity and has already been used successfully in both developed and intensively developing countries for over 30 years. It allows elaboration of a decision table and weight vectors on the basis of the pair comparison method taking into account the adopted superior objective. The ordering calculation is carried out using the weight additive method. Following the application of the AHP method, an ordering vector of decision variants is achieved.

Numerous computer software systems use the AHP method for multi-criterial assistance of decision-making processes, among others, the Expert Choice program. It employs the technique of pair comparison at individual levels of model hierarchy and reduces the area of uncertainty and guessing by the decision-maker.

Examples of practical application of the AHP method quoted in literature on the subject [1, 2, 5, 6, 7] make it possible to assume that the method can also be employed for ranking variants of agricultural machines on the basis of the adopted selection criteria.

2. Research objective and scope

The aim of this study was to demonstrate the usefulness of the applied AHP method for complex quality evaluation of agricultural machines. This kind of assessment carried out on a group of machines which belong to one group will allow their proper arrangement and, consequently, choice of the optimal variant.

The issue of ranking an arbitrary set of agricultural machines should be of interest not only for manufacturers of such machines but also for their potential users. Simulation investigations of the decision-making process were carried out on a group of cultivators similar to one another with regard to their working width as well as unit purchase price.

3. The object of studies and methods

Experiments were conducted on three 3-meter cultivators used for the cultivation of stubble fields and derived from different manufacturers. Out of several dozen measurable and non-measurable features of these machines, only several were selected (due to the limitations of the employed version of the *Expert Choice* program) and presented in Table 1.

Table 1. Basic technical-economic parameters of the assessed cultivators

Criterion symbol	Specification	Cultivator A	Cultivator B	Cultivator C
K1	Frame height [cm]	85	78	77
K2	Clamp protection	Service-free spring protection against stones allows clamp deflection up to 10 - 15 cm.	Tradional protection with a spring which allows clamp deflection up to 17 cm. Additionally, it is also equipped in shear safety device.	Tradional protection with a spring which allows clamp deflection up to 19 cm.
K3	Type of consolidation roller	Ring roller consisting of 19 rings 10 cm wide and 56 cm in diameter with rubber connectors between them. All elements are bolted.	Dual string roller works without scrapers. It is a combination of a pipe roller made up of eight pipes and a roller consisting of eleven flat steel bars. The diameter of both rollers is 40 cm.	Ring roller consisting of 19 rings 24 cm wide and 60 cm in diameter. There are skids between rings which also act as scrapers. They also crush lumps increasing In this way soil density.
K4	System of rapid exchange of working elements	No	No	Yes
K5	Number of lubrication points	2	9	34
K6	Working depth [cm]	2-7	4-6	2-6
K7	Minimum power requirement [KM]	115-160	100-150	100-150
K8	Net price [PLN]	50 820	52 500	47 880

The experimental cultivators were also assessed from the point of view of their prestige and reputation of the manufacturer (criterion K9). The actual process of ranking of agricultural machines, i.e. indication of the optimal variant, was conducted with the assistance of the AHP method which consists of the following stages:

1. Construction of the decision-making model,
2. Determination of criterion weights,
3. Determination of variant domination due to a given criterion (local priorities),
4. Arrangement of decision variants according to global priorities.

The decision-maker, in a subjective manner, assigns each pair of the assessed elements one number from the set of {1, 3, 5, 7, 9}. According to Saaty, the individual numbers designate:

1 – both elements are equally important,
3 – one element is slightly more important than the other,
5 – one elements is clearly more important than the other,
7 – one elements is significantly more important than the other,
9 – one elements is distinctly more important than the other,
Intermediate scores {2, 4, 6, 8} should be employed only in extreme situations.
Work using the AHP method begins with the model construction of the decision-making process which, for the analysed problem, assumes the form of a hierarchical tree (Fig. 1).

