RESEARCH ARTICLE

Evaluation and prioritization of rice production practices and constraints under temperate climatic conditions using Fuzzy Analytical Hierarchy Process (FAHP)

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Abstract

Due to overwhelming complex and vague nature of interactions between multiple factors describing agriculture, Multi-Criteria Decision Making (MCDM) methods are widely used from farm to fork to facilitate systematic and transparent decision support, figure out multiple decision outcomes and equip decision maker with confident decision choices in order to choose best alternative. This research proposes a Fuzzy Analytical Hierarchy Process (FAHP) based decision support to evaluate and prioritize important factors of rice production practices and constraints under temperate climatic conditions and provides estimate of weightings, which measure relative importance of critical factors of the crop under biotic, abiotic, socio-economic and technological settings. The results envisage that flood, drought, water logging, late sali, temperature and rainfall are important constraints. However, regulating transplantation time; maintaining planting density; providing training to the educated farmers; introducing high productive varieties like Shalimar Rice-1 and Jhelum; better management of nutrients, weeds and diseases are most important opportunities to enhance rice production in the region. Therefore, the proposed system supplements farmers with precise decision information about important rice production practices, opportunities and constraints.

Additional key words: analytical hierarchical process; multi-criteria decision making; fuzzy analytical hierarchical processing; biotic and abiotic constraints; rice production practices; *Oryza sativa*.

Abbreviations used: AHP (Analytical Hierarchical Processing); EA (Extent Analysis); FAHP (Fuzzy Analytical Hierarchical Processing); MCDM (Multi-Criteria Decision Making); TFN (Triangular Fuzzy Number).

Introduction

The history of agriculture is a history of site specific technological innovations and/or adjustments. Although in recent years, application of modern technologies in Indian agriculture has supplied the food demands of human consumption. However, with the ever increasing population and vagaries in climatic conditions, food security remains a big challenge (GOI, 2011). With the aim to increase the productivity of rice (*Oryza sativa*) in India, sizable number of improved practices of rice have been developed to boost rice production. Productivity of rice has increased from about 2 t/ha (2004-05) to about 2.4 t/ha (2013-14) but still we are lagging far behind in the productivity of rice as compared to countries like China and Japan where productivity is about 6.7 t/ha (GOI, 2012). Although improved technologies have shown high yield potentials (60-70 t/ha) to get par with the high productive countries (Wani *et al*., 2013), yield gaps are still very wide (Beigh *et al*., 2015). Therefore, for sustained food supply, new methods for minimizing yield gaps are needed urgently.

Yield-gap analyses have been undertaken for most of the field crops in different regions of India by several researchers in the past (Rajaram, 1998; Barman *et al.*, 2010; Pushpa & Srivastava, 2014). Similar studies have been undertaken elsewhere (Lobell *et al.*, 2009; Liker *et al.*, 2010; Laborte *et al.*, 2012). Thorough analysis of yield gaps and research evidences suggest that technological and socio-economic constraints account for 54% and 46% yield gap-II or extension yield gap respectively (Mahendra, 2011). On the other hand, it has also been established that physical, biological and climatic conditions are also contributing to these gaps and commonly limit the rice production goals (Adhya *et al.,* 2008; Chand *et al.*, 2011). These yield gaps are mostly due to non-adoption of improved cultivation practice of rice, particularly due to poor socio-economic conditions of farmers and/or high cost of cultivation (Adhyaet *et al.*, 2008; Mahendra, 2011). The adoption of improved practices vary from farmer to farmer as per their own preference (Singha & Baruah, 2011), which necessitate prioritization of rice production practices and constraints to equip farmers with effective decision support to achieve the overall objectives of enhanced rice production. But assessment of these strategies cannot be done using conventional quantitative methods given the imprecise and uncertain nature of interactions between multiple factors describing crop production.

Decision making in agriculture is based on combination of experience, empirical data and analysis of the situation in hand at a particular time, which may be imprecise and could not be handled using conventional methods. Research evidences suggest that biological, technological, environment and socio-economic factors play significant role in the farmer's decision making towards rice production practices (Baquet *et al.*, 1997; Stigter, 2008). These factors are again complex experience of several processes which are again unreliable, uncertain and vague in nature. Therefore, the situation needs qualitative approach for assessment of priorities amongst given set of diverse contributing factors. This research attempts to develop a decision support tool to address imprecise nature of rice crop production factors by providing an estimate of weightings that measure their relative importance by emphasizing on human thought, inference and cognitions of surroundings using Fuzzy Analytic Hierarchy Process (FAHP).

FAHP is one of the multi-criteria optimization methodologies developed by Saaty (1980). Like AHP, it allows decision makers to model a complex problem in a hierarchical structure, consisting of criteria and sub-criteria cascading from the decision objective or goal so as to assist in making decision amidst situations comprising of various scales and multiple levels of abstraction. The advantage of using FAHP is that it enables us to handle vagueness or ambiguity associated with the mapping of the decision maker's perception to exact numbers (Van Laarhoven & Pedrycz, 1983; Deng, 1999; Mikhailov, 2004). The foundation base of FAHP is on the basis of fuzzy sets (Bellman & Zadeh, 1970; Zimmermann, 1990), which cleared the way for a new family of methods to deal with problems which had been inaccessible to and unsolvable with standard Multi-Criteria Decision Making (MCDM) techniques, due to their inability to coop with the vague situations. To deal with vagueness of human thought, fuzzy set theory was introduced by Zadeh (1965), which was tailored to the rationality of uncertainty due to imprecision or vagueness. The demonstration of basic theory of triangular fuzzy numbers (Zhu *et al.,* 1999) improved the comparison logic of fuzzy numbers. Later on Extent Analysis (EA) method was introduced (Chang, 1996) and developed (Zhu *et al.*, 1999), which is now used widely as an advance method of FAHP.

