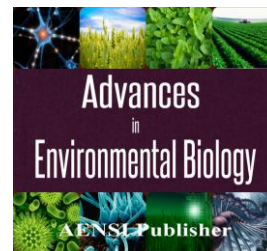




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The Necessity of Systematic and Integrated Approach in Water Resources Problems and Evaluation Methods, a Review

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ABSTRACT

Costly engineering solutions can not necessarily be accountable for deep concern of management for development of a region. The guidelines show vague and divergent picture of the future. However, a review of basic concepts could play a decisive role in providing efficient and effective solutions in the area of sustainable development. Implementation of integrated water resources management (IWRM) in the catchment area is the best example for this issue. Integrated water resources management problems is an important and complex task for planner and manager of water resources systems. In recent years, it has become increasingly evident that the water problems of a country can no longer be resolved exclusively by the water professionals, alone. The water problems are becoming increasingly more and more interconnected with social, economic, environmental, legal and political considerations, at local and national levels, and sometimes even at regional and international levels. One of the main questions is how can be successfully answered in a socially acceptable and economically efficient manner. The present paper analyzes the integrated water resources management with respect to principles and general objective of integrated catchment management. Also the toolbox of integrated water resources management, problems and challenges in implementation of IWRM and the necessity of implementing IWRM method are proposed.

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INTRODUCTION

Over the centuries, surface and ground water have been the important resources for agriculture, industry and urban areas usage and etc. Rivers have been considered very important because of energy generation [1] and making facilities for business and leisure activities and generally available water resources in each country is a source of income and water has been regarded as an economical resource [2].

In order to earn more income of rivers, water resources and floodplains close to the rivers, human activities caused costs and damages to the rivers, especially when the river would have in drought or high water period [3]. These costs can be economic, environmental and social issues which stems from a lack of coordination between our expectations and the usual nature of a river. Experts in the field of water resources have always been trying to solve this problem how a structure can be designed and implemented that could obtain the most benefit from a river or any other water source. Although there are some restrictions on the using of water resources, so some questions arises in the mind, and that how these limited resources can be managed and used? [4] And another question: How can the management projects be run in the environment with unknown sources, uncertain demands and increasing conflict between users of the resource? [5]

The need for water management:

In the past, although many countries were able to provide their water requirements in agriculture, domestic and industrial areas by using water supplies in the country, however, survival and water management is not a

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new discussion and it has attracted the attention of professionals for several past years. Along with population growth, we have witnessed rapid increase in water demand in the past two-three decades to improve living standards and industry in many countries. Due to the growing threat of water shortages, led to the decision makers seriously think about sustainable development and environmental protection. In this regard, the concept of Integrated Water Resources Management (IWRM) has been formed [6].

The Integrated Water Resources Management has been formed in response to the increasing pressure on water resources due to increasing of population and economical-social development. Water shortage and declining water quality are two factors cause that many countries reconsider on the way of their management and operation of their water supply. It was like that the concept of Integrated Water Resources Management was changed which its concept was converted from the view of supply and purely engineering approach to the view of demands and multi -division approach, and its new concept as Integrated Water Resources Management was formed.

According Dublin's Principles (1992) Integrated Water Resources Management considers using of water resources in relation to economical-social activities. This requires making a law for sustainable use of water resources. Dublin's rules and principles set forth in are as follows: [7, 8]

1. Water is a limited, in danger, and necessary resource and it is essential for maintaining a stable life, development and the environment.
2. Development and management of water resources should be based on a collaborative approach that involves participating of all users, planners and policy makers in all fields.
3. Women play a central role in the management of water resources.
4. Water has an economic value in all consumption sectors used in its competition and it must be considered as an economical stuff.

After all these discussions can be inferred that existing and current management practices are not enough to solve the problem of water shortages and concern about sustainable development and it needs re-evaluation of procedures in relation to the management and development of water and creation new frameworks and techniques. The basis of these methods and techniques is the important topic of optimization.

