Int. J. Nonlinear Anal. Appl.
Volume 12, Special Issue, Summer and Autumn 2021, 719-731
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2021.23423.2539

An optimal socialist Cooperative Game theory model in agricultural sector

Maryam Rezaei[a*], Sayed-Farhad Mousavi[b], Ali Moridi[c], Majid Eshaghi Gordji[d], Hojat Karami[e]

[a] *PhD candidate, Faculty of Civil Engineering, Semnan University, Semnan, Iran.*

[b] *Professor, Faculty of Civil Engineering, Semnan University, Semnan, Iran.*

[c] *Assistant Professor, Faculty of Civil, Water and Environmental Engineering, ShahidBeheshti University, Tehran, Iran.*

[d] *Faculty of Mathematics, Statistics and Computer Science, Semnan University, Semnan, Iran.*

[e] *Assistant Professor, Faculty of Civil Engineering, Semnan University, Semnan, Iran.*

(Communicated by Mohammad Bagher Ghaemi)

Abstract

The increase in exploitation from aquifers in an unbalanced way to meet the growing demands of agriculture has led to a decrease in the groundwater levels and as a result, an increase in the cumulative groundwater-reservoir deficit. In the long run, this will also reduce profits from agriculture due to declining water table levels and rising water extraction costs. In this article, is proposed the application of a socialist cooperativegame for propensity to cooperate and improve agriculture's cumulative net benefit and stimulate the balanced use of groundwater. The purpose of thisapproach is to prevent groundwater level drawdown and compensate for part of the groundwater-reservoir deficit in the Dezful-Andimeshk plain, southwest of Iran. In this study, the consumer behavior, as one of the main factors in groundwater resources management has been investigated. This method has been derived from the socialistcooperative game theory, taking the consumer as an effective factor on water table drawdown, and envisioned in the form of an eco-socialism model. Results revealed that maximum water table drawdown will be reduced by 21%, and as a result, 16 million cubic meters (MCM) of groundwater reservoir deficit will be compensated and the net benefit from agricultural activities will also increase by 26%.

Keywords: Water table drawdown, Groundwater reservoir deficit, Water resources management, Socialist cooperative game, Game theory.

*Corresponding author

Email addresses: maryamrezaei@semnan.ac.ir (Maryam Rezaei[a*]), fmousavi@semnan.ac.ir (Sayed-Farhad Mousavi[b]), moridi1978@gmail.com (Ali Moridi[c]), meshaghi@semnan.ac.ir (Majid Eshaghi Gordji[d]), hkarami@semnan.ac.ir (Hojat Karami[e])

Received: May 2021 *Accepted:* July 2021

1. Introduction

Inefficiencies in water use, especially in arid countries, have been one of the effects of human intervention in the natural hydrologic cycle due to industrial revolution and capitalism, which gradually led to undesirable changes in natural ecosystem(DelbourgaandDinarb, 2020).In the last decades, climate change and rainfall deficiency, along with the increasing water demand in the agricultural sector, have caused overuse of groundwater reservoirs and consequently forced us to face excessive water table drawdown (Bergius et al., 2019). Although it is clear that net agricultural economic benefit will increase in the short term, but, this issue can cause a major economic and environmental loss in the long term due to the increased pumping costs or even the loss of aquifer as a living source of water(SabzzadehandShourian, 2020). On the other hand, human ability to work together to reach the common goals, which is based on shared knowledge and objectives, and mutual trust, has paved the way for implementing the cooperative theory in a collective economy (Vatn, 2020).

Based on the ever increasing global population and current water consumption patterns, it is estimated that the world will face 40% lack of adequate water supply system until 2030. Nowadays, about 3 billion people globally depend on groundwater (World Bank, 2017). So, aquifer care and revival system is immensely important. Countries should improve their water resources management and related services in order to tackle with such complications.Water resources scarcity and competition among stakeholders in water allocation always highlights the optimal operation of water resources (Agostinoet al., 2019). It has been reported in the AQUASTAT data base (FAO, 2016) that in Iran, groundwater supplies 56.7% of total country's needs and 62.1% of irrigated areas depend on groundwater.

Water management in agriculture is an essential need for developing different parts of the countries,and rational management necessitates studyingenvironmental, economic and social factors(Li et al., 2020). These factors demonstrate the impact of water supply systems on aquifer behavior and surface flow of adjacent rivers, and also profits of agricultural activities for the farmers' welfare(Boughariou et al., 2018). It should be noted that water table drawdown in an area is not only noticeable but also harmful to surface water systems that support environmental habitats (Ahmad and Al-Ghouti,2020).

Environmental approaches cannot be implemented without logical decision-making tools. Game theoryimplements these approaches logically by simulating the behavior of different components of the society (Zeng et al., 2018).Game theory is a science that studies the way consumers interact in competitive environments (Zhang et al., 2020). In issues related to the environment, competition between players can easily be detrimental to consumers, environment and all the society. Therefore, balancing of a non-cooperative game is not a proper and sufficient solution (Mohammadpourand-Bagheri, 2017).