FAHP has been used in diverse area of agriculture viz., land suitability analysis for rice (Sánchez-Moreno *et al.*, 2014),water management plans (Srdjevican & Medeiros, 2008), environment vulnerability assessment (Li *et al.,* 2009), priority setting in agricultural land-use (Akpinar *et al.,* 2005), evaluation of risk factors in agriculture (Toledo, 2011), development of location indicators for agricultural service center (Zangeneh *et al.,* 2015), plant species selection in mine reclamation plans (Alavi, 2014), restoring degraded landscapes in lowland Namaqualand (Carrick & Kruger, 2007), evaluation of drought vulnerability (Jing & Jian, 2010), land suitability analysis (Prakash, 2003), forage selection (Juan *et al.,* 2004), crop area planning (Gupta *et al.,* 2000), drought risk assessment (Jing & Jian, 2010), assessment of global change (Colin *et al.*, 2007), land use planning (Biswas & Pal, 2005) and agriculture production planning (Mohaddes & Mohayidin, 2008). These studies have mainly been carried out to make assessment and/or prioritization of complex and vague factors to equip decision makers with more precise and key information.

The objective of this study was to identify and evaluate important factors for rice production under temperate climatic conditions, provide relative weights to prioritize each factor with the broader aim to identify most important constraint, technological component, production potentials and weaknesses in rice production practices.

Material and methods

The FAHP method used in the study is based on the algorithm derived from fuzzy sets, fuzzy numbers and Chang's extent analysis, which are introduced below.

Fuzzy sets and numbers

Introduced by Zadeh (1965), fuzzy set theory provides a strict mathematical framework in which vague conceptual phenomena can be precisely and rigorously studied (Zimmermann, 1994). It is a proper tool to reinforce the comprehensiveness and correctness of the decision making stages (Meysam *et al.,* 2012). Fuzzy set theory is a fundamental approach to measure extent of satisfaction and importance of vague and unclear linguistic variables associated with human subjective judgments. A linguistic variable is a variable whose values are not quantitative but qualitative. The concept of a linguistic variable is very beneficial in dealing with vogue, ill-defined and uncertain situations, which cannot be defined rationally using quantitative expressions. Lingual expressions such as satisfied, fair, dissatisfied, important, least important, more important etc. are usually regarded as natural representations of preferences or judgments of humans. They are expressed as a class of objects with a continuum of grades of membership. The methodological basis of the membership function can be found in the fuzzy sets, which defines the fuzzy set A in X by a membership function fA(x) that associates each point in X with a real number in the interval [0,1], where fA(x) is the degree of membership of x in A. The closer the value of fA(x) to 1, the greater the degree of membership of x in A. The main characteristic of fuzziness is the grouping of individuals into classes that do not have sharply defined boundaries. The uncertain comparison judgment can be represented by the Triangular Fuzzy Number (TFN). The TFN is the special class of fuzzy number whose membership function is defined by the triplet (l,m,u) as illustrated in Fig. 1. TFN helps the decision maker to make easier decisions.

For two given TFN $A = (l_1, m_1, u_1)$ and $B = (l_2, m_2, u_2)$ the calculation of fuzzy numbers can be done according to the extension principle of TFN. The basic arithmetic operations used in the analysis are given in Table 1, where A and B are positive.

A fuzzy number can always be given by its corresponding left and right representation of each degree of membership:

$$M^{\sim} = \left(f_\alpha(l), f_\alpha(u) \right) = \left((m-l)\alpha + l, u - (u-m)\alpha \right), y \in [0,1] \quad [1]$$

where $f_\alpha(l)$ and $f_\alpha(u)$ denote the left and the right side representation of a fuzzy number, respectively.

FAHP algorithm used

FAHP used in this study was originally introduced by Chang (1996). This section outlines the extent analysis method on FAHP to know the priority weights of different major and sub criteria for evaluation and prioritization of rice production practices and constraints.

Table 1. Fuzzy arithmetical operations using two TFNs.

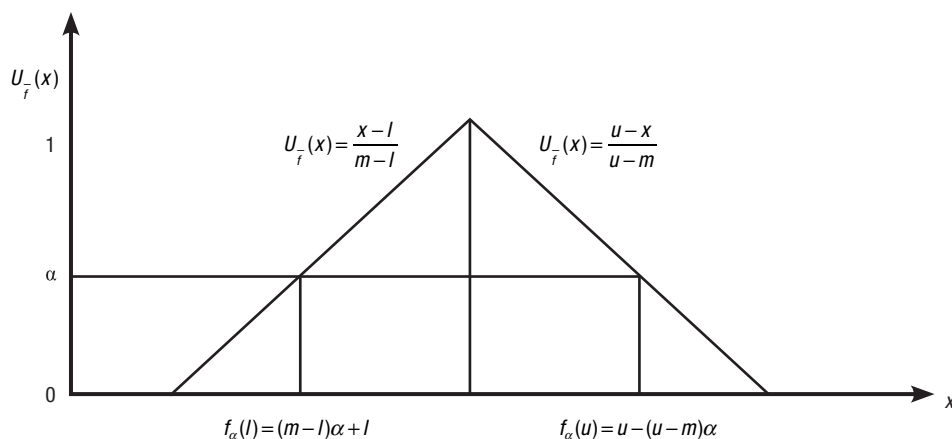| Operators	Formula	Results
Summation	$A + B$	$(l_1 + l_2, m_1 + m_2, u_1 + u_2)$
Subtraction	$A - B$	$(l_1 - l_2, m_1 - m_2, u_1 - u_2)$
Multiplication	$A \cdot B$	$(l_1 \cdot l_2, m_1 \cdot m_2, u_1 \cdot u_2)$
Division	A / B	$(l_1 / l_2, m_1 / m_2, u_1 / u_2)$

Figure 1. Left and right representation of Triangular Fuzzy Number (TFN) (Padma & Balasubramanie, 2011).

Let $X = \{x_1, x_2, x_3, \ldots x_n\}$ be an object set and $U = \{u_1, u_2, u_3, \ldots u_n\}$ be a goal set. According to the Chang's extent analysis method, each object is taken and extent analysis for each goal is performed, respectively. Therefore extent analysis values for each object can be obtained, with the following notations:

$$M_{gi}^1, \; M_{gi}^2, M_{gi}^3, \ldots\ldots\ldots M_{gi}^m, \; i = 1,2,3,\ldots,n \quad [2]$$

where all $M_{gi}^m (j = 1,2,3,\ldots,n)$ are TFNs.

