APPLICATION OF DECISION SUPPORT SYSTEM ON SPATE IRRIGATION PROJECTS MANAGEMENT

APPLICATION DU SYSTÈME D'AIDE À LA DÉCISION DANS LA GESTION DES PROJETS D'IRRIGATION PAR EPANDAGE DES EAUX DE CRUE

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ABSTRACT

The meager amount and uneven distribution of precipitation makes more than 90% area of Iran arid or semi-arid. Groundwater resources supply about 55% of the water used and over pumping, mostly for irrigation, depletes Iran's precious groundwater resources. If this trend continues, Iran will be faced with more aridity. Floodwater spreading (FWS) for the artificial recharge of groundwater (ARG) and spate irrigation (SI) of rangelands and croplands could be one of the most logical solutions for this problem. A management tool is needed to lead spate irrigation system based on sustainable development through the use of a decision support system. This article attempts to present the best method for planning of each land units of SI schemes.

Spate irrigation through floodwater spreading is conducted in the Gareh Bygone Plain (GBP), south east of Iran, to facilitate both drinking and irrigation of the desert dwellers. Combination of 48 environmental and socio-economic factors can affect SI schemes that can be categorized in 8 groups of data namely: Land, soil, flood, social, climate, groundwater, vegetation and flood damage. The hierarchy of effects tree was arranged based on analytical hierarchy process. Multi-criteria analysis is found suitable for alternatives appraisal in this condition. The weighted summation method is recommended for ranking and expected value method for weighting effects in different scenario of SI objectives.

The ranking results of system showed the alternative TQ1 is the best and the alternative FO is the weakest for the most scenarios. The sensitivity analysis of results showed that TQ1 in all condition was better than FO.

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Key words: *Arid and semiarid regions, Floodwater spreading, Landuse planning, Multicriteria analysis and analytical hierarchy process*

RESUME

La quantité faible et la distribution inégale de la précipitation sont les raisons de l'aridité ou semi-aridité de 90% des régions en Iran. Les ressources en eau souterraine fournissent environ 55% de l'eau utilisée. Le sur pompage de l'eau, surtout pour but d'irrigation, épuise les ressources en eau souterraine précieuses de l'Iran. Si cette tendance continue, l'Iran fera face à plus d'aridité. L'utilisant des eaux de crue (FWS) pour la recharge artificielle d'eau souterraine (ARG) et l'irrigation par épandage des eaux de crue (SI) pour les pâturages et les terres cultivées pourrait être l'une des solutions les plus logiques de ce problème. Un outil de gestion est exigé pour mener le système d'irrigation par épandage des crues pour le développement durable en utilisant le système d'aide à la décision. Cet article essaye de présenter la meilleure méthode de planification de chaque unité de terre des plans de SI.

L'irrigation par épandage des eaux de crue par diffusion d'eau de crue est conduite dans la Plaine de Gareh Bygone (GBP) au sud-est de l'Iran, pour but potable et agricole des habitants de désert. La combinaison de 48 facteurs environnementaux et socio-économiques peut affecter les plans de SI qui peuvent être catégorisés dans 8 groupes de données à savoir : Terre, sol, inondation, socio, climat, eau souterraine, végétation et dégâts causés par les crues. La hiérarchie des effets a été arrangée sur la base du processus de hiérarchie analytique. L'analyse à multi critères est appropriée pour l'évaluation des alternatives. On recommande la méthode d'addition pour le classement et la méthode de valeur attendue pour calculer les effets dans différent scénario d'objectifs de SI.

Les résultats de classement du système montrent que la méthode d'alternative TQ1 est meilleure et méthode d'alternative FO est faible dans la plupart des scénarios. L'analyse de sensibilité des résultats montre que TQ1 dans toutes les conditions est meilleur que FO.