Game theory techniques achieve the system's equilibrium point through the supply-demand process under cooperation and conflict (Zarei et al., 2019). This approach means that the game under changeable strategies applies accumulated profits of farmers due to the environmental costs. The results of this vision will provide a decision-making tool that is useful for both farmers and the environment by optimizing water resources management in relation to sustainable agricultural development (PodimataandYannopoulos, 2015).

Over-exploitation of water through deep and semi-deep wells leads to water table drawdown in the long-term which will tend to reduce the volume of groundwater reservoirs and consequently aquifer destruction. This subject is a serious issue in water resources management of developing countries because it has its own complications. Game theory, by simulating the behavior of involved stakeholders in the problem, is a suitable approach to simulate and solve such problems (Madani,2010).

Also, games can contribute to social learning about the role of crop choice and collective action, to motivate behavior change toward more sustainable groundwater extraction (Meinzen-Dick et al., 2018).They simulate groundwater resources systems as a social contract approachin a way that each person accepts that by losing part of his/her profit, he/she would cooperate in gaining maximum benefit for the society (Moreno-Terneroand Roemer, 2013).

Cooperation is defined as aconcept for reaching the same goals among individuals (Tomasello, 2016). Cooperation is an extended concept of altruism, only reachable among humans. Humans have more security by using collaborative trends as compared to the time that only get help from their altruism (Bowles andGinits, 2011;Roemer, 2019).

The creation of rational solution in sharingeconomy is defined in a way that each player benefits from end result pay-off according to their efforts. This balance is defined so that produces the Pareto efficiency (Roemer, 2014).Varied scenarios in the form of game-based models show that the players in the region which faces water issues cannot solve the problem without water diplomacy and cooperation with other players (Barua, 2018). The principal challenge in groundwater management is combination of cooperation concept in a way that helps the sustainability of decisions (ShanklandandGon alves, 2017). Understanding the value of groundwater can lead to balanced decisions in relation to using the ecosystem services. Therefore, solutions that lead to resource sustainability will use a key factor for stable management of groundwater (Conant et al., 2019). Maximizing consumer welfare by using the concept of cooperative game theory shows that coalitionincreasessocial welfare compared to when players only try for their own personal welfare (Ghadimiand Ketabchi, 2019).

It is time to accept the fact that the current consumption procedures and production conditions are actually looting all land resources (Michler,2020). There is a fact that despite the damages we have caused to limited resources, this process cannot be continued and need to change this approach seriously and rapidly. This is what the socialists have recognized in the 21st century and have described the reality of limited resources that are generating these kinds of productivity. The real socialism can make the relation between logical examination of the environment and fulfilling the human needs at the same time (Elster, 2017). Environmental crises due to unbalanced and over-exploitation of groundwater resources take the form of rising costs of accessing use values that are essential to production, and these costs are likely to rise further insofar communities are not able to cover the expense of protecting and compensating, and these resources are gradually being lost (Jia, 2019).

Actually, application of socialism in the environment, or ”eco-socialism”, is a combination of taking humans and environment into account. According to this idea, protecting the natural environment is one of the basic tasks of socialism, as opposed to capitalist agricultural logic which is based on maximum use of water and soil (Löwy, 2015).

Eco-socialist idea is the real values of resources by producing necessary goods for fulfilling human needs without unbridled welfare and this shows a remarkable decrease of force on natural environment (Löwy, 2018).

Djokić et al. (2018) by a focus on creating relationships between residential culture, social and cultural needs and changes and planning modernism and postmodernism and law of socialism, the values of a relationship active between the user, promote the culture of residence and the immediate residential environment and help to improve the living culture of the ”new working class” in the socialist.Dekel (2019) addressed the political movements of the farmers, which are involved in the tensions between nationalism and after nationalism and socialism and neoliberalism. He used changes in resource allocation and law to instill socialist logic and cooperation by farmers into civil society. The results of this method show that how national images are cited is effective in trying to regain the social status lost in the post-nationalist era.Badiu et al. (2019) believed Promoting green infrastructure and nature-based policy solutions is an effective approach to achieving the goals of sustainable development. These sustainable approaches to urban development lead to improved efforts and planning and, consequently, to the maximization of ecosystem services in cities.

This article is based on the real socialist concept signifying that the important matter is how to organize the production and resources distribution which prioritize the production while minimizing the environmental damages. This study seeks to apply the fair socialist thinking on using water resources.

There are three main goals in the present research:

1) numerical groundwater modeling to estimate the reservoir water deficit in the specified period,

2) simulation of socialist cooperative game theory under agricultural water demandsof Dezful-Andimeshk plain, and

3) maximizing public welfare in agriculture and simultaneously minimizing groundwater level drawdown in order to compensate for part of the groundwater reservoir deficit.

In this study, an attempt has been made to illustrate the applicability of socialist cooperative game theory in the water resources management ofDezful-Andimeshkplain, southwest of Iran. This research considers the active water resources issues and presents the importance of cooperative vision.

