# Explanation of evaluation criteria for rice weeding machine in paddy fields of Iran

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**Abstract:** Choosing the suitable weeding machines for paddy fields is of great interest to rice farmers. This choice requires exact evaluation and identifying its criteria can be very crucial .A Fuzzy decision-making system can be designed for a weeder machine by developing fuzzy sets of criteria for selecting suitable weeder machine and providing a good basis for comparison of different types of machines considering each rice farmer and paddy field. The objective of this study was to explain the evaluation criteria for rice weeding machine in paddy fields of Iran and present fuzzy sets of identified criteria. The methodology can be divided into three main parts: the examination of construct validity of instruments, their prioritization, and the relationships of variables. The present study, thus, used survey and analytical of hierarchy process methods. The tools included a researcher-made questionnaire using 5- point paired comparison statement. For the survey, the statistical population included all experts in education and research working in Ministry of Agriculture from which 310 people were selected. For AHP, 20 experts were selected by purposive sampling. The results of factor analysis showed that all criteria were strongly related. The results of analytical of hierarchy process prioritized the criteria as agronomic, technical, economic and environmental. Considering the "agronomic" and "technical" criteria, the experts preferred engine two- and three-row weeder machines, while regarding "agronomic" and "environmental" criteria, hand weeder machines are preferred. It is obvious that income amount and rising costs make the user give priority to hand machines, whereas under normal conditions, "agronomic" and "technical" criteria are considered.

**Keywords:** rice weeder machine, evaluation criteria, confirmatory factor analysis, structural equation model, analytical of hierarchy process

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## 1 Introduction

In Iran, mechanical weed control is laborious and difficult, particularly in fields infested with spinous weed species. However, this weed control is continued to be used in expensive crops. In addition, recently introduced individual plants or patches of noxious weeds are removed manually. In chemical weed management, the first herbicide was registered in 1967, rapid registrations of herbicides occurred after the Iran war with Iraq, which ended in 1988. So far, 108 herbicides from different groups of modes of action have been registered in Iran. However, not all the registered herbicides are commercially available for farmers. Collectively, the number and diversity of herbicides in Iran are lower than those in other developed countries (Nosratti et al., 2020).

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Rice (Oryza sativa L.) is one of the most important crops in the world due to its great economic and biological importance (Nabavi-Pelesaraei et al., 2018). The world annual production of paddy rice in 2020 was 460.8 million tones, respectively (FAO, 2020). About 90% of total world rice production takes place in Asia supplying the food need of 70% of world population (Hussain et al., 2020). Iran is the 11th largest rice producers in the world with average production of 4.9 tons per hectare (IRRI, 2010). Iran with an annual consumption equal to 45.5 kg per capita is the 13th largest rice consumer in the world (Tarang et al., 2013). Rice is cultivated from northern to southern Iran, producing annually about 3 million tons paddy (Alizadeh et al., 2013; Erfani et al., 2016). Introduction of row planting technologies and direct cultivation by rice transplanter machines as well as different types of linear rice cultivation machines has made the use of establishment machines especially weeder ones in paddy fields possible (Tajuddin, 2009). Employment of an efficient weeder machine in paddy fields is of crucial importance. Any action taken by a human is the result of a decision influenced by several criteria. Therefore, one of the most important decisions made by rice farmers is to choose the right rice weeding machine. They choose the suitable machine considering certain criteria. Structural Equation Model (SEM) is a powerful multivariate technique derived from multivariate regression, or more precisely it is an expansion of general linear model that allows the researcher to test a set of regression equations (Marohn et al., 2013) and examine the relationships among different variables, simultaneously (Hoyle, 2012). The importance of this technique in scientific researches is that researchers often examine the relationships between different variables in the form of a model or a network of relationships. Therefore, based on their assumptions about the relationships between variables, they design the general pattern of these relationships in a pre-constructed model (Adelson, 2012). The structure of the pre-constructed model is supported by the data in the real terms (Kline, 2011). They will be able to answer their questions through structural equation modeling and with the help of existing softwar (Beseler and Stallonese, 2006). SEM was first introduced in the early 1900s following Spearman and Wright´s studies, although no reference book was published until 1984. The application of this method in education-related researches has increased since 1980 (Teo, 2011). The reason for the widespread use and popularity of this technique among researchers, in addition to providing a quantitative method for testing the theory, it has overcome the difficulty of analyzing the relationships between variables in human researches and unlike the linear models used in traditional methods, it is able to estimate the measurement error as well (Hoyle, 2012).

In an investigation by Toma et al. (2018), impact of information transfer on farmers' uptake of innovative crop technologies was studied. A structural equation model applied to survey data. The model explains 83% of the variance in current technological uptake behavior and 63% of the variance in intentions to uptake new technologies. Results showed that economic characteristics to have the strongest effect on both uptake and intentions to uptake novel technologies. Education, access to technological information and perceived usefulness of sources of information transfer are also main influences on behavior and intentions. Technological uptake behavior is a strong determinant of intentions to uptake more technologies in the future. The results confirm established evidence from the literature that, besides economic factors, access to technological information and trust in/perceived usefulness of the different information sources will have an impact on technological uptake.