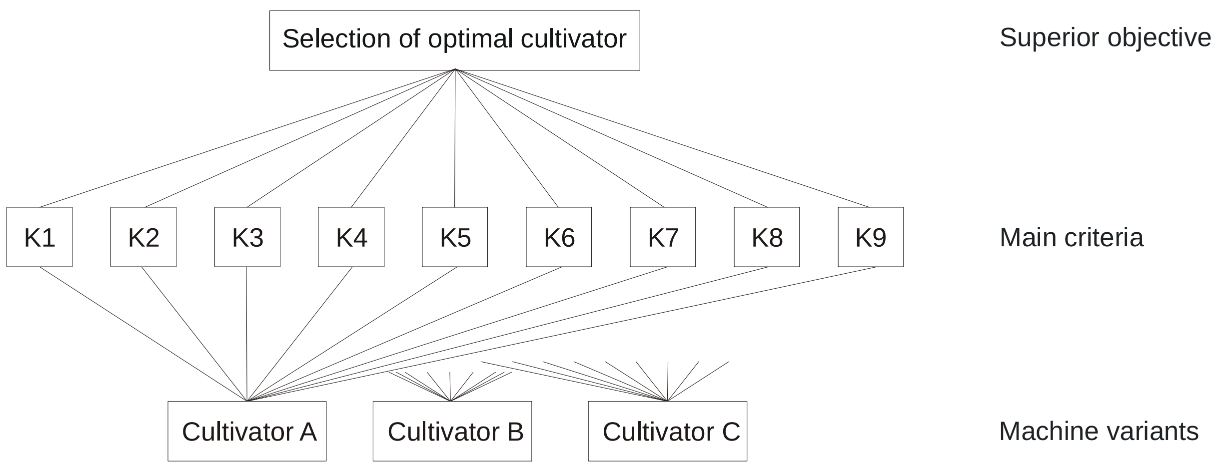


Fig. 1. Diagram of a hierarchical structure of the considered decision-making process

The superior objective of the performed decision-making process is the selection of the most suitable cultivator from among the adopted variants bearing in mind the assumed criteria (K1-K9). The optimal choice is the machine for which the calculated complex index of the variant is the highest.

The indispensable condition in Saaty's method is the required compatibility of pair element comparison expressed by the inconsistence coefficient *CI*. Its value should not exceed 0.1. The students' version of the Expert Choice v. 9.5 software was used in the study It is characterised by limits with regard to the number of levels in the hierarchical tree as well as to the number of adopted criteria and variants [4].

4. Results

Before work on the Expert Choice program began, a hierarchical model of the considered decision-making problem was constructed (Fig. 2) in accordance with earlier assumptions (see: Fig. 1).

The importance of individual criteria from the point of view of the main objective is obtained by comparing them in pairs by the decision-maker – in this case, the author (Fig. 3).

After performing appropriate calculations by the Expert Choice program, the following criteria weights were obtained (Fig. 4).

a) b)

