Agricultural Water Management 203 (2018) 87–96

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Review

Performance evaluation of irrigation projects: Theories, methods, and techniques

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ARTICLE INFO

Keywords:
Irrigation
Performance
Evaluation
Assessment
Indicators

ABSTRACT

The purpose of this paper is to review and represent the knowledge that has been gained in irrigation system performance evaluation. This article is based on the literature that is concerned with concepts, framework, and methodologies applied to the assessment and evaluation of irrigation projects and their performance. The development of irrigation performance evaluation concepts was represented and different frameworks were discussed. In order to assess and evaluate irrigation performance, several methods were developed and used. The main methods used to evaluate irrigation system performance are the Fuzzy set theory, direct measurements for indicators, Analysis Hierarchy Process (AHP), and Remote Sensing (RS). All these methods were identified and discussed. As for the criteria proposed in the literature, although they offer a wide range of choices for characterizing all aspects of performance evaluation, however, still there is no agreed approach that could be offered to assess the performance of different irrigation systems. It could be concluded that the selection of the evaluation framework and method largely depends on the nature of irrigation system and the purpose of evaluation.

1. Introduction

Irrigated agriculture is of major importance in many countries all over the world. It is important in terms of food security, public development, and settlement for rural people. As world population growths significantly, the need for more effective and efficient use of land and water resources is increasing (FAO, 2017). Despite their potential for agricultural growth, there is a remarkable decrease in the performance of several irrigation projects, especially large-scale systems, which usually perform far below their potential capacity (Alcon et al., 2017; Bos et al., 2005; Dejen, 2015; Murray-Rust and Snellen, 1993). This is mainly due to the poor resources management, absence of the planned benefits, and the negative health and environmental impacts (Biswas, 1990). This situation has resulted in an increase of interventions directed to improve irrigation projects performance. Many studies were conducted to investigate the performance assessment and diagnosis in irrigation systems from worldwide regions (Asia, Africa, Europe, and South America). These studies cover several irrigation projects all over the world in the developed and developing countries (e.g. China, India, Spain, Sudan… etc.) (Bouml et al., 2009; Gorantiwar et al., 2005; Molden et al., 1998; Murray-Rust and Snellen, 1993).

The purpose of performance assessment is to achieve efficient and effective use of resources by providing relevant feedback to the management at all levels (Bos et al., 2005; Small and Svendsen, 1992). Moreover, it helps with obtaining useful information in order that corrective actions may be taken to maximize the benefits of the irrigation project. The performance evaluation also could help with verifying the relevant project lessons learned and developing benchmarks to improve planning, implementation, and management of similar projects (Bastiaanssen and Bos, 1999; Bos, 1997). It worth mention that, the performance evaluation assists in improving the performance of irrigation systems and there are many case studies show how evaluation process helped in enhancing and developing the performance of irrigation projects (PEOPC, 2010).

The process of performance evaluation is complex, since a large number of regular tasks must be performed, both concurrently and sequentially, and these tasks should be coordinated within available resources constraints (Biswas, 1990; Small and Svendsen, 1992). In order to enhance this process, many efforts have been assigned to evaluate the effects of such interventions or to enhance understanding of performance so that further improvement might be introduced (Alcon et al., 2017; Bos et al., 2005; Small and Svendsen, 1992; Sun et al., 2017). Much has been written, including theories, methodologies, and frameworks related to irrigation performance assessment. It is time to review and evaluate what has been written in order to provide better understanding and enabling practitioners to select and apply suitable

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https://doi.org/10.1016/j.agwat.2018.02.034
Received 24 August 2017; Received in revised form 28 January 2018; Accepted 28 February 2018

Table 1
Categorization of the main references.

Category	Main publications
Concepts & Theories	Bos et al. (2005, 1993); Burton et al. (2008); Chambers (1976); Murray-Rust and Snellen (1993) and Small and Svendsen (1992)
Framework & organizational performance	Bos et al. (2005); Bottrall and Mundial (1981); Chambers (1980); Johnston et al. (1991); Murray-Rust and Snellen (1993) and Small and Svendsen (1992)
Tools & Techniques	
1 Direct measurements for indicators	Bos (1997); Bos et al. (2005); Bouml et al. (2009); Gorantiwar and Smout (2005); Habib and Kuper (1996); Molden et al. (1998); Mosse and Sontheimer (1996); and Zhi (1989)
1 Fuzzy set theory	(Elawad (1991); Ghosh et al. (2005); Malano and Gao (1992); and Zadeh (1978, 1965)
1 Analysis Hierarchy Process (AHP)	Alphonce (1997); Okada et al. (2008a,b); Saaty (1977); and Sun et al., 2017
1 Using Remote Sensing (RS)	Ahmed et al. (2010); Al Zayed et al. (2015); Bastiaanssen et al. (2000); Bastiaanssen and Bos (1999); Hamid et al. (2011) and Zwart and Leclert (2010)

evaluation procedures that fit their needs.