Li et al. (2019) studied the factors affecting the agricultural mechanization level in china based on structural equation modeling. The subsidy policy for the purchase of agricultural machinery and china's agricultural mechanization promotion law has been implemented since 1998 and 2004, respectively. The goal of the policy and the law is to improve the agricultural mechanization level (AML) in China. Policymakers expect that the AML could be increased by improving the agricultural equipment level (AEL). The AML in China is affected by many factors. However, only a few studies have investigated the effects of the AEL on the AML. To fill this gap, an integrative conceptual framework was built and a corresponding SEM using the relevant data collected from 30 provinces (cities and districts) in mainland China was estimated. The relevant data covered the years from 2001 to 2014. There were six factors in this framework, including AEL, level of economic development, land resource endowment, benefit factors, policy and environmental factors and demographic factors. The results showed that the AEL had the greatest impact on the AML. The level of economic development, the demographic factors, and the benefit factors not only directly affected China's AML but also indirectly affected the AML through the AEL.

One of the main objectives of the present study was to identify and explain the evaluation criteria for selecting rice weeder machine for paddy fields and provide fuzzy sets for the identified criteria. These parameters can help agricultural machinery manufacturers and authorities to make greater efforts to improve the quality of production and post-production services and make the right decisions for rice crop development according to viewpoints of users. In addition, the findings of the present study can be improve the researches on the qualitative evaluation of different types of rice weeding machines and the development of necessary information systems to identify the needs of farmers and users and to improve the weeding machines quality. In this study, in the first step, the evaluation criteria were identified by analyzing the relevant literature in the field of agricultural machinery and in the second step, using SEM, validation of the identified criteria was carried out by using the opinions of experts in the education and research fields and working in the Ministry of Agriculture of Iran.

## 2 Methodology

The methodology can be divided in to three parts. First construct validity of the instruments were examined by use of confirmatory factor analysis. Then, the relative weight of criteria was determined and they were prioritized. Next, the relationship among the variables was studied. Therefore this study used survey as well as Analytical of Hierarchy Process (AHP) methods. Confirmatory factor analysis is a form of construct validity obtained by factors analysis. Factor is an arbitrary variable affecting the scores of one or more variables. In other words, the purpose of factor analysis is to extract several variables from a large number of overlapping variables to be common. Each variable was analyzed by confirmatory factor analysis using AMOS software version 22. Factor analysis model can evaluate the construct validity and also reveal the relationship between variables (constructs). AHP is one of the most reliable multi-criteria decision making method (Vafaei, 2007). It was suggested in 1980 by Thomas L. Saaty that found various applications in sciences (Saaty, 1995). It is based on paired comparison of the values of a set of elements (Yu, 2002). It helps to make right decision for complex issues by simplification and directing the decision making steps. AHP provides an effective structure for decision making through organizing the thinking process. Designation of numerical values to the variables help the decision makers to have proper thinking patterns to achieve the desired results. The AHP procedure begins with determination of the model elements, decision making, prioritization these elements include different procedures and prioritization (Cheng and Wang, 2006).

### 2.1 Instruments

Two questionnaires were used for gathering data. A researcher-made questionnaire with items for respondents to express their opinions on the evaluation criteria for rice weeder machines was used. A 5-point Likert scale was used to score each of the indices, with the scores very low, low, medium, high and very high, scores 1, 2, 3, 4 and 5 were awarded respectively. The indices were selected using domestic and foreign scientific and practical reports confirmed by the experts (Chyung et al., 2017). The evaluation criteria and indices associated with each criterion as well as Cronbach´s alpha values, with the desirable ones being ⩾0/70, are shown in Table 1. Cronbach's alpha values represent the appropriate reliability of indices. In the other questionnaire first a hierarchy tree was generated based on the identified criteria then an AHP questionnaire was made according to the selected criteria and choices. The priority of criteria was first evaluated by the experts according to the 9-point scale and then the weeder machines were evaluated based on the criteria. The experts prioritized the criteria through pair-wise comparison. Number 1 shows an equal preferred twice and other 2-9 shows the preference as the larger the number, the higher the preference.