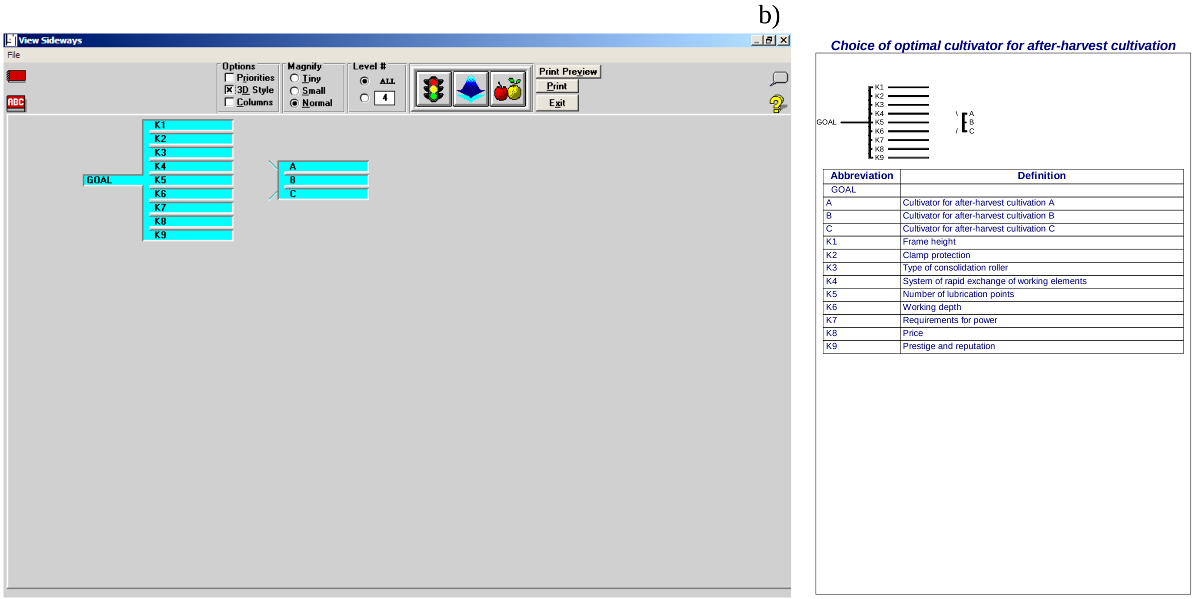


Fig. 2. Hierarchical structure of the decision-making process in Expert Choice program (a) and stage report (b)

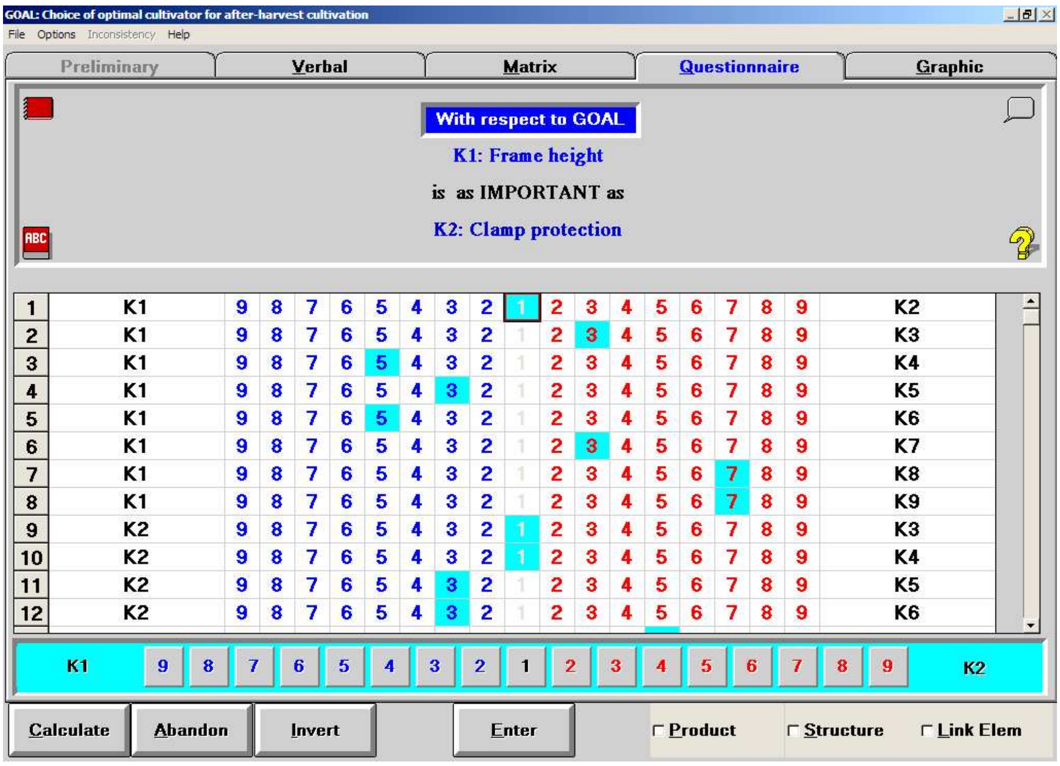


Fig. 3. Fragment of results of pair comparison for the determination of criterion significance

a) b)

