

Optimization methods and techniques applicable to food production in irrigation in Serbia

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Abstract: The main uses of the Danube water in Serbia are for domestic and industrial water supply, irrigation, navigation and cooling of thermal power plants. Using data from plans and previous projects and refer to the territory of Serbia, Danube basin were selected area within significant regional hydro system. Water Management Master Plan gives the map of constructed and future irrigation systems by 2021. These are planning 475,000 ha for the water area of Danube with a total water consumption of 1.588 billion m³. Each household that uses water for irrigation is difficult to identify the method of resource management that is optimal. Proposed and analyzed the methods and techniques can greatly facilitate finding a solution to this problem. The focus of this paper is to analyze the optimization methods and techniques applicable to food production in irrigation.

I. INTRODUCTION

Fresh water is most crucial resource in basic ecosystem functions. But it is also distributed variably over the planet and because of scarcity, lack of financial resources or mismanagement it can fail to meet all competing uses, even fail to meet essential human needs.

Sustainable development was first formalized in the report “Our Common Future”, issued by UN World Commission for the Environment and Development, in 1987. The Brundtland Report, as it is more commonly known, defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Key aspect clearly is concern over the impacts on the future generations of actions taken today.

Water is one of the key issues of sustainable development: current global water challenges and future targets are clearly stated in the Millennium Development Declaration (UN, 2000) in resolution 55/2 which securing equal access to safe drinking water and sanitation.

Nowadays, fresh water resources are being exhausted, polluted and overexploited. Human activities and water policies have heavily impacted on the regularity of the natural cycle and on the quality and quantity of water available for human use.

Management of the water system must answer on, at least, following questions:

- what should be the right price of fresh water and how should it be determined,
- how to achieve an acceptable water quality,
- What are the necessary investments to meet the future needs?

Since the beginning of the 1980s, a lot of countries have changed their local water management from public to private as the privatization process. International Institutions such as World Bank, Fao etc. are financing many regional projects. Water firms are becoming more and more international and services and policy are with less and less local influence.

Water being marked like any other good or product and its allocation and pricing are being controlled by economic criteria – supply and demands. Available water must be dividing between agricultural, urban and industrial purposes.

Growing demands are close linked with population growth which makes water scarcity.

Besides water quantity, water quality is very important. Changes in agricultural practices (Scheirring [1]) where agricultural water pollution is become a major concern (Bergman [2]). This is due to the intensification of agriculture, increasing use of fertilizers and pesticides and specialization and concentration of crop and livestock production.

Water is essential to all life, all human activity. Wisely used, water means harvest, health, prosperity. Badly managed, water brings poverty, disease, floods, erosion, salinisation, silting.

The sustainable use of water resources requires efficient tools that can assist decision making. Decision making is the process of choice that leads to action (Simon [3]) and useful tools are all methods, guidelines, software that can achieve implementation water management policy.

Decision process needs to analyze the multiple disciplinary viewpoints referring to the many objectives, judgment and constrains.

From the above it becomes clear that the decision process must use multi-criteria analysis methods based on

model with list of desirable and no desirable characteristics.

Decision Support Systems (DSS) may be tools to help solving operational problems and put the solutions to the practice. A DSS is a computer-based instrument for processing, analysis and presentation of information. It helps decision makers to identify which information is relevant and which strategy has the greatest impact.

DSS enable future forecasting, design and screening of alternatives, impact assessment, comparing and ranking alternatives etc. DSS is based on communication, interactive and participative decision-making process.

II. MULTI-CRITERIA DECISION MAKING

Decision process represents the structure of preferences of which decision maker find out a satisfactory decision. Terms “multiple objectives”, “multi-attributes”, “multi-criteria”, “multi-dimensional”, used by many authors, are synonyms. In order to understand the structure of Multi Criteria Decision Making model (MCDM), Zeleny [4], and Romero and Rehman [5] proposed term for definition parts of model.

- Decision variable: represents the lever on which the decision maker operates. It presents all the aspects within which the user decides to act. Usually decision variable are water quantity allocated in different users, water quality standard, etc.
- Attribute: The attribute is a parameter that represents any particular aspect of a given problem assumed by decision maker to make their decision (income, savings, debt, pollution level, and so on). It's expressed as a mathematical function of the decisional variables.
- Objective: The objective is the direction (min or max) that the decision maker chooses to follow for an attribute (maximize profit, minimize pollution, and so on).
- Target: Value set by the decision maker as a reference point for the attribute chosen.
- Goal: The goal is the expected level of the chosen attribute that the decision maker aims to achieve with their decision (amount of water for irrigation, nitrate levels in water, and so on).