The specific steps involved in the development and analysis of FAHP are as follows:

Using Triangular Fuzzy Number Scale (TFNs) as shown in Table 2, the individual pair-wise comparison matrix as shown in [3] are obtained. Upper triangular matrix is filled using numbers to represent the relative importance of one element to another. Lower triangular matrix was filled using the formulae $a_{ij} = \dfrac{1}{a_{ji}}$ automatically.

$$\tilde{A} = \begin{bmatrix} (1;1;1) & (a_{11}^l; a_{11}^m; a_{11}^u) & \cdots & (a_{1n}^l; a_{1n}^m; a_{1n}^u) \\ \left(\dfrac{1}{(a_{11}^u)}; \dfrac{1}{a_{11}^m}; \dfrac{1}{a_{11}^l}\right) & (1;1;1) & \cdots & (a_{2n}^l; a_{2n}^m; a_{2n}^u) \\ \vdots & \vdots & \vdots & \vdots \\ \left(\dfrac{1}{(a_{1n}^u)}; \dfrac{1}{a_{1n}^m}; \dfrac{1}{a_{1n}^l}\right) & \left(\dfrac{1}{(a_{2n}^u)}; \dfrac{1}{a_{2n}^m}; \dfrac{1}{a_{2n}^l}\right) & \cdots & (1;1;1) \end{bmatrix} \quad [3]$$

Perform fuzzy synthetic extent analysis (Chang, 1996) on [3] in four steps as shown below:

— **Step 1**: The value of fuzzy synthetic extent with respect to the object is defined as

$$S_i = \sum_{j=1}^{m} M_i^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_i^j\right]^{-1} \quad [4]$$

To obtain $\sum_{j=1}^{m} M_i^j$, perform fuzzy addition operation (Table 1) of extent analysis values on matrix [3] such that:

$$\sum_{j=1}^{m} M_i^j = \left[\sum_{j=1}^{m} lj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} uj\right] \quad [5]$$

And to obtain $\left(\sum_{i=1}^{n} \sum_{j=1}^{m} M_i^j\right)^{-1}$ perform fuzzy addition operation of $M_i^j (j = 1, 2, \ldots, m)$ on the values such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_i^j = \left[\sum_{j=1}^{m} lj, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} uj\right] \quad [6]$$

Then inverse of the vector in Eq. [6] is computed such that

$$\left[\frac{1}{\sum_{j=1}^{m} M_i^j}\right] = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \quad [7]$$

— **Step 2**: The degree of possibility of $M_2 = (l_2, m_2, u_2)$ and $M_1 = (l_1, m_1, u_1)$ is defined as

$$V(M_2 \geq M_1) = \sup_{y \geq x}\left[\min\left(\mu M_1(x), \min\left(\mu M_2(y)\right)\right)\right] \quad [8]$$

Table 2. Linguistic variable, weight of the criteria and triangular fuzzy value scale.

Linguistic scale	Fuzzy numbers	Membership function	Domain	Triangular fuzzy number (TFN) scale (l,m,u)	Reciprocal $\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}$
Just equal	$\tilde{1}$			$(1,1,1)$	$\left(\frac{1}{1}, \frac{1}{1}, \frac{1}{1}\right)$
Equally important	$\tilde{1}$	$(3-x)/(3-1)$	$1 \leq x \leq 3$	$(1,1,3)$	$\left(\frac{1}{3}, \frac{1}{1}, \frac{1}{1}\right)$
Weakly important	$\tilde{3}$	$(x-1)/(3-1)$ $(5-x)/(5-3)$	$1 \leq x \leq 3$ $3 \leq x \leq 5$	$(1,3,5)$	$\left(\frac{1}{5}, \frac{1}{3}, \frac{1}{1}\right)$
Strongly important	$\tilde{5}$	$(x-3)/(5-3)$ $(7-x)/(7-5)$	$3 \leq x \leq 5$ $5 \leq x \leq 7$	$(3,5,7)$	$\left(\frac{1}{7}, \frac{1}{5}, \frac{1}{3}\right)$
Very strongly important	$\tilde{7}$	$(x-5)/(7-5)$ $(9-x)/(9-7)$	$5 \leq x \leq 7$ $7 \leq x \leq 9$	$(5,7,9)$	$\left(\frac{1}{9}, \frac{1}{7}, \frac{1}{5}\right)$
Extremely important	$\tilde{9}$	$(x-7)/(9-7)$	$7 \leq x \leq 9$	$(7,9,9)$	$\left(\frac{1}{9}, \frac{1}{9}, \frac{1}{7}\right)$

This can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d)$$

(or)

$$\begin{cases} 1, \text{if } m_2 \geq m_1 \\ 0, \text{if } l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, \text{otherwise} \end{cases} \quad [9]$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} (Fig. 2).

— **Step 3**: The possible degree for a convex fuzzy number to be greater than k convex fuzzy numbers defined by $M_i(i = 1, 2, \ldots, k)$

$$V(M_2 \geq M_1, M_2, \ldots, M_k) =$$
$$= V[(M \geq M_1)] \text{ and } V[(M \geq M_2)] \ldots V[(M \geq M_k)] = \quad [10]$$
$$= \min V[(M \geq M_i)]$$

Assume that

$$\acute{d}(A_i) = \min V(S_i \geq S_k) \quad [11]$$

For $k = 1, 2, \ldots, n; k \neq i$ the weight vector is given by:

$$\acute{W} = \left(\acute{d}(A_1), \acute{d}(A_2), \ldots, \acute{d}(A_n)\right)^T \quad [12]$$

— **Step 4**: By using normalization, normalized weight vectors are:

$$W = \left(d(A_1), d(A_2), \ldots, d(A_n)\right)^T. \quad [13]$$

where W is non-fuzzy number.