**Table 1 Evaluation criteria and indices**

| Criteria | Indices | Symbol | Cronbach's alpha value |
|---|---|---|---|
| Agronomic evaluation | Plant height | A1 | 0.95 |
| | Plant tillering | A2 | |
| | Weed dry weight | A3 | |
| | Number of weeds | A4 | |
| | Damaged bushes | A5 | |
| | Number of grains per bush | A6 | |
| | Number of full seeds per bush | A7 | |
| | The number of empty seeds per bush | A8 | |
| | Grain length | A9 | |
| | Number of clusters per plane | A10 | |
| | Cluster length | A11 | |
| | The weight of one thousand seeds | A12 | |
| | Grain Yield | A13 | |
| | Straw performance | A14 | |
| | Biological function | A15 | |
| | Harvest index | A16 | |
| | Lodging | A17 | |
| | Seed breakage | A18 | |
| Technical evaluation | Power | C1 | 0.92 |
| | Work safety | C2 | |
| | Parts quality | C3 | |
| | Reparability | C4 | |
| | Maneuverability | C5 | |
| | Device control and monitoring | C6 | |
| | Convenience of work and equipment | C7 | |
| | Services and access to repairman and spare parts | C8 | |
| | Range of traveling speed | C9 | |
| | Field Capacity | C10 | |
| | Field Efficiency | C11 | |
| | Working Width | C12 | |
| | Total time to work | C13 | |
| | Wasted time | C14 | |
| | Reliability | C15 | |
| | Power proportional to size of fields | C16 | |
| | Trademark and manufacturer | C17 | |
| | Device design | C18 | |
| | Easy adjustments | C19 | |
| | Ergonomic issues | C20 | |
| Economic evaluation | The cost of capital gains of weeding machine | B1 | 0.91 |
| | The cost of depreciation of Weeding machine | B2 | |
| | The cost of maintenance, insurance and tax of weeding machine | B3 | |
| | Cost of fuel consumed | B4 | |
| | Cost of oil consumed | B5 | |
| | Operator wages for weeding per hectare with weeding machine | B6 | |
| | The cost of repair and maintenance of weeding machine | B7 | |
| | The price and cost of weeding machine proportion with farms size and farmers' incomes | B8 | |
| Environmental evaluation | Noise pollution | D1 | 0.87 |
| | Air pollution | D2 | |
| | Reduction of inputs consumption | D3 | |

**2.2 Statistical population, sampling method and data gathering**

The statistical population of this study was composed of experts in the field of education, research and working in the Ministry of Agriculture. The samples were selected differently due to the combined nature of the study. The number of samples used in this study was 340 but due to the confusion of some information and lack of proper accountability of some respondents, finally, the information of 310 persons was used. The experts were chosen based on their gender, age, work, experience, specialty, job, and education. They were selected by systematic random sampling method. A list of experts was prepared via phone call or attendance at universities, research centers and offices associated with Agriculture Organization of which 340 people were selected by use of random numbers table. The respondents were contacted by phone, e-mail, as well as in person. The participants in AHP purposive sampling based on informed samples selection. Random sampling is not appropriate here and the statistical population and samples were selected based on the purposes and theoretical frame work of study. To do this, an e-mail was sent to 45 experts in the Tehran Agricultural Organization and agricultural professors. They were invited to participate in the study. The 26 people expressed their consent, however, 4 questionnaire were not sent back and 2 questionnaire were rejected due to the inconsistency answers. Finally 20 questionnaire were introduced in to the calculations process.

## 3 Results

Every variable was assessed by confirmatory factor analysis using AMOS software. According to Figure 1, the arrows drawn from the oval shapes to the rectangles represent the standard factor loading for each index. Operating loadings above 0.70 are usually very desirable. The coefficients of these factor loadings are shown in Table 2. For example, rows 1 to 18 represent the factor loadings of the first criterion (agronomic) for each of their indices with the standardized factor loading of the first index being 0.783, sixth index 0.740 and seventh index 0.759, and the other factor loadings are presented in Table 2. All of these figures are large enough and statistically significant. The presence of the three stars in p values column means that the probability of obtaining a critical ratio of 18.289 is less than 0.001 i.e. regression weight for the first criteria (agronomic) predicted by A2 is significantly far away (two ranges) from zero ($p<0.001$).

