Strategic Planning for Remediation and optimization of Irrigation and Drainage Networks: A case study for Iran

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Abstract

Development of modern irrigation and drainage networks is one of the effective strategies to preventing water losses and optimal usage of water resources in agricultural section. So far, about 1.8 million ha of the total 8.5 million ha irrigated lands are irrigated using modern irrigation networks in Iran. Many new irrigation networks are also under construction. In the other hand, recent studies have shown that the most of the existing networks which have been constructed with huge costs suffer from various social and technical. The nature and type of these problems are different depending on the stages of construction and operation in different networks. In this research, an attempt has been made to determine the main problems of the networks, and remediation measures for rehabilitation and optimal modification of the networks. For this purpose, the methodology and principals of strategic planning was used. To do this, the pattern of strategic planning, including organizing of main and sub main committees with participating of stakeholders, review of literatures, field studies and visits, holding on workshops was applied. Based on arguments made in the workshops and main committee, the whole problems of the irrigation and drainage networks were followed in four principal subjects including drainage and environment, structural and construction, managing aspects and construction materials. The existing problems in the networks were drawn in the form of problem trees for each subject separately. Then in the basis of problem trees, target trees were developed to optimize and modification of irrigation and drainage networks. Based on the target trees, and considering previous studies and experiences, distinctive executive and research strategies were proposed considering various basic criteria. Finally temporal priorities (short, middle and long term) were determined to performance of the suggested executive and research strategies.

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1. Introduction

The main source of water in Iran is precipitation in the forms of 70% rainfall and 30% snow which is estimated to be about 413 billion cubic meters (BCM). About 71.6% of the total rainfall (295 BCM) is directly evaporated. Considering 13 BCM of water entering from the borders (joint border rivers) the total potential of renewable water

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resources is estimated to be 130 BCM. Currently, the total water consumption is approximately 88.5 BCM, out of which more than 93% is used in agriculture, while less than 7% is allocated to urban and industrial consumptions (Table 1).

Under the present situation 82.5 BCM of water is utilized for irrigation of 8.5 million hectares of irrigated agriculture (horticulture and field crops). About 3.0 million hectares of these areas under irrigation networks (main and secondary canals), 4.7 million hectares by means of traditional networks and less than 1.1 million hectares are under fully equipped networks or pressurized irrigation systems. Surface water resources provide 37.5 BCM water for different consuming purposes (about 42% of the total water consumed) in the country. The importance and existence of groundwater was explored by Iranians thousands years ago. The traditional method of groundwater extraction is Qanats, which brings water to surface by gravity. In recent years more than 50 thousands of various types of wells are used for extraction of groundwater from the aquifers. About 58 percent of total water consumption in the country (51 BCM) is extracted from groundwater resources.

Table 1. Water Availability and Use in Iran

<table>
<thead>
<tr>
<th>component</th>
<th>volume (BCM)</th>
<th>Percent of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>413</td>
<td>100</td>
</tr>
<tr>
<td>Evaporation</td>
<td>283</td>
<td>70</td>
</tr>
<tr>
<td>Water yield</td>
<td>130</td>
<td>30</td>
</tr>
<tr>
<td>Total water use</td>
<td>88.5</td>
<td>100</td>
</tr>
<tr>
<td>Agriculture</td>
<td>82.5</td>
<td>93.22</td>
</tr>
<tr>
<td>Urban</td>
<td>5.6</td>
<td>6.32</td>
</tr>
<tr>
<td>Industry</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>0.37</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Due to inefficiency of traditional irrigation methods and water conveying systems, about 60% of the valuable water is lost, and in practice only 40% of available water is utilized in agricultural production. Due to special climate conditions of Iran, sustainable agricultural and food production for feeding the ever-increasing population mainly depends on the efficient use of the limited water resources. The total arable land in Iran is estimated to be about 37 million ha, out of which 18.5 million ha is now under cultivation. Also, 1.8 million ha of the total 8.5 million ha irrigated lands are irrigated using modern irrigation networks. The details of agricultural land use and modern irrigation and drainage development are presented as tables 2 and 3.