Study area

Agriculture is the mainstay of more than 70% of people of the Indian Kashmir having temperate climatic conditions. This region is rich in rice culture from centuries. Rice crop plays a significant role in livelihood of people, which is the main staple food crop of this region. Rice production is considered to be main farming activity in the study area. Rice occupying area of 261,300 hectares, which is 11% of the total area occupied by the field crops. Annual production of rice is 507,700 t with an average yield of 1.943 t/ha (JKES, 2014).

Towards decision support tool

After threadbare discussion with the domain experts as well as considering historical literature accounts (Narayanamoorthy, 2007; Adhya *et al.,* 2008; Stigter, 2008; Chand *et al.,* 2011; Mahendra, 2011; Singha & Baruah, 2011; Faisul-ur-Rasool, 2013; Nag *et al.,* 2013; Wani *et al.*, 2013), most important factors (biotic, abiotic, socio-economic and technological) and alternatives (important rice varieties) for rice production in temperate climatic conditions were identified. The factors were broadly categorized into five criteria viz., physical, biological, climatic, technological and socio-economical. Each criterion was decomposed into sub-criteria to get reasonable candidature of contributing factors for each criterion based on earlier studies related to improved rice production technologies. Regarding physical criteria, drought, flood, animal wading, water logging and lodging were identified as sub-criteria. Climatic criteria were represented by temperature, late sali and rainfall. Sub-criteria for biological aspects were identified as diseases, insects, pests and weeds. Farm
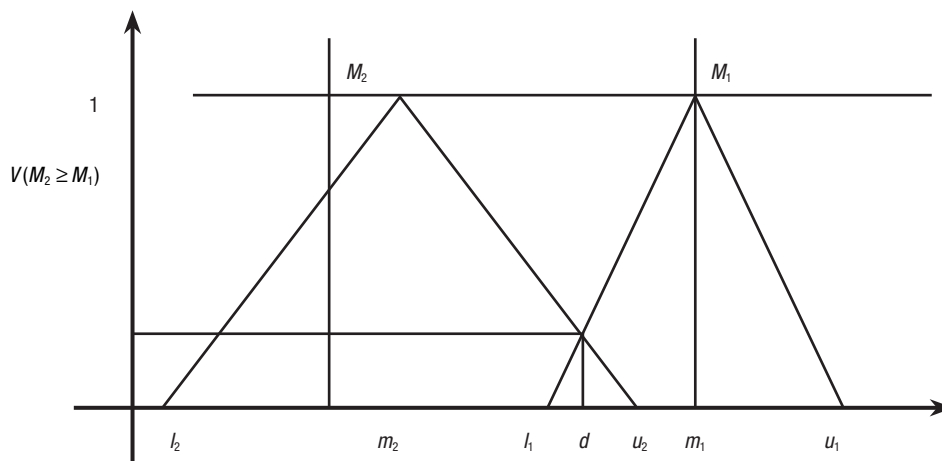

Figure 2. The intersection between M_1 and M_2 (Padma & Balasubramanie, 2011).

size, productivity, cost of cultivation, education and net return were identified as important sub-criteria for socio-economic criteria. Regarding technological criteria, variety, nutrient management, insect-pest management, nursery management, sowing practices, transplanting practices, planting density, weed management and water management were identified as sub-criteria. The selected alternatives were important improved varieties (Shalimar Rice-1 and Jhelum) as well as traditional rice varieties (K-39, K-1007 and Ch-1039), cultivated in the area with diverse qualitative and quantitative characteristics determining their relative potentials and weaknesses. FAHP structure was devised based on the earlier studies related to drought vulnerability (Jing &Jian, 2010), land suitability (Prakash, 2003), environmental vulnerability assessment (Lu *et al.*, 2009) and FAHP methodology (Padma & Balasubramanie, 2011). The hierarchy of decision problem was reached out which is given in Fig. 3. Strategies were prioritized using FAHP method defined already.

The individual assessment score was obtained using excel based programmed questionnaire from 10 domain experts. The results were combined to get the mean fuzzy comparison judgments with respect to the overall goal, sub-criteria and alternatives. The fuzzy com-

parison matrices related to main criteria viz., physical, climatic, biological, technological and socio-economic and sub-criteria were obtained respectively (See Tables S1 to S6 [suppl.]).

It has already been reported that variety accounts for more than 20% of rice production (Fairhurst *et al.,* 2007). Therefore, it was also essential to evaluate and prioritize most common rice varieties grown in the under area using FAHP technique. In this regard, two newly introduced rice varieties (Shalimar Rice-1 or SR-1 and Jhelum) and three already introduced rice varieties cultivated in the region for decades(K-39, K-1007 and Ch-1039), were evaluated and prioritized involving 26 sub-criteria based on the physical, biological, environmental, technological and socio-economic factors. The fuzzy comparison matrices were worked out considering the mean value of assessments made by the experts (Tables S7 to S9 [suppl.]).