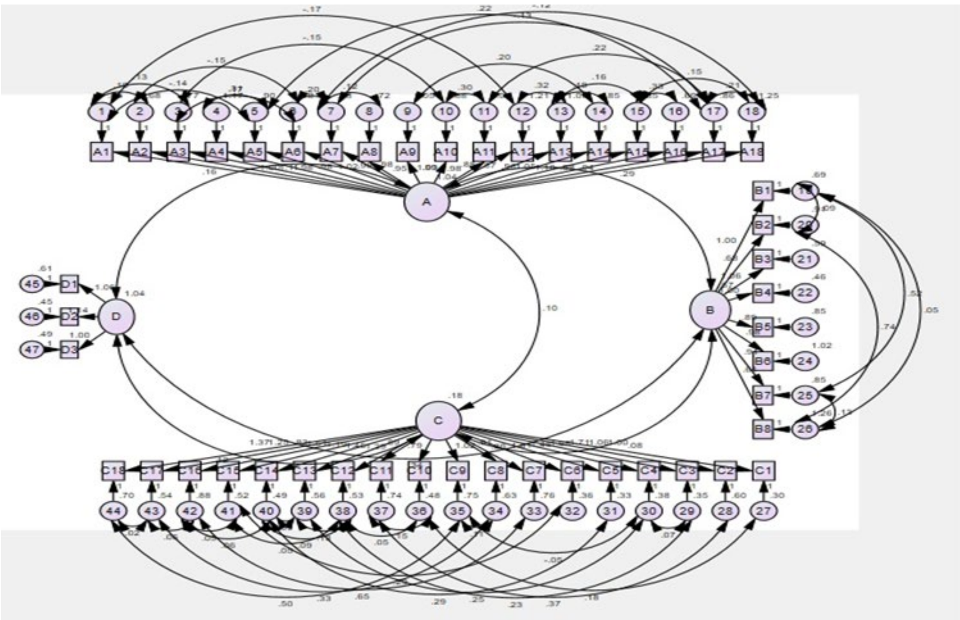


Figure 1 Confirmatory f

Another main element in construct validity evaluation by confirmatory factor analysis is goodness-of-fit. Goodness-of-fit >0.90 indicates an acceptable value and 1 means perfect goodness-of-fit. As shown in Table 2, the values of three goodness-of-fit (IFI, TLI, CFI) are greater than 0.90, of CMIN/DF less than 2 and of RMSEA less than 0.5 indicating good fit of the model. In other words, the indices used for criteria evaluation assessed the criteria well indicating the acceptability of construct validity. Furthermore, the present study was to investigate the correlation of the four criteria. It was hypothesized that there was a significant direct correlation between the criteria. Experts state that variations of criteria's scores are related. The results of correlation test are shown in Figure 1 as well as Table 3.

**Table 2 Confirmatory factor analysis of evaluation criteria**

| | | | Estimate | S.E.[1] | C.R.[2] | P[3] | Standardized Regression Weights | CMIN/DF[4] | GFI[5] | NFI[6] | RFI[7] | IFI[8] | TLI[9] | CFI[10] | RMSEA[11] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1** | <--- | A* | 1.000 | | | | 0.783 | 1.735 | 0.809 | 0.847 | 0.831 | 0.929 | 0.921 | 0.928 | 0.049 |
| A2 | <--- | A | 1.113 | 0.061 | 18.289 | *** | 0.808 | | | | | | | | |
| A3 | <--- | A | 0.984 | 0.063 | 15.700 | *** | 0.751 | | | | | | | | |
| A4 | <--- | A | 0.982 | 0.078 | 12.629 | *** | 0.679 | | | | | | | | |
| A5 | <--- | A | 1.016 | 0.079 | 12.811 | *** | 0.736 | | | | | | | | |
| A6 | <--- | A | 0.957 | 0.069 | 13.954 | *** | 0.740 | | | | | | | | |
| A7 | <--- | A | 0.979 | 0.068 | 14.384 | *** | 0.759 | | | | | | | | |
| A8 | <--- | A | 0.946 | 0.067 | 14.221 | *** | 0.750 | | | | | | | | |
| A9 | <--- | A | 1.034 | 0.077 | 13.441 | *** | 0.716 | | | | | | | | |
| A10 | <--- | A | 0.992 | 0.072 | 13.814 | *** | 0.733 | | | | | | | | |
| A11 | <--- | A | 0.976 | 0.076 | 12.880 | *** | 0.691 | | | | | | | | |
| A12 | <--- | A | 0.880 | 0.082 | 10.721 | *** | 0.631 | | | | | | | | |
| A13 | <--- | A | 0.873 | 0.072 | 12.059 | *** | 0.654 | | | | | | | | |
| A14 | <--- | A | 0.982 | 0.071 | 13.893 | *** | 0.736 | | | | | | | | |
| A15 | <--- | A | 1.050 | 0.073 | 14.409 | *** | 0.758 | | | | | | | | |
| A16 | <--- | A | 1.100 | 0.071 | 15.518 | *** | 0.804 | | | | | | | | |
| A17 | <--- | A | 0.977 | 0.071 | 13.766 | *** | 0.731 | | | | | | | | |
| A18 | <--- | A | 0.938 | 0.078 | 11.952 | *** | 0.649 | | | | | | | | |
| C1** | <--- | C* | 1.000 | | | | 0.572 | | | | | | | | |
| C2 | <--- | C | 1.006 | 0.136 | 7.393 | *** | 0.453 | | | | | | | | |
| C3 | <--- | C | 1.983 | 0.193 | 10.266 | *** | 0.858 | | | | | | | | |
| C4 | <--- | C | 1.940 | 0.186 | 10.446 | *** | 0.841 | | | | | | | | |
| C5 | <--- | C | 1.535 | 0.155 | 9.871 | *** | 0.719 | | | | | | | | |
| C6 | <--- | C | 1.616 | 0.172 | 9.419 | *** | 0.706 | | | | | | | | |
| C7 | <--- | C | 0.895 | 0.153 | 5.851 | *** | 0.378 | | | | | | | | |
| C8 | <--- | C | 0.927 | 0.146 | 6.371 | *** | 0.418 | | | | | | | | |
| C9 | <--- | C | 1.022 | 0.156 | 6.550 | *** | 0.432 | | | | | | | | |
| C10 | <--- | C | 0.814 | 0.094 | 8.654 | *** | 0.423 | | | | | | | | |
| C11 | <--- | C | 0.877 | 0.149 | 5.875 | *** | 0.379 | | | | | | | | |
| C12 | <--- | C | 1.528 | 0.170 | 8.996 | *** | 0.659 | | | | | | | | |
| C13 | <--- | C | 1.692 | 0.181 | 9.332 | *** | 0.696 | | | | | | | | |
| C14 | <--- | C | 1.227 | 0.151 | 8.144 | *** | 0.571 | | | | | | | | |
| C15 | <--- | C | 1.508 | 0.175 | 8.623 | *** | 0.619 | | | | | | | | |
| C16 | <--- | C | 0.818 | 0.158 | 5.173 | *** | 0.328 | | | | | | | | |
| C17 | <--- | C | 1.264 | 0.159 | 7.949 | *** | 0.553 | | | | | | | | |
| C18 | <--- | C | 1.370 | 0.176 | 7.791 | *** | 0.538 | | | | | | | | |
| B1** | <--- | B* | 1.000 | | | | 0.703 | | | | | | | | |
| B2 | <--- | B | 0.685 | 0.081 | 8.461 | *** | 0.508 | | | | | | | | |
| B3 | <--- | B | 1.063 | 0.093 | 11.468 | *** | 0.750 | | | | | | | | |
| B4 | <--- | B | 1.004 | 0.086 | 11.712 | *** | 0.770 | | | | | | | | |
| B5 | <--- | B | 0.889 | 0.092 | 9.691 | *** | 0.619 | | | | | | | | |
| B6 | <--- | B | 0.982 | 0.101 | 9.745 | *** | 0.623 | | | | | | | | |
| B7 | <--- | B | 0.908 | 0.054 | 16.955 | *** | 0.627 | | | | | | | | |
| B8 | <--- | B | 0.606 | 0.093 | 6.542 | *** | 0.404 | | | | | | | | |
| D3** | <--- | D* | 1.000 | | | | 0.824 | | | | | | | | |
| D2 | <--- | D | 1.144 | 0.071 | 16.170 | *** | 0.867 | | | | | | | | |
| D1 | <--- | D | 1.059 | 0.069 | 15.383 | *** | 0.810 | | | | | | | | |
| C19 | <--- | C | 1.808 | 0.183 | 9.896 | *** | 0.769 | | | | | | | | |
| C20 | <--- | C | 1.645 | 0.172 | 9.564 | *** | 0.726 | | | | | | | | |