In developing countries and in countries that suffer from water shortage, a comprehensive resource management seems necessary by considering the social and economic aspects [9]. Water resources provide a wide system with all its natural components and hydrological relationships. This system contains not only natural components but also artificial components which are made by human.

Therefore, water management is becoming a significant and important part in which purposeful and rational use of water is not possible regardless of Water Resource System (WRS) which includes water resources, users and the factors that impact on the system or the system impacts on them. Finding optimal solutions to such problems along with all water needs (are often competitive), requires that system performs after considering all aspects and internal and external features through Methodological Procedure and by applying the updated theories and using computer and current software .

Water Resources Systems:

The concept of Water Resources Systems is true when its components are true. Defining of system depends on choosing the goals and its details. The components of the system can be natural (rain, waterways, lake, underground waters) and also made by humans (dams, reservoirs, canals, barriers, hydropower stations, pumping and...). The Water Resources Systems are open systems so that the components make relations with system environment. If a number of chain components have better and closer connection than the other components within a system, it can be said there is an independent part within the system and it is called sub-system. Water Resources System can be defined as a group including a series of different water sources which are linked together as a chain. So the distinction between components and the concept of water resources systems is arbitrary. To further clarifying the concept of Water Resources Systems and distinction between components, a country can be considered as a whole system. The main system is defined General Water Management of Country (vs., The General Economy of the Country), all of the defined sub-systems are absolutely made by human and therefore, they have goals.

Every targeted water resources system (a man-made system) is formed of a set of inputs, and laws related to the system. Based on the present goals, Water Resources System can be defined as follows:

1. Irrigation and drainage systems [10], Hydroelectric power generation systems [11], water supply systems [12], Fishery system, reservoir systems [13]and...
2. Single-objective systems or multi-objectives systems [14-16].

Each single-objective system includes several different components but it follows just only one objective like hydroelectric power generation and or flooding control, its objective is usually expressed as technical units, for instance, the objective of water supply with specific rate of discharge is Q and Confidence Coefficient is po .

Multi-objective Water Resources Systems also have different components and different objectives. The main objective of identifying this system is to determine what combination of these objectives have been the

optimal answers and which criteria for evaluating answers are. As different objectives are often competing, these methods are difficultly to be optimized. But, on the other hand, conditions prevail in some of these systems which cause to simplify the problem of the system and this is when one of objectives has higher priority to other objectives (for instance, urban water supply). In this case, this system can be considered a single-objective system with additional objectives which are stated like constraint in the problem. Multi-objective Water Resources System has all signs of complexity in the system. Some of these complexities can be as follows:

- Having large dimension, the number of components (sub-systems and its elements), the number of input and output parameters to the system and the number of their dependence
- Change in one quantity causes change in the various components (for example, changing in hydrological data).
- System is dynamic (both of water resources and water demands are changing over the time).
- Natural hydrological data logging into the system and demand is stochastic (the rate of discharge, deterioration of water, water quality parameters and ... all of them have been unknown and only their statistical parameters have been known like mean, standard deviation and...).
- Demand for water is usually competitive in multi-objective systems (for instance, the required level of reservoir volume for flood controlling and useful reservoir volume and etc.) [17, 18].
- For implementation and controlling, every water resource system requires different equipment for reviewing and processing of information which all of them will be happened by computer hardware and software and automating some activities [19].
- Multi-objective systems require personnel who are responsible for the activities like measuring, reviewing, evaluating and control of implementation process in order to prevent a failure in the system operating.
- The nature of the multi-objective system requires not only technical and economic parameters, but also it needs the environmental and invisible parameters to assess its objectives, because these parameters have great effects on the environment [20].

After description of these cases, Multi-objective Systems are evaluated with all their complexities, but, on the other hand, due to the tendency of simplification of complex systems, the risk of doing this action must not be considered insignificant, but it should be tried to provide a basis for evaluating the validity and authority of solutions obtained from simplified system.