The fuzzy comparison matrices so obtained for main criteria, sub-criteria and alternatives were entered to an asp.net and SQL server-based software designed by the authors for carrying out FAHP analysis, using the 4-step extent analysis method (Chang, 1996) as presented earlier. The individual results were documented and interpreted accordingly.
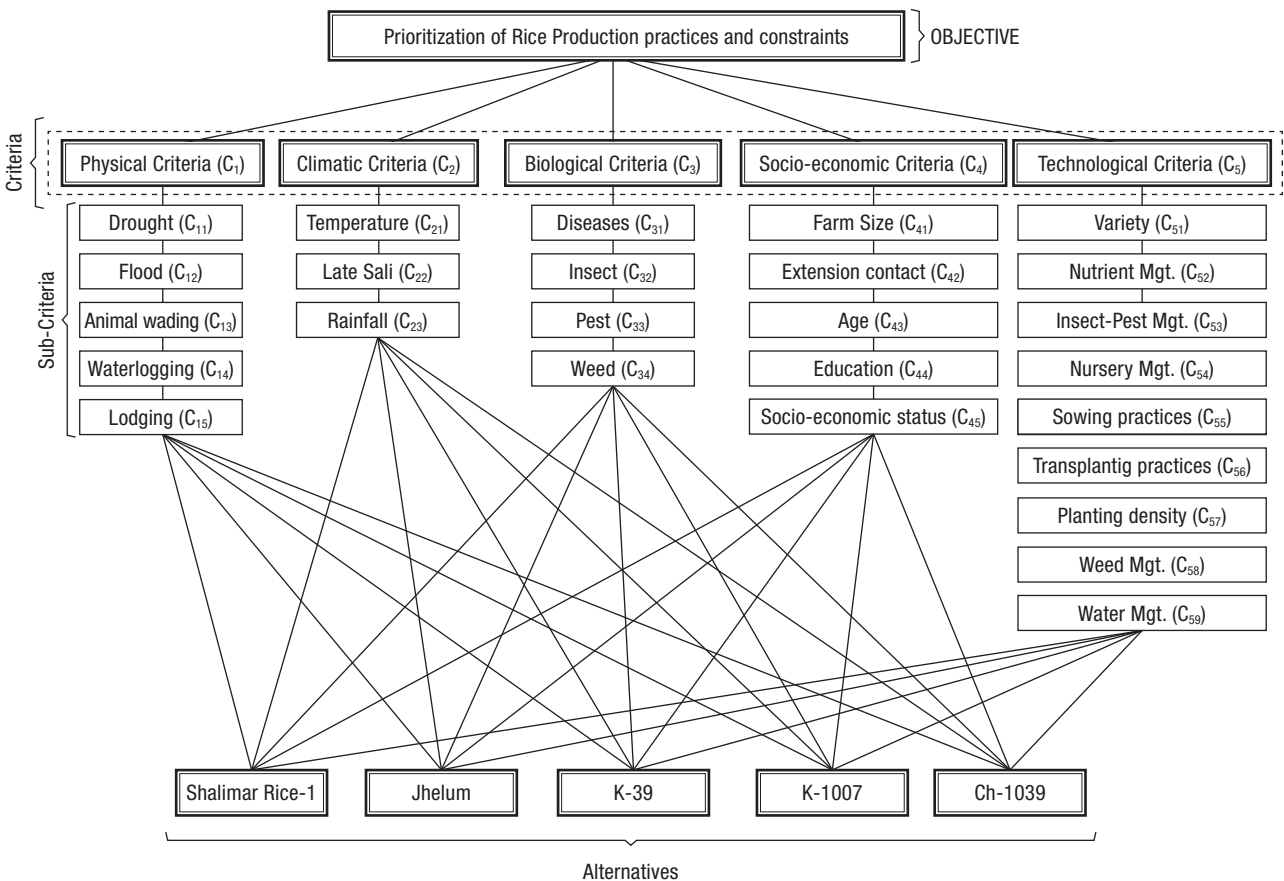

Figure 3. FAHP structure of the study.

Results and discussion

Evaluation and prioritization of main criteria

The priority weights obtained by five main criteria viz., physical, climatic, biological, socio-economic and technological, with respect to the goal are given in Fig. 4a.

The results indicate that with weight score of 0.317 each, physical and technological criteria are most important constraint and opportunity respectively for rice production under temperate climatic conditions. With weight score of 0.191, climatic criteria ranked second. Biological and socio-economic criteria were ranked third and fourth with weight score of 0.106 and 0.017 respectively. The fact that physical and technological criteria represented highest weight score reflects their important contribution to the overall development of the rice crop. Based on the implications of the study, physical constraint can be minimized by adopting a risk management strategy, and technological aspect can be addressed with training, skill development, method demonstrations, front line demonstrations etc., to boost rice production in the area.

Evaluation and prioritization of sub-criteria

Physical criteria

Amongst physical criteria maximum weight score of 0.422 was obtained by flood followed by drought (0.289). Animal wading factor got lowest weight score of 0.036 and was ranked 5th in the criteria (see Fig. 4b). The results indicate that both flood and drought are important constraints for rice production. Therefore, it can be implied that rice production must be avoided in flood and drought vulnerable areas.

Climatic criteria

Priority weights of three climatic factors viz., rainfall, late Sali (night temperature during flowering season) and temperature were obtained (see Fig.4c). The results envisage that late sali and temperature contribute equally with weight score of 0.399, while as rainfall accounts to the extent of 0.202. This reflects that temperature, late Sali and rainfall are most important factors for rice production under temperate climatic conditions and need to be taken into consideration before recommending advisories for rice cultivation.

Biological criteria

The relative weights of four factors with respect to the biological criteria are shown in Fig. 4d. The results indicate that disease and weed factors contribute equally with relative weight score of 0.281 followed by pest (0.273). With weight score of 0.165, insect contributes least rice production under temperate conditions. Therefore, it can be concluded that disease and weed are most important constraints for rice production in the studied temperate region, which needs to be managed with better planning and technology dissemination.

Socio-economic criteria

Relative weights of socio-economic criteria envisage that extension contact (0.582) contribute more than half of overall weight (Fig.4e). With weight score of 0.268, socio-economic status, age and farm size contribute equally. Whereas, education ranked last with a weight score of 0.138. Therefore, it can be inferred that constant extension contact with the rice cultivating farmers, targeting large holdings and young farmers is necessary to boost the rice production in the study area. Importance of extension contact for dissemination of improved practices of rice under temperate conditions has recently been reported from the same area (Beigh *et al*., 2015) and elsewhere (Haq, 2011).