Note: 1Standard error; 2Critical ratio; 3Significant; 4Relative squares; 5Goodness of fit index; 6Normed Fit Index; 7Relative of Index; 8Incremental fit index; 9Tucker-Lewis Fit Index; 10Comparative fitness index; 11Root Mean Square Error of Approximation

**Table 3 Correlation of research criteria with each other**

| | | | Estimate | S.E. | C.R. | P | Correlations |
|---|---|---|---|---|---|---|---|
| A | <--> | C | 0.088 | 0.027 | 3.251 | 0.001 | 0.215 |
| A | <--> | B | 0.289 | 0.060 | 4.845 | *** | 0.347 |
| A | <--> | D | 0.157 | 0.066 | 2.371 | 0.018 | 0.151 |
| C | <--> | B | 0.076 | 0.023 | 3.273 | 0.001 | 0.232 |
| C | <--> | D | 0.112 | 0.029 | 3.886 | *** | 0.275 |
| B | <--> | D | 0.337 | 0.063 | 5.339 | *** | 0.404 |

As shown in the Table 3, all criteria are significantly and directly related. The correlation between "agronomic" and "technical" criteria is 0.289 which is significant at 99% confidence level meaning that one unit increase or decrease in criterion leads to a 0.215 increase or decrease in another one. The correlation between "agronomic" and "economic" criteria is 0.347 at 99% meaning that one unit increase or decrease in one criterion results in a 0.347 increase or decrease in another criterion. The correlation between "agronomic" and "environmental" criteria is 0.151 at 95% confidence level meaning that with one unit increase or decrease in a criterion, a 0.151 increase or decrease occurs in another one the correlation between "technical" and "economic" criteria is 0.232 at 99% meaning that with one unit increase or decrease in a criterion, a 0.232 increase or decrease in another one. The correlation between "technical" and "environmental" is 0.272 at 99% meaning one unit increase or decrease in a criterion results in a 0.152 increase or decrease in the other criterion. The correlation between "economic" and "environmental" criteria is 0.404 at 99% confidence level. It means that with one unit increase or decrease in a criterion, a 0.215 increase and decrease occurs in another criterion.

### 3.1 Calculation of pair-wise compared scoring matrices

Paired scoring matrix was calculated as follows: The preference for a criterion against the preferred choice was $\frac{1}{n}$ of the value selected by the experts for comparison. For example, the experts selected preference 2.02 for "agronomic" over "technical" criteria meaning that "agronomic" criteria was 2.02 times preferred over "technical" criteria. Thus, score 2.02 and $\frac{1}{2.02}$ or 0.49 were given to "agronomic" and "technical" criteria, respectively. Inconsistency also is shown in the Tables 4 and 5. It indicates the reasonable inconsistency of the paired choices. If A is preferred over B and B is preferred over C then A is preferred over C. If C is chosen instead of A, it is an inconsistent case. Inconsistency greater than 0.1 is not acceptable. As shown in Table 2, all comparisons have an acceptable inconsistency rate (<0.1) and it should be noted that since AHP was used in this study, geometric mean of scores was used for comparisons. The results for the criteria and choices are presented in Tables 4 and 5.