2. Materials and Methods

2.1. Case Study

Dezful-Andimeshk study area, as the widest basin in Dez aquifer and Khuzestan plain, southwest of Iran, covers more than 2070 km^2 of northern mountainous areas to the low lying areas of the Khuzestan province. This case study is located between 47° 48′ and 48° 9′ east longitude and 32° 2′ and 32° 32′ north latitude. Known as an important Iranian agricultural center, the area has a semi-arid climate and most of the rainfall is Mediterranean type. Figure 1 shows the area map and details of scattered operational wells.

Six types of land use are present in this area, which include: agriculture, residential, industrial, military, river basin and wasteland (Figure 2). Agriculture occupies 1573 km^2 (about 76% of the land use), residential areas include 206 km^2 (10%) and industrial areas include 30 km^2 (1.5%) of the plain. Twenty-year annual average rainfall (1992-2012) in mountainous areas is 633.7 mm and in the plain areas is 345 mm. Also, 50-year (1962-2012) average river discharge is 249 m^3/s. The annual average temperature is 24-24.6 ° C. Annual evaporation rate in Dezful is 2524 mm and is estimated at 2510 mm in Dezful dam hydrometric station.

Khuzestan province is faced with 2471 million cubic meters(MCM)cumulative deficit of groundwater reservoirsby the end of 2017and has 13critical plains for groundwater abstraction (Noroozi, 2018). Dezful-Andimeshk plain was facing water resources shortages and 75 MCM annual deficit of groundwater reservoir to the end of 2012because of overexploitation of groundwater aquifer, its semi-arid nature and high evaporation rate(Sazeh Ab, 2013). Traditional irrigated-agriculture and gardening is the most important economic activity in Dezful-Andimeshk plain. The most important crops are wheat, vegetables, and citrus. Total cultivated area in this region is 157300 ha, which consists of 116402 ha of wheat, 31460 ha of vegetables, 4105 ha of citrus and the rest is allocated to other crops. There are 2604 operation wells in the plain, 2016 of which pump 337 MCM per year for agricultural purposes and 558 operation wells pump more than 88 MCM per year for residential and industrial uses.

The direction of groundwater flow in the plain is from north and northwest to south and southeast. The highest groundwater head in the northern part of the plain is 140 meters, and the lowest amount is recorded in the southern parts of the plain and is equivalent to 55 meters. Also, the modeling results illustrate that the maximum water table drawdown reaches 21.6 m. This value indicates a 75 MCM groundwater reservoir deficit in this plain. However, overexploitation of Dezful-Andimeshk aquifer has led to GWL drawdown.

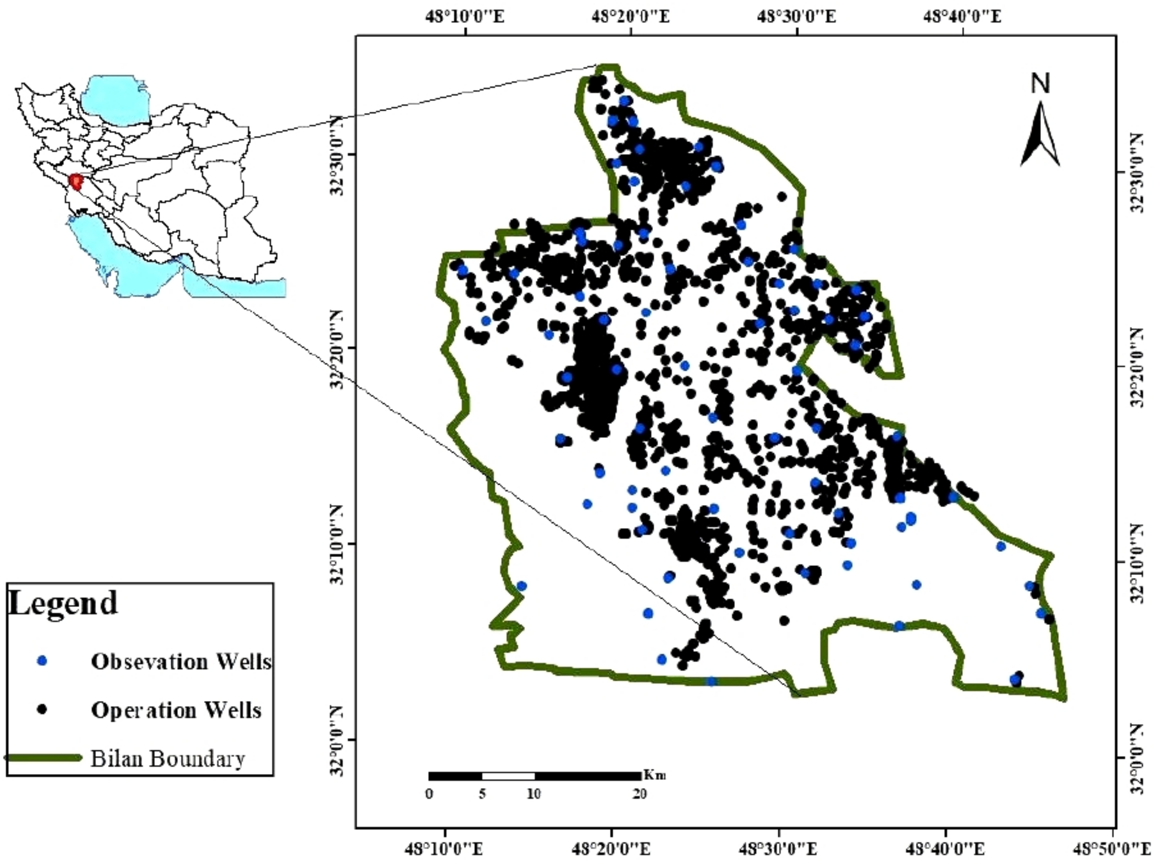

Figure 1: Geographical area of Dezful-Andimeshk basin and operation wells.