Definition of Water Resources Systems:

For water management purposes, a limited number of systems can be defined so that each has different goals, different distinction aspects, simplified aspect and so on. If they are defined as the real objective, it means that the system has been real and not conceptual. Usually, a summarized system is used in nature and natural sciences which shows only the main and basic features of the real system.

Despite having advanced sciences and different scientific methods, modelling any complex system is easier so that it is so close to reality. Even though, simplification of Nature (consistency with computer equipment and software) may lead to results far less than expected and it is not acceptable. Accordingly, the interpretation of the results of models and systems should be based on the view that the model should be a reflection of the simplified nature not itself.

As a result, while implementation of every water system, human control functions cannot be ignored on them for two reasons mentioned below [21]:

- Their function is very complex and their modelling cannot be replaced for reality.
- System behavior is not definite; the calculations can only be done with some degree of confidence.

Thus the number of human resources should be considered as a key component even in the fully automated system and its career can be named as the career of the century. After discussion about natural systems, in the case of man-made systems must also be said that each of these systems has been made to estimate a specific purpose with the optimal behavior (for example, the objectives like economics and the other optimized criteria). The optimization of such systems occurs in three areas:

- There is a system and its performance can be optimized by changing its behavior.
- There is a system that is willing to develop and accept new components in order to meet new goals and or improve their performance.
- There is no system but it is supposed to be designed and constructed in future. Components of the current system can also be used in the new system.

The discussion of simplify regarding man-made systems can be done in three steps [21]:

- Definition of units of each system and its schematic presentation
- Analysis of the structure and behavior of the system
- Designing possible changes for each component in the system and apply them to the system

The most appropriate definition for the system is introduction and requirements to achieve successful results regarding to problems of water resources system. Choosing the right and appropriate features for a

system, the most important action to achieve desired objective or objectives and improper selection can be a big obstacle to all efforts made, although the best practices and methods have been used. In this case, the system doesn't reflect the truth and the results cannot be practically applied and may lead to wrong decisions. If inaccuracy of the results is clearly distinguishable, it can be said that making errors will be minimized in decision making, but the danger is that the inaccuracy of the results is not clearly distinguishable. During this time, it is possible errors be also remained uncorrected and maximized the likelihood of error.

The following points are essential in defining water resources systems [21]:

- The accuracy and correctness of the results obtained from the objectives and verifying of formulation should be investigated, this will be the most important when the goal of the system are in competitive mode.
- What distinguishes the system from other systems and its components need to be identified.
- The relationship between the components of the system and between the environment and system must be identified.
- Schematic presentation of the system should be done (for instance, presenting graphs, matrices, and operational scheme and so on).

In defining of system, the most preferred activities are "creative designing" which is not possible without considering the human resources and its insights. Selecting the most important system components and their relationships and also appropriately decreasing of problem constraints and determining the appropriate alternatives, not only implies the credibility and reliability of system definition, but also implies the merit of simplification and manageable of mathematical models.

The system definition consists of two main methods as follows:

- Division into different subsets and definition of relationships among them
- Simplification

Every simplification of complex systems and in large-scale is often a combination of the following two conditions [21]:

- The system has not been simplified (more accurate results, no fee is intended to simplify but the operation is very expensive).
- The system is too simplified (decreasing costs extremely in operation and etc.)

With the increasingly rapid growth of information processing, the possibility of acceptance of less simplified systems is greater. The following Direct Methods can be used for simplification of Water Resources Systems [21]:

- Remove or compress the components and the relationships between them
- Replacement and transfer variables and the relationships between them
- Division into sub-systems

Evaluation and Estimation of Water Resources System:

Evaluation of Water Resources System and Decision-Making is often difficult to find the optimal in order to develop a system and has its own characteristics, so that usual (classic) methods may fail. Decision-Making process involves many different organizations with their own priorities and special criteria for Decision-Making. Even a decision maker finds much difficulty while coming across with multi-objective systems with inconsistent objectives and or a single-objective system using various multiple criteria. Furthermore, such decisions have been irreversibly and have significant effects and involve a lot of uncertainty in the input data to the system.

