



Optimization model for the allocation of water resources based on the maximization of employment in the agriculture and industry sectors



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SUMMARY

In many discussions, work force is mentioned as the most important factor of production. Principally, work force is a factor which can compensate for the physical and material limitations and shortcomings of other factors to a large extent which can help increase the production level. On the other hand, employment is considered as an effective factor in social issues. The goal of the present research is the allocation of water resources so as to maximize the number of jobs created in the industry and agriculture sectors. An objective that has attracted the attention of policy makers involved in water supply and distribution is the maximization of the interests of beneficiaries and consumers in case of certain policies adopted. The present model applies the particle swarm optimization (PSO) algorithm in order to determine the optimum amount of water allocated to each water-demanding sector, area under cultivation, agricultural production, employment in the agriculture sector, industrial production and employment in the industry sector. Based on the results obtained from this research, by optimally allocating water resources in the central desert region of Iran, 1096 jobs can be created in the industry and agriculture sectors, which constitutes an improvement of about 13% relative to the previous situation (non-optimal water utilization). It is also worth mentioning that by optimizing the employment factor as a social parameter, the other areas such as the economic sector are influenced as well. For example, in this investigation, the resulting economic benefits (incomes) have improved from 73 billion Rials at baseline employment figures to 112 billion Rials in the case of optimized employment condition. Therefore, it is necessary to change the inter-sector and intra-sector water allocation models in this region, because this change not only leads to more jobs in this area, but also causes an improvement in the region's economic conditions.

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1. Introduction

Providing the society with jobs and stable incomes is the most important mechanism of establishing socioeconomic welfare in human societies, so as for the developing countries, creation of jobs has become a major goal of development. Moreover, unemployment constitutes the biggest pain and social and economic dilemma in various countries, and the existence of extensive unemployment foments social crises. In this regard, stable water resources contribute the most to the existence and continuation of agricultural systems and they are intensely affected by cultivation practices and consumption patterns. Throughout the world,

water shortage is a major problem, and this dilemma is more pronounced in arid and semi-arid regions. Water shortage has become more severe with the increase in demand as a result of population explosion, improvement of living standards, and small-scale climate change (World Bank World, 1992; Mariolagos, 2007).

The propagation of information and communication technologies and the automation of production processes bring about reduction of this sector's share of employment in national production. Production efficiency increase due to market competition also results in fewer jobs for people involved in production. Moreover, in economic development sequence, based on Chenery's theory, the share of economic sectors in gross domestic product and the consequent employment, has been transformed (Chenery, 1979). Accordingly, with the gradual increase of per-capita income in a society, the share of the agriculture sector in creating jobs has diminished and the share of industry and service sectors has

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increased. In this regard, Eisazadeh has shown that in all the economic sub-sectors, the production growth rate, the accumulation of capital, and the production technology have a positive impact on demand for employment in Iran's economy, which means that prospective employment rates will be 0.1 and 0.62 in agricultural and industrial production sectors, respectively. It indicates a higher capability of the industry sector in creating jobs compared to the agriculture sector (Eisazadeh, 2000; McKinney and Cai, 1996).

According to the research works of Sameti in Iran to obtain the employment functions in various agricultural and industrial entities, it can be stated that for each one billion Rial increase for government's current expenditures in fixed prices in the agriculture sector, approximately 35.7 jobs have been created in this sector (Sameti, 2004). This means that, on average, for each job in the agriculture sector, 280 million Rials should be provided in the government's current expenditures. Also in the industry and mines sector, for each one billion Rial of development expenditure, about 2030 jobs have been created in this sector. Therefore, it can be observed that for employing each person in the country's mines and industry sector, an investment of about 492,610 Rials is needed. Taking into account such investigations, it should be emphasized that job creation and higher labor productivity obtained from ideal workforce, as a goal of social optimization, can drastically impart a country's economy. Nevertheless, achieving such a goal requires optimal management practices in the agriculture sectors (related to land areas under cultivation, cultivation and irrigation varieties, limitation of water resources, etc.) and in the industry sectors (pertaining to demand and production functions, level of production, etc.) (Leung et al., 2004; Morrison, 2004; Richmond, 1993; Ringler, 2001; Rockström and Gordon, 2001; Rockström et al., 2007; Rodgers and Zaafrano, 2002; Rosendo and Pozo, 2010; Sameti, 2004).