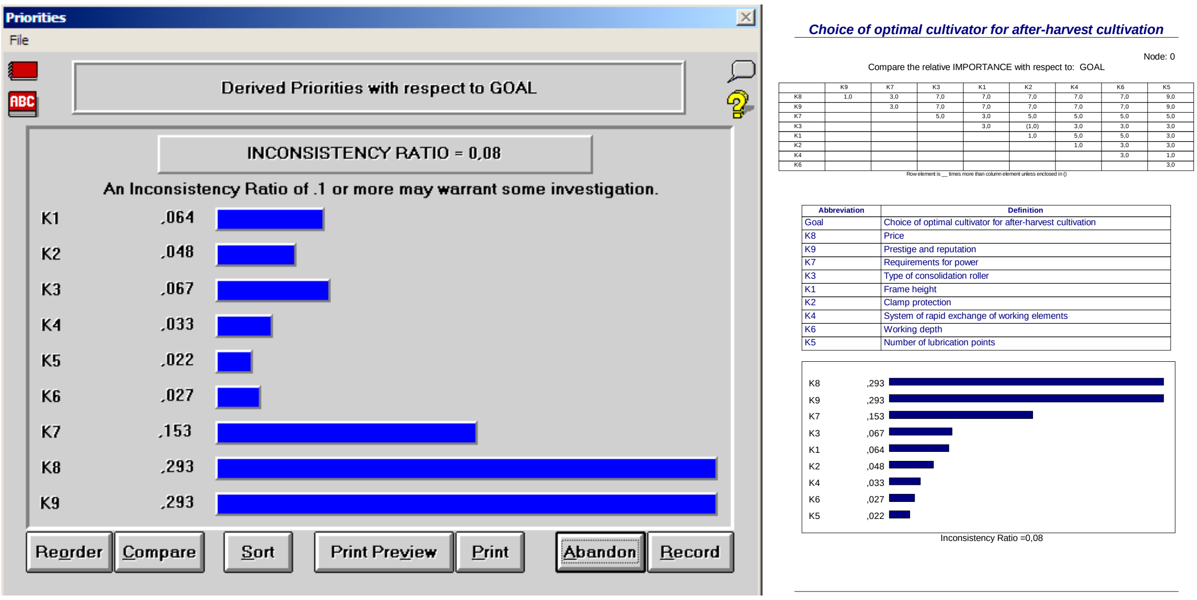


Fig. 4. Calculated weights for assumed criteria (a) and stage report from the arrangement according to mutual domination by criteria (b)