**Table 4 Pair-wise comparison of choices economic and associated with agronomic criterion**

| Pair-wise comparison of choices associated with agronomic criterion | | | | |
|---|---|---|---|---|
| Engine triple-row | Engine double-row | Engine single-row | Manual | |
| 2.43 | 2.62 | 1.19 | 1 | Manual |
| 2.02 | 2.14 | | 0.84 | Engine single-row |
| 1.23 | 1 | 0.41 | 0.38 | Engine double-row |
| 1 | 0.81 | 0.49 | 0.41 | Engine triple-row |
| 0.0028 | | | | Inconsistency rate |
| Pair-wise comparison of choices economic | | | | |
| Engine triple-row | Engine double-row | Engine single-row | manual | |
| 0.45 | 0.29 | 0.36 | 1 | Manual |
| 0.36 | 0.31 | 1 | 2.77 | Engine single-row |
| 0.58 | 1 | 3.23 | 3.48 | Engine double-row |
| 1 | 1.72 | 2.73 | 2.21 | Engine triple-row |
| 0.04 | | | | Inconsistency rate |

**Table 5 Pair-wise comparison of criteria, associated with technical and environmental**

| Pair-wise comparison of criteria | | | | |
|---|---|---|---|---|
| Environmental | Economic | Technical | Agronomic | |
| 3.87 | 3.10 | 2.02 | 1 | Agronomic |
| 3.75 | 2.21 | 1 | 0.49 | Technical |
| 2.51 | 1 | 0.26 | 0.32 | Economic |
| 1 | 0.40 | 0.27 | 0.26 | Environmental |
| | 0.03 | | | Inconsistency rate |
| **Pair-wise comparison of choices associated with technical** | | | | |
| Engine double-row | Engine single-row | Manual | | |
| 0.81 | 0.28 | 0.52 | 1 | manual |
| 0.57 | 0.29 | 1 | 1.91 | Engine single-row |
| 0.59 | 1 | 3.46 | 3.5 | Engine double-row |
| 1 | 1.68 | 1.76 | 1.23 | Engine triple-row |
| | 0.01 | | | Inconsistency rate |
| **Pair-wise comparison of choices associated with environmental** | | | | |
| Engine triple-row | Engine double-row | Engine single-row | Manual | |
| 3.47 | 2.96 | 2.81 | 1 | Manual |
| 1.07 | 1.23 | 1 | 0.35 | Engine single-row |
| 1.14 | 1 | 0.81 | 0.34 | Engine double-row |
| 1 | 0.88 | 0.93 | 0.29 | Engine triple-row |
| | 0.00155 | | | Inconsistency rate |

## 3.2 Calculation of the final weight of criteria

One of the main goals of this study was to calculate final weight of the four criteria. This calculation is important both for rating and final weight of criteria. Final weight of criteria with the associated diagrams are given in Table 6. As shown in the Table, the experts preferred "agronomic" criteria with the final weight of 0.462 over the other criteria followed by technical (0.292), economic (0.161) and environmental (0.85).

**Table 6 Final weight of criteria**

| Criterion | Final weight |
|---|---|
| Agronomic | 0.462 |
| Technical | 0.292 |
| Economic | 0.161 |
| Environmental | 0.085 |

## 3.3 Calculation of the final weight of choices for criteria

The importance of each criterion is considered individually for determination of the final weight of choices. In Table 7, the final weight of choices is calculated regarding the associated criteria. In the first part, "agronomic" criteria has been considered. D (engine triple-row machine) with the weight of 0.357 was given the highest score. C (engine double-row machine) with the weight of 0.336 was rated as the second followed by B (engine single-row) with the weight of 0.167 and A (manual) with the weight of 0.139. In the second part, "technical" criterion is considered. D (0.403) was given the highest score followed by C (0.281), B (0.215) and A (0.102). In the third part, "economic" criterion is regarded. A (0.473) has the highest score followed by B (0.260), C (0.158) and D (0.108). In the fourth part, choices have been calculated based on "environmental" criterion. A (0.506) was given the highest score followed by B (0.180), C (0.162) and D (0.152).

**Table 7 Final weight of criteria**

| Criterion | Choices | Final weight |
|---|---|---|
| Agronomic | A | 0.139 |
| | B | 0.167 |
| | C | 0.336 |
| | D | 0.357 |
| Technical | A | 0.102 |
| | B | 0.215 |
| | C | 0.281 |
| | D | 0.403 |
| Economic | A | 0.473 |
| | B | 0.260 |
| | C | 0.158 |
| | D | 0.108 |
| Environmental | A | 0.506 |
| | B | 0.180 |
| | C | 0.162 |
| | D | 0.152 |

Note: A: Manual; B: Engine single-row; C: Engine double-row machine; D: Engine triple-row machine.

### 3.4 Sensitivity analysis of criteria based on efficiency

Figure 2 displays the rating of different choices regarding the criteria. As shown in the diagram, D had the highest sensitivity to "technical" criterion. A showed the highest sensitivity to "economic" and "environment" criteria. C had the highest sensitivity to "technical" criterion.