Evaluation of Water Resources System by Decision Analysis:

The decision-making process consists of three stages:

1. Defining criteria for assessment of the problem and identifying the variable which estimates the objective
2. A simple evaluation of problem criteria in a scale
3. Evaluation of weighted criteria

Each criterion should define the main goal of the system and shouldn't convergence other criterion. These criteria have been selected according to the subject under analyzing. Criteria that can be defined in the assessment of water resources systems include the followings that in this area we will confine ourselves just to mention them:

1. Cost Criterion
2. Production Criterion
3. Environmental Criterion
4. Economic Effects Criterion
5. Performance and Construction Criterion
6. Optimization Criterion
7. Development and progress Criterion
8. Other Criterion including:

8.1. Conflict with the activities of other departments so that the conflicts have been a two-way and make specific provisions.

8.2. Preparing to build and run

8.3. Cooperating with local political parties

Those all the criteria mentioned, those will be selected which best have describe the performance options outlined. There are also different methods to evaluate these criteria which are beyond the scope of this research [22].

System Evaluation by Multi-Objective Optimization:

The optimization of multi-purpose water resources systems, several criteria are applied to the problem formed as a result of multi-objective optimization. Researches in this field started to spread since 90s. Mathematical problem modelling requires the individual to define the objects one by one and their relationships in the system and the global objective of the system that all of which result in a single algorithm to select the best option. In this process, all possible values of criteria and good ideas are reviewed that result in a compromise solution. A compromise solution is a solution which considers interaction among criteria and also decision-makers' needs. Also, all the objectives can be put in the model in this process and or act as a constraint. If in a system, one objective (for instance, Economic performance) has the highest value in comparison with other objectives; it is possible to use of single-objective model. Secondary objectives can be estimated in constraint mode with the minimum and maximum values and used in the model. Recently, however, there has been a tendency in order to pass the same value between the objectives and to optimize the model with all desired objectives.

Integrated Water Resources Management:

Sustainable Water Resource Systems:

Systems which are designed for better serving to the lives at present and in future in such a way will be effective in our present life and also future life and lead to relaxation are called sustainable systems. We must consider future generations while meeting our needs, goals and aspirations. We need to look at the changes that have been forced into. These changes may effect on the physical, biological, social of water storage systems. Essential element in the planning, design and management of sustainable systems is to anticipate changes. Sustainable water resource systems are designed and exploited so that they have the ability to adapt and strong and flexible structure for changing and uncertain future. Sustainable systems as well as other systems may fail, however, when these systems fail, they must have the ability to modify and control their own without additional cost. Inflexibility in dealing with information, issues and Social and political spaces is a sign of reducing system stability.

The Need for Integrated Water Resources Management:

Until the early 1990s, various aspects of water resource management (including water quality, ground water, water collecting, sanitation, water supply, irrigation, hydropower, etc.) are often managed separately and independently in different institutions. Development the scale of operation of surface water resources and especially groundwater due to increasing population with taking into account resource constraints, led to the emergence of competition and conflicts between water users, increasing pollution in water resources, increasing development costs and emerging environmental problems. Costly engineering strategies are not necessarily the answer deep concern management to fix the problem permanently (based on three aspects of economy, society and the environment). In recent years, it has been seen frequently at international conferences and statements water that the purely physical and structural development debate e cannot just be considered a solution to the problem [23, 24]. According necessity and in order to solve this problem, advanced management of water resources scientists proposed a method to water management that makes possible providing the maximum conflicting interests for all the beneficiaries. This multi-sectoral, coordinated, multidisciplinary, collaborative, flexibility and transparent approach is so-called "Integrated water resources management".