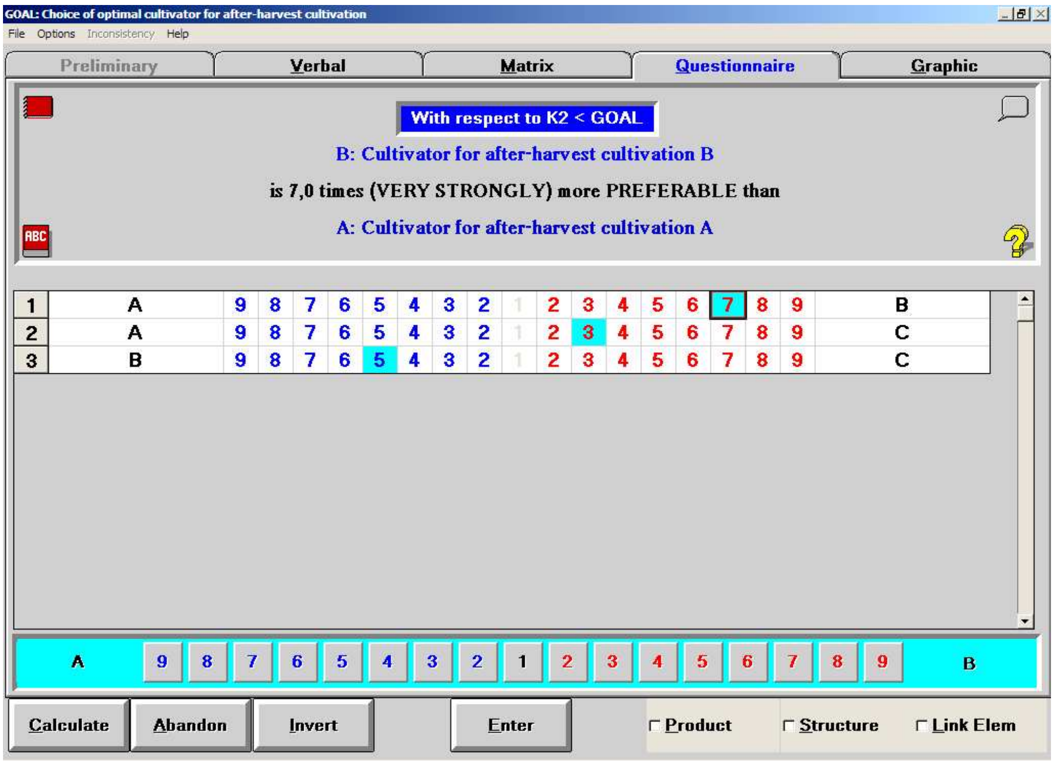
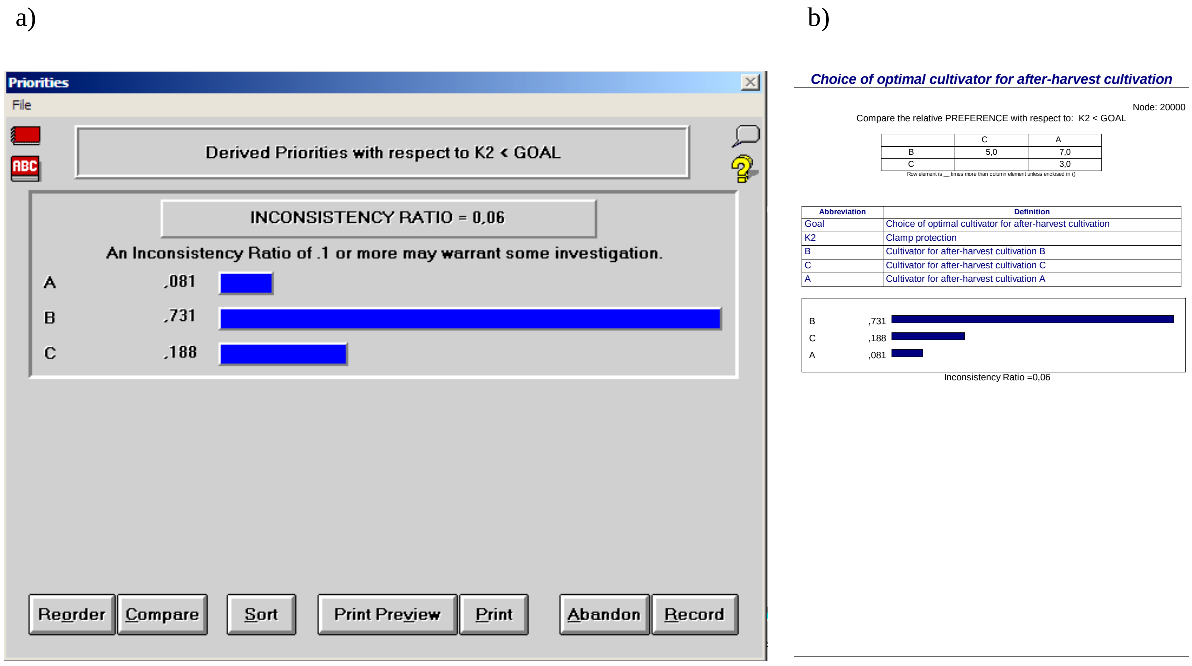


Fig. 5. Results of variant pair comparison taking into account criterion K2

It is evident from the diagram that manufacturer's reputation and unit purchase price of the machine turned out to be the most important criteria for the decision-maker. On the other hand, the low value of the significance coefficient (CI = 0.08) shows that the presented scores are very consistent and coherent.

During the successive stage of work with the Expert Choice program, machine variants are evaluated again by comparing appropriate pairs with regard to the fulfilment of requirements of each criterion. Figure 5 presents example results of a series of comparisons as scores concerning the examined cultivators (A, B and C) taking into account criterion K2.