Mots clés : *Régions arides et semi-arides, diffusion d'eau de la crue, planification d'aménagement des terres, analyse à multi critères, processus de hiérarchie analytique.*

1. INTRODUCTION

Water shortage and land degradation are the main limiting factor in the economic development of Iran, particularly in the agricultural sector. Iran, on average, has 57 billion m^3 of wasted floodwater a year (Shoaee, 2006). Floodwater management is the key to water conservation and optimizing its use (Kowsar, 2006). In arid and semi arid zone water conservation and soil conservation are synonymous because conserved water helps maintain an effective vegetative cover over the land and reduces water erosion (Nejabat, 2003). Floodwater spreading (FWS) is a multipurpose technique (Figures 1 - 3) that is also less costly and easy to implement in the field for floodwater management (FAO, 2001).

Soil conservation and watershed management research institute studies from 2001 to 2004 showed 14.9 million hectares marginal drylands of Iran are suitable for FWS (Fig. 4).

Governmental goal (Ministry of Agriculture) is to increase FWS schemes to 1.5 million hectares by 2010. Selections of the best site require a suitable method that can screen larger areas or zones of feasible areas that do not have much data base. Decision support system (DSS) is an interactive computer based system, which help decision makers utilize data and models to solve unstructured problem (Turban, 1998). Site-specific condition of FWS lead to special DSS based on multi-criteria analyses (MCA). Different methods have been suggested for MCA alternative appraisal (Janssen and Munda, 1999).

The Analytic Hierarchy Process (AHP) is a structured technique for dealing with complex decisions. Based on mathematics and human psychology, it was developed by Saaty in the 1970s and has been extensively studied and refined since then. The AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. It is used throughout the world in a wide variety of decision making situations, in fields such as government, business, industry, healthcare, and education (Casini et al., 2005).

Multi-Criteria Decision Analysis is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process (Antoine, 2005).

Weighted Summation is a simple and frequently used evaluation method. As a first step, all effect scores are standardized. An appraisal score is then calculated for each alternative by first multiplying these standardized effect scores by its appropriate weight, followed by summing the weighted scores of all effects. The final ranking of the alternatives is assessed based on the resulting appraisal scores for each alternative (Sharifi and Rodriguez, 2002).

The objective of this study is: To find a suitable appraisal method for multi-criteria analyses and weighting effects for spate irrigation projects management.

Fig. 1. Flood in ephemeral river

Fig. 2. Before FWS implementation

Fig. 3. After FWS implementation

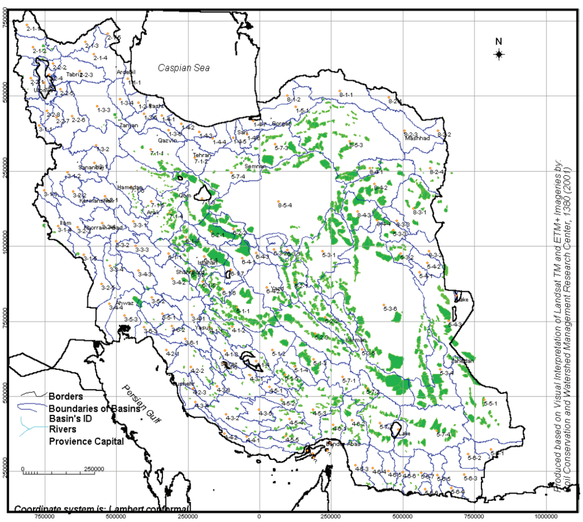

Fig. 4. Iran land suitability map for floodwater spreading (FWS)

2. MATERIALS AND METHODS

A DSS needs an AHP to provide a comprehensive and rational framework for structuring the problem (main factors), and for representing and quantifying its elements (effects) (Saaty, 1994). Literature review led to the identification of 48 effects that affect FWS site selection and planning desirable landuse (SI) for selected lands. The effects tree was arranged including those effects according to AHP.

This tree has 8 main branches (main indicators) (Fig. 5) that generate 18 secondary branches (sub indicators) (Fig. 6) and 48 tertiary branches (effects) (e.g. Fig. 7).The weighting and decomposing of effects are carried out based on this effects tree (Nejabat, 2009).