Table 2. Agricultural land use distribution

<table>
<thead>
<tr>
<th>Land use situation</th>
<th>area (Mha)</th>
<th>Percent of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>165</td>
<td>100</td>
</tr>
<tr>
<td>Potential for cultivation</td>
<td>51</td>
<td>31</td>
</tr>
<tr>
<td>Rain fed</td>
<td>10.5</td>
<td>20</td>
</tr>
<tr>
<td>Irrigated lands</td>
<td>8.15</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 3. Modern irrigation and drainage development

<table>
<thead>
<tr>
<th>component</th>
<th>Area(Mha)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation and drainage networks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating total</td>
<td>2.2</td>
<td>26</td>
</tr>
<tr>
<td>Dams main</td>
<td>2.0</td>
<td>23</td>
</tr>
<tr>
<td>secondary</td>
<td>1.1</td>
<td>13</td>
</tr>
<tr>
<td>Under construction</td>
<td>1.3</td>
<td>15</td>
</tr>
</tbody>
</table>
It can be concluded from table 3 that there is a great potential for increasing the irrigated areas in Iran. Performance of modern irrigation and drainage networks is one of the main and long-term strategies for optimal and efficient use of water and thereby increasing irrigated lands. On the other hand, most of the networks which have been constructed with huge costs suffer from various problems in operation and result in low efficiency. These lead that the main and primary objectives of the projects to be questionable. Destruction of concrete lining of canals is the most common form of the problems in irrigation and drainage networks. But the nature and reasons of problems vary in different networks. Rahimi (2000) categorized these factors as; designing issues, execution, quality of construction material, operation and maintenance, social issues and geotechnical properties of bed soils. Rahimi and Abbasi (2008) presented that the difficulties soils as geotechnical characteristics of canals bed are the most important factor for destruction of canal lining. He also classified difficulties soils as expansive, collapsible, liquefiable, soluble and dispersive soils. Bara (1969) found that existence of expansive soil is the reason for destruction of Sant Louise canal and developed a relation between maximum dry density, liquid limit and swelling percent. El-Refahi (1976) presented that the existence of gypsum in the bed soil and leaching of such soluble materials was the reason for destruction of irrigation canals lining in the lands around the Phrates River in Syria. Rahimi and et al (2011) showed that dispersivity of bed soils has been the main factor of the lining destruction in Moghan irrigation canals. Golabetoonchi and Talebi (2000) studied the reasons of lining destruction of canals in different parts of Iran, including the Poldasht Network in Northern Khouzestan, Souf Chay networks in East Azerbaijan and Zarrinehroud Network in West Azerbaijan and concluded that difficulty soils (dispersive and expansive) and also lining freezing in cold seasons were the main reasons. Bahramloo (2004) showed that the problems involved with Hamadan irrigation network were: cracking and destruction of concrete linings, minor repairs and damage of gates, growth of weeds, lack of stilling basin, turn up sediments to canals and lands, arrival of sewage and sweepings to canals and disregard of canals limit. Also conveyance efficiency in different types of irrigation canals was determined to be 93.5, 71 and 52 percent for stony, concrete and earth linings respectively. Mamanpoosh (1999) presented the main problems of Esfahan network as; insufficient information about crop water requirements, low field application efficiency, low conveyance efficiency in traditional canals, abuse of ground water resources by operators and undesirable conditions in maintenance of canals. As note, So far, a variety of studies and research measures in various fields of irrigation and drainage network has taken place. But most of these measures because had not a wide view were not entitled to significant success. In this study, it is tried to recognizing the current situation and issues of the irrigation and drainage networks of the country and offering comprehensive executive and research approaches to solve these issues with the use of strategic planning concepts.