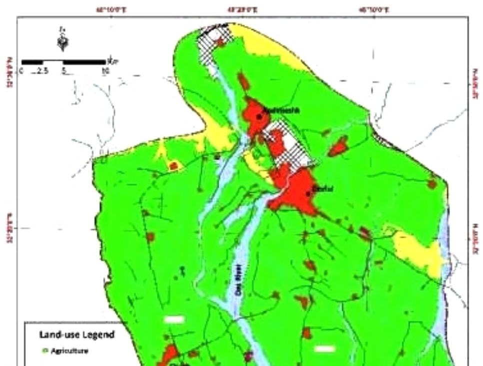

Figure 2: Land use of Dezful-Andimeshk basin(Department of Environment, 2017).

2.2. **Numerical Model**

In order to compare the results of socialist cooperative modeling, the operational wells are simulated with MODFLOW in GMS software. To prepare the flow model of the studied area, seven layers of information are used. This information consists of aquifer boundary (input, output and no-flow), piezometers, operation wells, recharge, drainages and rivers, hydraulic conductivity and evaporation. Observed water-level fluctuations are used from 76 piezometers driven in the aquifer. The network has cells of equal size of 500 × 500 m, 138 rows,130 columns and unconfined aquifer type. In total, there are 17940 cells, 8023 of which are active and the rest are inactive. This model is created based on the Iran Water Resources Management data for 2011-2012 water year, calibrated for 3-year period ending to 2012 and validation was performed over a 5-year period endingto 2017.

2.3. **Game theory**

What we call a game in game theory is the interaction and mutual relations in which two (or more) persons decide with dependency and mutual connection. In other words, utility, profit, income, welfare and whatever a player follows is not only affected by its efforts and decisions, but also by others' positive/negative attempts and decisions (Tadelis, 2013). The main factor of decision making in game condition is that each player should analyze others' reactions prior to choosing and deciding, and finally make the best decision. This decision should have maximum profit by considering others' reactions (Jhawar et al., 2018).

Cooperative games are those games that players may play for obtaining mutual or multilateral benefits; they do not compete with each other, but agree on some strategies to obtain the most profits in their choice. This agreement, called coalition, can be among all players or some of them. In addition, this agreement should be based on players' motivation and without using any force. In the first step, the cooperative game theory is searching agreements or possible coalitions in a game with their pay-off.

In game theory concept, each game consists of 3 main elements:Players, group of possible strategies, and players' pay-off of choosing a strategy. In the case of present research, in fact, the group of players are the number of wells in the Dezful-Andimeshkbasin that are used for agricultural purposes ($N = \{1,\ 2016\}$), the group of strategies are the well discharges ($S_i = \{0,\ Q_{max}\}$) and the most important issue is the pay-off function that is the net benefit from agriculture. This net benefit is equal to subtraction of the pumping costs of the wells and the income from planting crops. The income is calculated based on the parcel of land dedicated to each crop, the amount of land covered by each well and its discharge, cropyield in the region, and the price of sold products ($Max\ Z = NB = B - C$).

2.4. **Socialist cooperative game**

A game which is based on eco-socialist principal consists of an approximate production function (G). This function is a series of all players' attempts who joined the game. If we denote the amount of work done for each crop with E and total efforts of all players in the game with E^S, then the game production function will be equal to $G(E^S)$. Two main items, x and E, in eco-socialist game are the produced goods and the work done to produce x, respectively. The amount of work done is actually the chosen strategy of player i. In the modeled game, x is equal to the amount of cultivated and irrigated land by well i and E as an attempt and the chosen strategy by each player is the amount of discharge by well i.

Based on the availability of data until 2011 in Dezful-Andimeshk plain, dominated crops are wheat, vegetables and citrus (74%, 20% and 2.6% of the cultivated area). Thus, the system is modeled according to the water demand for each crop in different months and the amounts of crop yield. Actually, each operating-well discharge differs from the others.