The purpose of this paper is to provide a comprehensive review of the empirical literature on different approaches and methodologies applied to irrigation performance evaluation. Furthermore, it provides concluding remarks that represent the strengths and limitations of different performance assessment methods. This will provide a guideline to select the appropriate method for a variety of irrigation professionals, including scheme managers, researchers and consultant agencies.

2. Methodology

A comprehensive review was carried out of empirical literature on the theories and methodologies applied to irrigation performance evaluation (up to 2017). More than 70 studies were identified for the literature review that mainly based on published researches including manuscripts from academic journals, in addition to some researches presented in books, Ph.D. thesis, and international agencies reports. These studies were categorized into three groups (Table 1). The first one focus on the concepts and theories related to irrigation performance evaluation. The second group is mainly concentrated on the framework and evaluation process. The last group is related to the methods, tools, and techniques applied by different researchers.

3. Historical review

3.1. The irrigation performance definition

There are numerous definitions of irrigation performance referred to by different authors. Chambers (1976) and Lenton (1983) described irrigation performance as knowing the extent to which an irrigation scheme achieved established objectives. Using the same concept, Abernethy (1989) stated that the objectives are measured with one or several parameters which are chosen as indicators of the system's goals. Instead of focusing on the objectives, a more general concept for performance developed by Small and Svendsen (1992) to include the whole system activities, including acquisition of inputs and the transformation of inputs into intermediate and final outputs, in addition to the effects of these activities on the system itself and on the outside environment. Considering the concept of Strategic Management developed by Ansoff (1980), Murray-Rust and Snellen (1993) defined the system performance as the degree to which an organization's products and services respond to the needs of their customers or users and the efficiency with which the organization uses the available resources. This definition considers two type of performance: Strategic performance and Operational performance. This definition include all the above definitions, since the *Strategic Performance* deals with objectives and goals (Abernethy, 1989; Chambers, 1976; Lenton, 1983), while *Operational Performance* deals with the processes and resources (Small and Svendsen, 1992). While discussing and reviewing different methodologies for assessing the performance of irrigation schemes, (Bos et al., 2005) concluded that, the performance assessment is related to the activities that support all the actions during and after the planning and implementation processes. Similarly, Gorantiwar and Smout (2005) introduced a detailed definition to describe irrigation scheme performance as the extent to which land and water resources allocated and distributed for users in planning and operation stages to achieve the objectives of the irrigation scheme.

In total, the irrigation performance assessment includes different levels, starting from strategic goals, through operation process, and ending with customer satisfaction with outputs. This can be described as an indicator for resources management of the irrigation schemes. By measuring this indicator, irrigation systems efficiency and sustainability can be observed and monitored through different levels.

3.2. The performance evaluation characteristics

Since the late 1970's, the focus of research in irrigation management moved from the conventional diagnosis, which concentrates on the farm level system, towards adopting a "whole system" approach (Elawad, 1991). Several workers have developed or advocated various forms of evaluation criteria for irrigation system. However, in choosing their criteria, different approaches have been adopted.

Chambers (1976) states that two steps should be considered in the irrigation system evaluation process. First step is to identify the objectives of the irrigation system and then select criteria and indicators which reflect the degree of achievements compared with the set objectives. Lenton (1983), addressed the performance of large scale irrigation systems, which may be serving several thousands of users the criteria which reflect the level of achievement in the objectives require unmanageable volumes of data. Bhuiyan (1982) discussed the different methodologies for evaluation field research to improve irrigation system performance.

A different approach concentrating on a single key phenomenon and using it as an index to reflect the overall health of the irrigation system performance. The idea is that such an index could easily be measured. Such approach was adopted by, for example, (Malhotra et al., 1984; Seckler et al., 1988). They concluded that for continuous monitoring of large irrigation systems, a single approximate indicator of the performance should be adopted.

Several other workers adopted a more comprehensive approach by decomposing the irrigation system into subsystems that reflect the performance at different parts of the irrigation system (Biswas, 1990; Bottrall and Mundial, 1981; Bouml et al., 2009; Garces, 1983; Gorantiwar and Smout, 2005; Johnston et al., 1991; Zhi, 1989). The Analytic Hierarchy Process (AHP) used as a tool for irrigation project improvement and help to establish index system of agricultural water management performance (Alphonce, 1997; Sun et al., 2017). An