It should also be noted that water resources which are used for the irrigation of agricultural products are shrinking on a daily basis; therefore, these limited water resources should be optimally managed and allocated so as to maximize the economic and social benefits (García-Vila and Fereres, 2012; Kumar and Young, 1996; Leung et al., 2004; Zhang et al., 2010). One of the methods of increasing the efficiency of agricultural irrigation water is the technique of deficit irrigation using the empirical functions of production. Deficit irrigation practices have been applied in various regions with different degrees of success. For example, Gorantiwar and Smout have declared that deficit irrigation leads to an increase of 30–45% in the land area under cultivation and an increase of 20–40% in the amount of agricultural products (Gorantiwar and Smout, 2013).

With rapid socioeconomic development, the contradiction between the increase in water demand and the decline of available water resources has been revealed. Water shortage has also curtailed the trend of urbanization and socioeconomic development (Botzan et al., 1999; Lu et al., 2008; Van Ast and Boot, 2003; Vaux and Howitt, 1984; Wang et al., 2011; Ward et al., 2006; Yadav and Wall, 1998). In light of today's socioeconomic activities and the excess utilization of water resources, the management and allocation of these resources have gradually become more complex. In the practical management of water resources, the decision maker needs to consider multiple objectives, disputes and conflicting objectives. In these matters, the reasonable allocation of water from several resources to multiple users becomes an appropriate approach for reducing the urban water crisis and attaining sustained utilization of urban water resources (Han et al., 2008; Harou et al., 2009; Heinz et al., 2007; Kumar and Young, 1996; Rodgers and Zaafrano, 2002; Young and Bredehoeft, 1972).

Amini confirmed that a comprehensive planning of cultivation model is highly associated with the environmental, economic and social aspects of agricultural systems. So, they expressed the

sustainability of water resources and the determination of optimum cultivation model in agricultural systems by two ratios of net income to utilized water and workforce to utilized water, respectively. They also tried to simultaneously optimize these ratios as 'sustainability indexes'. With this objective, they considered the component-by-component multi-objective planning process as the major approach in their article so that single-objective and multi-objective linear planning models could be implemented part by part (AminiFasakhodi et al., 2010; Bagheri and Hjorth, 2007; Bateman et al., 2006; Bennett, 2002; Odom et al., 1999; Prodanovic and Simonovic, 2010).

In previous research works, the researchers have presented various applied models. (Noel and Howitt, "Economy of water"; Lefkoff and Gorelick, "Economical-hydrological-agricultural"; Ward and Lynch, "Integrated optimization of river basins"; Cai and Wang, "Water resources-economic"; Griffin, "Supply and demand") (Cai and Wang, 2006; Cai, 2006; Griffin, 2006; Lefkoff and Gorelick, 1990; Noel and Howitt, 1982; Ward and Lynch, 1996). Since previous investigations overlook social parameters such as job creation and higher labor productivity, in this research, a new nonlinear model of water resources allocation has been presented which takes into consideration the concurrent effects of many of the mentioned factors in light of employment in the agriculture and industry sectors and the allocation of water resources throughout the watershed area. On the other hand, evolutionary and intelligent algorithms have found their way in different branches of science and engineering (Jalal, 2015).

Particle swarm optimization (PSO) is a one of the evolutionary algorithms developed by Engelbrecht (2007), Kennedy and Eberhart (1995). PSO is one of the population based algorithms. It is works on the basis of swarm intelligence and inspired on the behavior of birds in flocks where solutions to a given optimization problem, called particles, "fly" (like birds) through a multidimensional search space (Engelbrecht, 2007; Kennedy and Eberhart, 1995; Martins et al., 2013).

However, research of PSO applications for combinatorial optimization problems can be found in the recent literature (Wang et al., 2011; Kennedy and Eberhart, 1997; Rosendo and Pozo, 2010; Souza et al., 2006; Hu, 2011) and the PSO method has been used successfully for continuous optimization problems (Branke et al., 2000; Hongbo and Ajith, 2005; Kennedy and Eberhart, 2001; Martins et al., 2013; Reyes and Coello, 2005). As mentioned earlier, in this research, the use of the optimum water resources allocation model has been studied with regards to the optimization of employment in the agriculture sector (the combined model of linear variation of cultivation pattern and optimal deficit irrigation) and industrial sector and in view of the water shortage problems and the existing limitations in the region. Ultimately, by implementing the particle swarm optimization (PSO) algorithm, the maximum value of the objective function was obtained. The final outcome indicated a 13% rise in employment in the central desert region of Iran.

2. Materials and methods

2.1. The investigated region

The studied region in Iran's central desert (code: 4701), with an area of more than 57,000 km², constitutes a degree IV watershed region of the central desert. The average altitude of this desert from the sea level is about 700 m; with the lowest point (at about 650 m) in central parts close to the north, and the highest point in the north of 'NamakkhorvaBiabanak' lake (at about 838 m). The schematic position of the central desert region and the studied area has been depicted in Fig. 1.

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