According to the above explanations, production functions in this game will be equal to the sum of all players' attempts to obtain the desired pay-off. This function is defined as an agricultural profit. The profit function in this issue is agricultural production net benefit in the area which will be equal to the income of selling products after deduction of the costs of pumping for irrigating the crops.

$$G(E^S) = \sum_{i=1}^{2016} E^i = Max\ Z = \sum_{i=1}^{2016} B_i - \sum_{i=1}^{2016} C_i = B - C \tag{1}$$

where, Z is net benefit of cultivation in the area (USD), B is income of agricultural products, (USD) and C is the water pumping cost (USD). The model constraints are represented by Eqs. (2) to (5) (Karamouz et al., 2010):

$$B - C = \sum_{i=1}^{2016} \sum_{p=1}^{3} [A_i p * T_p \eta_p] - \left[\frac{9.8 * 10^6}{3600 * \eta_{po}} * \sum_{i=1}^{2016} Q_{ip} * H_i * T_{(pow)i} * h_{(pow)i} \right] \tag{2}$$

where, A_{ip} is cultivated area (ha) of crop p due to the discharge from well i, T_p is price of crop p (USD), η_p is yield of crop p (kg/ha), η_{po} is well pumping efficiency, Q_{ip} is water discharge allocated to crop p from well i (m^3/year), H_i is aquifer water table (m) after pumping in well i, $T_{(pow)i}$ is price of electricity (USD/kWh) spent on pumping from well i and $h_{(pow)i}$ is pump's operating hours (h) from well i.

In Eq. (2), the yield of each crop is calculated as:

$$\eta_p = \eta_m ax * (1 - Ky_p * \left(1 - \frac{Q_{ip}}{D_{ip}}\right)) \tag{3}$$

where, $\eta_m ax$ is maximum yield of crop p (kg/ha) in the plain under ideal conditions, Ky_p is crop sensitivity coefficient in the region according to crop growth periods and D_{ip} is total water demand of crop p (MCM), which is given by Eq. (4):

$$D_{ip} = A_{ip} * q_{ip} \tag{4}$$

where, A_{ip} is area under crop p and irrigated by well i, and q_{ip} is consumptive use of crop p which will be provided by well i. The consumptive use is obtained by actual evaporation and transpiration of the plant in each region or is calculated by empirical equations. Also we should know the pumping height or water table height after pumping:

$$H_i = H_{int} + H_{pump} + \Delta H \tag{5}$$

where, H_{int} is initial water table height in well i before pumping (m), H_{pump} is height of pump location (m) and ΔH is changes in aquifer water table in each well (m). ΔH is a function of aquifer volume changes of water inflow and outflow.

As mentioned before, the G function is created by the players' attempts and is measured with performance unit. So, if the personal total attempts of all the players in the game are defined as E^S, the production function is equal to $G(E^S)$. In addition, the output allocation for those players who play under distinguished allocation law is $X(E,\ G)$, which is dependent on attempts and production functions of all players. This rule is defined as a vector with real distinguished values like $X = (X^1, \ldots, X^n)$. Finally, the allocation rule for each player is equal to $X^i(E^1, \ldots, E^n, G)$ that creates the output value of all players. So, without any type of allocation, we will have the following production function (Roemer, 2014):

$$\sum_{\gamma} X^{\gamma}(E^1, \dots, E^n, G) \equiv G(E^S) \tag{6}$$

Allocation rule in quota conditions leads to making a stock vector for each player, which is defined as:

$$X^{\gamma}(E, G) = \theta^{\gamma}(E, G)\; G(E^S) \tag{7}$$

According to this rule, each player has a share in the production function. This ratio can be defined in line with the target community. The sharing concept is created based on part of the total attempts, which means that ratio of each player's stock is equal to the per player attempt to all the attempts in the game. This sharing is known as the proportional rule:

$$\theta^{\gamma,pr}(E^1, \dots, E^n) = \frac{E^{\gamma}}{E^S} \tag{8}$$

where, E^{γ} is the amount of player i's attempt due to his/her chosen strategy and E^S is all players' attempts due to this strategy.

These kinds of sharing are fair for having parts of the entire profit function, because each player will benefit in accordance with his/her attempts and the performance in the system. This style of modeling considers consumers as responsible people in the society which are attentive to their decisions. Self-image, as a social responsibility, internalizes the correct choice of each player by comparing real behavior of a person to the ideal internal behavior. So, it must be remembered that achieving the balance of an eco-socialist system, whether it's symmetrical or not, is an efficient Pareto (Brekke et al., 2013).

3. Results and Discussion

Results of the calibrated groundwater model for groundwater head and water table drawdown are illustrated in Figures. 3*A* and *B*, respectively.