There are many definitions for IWRM. According to the definition of the Global Water Partnership GWP, IWRM is a process that improves management and development of water, soil and other related resources with them to maximize economic - social welfare obtained from an equitable manner without putting in danger the sustainability of vital ecosystems [25]. According to Loucks (2000) sustainable water resource systems are those designed and managed with the goal of full participation of society now and in the future while preserving also its hydrological, environmental, and ecological integration [26]. The issues mentioned above has been expressed in the form of sustainability of three principles of economic, social, environmental with the concept of sustainable development [27]. This economic stability implies this point that that water must be used with maximum utility. Social sustainability implies on the fundamental rights of people with access to water with appropriate quantity or quality and has stated environmental sustainability, renewable and restoration of ecosystems and their ability to exploit it and guarantees use of these resources for future generations. Generally, the foundation of integrity in water resources management is the coordination and alignment of all systems and decision making institutions between the various levels.

In this approach, all the components do not have equal status and there is greater emphasis on key variables and relationships affecting the system. Being objective, non-static attitude to relationship and variables and finally the effectiveness (rather than efficiency) is major features integrated water resources management. For example, allocating excessive resources to both agricultural and industrial sectors as the focus of economic development led to be ignored the environment sector's ability in production and income and thus endanger the stability of the IWRM. Another benefit of integrated management is the ability to be aware of the possibility of the occurrence of potential problems, providing the conditions for the reaction. The integrated program comparing with the comprehensive program gives more importance to not only human problems but also technical and economic issues. In fact, the integrated management is art and science to combine various sectors to achieve sustainability. Whatever movement is done from single-purpose and multi-purpose programs to the definitions integrated and holistic programs; it goes beyond to propose the details of the problem and moves from technical and specific discussion toward general programs, but based on natural and humanity cycles.

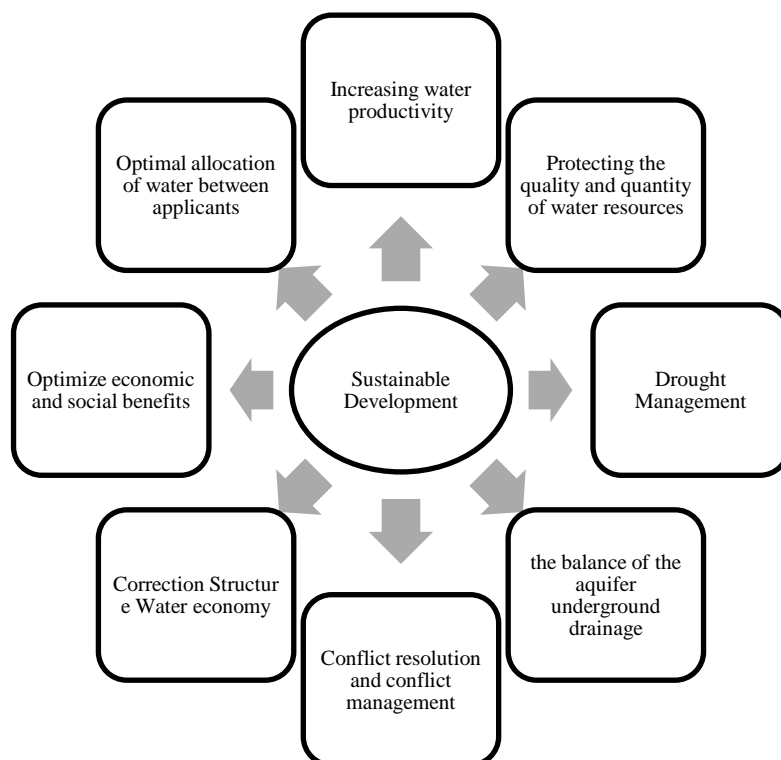


Fig. 1: Some other benefits of integrated management of water resources based on sustainable development (taking into economic, social, environmental and catchment scale considerations).