Goicoechea et al [6] suggest that goal and target are synonyms and term goal reassumes objective the definition of objective and target.

A. The Multi-objective Approach

The multi-objective approach is a development of traditional mathematical programming models. The representation of model is with rational structure and can provide good simulation of the economic facts.

Traditional mathematic models are based on the assumption that the decision maker formulates with well-defined parameter. Model is

$$\max/\min Z = \sum_{i=1}^n c_i x_i \quad (1)$$

with

$$\sum_{i=1}^n a_{ji} x_i \leq b_j \quad (2)$$

where

c_i – contribution of the i^{th} decision variable

x_i – decision variable

a_{ij} – use level of the j^{th} resource to accomplish one unit of the i^{th} decision variable

b_j – availability of the j^{th} resources

The problem is solved by finding the vector x that optimizes Z according to the restriction b_j . This approach optimizes just one parameter (Z). But, decision maker does not usually make a choice based on just one parameter, but refers to multi-criteria utility function. Choice must be made on the basis of just one objective. If problem have more than one (conflict) objectives, compromise must be established.

Efficient solution is weights methods and constraints method.

In the weights method, function expressing the different objectives through attributed arbitrarily. The model (1) change to

$$\max/\min \sum_{i=1}^n w_i f_i(\vec{x}) \quad (3)$$

with

$$\vec{x} \in X, \quad w_i \geq 0$$

The constraint method uses a model which one of the objectives is set in objective function and others are transformed into constraints:

$$\max/\min f_j(\vec{x}) \quad (4)$$

with

$$f_i(\vec{x}) \leq L_i, \quad x \in X, \quad i \neq j$$

where L_i is parameterizing the constraints.

Compromise programming

Compromise programming was proposed by Zeleny [7] as a method for rationalize set of solution consistence with the preference of decision maker.

Decision maker aspires to come as close as possible to the solution that they consider ideal. Objective function must be defined and quality is measure of the distance between efficient solutions and the ideal one.

A generalization of the concept of distance in n dimensions between an ideal and efficient feasible solution can be represented as

$$\overline{DI}_p = \left[\sum_n |i_n - d_n|^p \right]^{1/p} \quad (5)$$

where is

i_n – ideal solution

d_n – efficient feasible solution, if p equals 2, the Euclidean distance is obtained

Distance for $p=1$ is algebraic sum of the absolute value of the gaps in n dimension and if $p=\infty$ distance is equal to the maximum deviation in n dimensions. To compare deviation expressed with different dimensions, normalization must be done. Usually, it can be done with respect to the maximum interval of variation given by the difference between the best and the worst performance for each criterion.

Goal programming

Goal programming is the first method in multi-objective decision making field introduced by Charnes [8]. Method simulates a decision making process that tries to satisfy several objectives at the same time. Decision maker introduces their preferences by establish satisfactory value for each criterion.

First step is the identification of the set of criteria to adopt as decisional parameters. The objective value or goal must be defined for each attribute. Also, deviation variable, positive or negative, must be defined, and how close goal must be.

Based on this, generic i^{th} goal can be expressed as

$$f_i(\vec{x}) + n_i - p_i = b_i \quad (6)$$

where $f_i(\vec{x})$ is the function expressing the value of the i^{th} attributes.

Decision maker can pursue their goals simultaneously, with different intensity, or can favorite some of them. Normalization is necessary for comparing criteria in different unit measures.

B. The Multi-attribute Approach

Multi-Attribute Decision Making solve problem with finite number of solutions. Predetermined alternatives must be evaluate to a k attributes and each alternatives has a given performance index. Solution can be interpreted as result of a function of the relative vector of decision variables referring to each n alternative. Alternatives and criteria can be related through an evaluation matrix (Goicoechea, [9]). In some cases, evaluation matrix already offers a clear ranking of the alternatives.