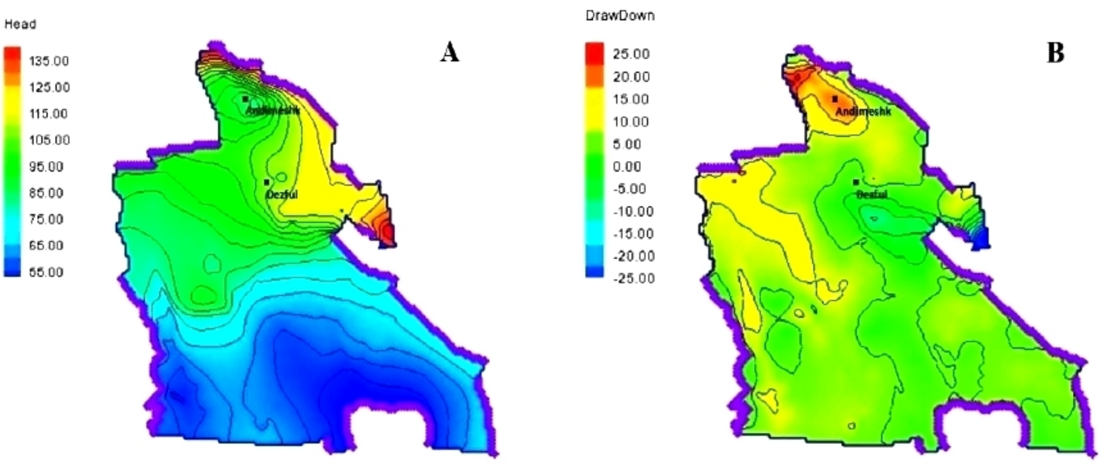

Figure 3: Aquifer model in water year 2011-2012:A) Head andB) Drawdown

The modeling resultsillustrate that maximum drawdown reaches 21.6 m in cell number 2636 in the 21^{st} raw and 36^{th} column, in the northern parts of the plain. Total water table drawdown throughout the plain in the 8023 activated cells is 1265.41 m.This value indicates 75 MCM groundwater reservoir deficit in this plain. A summary of groundwater balance calculations, which is the GMS output, is given in Table 1. Moreover, the net benefit from agricultural activities (842.85 USD per ha) is based on the data in 2012 for the price and yield of agricultural products, as well as the cost of pumping in this year.

Table 1: Groundwater flow budget(2011-2012).

Groundwater balance (MCM)		
Sources/Sinks	flow in	flow out
Constant heads	61.745	-13.122
Drains		-654
Wells		-434
Evapotranspiration		-12.85
Recharge	967.98	
Rivers	19.924	-11.448
Total Sources/Sinks	1049.649	-1125.42
Reservoir volume change	-75.771	

The total water demand for the plain is contingent on an existing cropping pattern and its water demand. Based on the conducted research studies, average irrigation efficiency is 30.5% in the Khuzestan province (Abbasi et al. 2016). Water demand is calculated based on environmental conditions and rainfall amount and distribution. In the water year 2012, net water demand of wheat in Khuzestan province was 2300 m^3/ha, citrus water demand was about 9200m^3/haand average demand for vegetables was 30000m^3/ha.

It should be mentioned that about 70% of crops'water demand in Dezful-Andimeshk plainis fulfilled from surface irrigation networks by Dez and Karkhehrivers. So, about 30% of agriculturalwater needs will be provided by the aquifer. Due to the water demand of the 3 main crops, total water demand that is provided by the aquifer is almost equal to total aquifer discharge for agricultural uses. So, in the predicted model, the amount of water withdrawal from all wells is kept constant and just well sharing is changed based on the mentioned proportions.This sharing is calculated based on the effort levelsthat each well has from all the utilityfunctions. This effort is water discharge, and water discharge for each well is proportionalto the cultivated land to that well, crop water demand and crop yield. To put is simply, each well is allowed to discharge the amount of water that can irrigate the target land:

$$\theta^{i,pr}(E^i) = \frac{E^i}{E^S} = \frac{q_i}{Q_T} = \frac{A_i * \eta_p * q_d}{\sum A_i * \eta_p * q_d} \tag{9}$$

where, A_i is cultivation area for well i (ha), η_p is crop yield (ton/ha) and q_d is crop water demand (m^3/year). Water demand depends on evaporation and transpiration in each region.

In the first state, we assumed that the same crop(wheat) is grown across the plain, and the issue is considered homogeneous. So, sharing ratio is summarized as:

$$\theta^{i,pr}(E^i) = \frac{E^i}{E^S} = \frac{q_i}{Q_T} = \frac{A_i}{\sum A_i} \tag{10}$$

It is clear that each well will share due to the parts of the farm which irrigates the crops. The solved problem shows that the water level in Dezful-Andimeshk plain improves up to 61% and reaches a maximum of 5.43 m. So, groundwater reservoir deficitdecreases to 32 MCM. But, at the same time its agricultural benefit will decrease by 73%.Therefore, this cannot be an optimum economic model.

In the second state (as a real condition), wheat, vegetables, and citrus are grown in the plain. In this case, due to different crop yield and water demand, the issue is heterogeneous. According to the reported valuesof water demand and crop yield in Dezful plain, these values are summarized in Table 2.

Table 2: The water demand ratio and crop yieldratio with respect to wheat.

Crop	Net water demand (m^3/year)	Water demand ratio	Crop yield	Yield ratio
Wheat	2300	1	2603	1
Vegetables	30000	13	14741	5.66
Citrus	9200	4	14437	5.54

As a result, sharing is written as follows:

$$\theta^{i,pr}(E^i) = \frac{E^i}{E^S} = \frac{q_i}{Q_T} = \frac{A_i^W * \eta_p^W * q_d^W}{\sum A_i * \eta_p * q_d} + \frac{A_i^V * \eta_p^V * q_d^V}{\sum A_i * \eta_p * q_d} + \frac{A_i^C * \eta_p^C * q_d^C}{\sum A_i * \eta_p * q_d} \tag{11}$$

According to the obtained ratios in Table 1,Eq. (11) can be rewritten as:

$$\theta^{i,pr}(E^i) = \frac{E^i}{E^S} = \frac{q_i}{Q_T} = \frac{A_i^W * \eta_p^W * q_d^W}{\sum A_i * \eta_p * q_d} + \frac{A_i^V * 5.66\eta_p^W * 13q_d^W}{\sum A_i * \eta_p * q_d} + \frac{A_i^C * 5.54\eta_p^W * 4q_d^W}{\sum A_i * \eta_p * q_d} \tag{12}$$

Therefore, $\theta^{i,pr}(E^i)$ will be 0.0045 for wheat, 0.33 for vegetables and 0.13 for citrus.