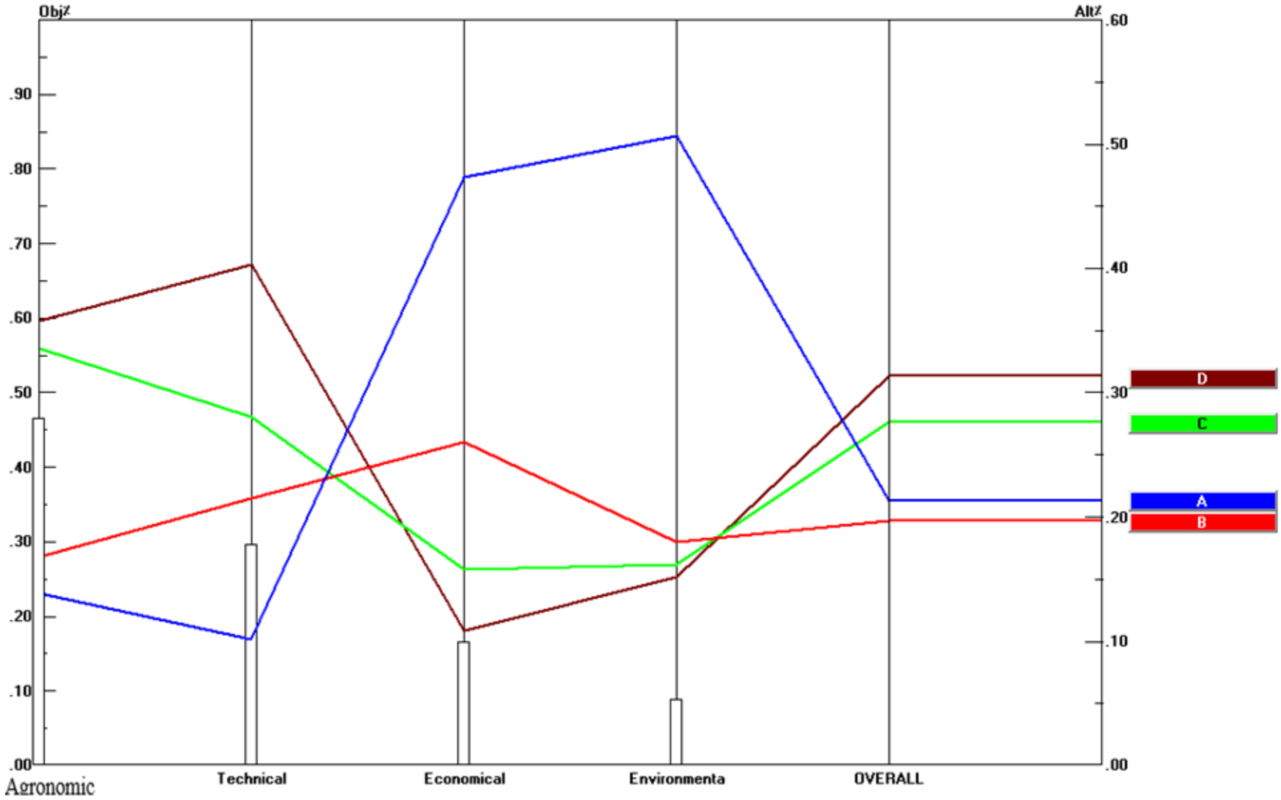


Figure 2 Sensitivity analysis of criteria based on efficiency

### 3.5 Final prioritization of choices

Another main goal of this study was to prioritize the choices according to the criteria. First the weights of pair-wise compared choices are multiplied by the weight of criteria. The choice with the highest weight is prioritized as the first and so on.

**Table 8 Final weight of choices and their prioritization**

| Choice | Final weight | Rate |
|---|---|---|
| A (Manual) | 0.213 | 3 |
| B (Engine single-row machine) | 0.197 | 4 |
| C (Engine double-row) | 0.246 | 2 |
| D (Engine triple-row machine) | 0.313 | 1 |

Table 8 shows the final priority of choices with their associated diagrams. The results demonstrated that the experts give the highest priority to D (engine triple-row machine) followed by C (engine double-row machine), A (manual) and B (engine single-row machine).

## 4 Discussion and conclusion

The main objective of the present study was to identify important indices for evaluation of rice weeder machine in Iran. To do so, four criteria and 49 indices for evaluation of these criteria were determined according to the literature and background. The purpose was to confirm the validity of the criteria. A survey was conducted by the experts and data were collected by a researcher-made questionnaire. Confirmatory factor analysis showed that both factor loadings and indices had acceptable goodness-of-fit. So it could be claimed that the measurement of criteria was appropriate and the instruments for data gathering had acceptable construct validity. One of the most important goals of survey was to determine the amount and direction of variables. It was observed that all variables (constructs) were significantly and directly related. The general results of this study are presented in Table 9.