Technological criteria

Cursory look at the results of relative weights of technological criteria envisage that with weight score of 0.211, variety is the most important component amongst technological criteria, followed by nutrient management with score of 0.208 (Fig. 4f). Weed management ranked third with weight score of 0.178. Transplanting time ranked 4th with weight score of 0.146. Insect and pest management got least weight score of 0.012 and was ranked 9th. The fact that variety and nutrient management having highest weight score reflects their important role in overall productivity of rice. It has already been reported that variety, nutrient, weed, nursery, planting density, transplanting practice can limit the yield by more than 60% (Fairhurst *et al*., 2007). Therefore, it can be concluded that the results obtained using fuzzy AHP technique are reliable. These results indicate that seed replacement using improved varieties, nutrient and weed management practices, and maintaining transplantation time should be given prime importance in the study area to enhance production of the rice.
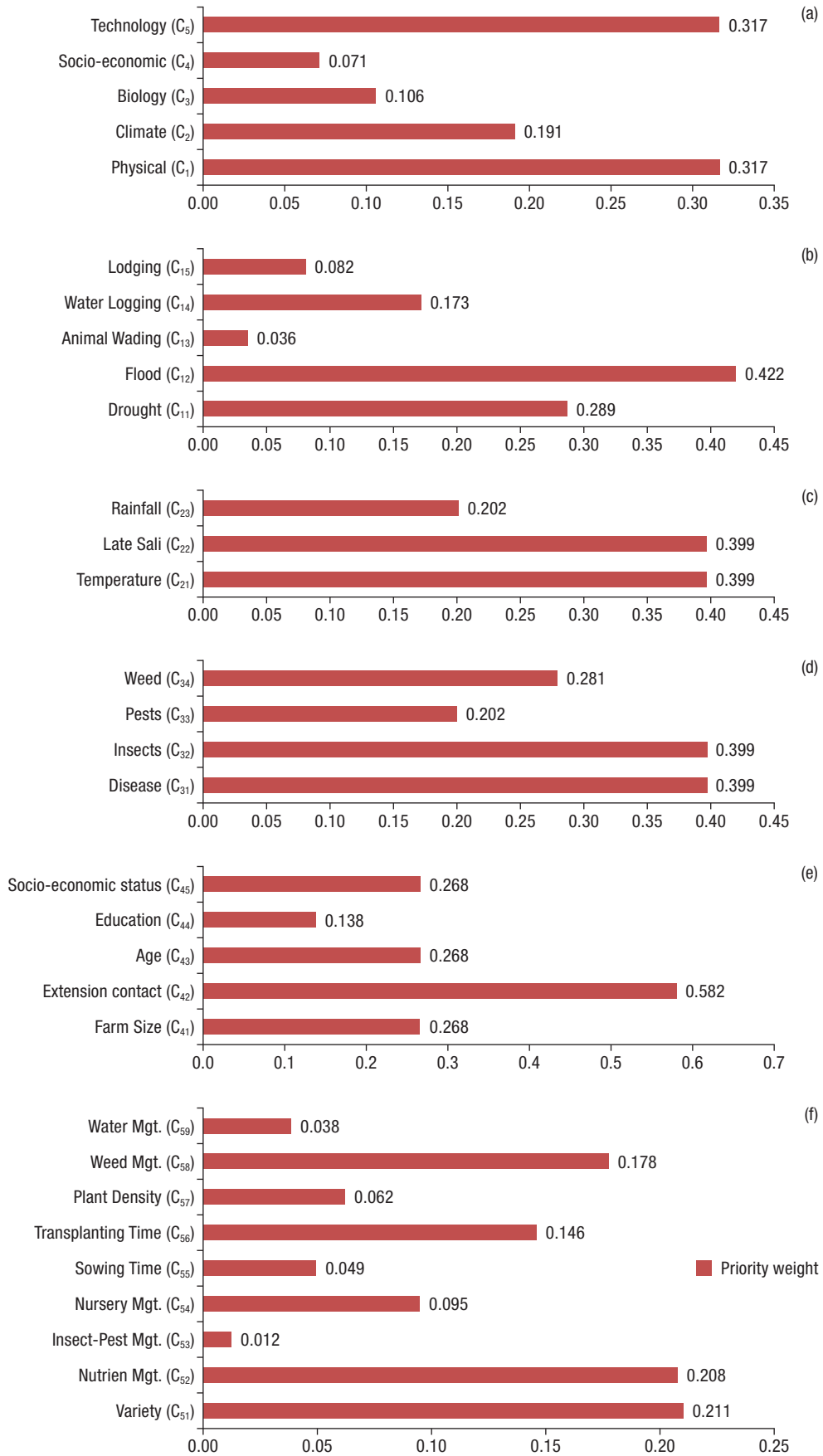
Figure 4. Weight score of main (a), physical (b), climatic (c), biological (d), socio-economic (e) and technological (f) criteria.