Principles and General Objectives of Integrated Catchment Management:

Maintaining normal relations of water resources, soil and optimal utilization of resources based on the principles of sustainable development requires that responsibility area for managing the water resources is physical geography of main watershed area of the river; Whether these watersheds are based on country division range or not. Watershed has been taken from the German word "Wasserscheide" which means water separator [24, 28]. In many studies, integrated watershed management is used instead of using integrated water resources management. According to a consensus of different experts, using the "watershed" is emphasized as appropriate territory of water planning. Consumer participation and effective collaboration with management will be crated just by integrated management, because the consumer sectors benefit from advantages of partnership and collaboration with water management directly or indirectly. The overall objectives of integrated management of water resources can be summarized in the following cases:

- 1- Water and land should be managed as integrated.
- 2- Water and land should be managed at the lowest appropriate level.
- 3- Water and land has economic value and should be treated as economic goods [29, 30].
- 4- All those benefit must be considered while allocation of resources.
- 5- Efficiency of water, land and vegetation is maximized while being fairness.

Tools for Integrated Management of Water Resources:

Implementation of new technologies [31]:

- 1- Implementation of new technologies in water, wastewater, and storm water systems [32]
- 2- Using of appropriate tools and water utilities and irrigation
- 3- Using the right tools for water transmission and distribution
- 4- Using appropriate measurement system for water supply
- 5- Selecting the most appropriate available technology

Economic Tools:

- 1- Putting price on water (considering water as an economic good) [2]
- 2- Stable and secure investment
- 3- Simultaneous management of both Supply and Demand
- 4- Establishment of financing and incentive structures
 - a- Encouraging farmers to water-efficient products with high economic efficiency
 - b- Encouraging the use of non-conventional water
 - c- Grants to optimize water use
- 5- Establishment of financial and fine structures
 - a- Fines for polluting water [33, 34]
 - b- Get surcharge for the usage over consumption pattern

Cultural -Social Tools:

- 1- To spread public awareness about the conservation and utilization and water policy [35]
- 2- Training of manpower
- 3- Creation of stakeholder participation in water resource management [36, 37]
- 4- Promotion of recycling and water recycles
- 5- Expanding the role of women in water management [38]
- 6- Participation of Different classes of people in community in decision making processes and providing benefits [39]
- 7- Considering the social dimension [40]
- 8- Linking with environmental decision making [41]

Infrastructure and Management Tools:

- 1- Water resource management practices within the watershed area [42]
- 2- Set targets for exploitation, conservation and protection of water
- 3- Creating a systematic approach to water resources management [43]
- 4- Developing and updating the optimal intake of water (potable, industrial, agricultural)
- 5- Strengthening of Water Resources Audit
- 6- Legislation to enforce demand management [44]
- 7- Rationing or prohibition in critical condition [45]
- 8- Fair allocation of water resources [46]
- 9- Law-centered and applying law appropriately and fairly
- 10- Transparency of processes and institutions
- 11- Accessing to information for policy making and predicting responses
- 12- Decentralization and democracy [47]

Conclusions:

Integrated management of water resources has been shown important and positive results in most investigations, especially in developing countries. Results indicate the importance role of public participation components, educating and informing for the successful implementation of integrated management of water resources in the social sector and the environment and putting the value on the economic section which caused the consequences like justice, saving money and reducing conflicts [48]. Successful management of water resources is as a result of a comprehensive understanding of the processes of system resources. Researchers have also studied the reasons of failure of integrated management of water resources and concluded that The lack of strong structures for running programs, being several inconsistent organizations with the separated and isolated institutional infrastructures, lack of awareness and suitable familiarity of different sectors with the effects and benefits of the management, data inconsistency and the statistics of water resources can be considered the challenges which limit the growth of this sector. Political pressures, lack of comprehensive policies, inefficient and outdated legislation, lack of human resources and pricing by the government are considered the other challenges of integrated water resource management, especially in developing countries [49, 50]. Indeed, the integrated management of water resources for the realization in practice requires effective governance of water or Effective Water Governance [51]. Governance is balancing acts for distribution of power, and regulating the activities of various levels of administration. Management and governance are correlative and management tools will not be effective without good governance in water [52, 53].

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