Search for the desired approach for MCA leads to four methods, which can designate suitable sites after structuring all the major criteria for land use evaluation. These methods support the application of MCA: A.Weighted Summation, B. Electre 2 method, C. Regime method and, D. Evamix method (Bares, 2001). Six scenarios for land use were defined based on FAO recommendation: 1- Spate irrigation, 2- Forestry, 3- Rangeland, 4- Preserved. 5- Vegetation covers improvement and 6- Artificial groundwater recharge. The Data collection and field study from relevant scheme was used for identify suitable approach in each scenario.

Weighted summation was found most appropriate method that include four weighting procedure: A.1- Direct assessment, A.2- Pair-wise comparison A.3- Expected value method and A.4- Random weights (Hilla et al., 2005).All of those weighting procedure was tested with real data to choose the best one.

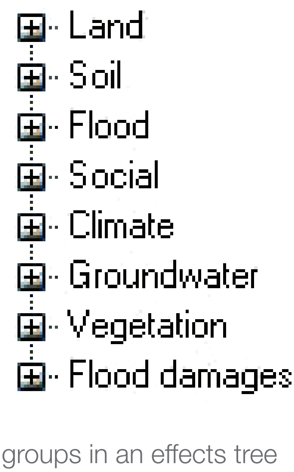

Fig. 5. Main indicators or effect groups in an effects tree

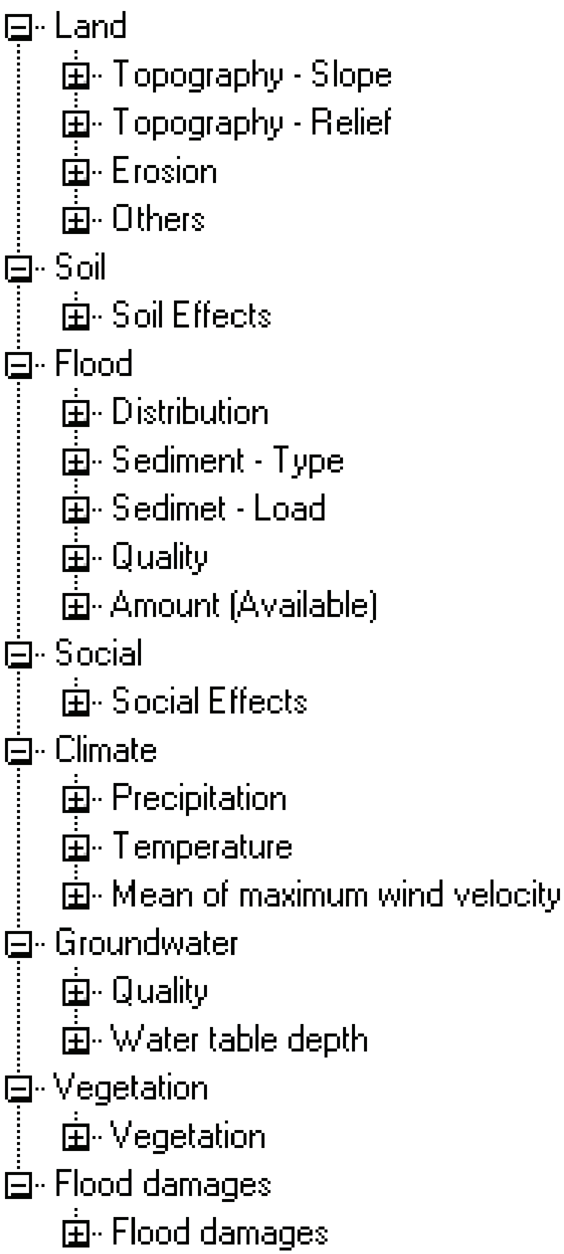

Fig. 6. Sub indicators or sub effect groups in an effects tree

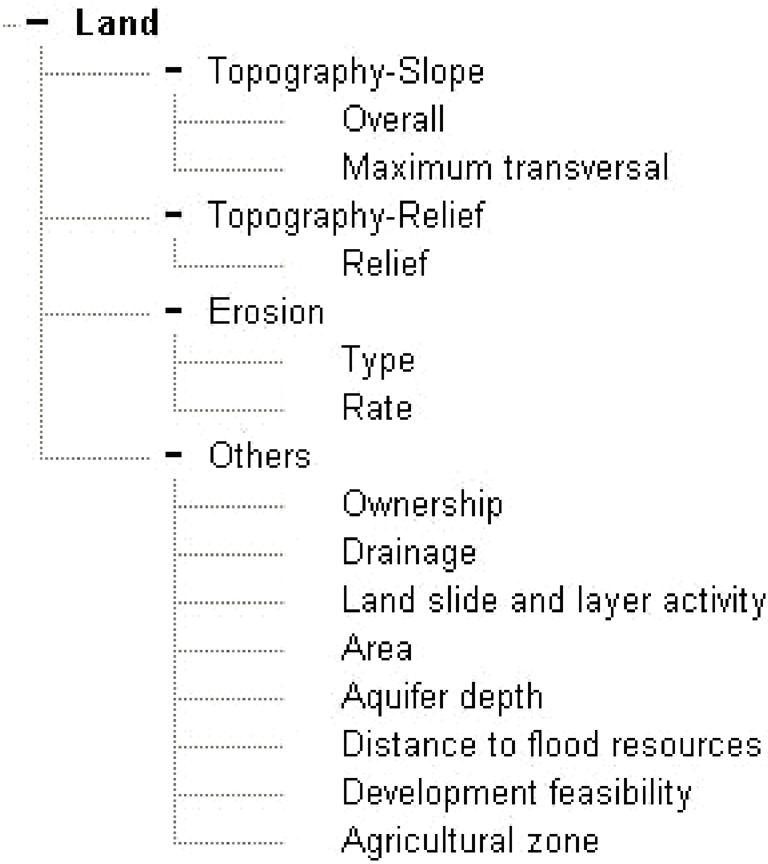

Fig. 7. Land effects in an effects tree

3. RESULTS AND DISCUSSION

Test of all suggested DSS appraisal methods for FWS site selection showed:

The result of alternative ranking with weighted summation method is similar to the result of traditional assessment of those lands.

The weighted summation method is best for all scenarios, using data from control FWS research station.

The Electra 2 method is second best, but has effects score uncertainty more than 20% and hence, is not accurate.

The pair-wise comparison method is done by matrix rule and for matrix bigger than 7x7, inconsistency ratio can not be calculated.

The expected value method is suitable for FWS site selection because this method based on AHP and ordering relative importance of factors is presented with FWS expert's experiences.