The most popular procedures are:

- value function
- Analytic Hierarchy Process

The value function methods

The value function method is widely used by decision maker particularly because method guarantees internal

coherence. First publish by Keeney and Raiffa [10], well known in literature and in real cases (Beinat, [11]).

This method attempts to obtain a true value for every alternative. To obtain this value, a value function is identified for each considered criterion and relative importance in global value. The solution is made by finding the criterion which maximizes multi attribute value function. Final choice is made by identifying alternative that maximizes multi-attribute function.

Simplified method with one-dimensional function is more often in use. Scores are normalized from natural scale to a scale between 0 and 1, where 0 represent minimum utility and 1 represent maximum satisfaction for decision maker. The ranking of alternatives is implicitly determined by the transformation and ranking can depend of decision maker choice.

The only problem with this method is the assigning of the value function.

The Analytic Hierarchy Process

The Analytical Hierarchy Process (Saaty) [12] is based on assumption that the decision maker always expresses his preference. It is possible to represent the relative importance on each attribute.

The Analytical Hierarchy Process is realized trough few steps. First step is defining objectives, criteria of valuation and alternatives. Next step is evaluating weight between the options. The most satisfactory alternatives have, at the same time, top rank.

The analysis phase is based on a decomposition principle, comparisons and hierarchical composition. Decomposition principle leads to the definition structure with ranking the reciprocal relation. Procedure can be from bottom-up or top-down.

Structure do breakdown are defined on four levels: super-criterion, attributes, parameters and alternatives. Saaty [12] proposed scale for ranking qualitative preferences with number from 1 (equal importance) to 9 (extreme importance). Some other authors suggest different scale (from 1 to 5 or from 1 to 100).

Estimating weights is very important and many authors have different ideas (Srdjevic [13]). There are many papers (Srdjevic B., Srdjevic Z., Zoranovic T. [14], Srdjevic B., Srdjevic Z., Zoranovic T., Suvocarev K. [15]) where AHP is practically illustrated.

Limitations of this process is highly depending on assumed hierarchy, requires large amount of data and process is very long.

III. STRATEGIC PLANING

Strategic planning is an organization's process of defining its strategy, or direction and making decisions on allocating its resources to pursue this strategy.

Various business analysis techniques can be used in strategic planning, including SWOT analysis (Strengths,

Weaknesses, Opportunities, and Threats), GE/McKinsey portfolio analysis, STEER analysis (Socio-cultural, Technological, Economic, Ecological, and Regulatory factors), and EPISTEL (Environment, Political, Informatics, Social, Technological, Economic and Legal).

SWOT analysis is very popular and understandable and Potkonjak [16] illustrates this method (Fig. 1).

Figure 1. SWOT analysis of irrigation development [16]

Strengths - Available large areas of land; - Relatively sufficient water for irrigation; - The possibility of using water transport; - Education of professionals for the irrigation purposes; - Previous experience and knowledge of irrigation; - Hs DTD already built for the use of water; - Start of construction of other regional hydro systems; - Regional hydro projects that would use the water of the Danube.	Weaknesses - Different quality of land suitable for irrigation; - A possible deterioration in water quality due to increased use of fertilizer; - Population age structure; - Restrictions on the use of irrigation water for other users; - The low level of use of irrigation systems; - Insufficient technical equipment of agricultural farms; - Poor maintenance of regional and local systems;	Internal factors
Opportunities - Possible use of water in summer; - Needs to use water as the dry year; - Better cooperation with countries in the Danube region; - Increase employment in the water management, agriculture, civil engineering and industry; - Increase productivity; - Rural development; - More investment in water management and agriculture; - Increasing exports of agricultural products.	Threats - Deterioration of water quality above the prescribed; - Reduction of water supply due to greater use of upstream; - Labor shortages for intensively production; - Adverse measures of agricultural and water policy; - Unfavorable funding to build local irrigation systems; - Unfavorable conditions of financing agricultural production. - The lack of recent development of water management strategies.	External factors
Positive	Negative	

IV. CONCLUSION

Fresh water is most crucial resource and sustainable development is demand today. Management of the water system and choose best solution is very complex task. Decision process needs to analyze the multiple disciplinary viewpoints referring to the many objectives. Decision Support Systems (DSS) may be tools to help solving operational problems and put the solutions to the practice. In this paper, some multi-criteria decision making model are analyzed.

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