After analyzing main-criteria and sub-criteria weights, criteria weight scores were obtained. The results envisage that flood with weight score of 0.134 and drought with weight score of 0.092 are most important constraints for rice production in the area while as late Sali (0.076), temperature (0.076), transplantation time (0.067), planting density (0.066) and education (0.056) are the most important contributing factors (Fig. 5). These results indicate that rice production should be avoided at upper altitudes, were apprehension of scar-city of water remains at peak time. Also huge fluctuation of temperature at flowering stage occurs at upper altitudes. The results also envisage that rice cultivation at waterlogged conditions should also be avoided. But on other suitable places, transplantation time and plant density should be managed and maintained strictly as per the package of practices. For technological interventions educated people should be contacted and targeted for trainings, method demonstrations, skill development and front line demonstrations.
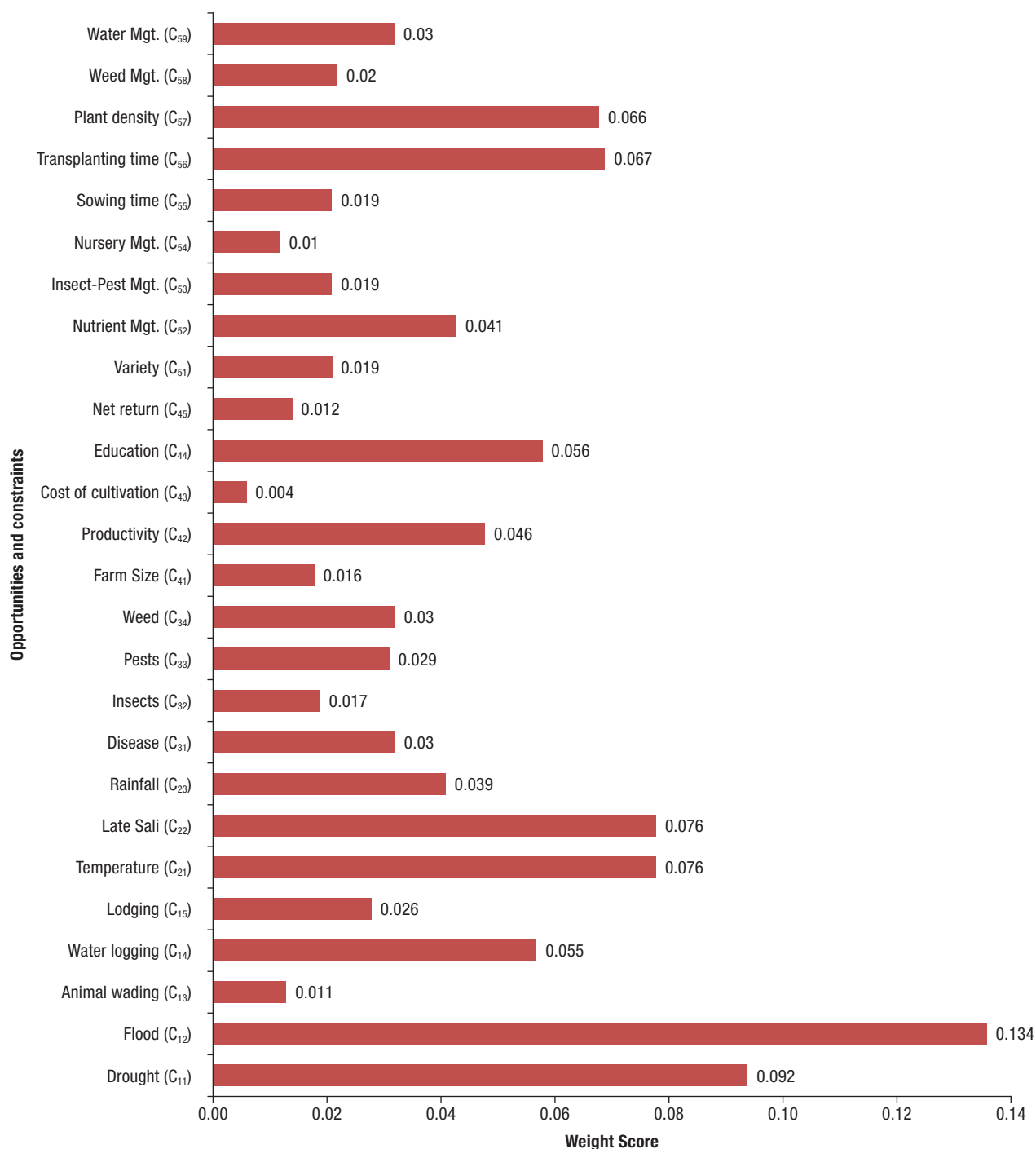

Figure 5. Criteria weight score.

Evaluation and prioritization of alternatives

Shalimar Rice-1 (SR-1)

The priority weights obtained by each alternative (variety) suggest that SR-1 (Fig. 6) is best for water-logged conditions (0.441) and disease tolerant (0.399). But cost of cultivation using this variety is little high (0.292) as compared to other varieties and net returns are moderate (0.285). It is also evident that the variety is more susceptible to late Sali (0.027) and lodging (0.103). However, this variety needs management of transplantation time (0.285) very meticulously. Cost of cultivation for improved varieties is relatively high due to the fact that it demands line sowing, well preparation of land and balanced inputs as compared to traditional practices. Therefore, it can be implied that SR-1 is best

suited for waterlogged conditions and paddy blast prone areas with moderate to high returns.

Jhelum

Jhelum as alternative got highest weight against cost of cultivation (0.333) followed by transplanting time and net return both with weight score of 0.312 (Fig.6). With weight score of 0.262, weed management got third highest score for the alternative and it was followed by plant density with weight score of 0.254. Late sali got lowest score of 0.021. These results indicate that Jhelum can give more returns than Shalimar Rice-1, when transplanting time is adjusted as per the recommendations. But cost of cultivation is slightly higher than SR-1 and variety is more susceptible for blast, late sali
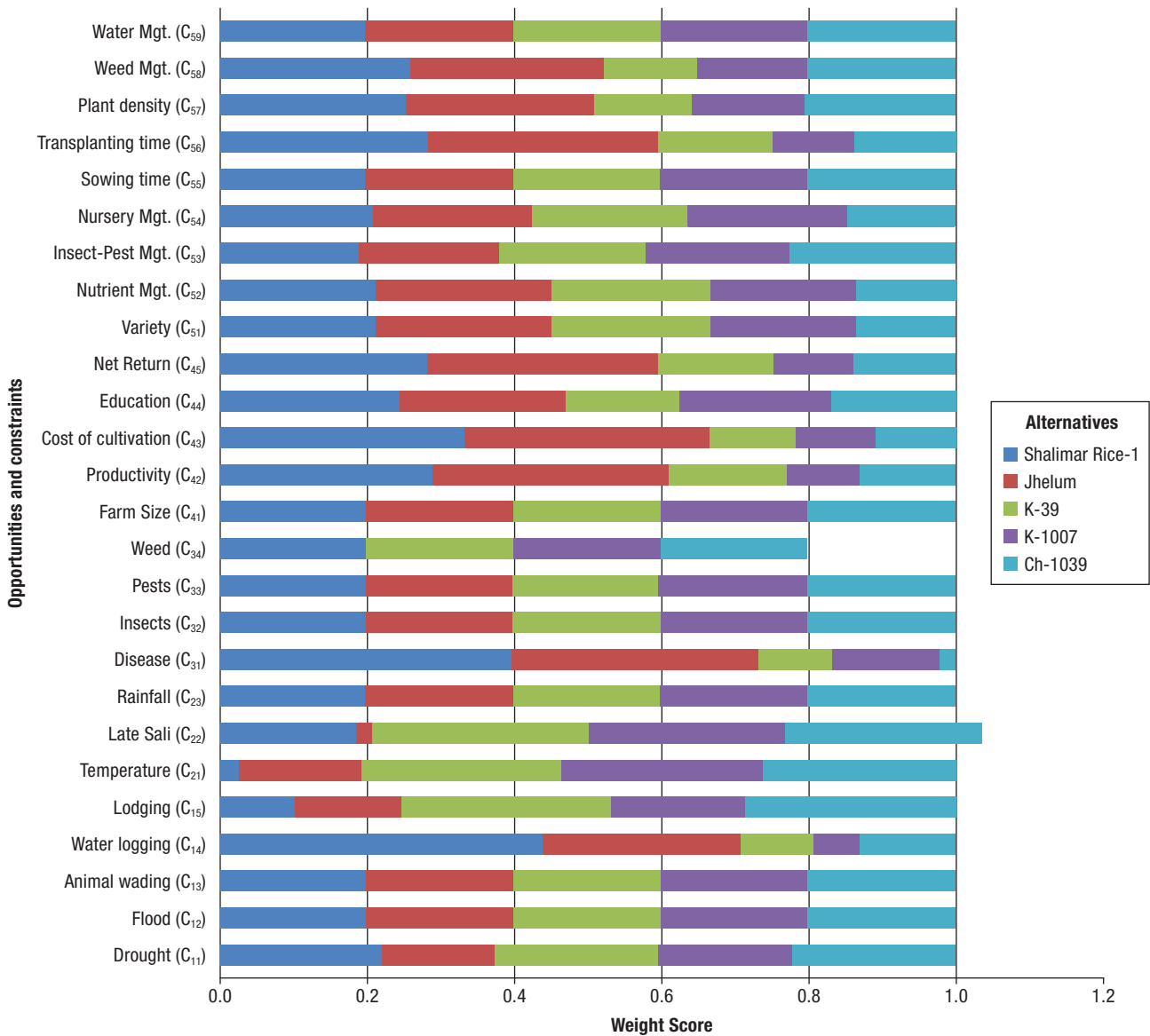