The random weights after expected value are the best method for FWS site selection but so sensitive to effects score uncertainty.

The conclusion of uncertainty analysis is based on the differences between the weighted sums of the probabilities of all rank numbers of alternatives that are adjacent in their rankings. Sensitivity analysis on alternatives rankings is performed for uncertainties in the provided scores. For every alternative, the smallest and largest final score are determined. If two alternatives do not have any overlap in ranges of total scores, then it means that their rank order can not be interchanged in any condition. The results of alternatives ranking under effects score uncertainty for SI are presented in Table 1.

Table 1. Uncertainty analysis of alternative under effects score uncertainty

Scenario	uncertainty	Alternative				
		BZ1	BZ4	FO	RA1	TQ1
Spate irrigation	Max.	0.607	0.649	0.486	0.641	0.808
	Total	0.471	0.509	0.393	0.500	0.611
	Min.	0.335	0.368	0.300	0.359	0.415

4. CONCLUSIONS AND RECOMMENDATIONS

The weighted summation method is recommended for multi-criteria analyses in environmental DSS because it is simple in assigning weights and its rule is comprehensible.

The results of uncertainty analysis indicate that under different conditions (different effects score) the alternatives rank can vary to upper or lower levels. Another conclusion of these results is their application to determine relative priority of some alternatives under any condition (e.g. alternative TQ1 is better than alternative FO at all times). This conclusion can show absolute priority of some alternatives in a specified scenario.

For precise ordering priority in expected value methods must be used several different expert judgment and applied combination of them. Scientific research in all aspects of FWS is needed to determine their coefficients, criteria and preferences.

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