2. Material and Methods

The pattern used in this research was the general pattern of research strategic planning. Strategic planning involves defining a mission, establishing goals and objectives, and creating strategies to attain those goals and objectives. This template consists of three main stages of formulating strategy, implementation strategy and evaluation strategy. The desired type of activity means that the beginning has turned out and how to allocate the financial and human resources will be turned on. Then short-term goals, based on the long-term objectives of the strategy for the implementation of Executive policies are selected. Finally the selected policies implemented and evaluated. Strategic planning consists of different operational steps or stages, including the following (Below, 1987):

- A revision to the desired topic status based on existing information and statistics of the country's irrigation and drainage network
- Study and analysis of the issues and constraints and drawing the diagram of the problem tree
- Comprehensive literature review on the topic
- Determination of the objectives of the study (drawing the diagram of the objective tree)
- Identification and prioritization of research and executive plans and strategies.
Preparation of premises And implementation of the plan

Strategic planning for modification and optimization of irrigation and drainage network is one of the thematic defined programs by the Agricultural Research, Education and Extension Organization (AREEO) which has been accomplished by the Agricultural Engineering Research Institute (AERI). Methodology used to compile the program, and perform the aforementioned steps, consist of formation of the main and sub committees of planning, the formation of the provincial committees, field studies and data collection, data analysis and holding of workshops.

2.1. Formation the main Planning Committee

Considering the role and importance of the main Planning Committee on the success of the program, an extensive effort was made for recognition of main and effective stakeholders and persons who directly or indirectly are beneficiaries in respect of the program results were invited to be as main committee members. So that, the main stakeholders and governmental organizations related with irrigation and drainage networks were determined as follows:

• Ministry of energy (water works deputy)
• Ministry of agriculture (water and soil deputy)
• Consulting engineers and contractors Companies
• Universities and educational centers
• Research and extension organizations

Then the expert persons from the mentioned organizations were invited to forming of main planning committee.

2.2. Formation of the scientific sub-committees of the program

After determining the main Planning Committee members, meetings of the Committee's work began. At the first meeting of the main committee, extensive and comprehensive discussion and arguments were made on the objectives of the strategic planning and different issues of the irrigation and drainage networks. After presentation of different opinions and brainstorming of the participants, it was decided that the irrigation and drainage networks issues to breakdown in four axial topics. Based on the importance and the roles of the issues on the networks, the topics of drainage and environmental aspects, structural and constructional, management, and construction material were determined as the four axial topics. Then, four technical sub-committees were formed on the basis of axial topics.

2.2.1. Subcommittee on drainage and environment:

working range of the this committee consists of reviews of environmental impact of irrigation and drainage networks in various regions of the country, the use of marginal waters, design, implementation and operation of drainage systems. Preparation and drawing of the problems and objectives trees, prioritize research projects regarding various issues of drainage and environment were determined as the major tasks of this working group.

2.2.2. Subcommittee on the management of irrigation and drainage network:

Tasks related to this committee include evaluation of operation and maintenance issues of the networks, assessment of networks performance, evaluation of governmental policies and legal, social and economical and other management aspects related to the irrigation and drainage networks. Also determination and drawing of problems and goals trees of the topic were the other tasks of the working group.

2.2.3. Structural and construction Committee:

The duties of structural and construction Committee include reviews of existing issues in the design and
implementation of various regulating, diversion, conveyance and distribution structures and pumping stations. Also preparation of a database on the traditional and modern irrigation networks, determination and drawing of problem and goals trees of the topic were the other tasks of this working group.

2.2.4. Construction material Committee:

evaluation and study on the feasibility and quality of construction and consumable materials in irrigation and drainage networks, including cement, concrete, soil, aggregates, additive’s, pipes, stabilizers, metals, rubber, plastics, geosynthetics, geomembrane and etc. as well as evaluation of their application and limitation in different structures were determined as the main task of construction material committee.

3. Results and discussion

After formation of mentioned main and sub committees, different meetings and workshops were held in order to discuss and evaluation of current situation, involved problems, advantages and disadvantages of the implemented networks. The outputs of sub committees were analysed and scrutinized in main committee. Then according to the existing conditions and issues, and taking into account the country's development programs, the overall targeting of the plan was made and the executive measures and required research topics to achieve the goals were identified.

3.1. Analysis of existing situation of irrigation and drainage network

As mentioned before and presented in table 3, it is obvious that total area under operating, construction and studying dams will be limited to about 4 million hectares. That means the rest approximately 4 million hectares will remind as traditional condition. It can be concluded that the traditional irrigated lands are a great portion of arable land and should considered and modified as well as modern networks by improving the irrigation technics and designing. Therefore, parallel to the physical and qualitative development of the modern network, modification and optimization of traditional systems in order to increase water use efficiency is inevitable. Also the general specifications of the operating networks were determined as details shown in table 4.