The dischargeratio for each well is calculated based on the above amounts and the well's area under cultivation. In this state, the issue is modeled as heterogeneous. According to the obtainedresults by socialist game theory that leads to changes in water allocation of operationalwells, MODFLOW model has been run in the GMS software and its results are shown in Figure 4. It should be mentioned that hydrogeological aspects such as water balance between rivers and aquifer, rainfall infiltration, evaporation and transpiration, general hydraulic conditions and aquifer discharge thru drainageare fixed and just operational wells' discharge and return water is changed in the model.

The results show that with the created model, and in order to have sustainable groundwater reservoir, the total drawdown in the aquifer decreases by about 23% and becomes 1004 m in the plain. As can be seen in Figure 4, maximum drawdown in the northern areas of the plain has reached 17.2 m, which is a 21% decrease, as compared to the same number in the current situation (21.6 m).

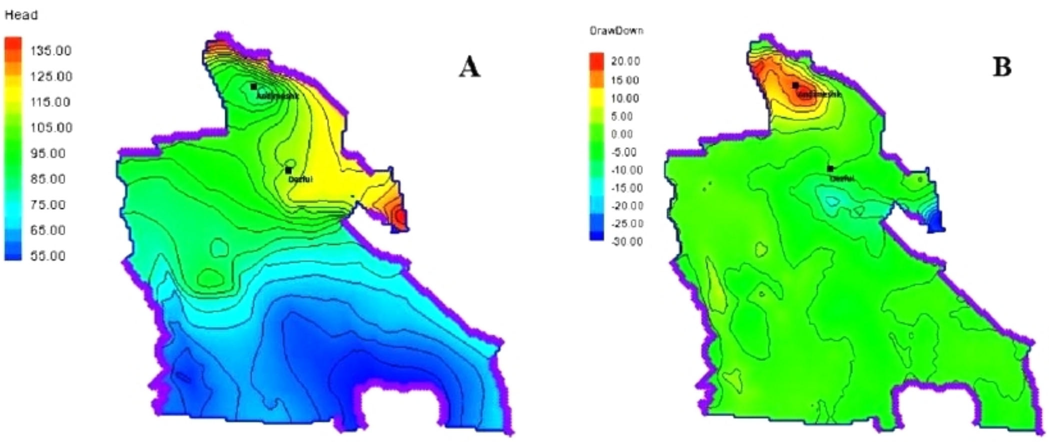

Figure 4: Aquifer status in socialist equilibrium operation mode; A) Head and B) Drawdown

As a result of this decrease in groundwater level drawdown, 16 MCM, equal to 20.6%,of the groundwater reservoir deficit of Dezful-Andimeshk aquifer will be saved. The summary of groundwater balance (GMS output) based on eco-socialist sharing is illustrated in Table 3. Also the net benefit of agriculture with price,crop yield and energy cost in 2012 has increased by 26% and 1061.9USD/ha.

Table 3: Groundwater flow budgetbased on eco-socialism proportion.

Groundwater balance (MCM)		
Sources/Sinks	flow in	flow out
Constant heads	64.165	-15.392
Drains		-668.455
Wells		-434
Evapotranspiration		-71.487
Recharge	1002.928	
Rivers	67.066	-4.400
Total Sources/Sinks	1173.805	-1233.149
Reservoir volume changes	-59.377	

4. Conclusion

In this study, aquifer management inDezful-Andimeshk plain has been revised for the national plan of groundwater resources revival. Thisrehabilitationwas done by developing anenvironmental-economic cooperative model,under the socialist game theory, to decrease the water table drawdown,compensate part of the groundwater reservoir deficit, in addition to increase the economic efficiency. The intended factor in this research is the withdrawal by operational wells and their effects on equilibrium water table drawdown. At first, net benefit under current conditions was calculated by simulating plain conditions in cost-benefit equations of agriculture. In this economic state,the net benefit was equal to842.85 USD per ha.Then, it was assumed that if we grow only wheat in the whole plain (a homogenous state), despite the 61% reduction of water table drawdown, this model was not considered optimal because agricultural net benefit was reduced by 73%. But, in the heterogeneous state,which is close to the real conditions, wells' withdrawal is related to the cultivation area, crop yield and crop price. In this case, vegetables and citrus yields are 5.66 and 5.54 times more than wheat and theirwater demandsare 13 and 4 times more than wheat, respectively. In this status, water table drawdown was decreased by 21%,16 MCM of groundwater reservoir deficitwas compensated, and agricultural net profit was increased by 26%. Therefore, natural resources sharing in a socialist way as an economic-environmental model can be considered as an optimal policy for creating aquifer and environment stability.Although developing cooperation among players can lead to better results, in the meantime, some of them may seek considerable personal gain and disrupt the coalition. Therefore, it suggested that by enacting legal laws and implementing some financial penalties, as a guarantee of this cooperation, the way to achieve the desired goals will be smoother.