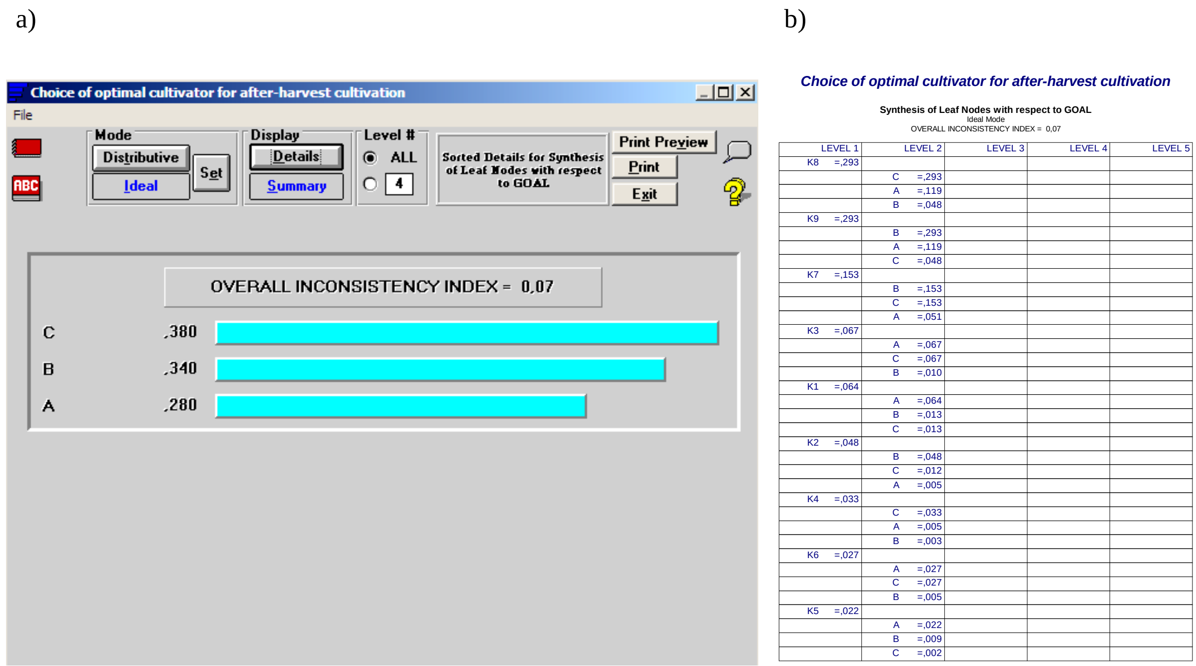
The results of calculations of the introduced scores together with the inconsistency rate are presented in forms of diagrams. (Fig. 6).



	C	A
B	5,0	7,0
C		3,0

Abbreviation	Definition
Goal	Choice of optimal cultivator for after-harvest cultivation
K2	Clamp protection
B	Cultivator for after-harvest cultivation B
C	Cultivator for after-harvest cultivation C
A	Cultivator for after-harvest cultivation A

Fig. 6. Determined local priority values for decision variants with reference to criterion K2 (a) and stage report (b)



LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
K8 =,293				
	C =,293			
	A =,119			
	B =,048			
K9 =,293				
	B =,293			
	A =,119			
	C =,048			
K7 =,153				
	B =,153			
	C =,153			
	A =,051			
K3 =,067				
	A =,067			
	C =,067			
	B =,010			
K1 =,064				
	A =,064			
	B =,013			
	C =,013			
K2 =,048				
	B =,048			
	C =,012			
	A =,005			
K4 =,033				
	C =,033			
	A =,005			
	B =,003			
K6 =,027				
	A =,027			
	C =,027			
	B =,005			
K5 =,022				
	A =,022			
	B =,009			
	C =,002			

Fig. 7. Arrangement sequence of adopted variants (a) and tabular detailed list of global and local priorities (b) in Ideal mode

The final results in the form of complex coefficients of the machines accepted for assessment obtained with the assistance of the AHP program are presented in Figure 7.