<table>
<thead>
<tr>
<th>Total No. of networks</th>
<th>Total area(ha)</th>
<th>Total capacity(m³/s)</th>
<th>Average conveyance efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>66</td>
<td>1714830</td>
<td>1701</td>
<td>89</td>
</tr>
</tbody>
</table>

Based on the data presented in the table 4, in spite of that the modern network conveyance efficiency is suitable (89 percent), but due to the high capacity of the networks (a total of 1701 m³/s), improving a few percent of the conveyance efficiency, will provide significant amounts of water in the agricultural sector. For example, Abbasi et al. (2008) estimated that increasing of conveyance efficiency about 1 percent will be equivalent to creating a capacity of 17 cubic meters per second of water that could be inserted into agricultural production cycle. (Abbasi et al., 2008).

3.2. Issues and problems of irrigation and drainage

In order to classification of major problems involved with different networks, all problems of different networks were listed with details in sub committees and then analysed in main committee. Based on discussion and challenges during various meeting the common problems of the networks were evaluated and categorized for four axial topics separately. In such a way the problems were classified in different levels based on their importance and frequents. Then for each topic a diagram named problem tree were drew showing the most probability and frequency problems in different levels. Figure 1 shows the summerized problem tree of the management aspects of the irrigation and drainage networks typically.
3.3. Objectives of the strategic plan to optimization of irrigation and drainage networks

After identifying the problems set in various stages of design, implementation, operation and maintenance of irrigation and drainage networks and an extent literature review on national and international levels, the goals and objectives were identified and introduced in order to overcome or reduce the impacts of various issues. Thus, according to topics and based on the provided problem trees and considering the available approaches, the overall objectives of the program were determined as follows:

- Study and detailed design of modern networks.
- Enhancement of the management system during the execution
Improvement of the traditional networks.
- The appropriate use of modern methods in the design, implementation and operation of the networks.
- Improvement the economic, social and cultural conditions of stakeholders.
- Providing of appropriate and local standards and guidelines for the networks
- Improvement the quality of materials
- Sufficient and comprehensive evaluation of the performance of irrigation and drainage networks
- Development of drainage system
- Evaluation and improvement of irrigation and drainage network environment

In addition for each topic a diagram called objective tree was drew proportional to problem tree, showing different objective in different level for overcoming on the problems. Figure 2 shows a typical objective tree for environmental and drainage aspects of irrigation and drainage networks.

3.4. Comprehensive Executive plan

After determination and identification of strategic objectives, set of executive measures that can be acted by executive authorities and policy-makers without doing any research have been prioritized according to the time dependent rules including; short term, medium term and long term.

3.4.1. Short term measuring

- The participation of the beneficiary in all stages of the projects.
- The use of conduits and pipe systems for subnets.
- Creating coordination and collaboration between the executive and research departments.
- Pay special attention to the geotechnical investigation of the network bed.
- Serious attention to environmental studies and makes it mandatory for the entire network.
- Seminars and workshops on various issues regarding networks.
- The allocation of credits required for the repair and reconstruction of the existing network.
- Create a trustee for repair and maintenance of irrigation and drainage.
- Create a up to date and dynamic database for irrigation and drainage networks, Qanoat and springs
- Planning for storage of Qanoat and spring water in the non-agricultural seasons.
- Avoiding the use of stereotypes maps for projects with considering the specific conditions to each project.

3.4.2. Medium term plans

- The use of materials and affordable and appropriate materials.
- Completion of subnets.
- Performance assessment of existing irrigation and drainage projects.
- Creating coordination and collaboration between ministries involved with water.
- Monitoring of the networks periodically.
- Strengthening and development of the structure of water users' associations.
- Embedding of measuring flow in important parts of the irrigation and drainage networks.
- Lining of traditional canals and ditches.
- Modification of the laws concerning the efficient use of water resources in the country.
3.4.3. long term plans

- Changing the cropping pattern in order to efficient use of water.
- Equipping and modernizing of the lands.
- Network management transfer to water users' associations and organizations.
- The development of modern networks.
- Study and implementation of the network and dams at the same time.
- Reform of the laws in order to prevent land crushing.
The development of highly qualified personnel equipped with laboratories for control of irrigation and drainage projects.
Organize local contractors and the use of contractors is equipped and experienced.