**Table 9 Analysis and interpretation of finding**

| Main goal | Sub goals | Related questions | Method of answering questions | Research findings |
|---|---|---|---|---|
| Identification of important indices in the evaluation of rice weeding machine in Iran | Identification of evaluation criteria and indices | What criteria and indices are considered in evaluating rice weeding machines in Iran? | Documentary study method | The criteria and indices are written separately in Table 1, which contains four criteria and 49 indices. |
| | Experimental examination of the validity of the indices | To what extent are the identified dimensions and indices supported by empirical studies? | Confirmatory factor analysis | Confirmatory factor analysis for each of the dimensions shows that there is a good fit between the dimensions and the experimental data, indicating the validity of the data collection tool and the success of the researcher in operationalizing the main variables of the study. |
| | Determine the importance of indices | How important are experts to each of the indices specified? | Distribution of mean scores of indices and statistical charts | In terms of agronomic evaluation, damaged bushes, the number of weeds and plant tillering gained first to third priorities. In terms of economic evaluation, price and cost of weeding machine proportion with farms size and farmers' incomes, operator wages for weeding per hectare with weeding machine and The cost of capital gains of weeding machine ranked first to third. For the technical evaluation criterion, farm capacity, farm efficiency and total time to work were the top three priorities. For the environmental evaluation criterion, reduction of input consumption, noise and air pollution were ranked first to third, respectively |
| | Evaluate the amount and direction of the relationship between the evaluation criteria | What is the extent and direction of the evaluation criteria relationship? | Pearson correlation coefficient calculated in confirmatory factor analysis | The results show that all criteria have a relatively strong and direct relationship with each other. |

The choices were prioritized by use of group hierarchy analysis process. Four criteria including "agronomic", "technical", "economic" and "environmental" as the criteria affecting the selection of rice weeder machine were evaluated. The results showed that "agronomic" criterion was given the highest priority followed by "technical", "economic" and environmental". The experts mostly considered technical and agronomic indices. Environmental indices such as noise pollution, air pollution and input usage were given the lowest priority. Considering "agronomic" and "technical" criteria, the expert preferred engine triple-row and double-row machines while regarding "economic" and "environmental" criteria, manual machines were preferred. It demonstrates that income amount and rising costs lead the users to prefer manual machines however under normal conditions, "agronomic" and "technical" criteria are considered. The final evaluation by the experts is summarized in Table 10. To sum up the priorities, the weights of each of the options obtained in pairwise comparison are multiplied by the weight of the criteria, and finally the option that gains the most weight is placed in the first priority and the next weights are placed in the next priorities. The final priority of the options is shown in Figure 3. The results showed that by considering all the criteria, the experts have finally given the highest priority to option D (Engine triple-row machine). The second rank belongs to option C (Engine double-row), the third rank belongs to option A (manual) and the last rank belongs to option B (Engine single-row machine).

The results of this study showed that there was a significant difference between different weed control treatments in terms of yield related to rice and vegetative traits of weeds. Examination of the percentage of damaged plants after weeding indicates that factors such as operator skill, weeding speed and seedling planting distance can have an important effect on increasing and decreasing the amount of seedling damage during weeding operations. Regarding the speed of the weeding machine, factors such as the type of weeding, the type and variety of weeds and the time of weeding seem to be very important. Triple-row motor weeding machine in the first place compared to other weeder tested, and according to the findings of this study, it can be considered as the most suitable type in controlling of rice weeds. From a macro perspective, we relevant four model weeding machine including manual, engine single-row, engine double-row and engine triple-row investigated in this study. Due to cultivation and herbicide (killing weed) are some of the most important processes in early stage of rice farming. There are many good reasons to cultivate and kill weeds by the cultivating and weeding machine: Expedite shooting (tillering) of rice plants and make sure rice plants in early stage of planting rice, Increase the temperature of the ground and raise well-sprout rice plants, Reduce bad gas and provide oxygen to the paddy field, Increase the effectiveness of fertilizer, kill weeds that have stronger resistance against weed killer. In addition to the above, the use of a device that can be technically more efficient, less economically expensive, and more suitable for agriculture, as well as less polluting in terms of environment, all these cases were investigated and according to the nature of the issue the best machine for weeding rice was selected in this research.

**Table 10 prioritization of choices according to criteria**

| Environmental | Economic | Technical | Agronomic | |
|---|---|---|---|---|
| 1 | 1 | 4 | 4 | A (Manual) |
| 2 | 2 | 3 | 3 | B (Engine single-row machine) |
| 3 | 3 | 2 | 2 | C (Engine double-row) |
| 4 | 4 | 1 | 1 | D (Engine triple-row machine) |

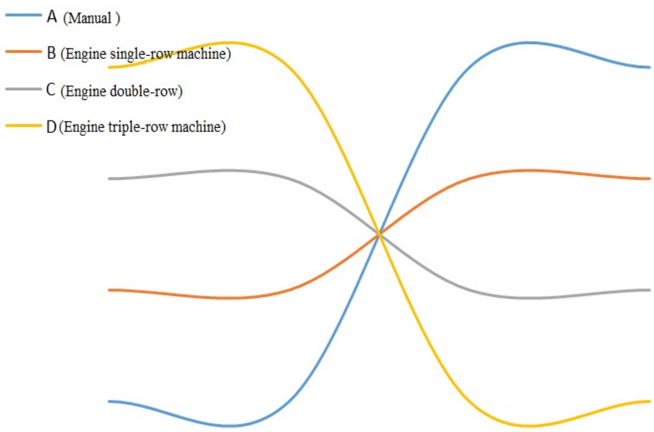


Figure 3 Prioritization of choices according to criteria

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