At the determined inconsistency coefficient IC at the level of 0.07, it can be said that the most optimal solution (when only K1-K9 criteria were taken into consideration) is the choice of cultivator C for which the complex index amounted to 0.380. In the performed test, it was followed by cultivator B, which was the most expensive machine in the examined group (0.340) with cultivator A taking the last position with the overall ranking result of 0.280. Therefore, it can be concluded that cultivator C realises best the objective function, i.e. good quality of execution and operation at a simultaneous attractive purchase price.

In addition, the employed Expert Choice program makes it possible to perform a comprehensive analysis of the sensitivity of the obtained results (Fig. 8).

It is very simple to change the importance of individual criteria by clicking the cursor of the computer mouse on the vertical column of the given criterion. The column will redraw to the indicated height and overall variant indices situated on the right side of the diagram will change their position. For example, the increase of the significance of the K2 criterion from 4.8% to 15% leads to the change of the final ranking of the adopted machine variants (Fig. 9).

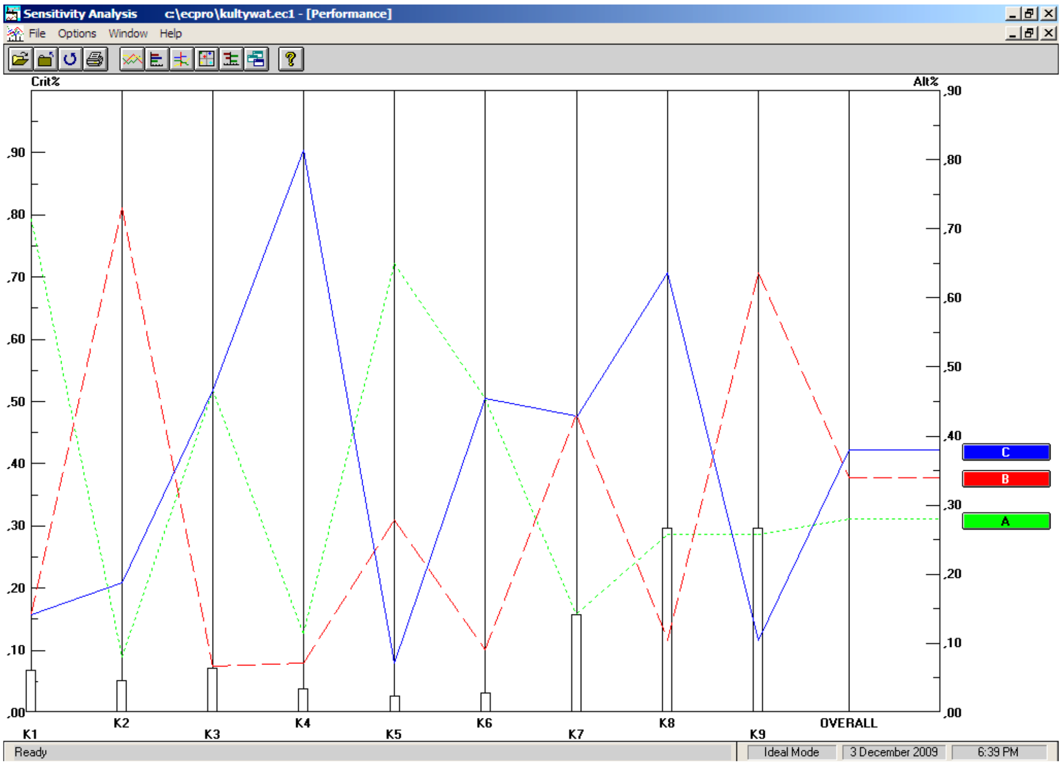


Fig. 8. Diagram of the sensitivity analysis in Performance mode

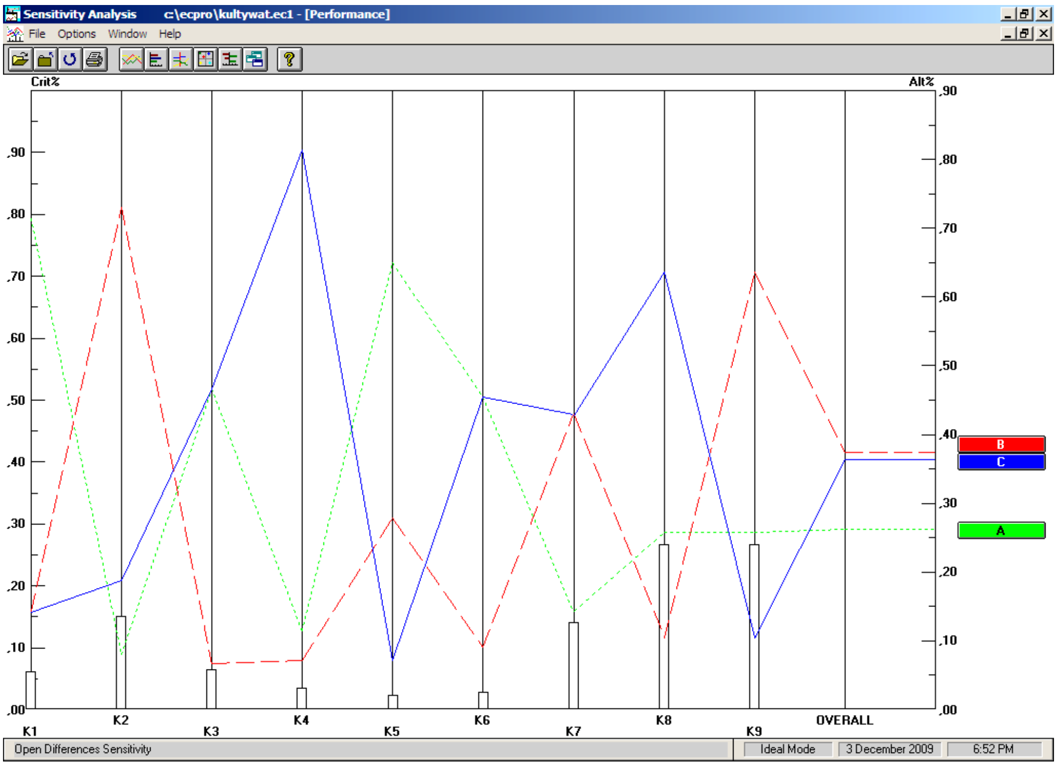


Fig. 9. Change of arrangement of machine variants caused by the change of significance of the K2 criterion in relation to the remaining criteria

5. Recapitulation and conclusions

The paper analyses possibilities of utilisation of the AHP method to assist decision-making processes when selecting an optimal agricultural machine for a farm. The performed simulation studies utilising special Expert Choice software revealed advantages and shortcomings of the AHP method and made it possible to draw the following conclusions:

1. The analytic hierarchy process (AHP) method is suitable for ranking machine variants in accordance with the adopted selection criteria and, consequently, makes it possible to indi-

cate the optimal solution. Logical structure of the method as well as its functional efficiency deserves attention.

2. The necessary condition for the application of the AHP method is full information from the decision-maker during the pair comparison of both criteria themselves as well as variants regarding a given criterion. Leaving gaps in evaluation matrices makes it impossible to move on to the next stage in the Expert Choice program.

3. The advantage of the AHP method is that it makes it possible to compare criteria whose values are both in numerical and descriptive forms. In both of these cases, extensive knowledge of the decision-maker who should be a specialist from the area of agricultural engineering is indispensible during their comparison.

4. The shortcoming of the AHP method is the subjective nature of scores assigned by the decision-maker.

5. The application of computer technique improves considerably practical possibilities of the AHP method. It accelerates calculations and controls current compatibility of assessment.

6. The method is useful and relatively simple but due to the number of necessary comparisons, it is recommended for application in small groups of machines (maximum 3-5).

7. After each pair comparison of model elements, attention should be paid to the value of significance coefficient CI which indicates inconsistency of assigned scores. Whenever the basic and recommended Saaty's five-point scale does not allow proper element differentiation of the decision-making model, indirect scoring (even numbers) should be employed.

6. References

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