3.5. Comprehensive Research plan

It was also found that some of the problems caused by the lack of attention to applied research. In this regard it is necessary to do applied research prior to the implementation of networks or during the implementation and operation of networks. On the basis of problems and objectives trees, research priorities for different axial topic were determined separately as following:

3.5.1. Research priorities on Drainage engineering and environmental aspects

- Research on agro forestry drainage systems and compatible with environment.
- Compilation of the necessary criteria for the selection of the proper method of drainage and determining design parameters.
- Quality management of drainage waters and unconventional water.
- Evaluation of the environmental impact of the construction and operation stages of irrigation and drainage and reduce its adverse effects.
- Research on determination of design criteria for drainage system with considering environmental aspects
- Research on application of geosynthetic filters and local materials in the drainage.
- Research on guidelines, criteria and monitoring methodologies for irrigation and drainage networks.

3.5.2. Research priorities on management aspects

- Identification and assessment of economic, social and cultural issues and problems in irrigation networks and provide a playbook in order to fix them and
- Sustainable development of networks with the participation of water users ' associations.
- Research on the compilation of comprehensive and applied instructions for improvements and modification of irrigation and drainage networks.
- Research and review on the information required using of network information technology in the management of networks.
- Research and reviews regarding the use of the new systems and automation in the network
- Investigation and research on the effects of unified management in the design, construction and operation of dams and irrigation and drainage networks.
- Investigation and research on the problems and issues of hydraulic structures.

3.5.3. Research priorities on Structural aspects

- identifying and evaluation of different structures of modern irrigation network (supply structures, conveyance, and distribution of water)
- Providing national code and compiling the different climatic conditions in the country's design criteria.
- Evaluation of the conveyance and distribution efficiencies of the traditional and modern
- Assessment of legal issues of modern network and the possibility of the implementation of the reform and their handling.
- Rehabilitation and modification of traditional irrigation network.
- Evaluation of the technical, economical and hydraulic issues of pumping stations.
Technical and hydraulically evaluation of Qanat and springs in the country.

3.5.4. Research priorities on construction Materials

- Formulate appropriate strategies to repair the cracked concrete
- Formulation of standards for all kinds of high quality concrete
- Enhancement of concrete durability used in irrigation and drainage networks.
- Research on the geotechnical properties of irrigation and drainage networks.
- Research in the field of provision of proper synthetic filters.
- Evaluation of performance and technical specifications of the equipment used in the irrigation and drainage networks.
- Research in the field to soil stabilization.
- Set the necessary standards for the use of plastic pipes with diameter up to replace the grid collector made of concrete.
- Investigation and research in the field of application of appropriate methods and types of contrition materials for canal lining and other structures.

4. Conclusion

In the review and analysis of the issues and problems related to irrigation and drainage networks, it was found that some of the problems of irrigation and drainage network results from weak execution and some others arising from the failure to perform the required research. Therefore, the required actions in order to achieve the set objectives have been clarified in the application as two parts of the executive actions and research needs was provided. It should be noted that programs offered in each section were prioritized based on several criteria. The Important criteria used for presenting of executive actions and required research priorities were as following:

- Participation of the network users in different stages.
- Adaption with the water scarcity.
- Using local and simple construction.
- Using simple and practical techniques.
- Emphasis on secondary networks.
- Considering the early refund scenarios.

The program was also prioritized according to the time needed to carry out the executive and research activities including; short term, medium term and long term.

Furthermore based on the overall evaluation of discussion some important point in optimization of irrigation and drainage networks can be addressed as following:

- Participation of the farmers and other beneficiary in all stages of the projects has important and effective rules in success and proper performance of the networks.
- Geotechnical investigation and environmental studies of the project should be mandatory for the entire for any networks.
- Periodical monitoring and performance assessment of the networks are necessary and inevitable.
- Different elements of a network should be designed and implemented with together or parallel as a master plan.
- In parallel to physical development of the networks, the quality control and improvement should be considered.
- Collaboration and having similar polices between different governmental organization is very important point in development and performance of the networks.
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References