Figure 6. Weight score of alternatives.

and lodging. Therefore, it can be concluded that Jhelum should not be used on waterlogged and blast prone areas to fetch maximum returns. The variety should be used on the plains where temperature does not fall below threshold at flowering stage.

K-39

K-39 got highest weight score for Late Sali (0.295) followed by lodging (0.285). It got lowest weight score of 0.099 for water logging (Fig.6). Highest score for Late sali indicate that the variety is cold tolerant and is not lodging usually. However, the least score for water logging reflects its inability to perform under water logging conditions. Therefore, it can be said that K-39 is best suited for mid-altitudes, where other varieties cannot perform well due to variation in the temperature.

K-1007

K-1007 got highest score for temperature (0.273) succeeded by Late Sali (0.267) and then followed by nursery management (0.217). For water logging it got lowest score of 0.064, which may be due to the fact that it is worst suited for water logging conditions (Fig. 6). From these results it can be concluded that the variety can perform even under low temperature and maturity of flowering will not suffer even when night temperature is dropped. However, K-1007 cannot be cultivated under waterlogged situations. Like K-39 it got similar weight score (0.200) for farm size, water management, sowing time, weed, pest/insect management, rainfall, animal wading and flood.

Ch-1039

Ch-1039 got highest weight score for lodging (0.285) followed by Late sali (0.267), which reflects its short

size, resistance to lodging and tolerance to cold (Fig. 11). It got lowest weight score for disease (0.021), which may be due to its susceptibility to paddy blast. The variety also got low score for net returns (0.137), which reflect that the variety is low productive.

While taking all the criteria, sub-criteria and alternative weights in consideration, it can be concluded that with priority weight score of 0.232, Shalimar Rice-1 is most important variety followed by Jhelum with weight score of 0.217 (Fig. 7). Whereas, K-1007 has obtained last priority with overall weight score of 0.192.

In conclusion the results envisage that physical criteria are most important constraint followed by climatic criteria. On the other hand technological criteria comprising a set of improved technologies are the most important opportunity for rice production in the study area. Therefore dissemination of improved technologies is very important and needs better planning and implementation.

As for as sub-criteria are concerned, flood and drought are most important constraints while as late sali, temperature, transplantation time and planting density are most important contributing factors. Avoiding cultivation of rice at farming situations, where apprehension of dropping temperature below required threshold at flowering stages, regulating transplantation time and maintaining plant density are crucial aspects for better yield and returns.

As alternative, Jhelum is most productive and can give farmers with highest net returns. However, it cannot be used under waterlogged and high-altitude conditions. Besides, nursery management is very important for this variety and needs extra investment. Shalimar Rice-1 is less productive than Jhelum, but is cold tolerant, resistant to lodging, requires less nursery management and transplantation time can slightly be adjusted to avoid hire of highly paid labour. K-39, K-1007 and Ch-1039 are very less productive with fewer returns. However, these varieties are resistant to cold, water logging and diseases besides having enough transplantation feasibilities.
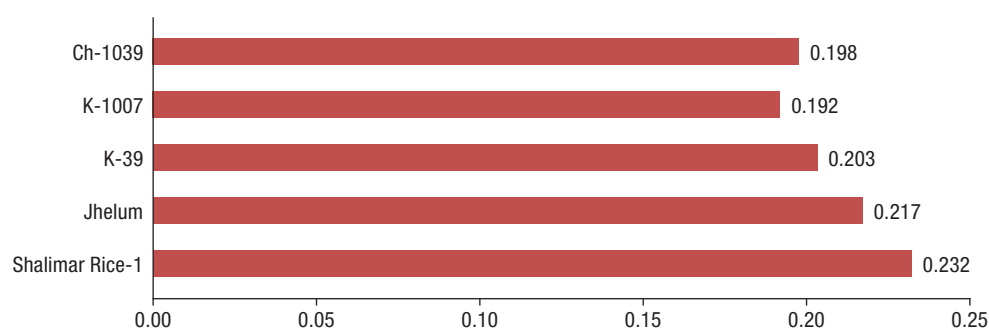

Figure 7. Final priority weights.

Acknowledgements

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