References

[1] F. Abbasi, F. Sohrab and N. Abbasi, *Irrigation efficiency and its temporal and spatial variations in Iran*, Institute of Agricultural Engineering and Engineering Research, 3rd edition, 2016.

[2] D. D. Agostino, M. Borg, S. H. Hallett, R. S. Sakrabani, A. Thompson, L. Papadimitriou and J. W. Knox, *Multi-stakeholder analysis to improve agricultural water management policy and practice in Malta*, Agricultural Water Management, January 2019, 105920, https://doi.org/10.1016/j.agwat.2019.105920.

[3] A. Y. Ahmad and M. A. Al-Ghouti, *Approaches to achieve sustainable use and management of groundwater resources in Qatar: A review*, Groundwater for Sustainable Development, 2020, 100367, https://doi.org/10.1016/j.gsd.2020.100367.

[4] D. L. Badiu, D. A. Onose, M. R. Niță and R. Lafortezza, *From "red" to "green"? A look into the evolution of green spaces in a post-socialist city*, Landscape and Urban Planning, 187 (2019) 156-164, https://doi.org/10.1016/j.landurbplan.2018.07.015.

[5] A. Barua, *Water diplomacy as an approach to regional cooperation in South Asia: A case from the Brahmaputra basin*, Journal of Hydrology, 567 (2018) 60-70, https://doi.org/10.1016/j.jhydrol.2018.09.056.

[6] Behkar, *Semi-detailed hydrogeology studies of Dezful-Andimeshk groundwater*, Abe Ahwaz Consulting Engineers, 2017.

[7] M. Bergius, T. A. Benjaminsen, F. Maganga and H. Buhaug, *Green economy, degradation narratives, and land-use conflicts in Tanzania*, World Development, 129 (2019) 104850. https://doi.org/10.1016/j.worlddev.2019.104850.

[8] E. Boughariou, N. Allouche, I. Jmal, N. Mokadem, B. Ayed, S. Hajji, H. Khanfir, S. Bouri, *Modeling aquifer behaviour under climate change and high consumption: Case study of the Sfax region, southeast Tunisia,* Journal of African Earth Sciences, 141 (2018) 118-129, https://doi.org/10.1016/j.jafrearsci.2018.02.006.

[9] S. Bowles and H. Gintis, *A Cooperative Species: Human Reciprocity and Its Evolution*, Princeton University Press, New Jersey, ISBN: 0691151253, 9780691151250, 2011, https://www.sciencedirect.com/science/article/abs/pii/S0047272701002225, K. An economic model of moral motivation, Journal of Public Economics, 87(9-10) (2013) 1967-1983, https://doi.org/10.2139/ssrn.260583.

[10] B. Conant, C. E. Robinson, M. J. Hinton and H. A. J. Russell,*A framework for conceptualizing groundwater-surface water interactions and identifying potential impacts on water quality, water quantity and ecosystems*, Journal of Hydrology, 574(January 2019) 609-627, https://doi.org/10.1016/j.jhydrol.2019.04.050.

[11] T. Dekel, *Mobilization against "agricultural terrorism" and the political-economy of agriculture in Israel*, Journal of Rural Studies, 72 (2019) 37-44, https://doi.org/10.1016/j.jrurstud.2019.10.018.

[12] V. Djokić, J. R. Trajković, D. Furundžić, V. Krstič, D. Stojiljkovič,*Urban garden as lived space: Informal gardening practices and dwelling culture in socialist and post-socialist Belgrade*, Urban Forestry & Urban Greening, 30 (2018) 247-259, https://doi.org/10.1016/j.ufug.2017.05.014.

[13] E. Delbourg and S. Dinar, *The globalization of virtual water flows?: Explaining trade patterns of a scarce resource*, World Development, 131 (2020) 104917, https://doi.org/10.1016/j.worlddev.2020.104917.

[14] Department of Environment, *Studies on pollution sources, prevention and reduction of Dezful aquifer pollution*, Geology and hydrogeology of Dezful-Andimeshk aquifer, 4 (2017) 19 p.

[15] J. Elster,*On seeing and being seen*, Social Choice and Welfare, 49 (2017) 721-734, https://doi.org/10.1007/s00355-017-1029-9.

[16] FAO, *AQUASTAT country profile of Iran (Islamic Republic of)*, FAO, Rome, Italy, version 2016.

[17] S. Ghadimi and H. Ketabchi, *Possibility of cooperative management in groundwater resources using an evolutionary hydro-economic simulation-optimization model*, Journal of Hydrology, 578(January 2019) 124094, https://doi.org/10.1016/j.jhydrol.2019.124094.

[18] S. Jhawar, S. Agarwaal, T. Oberoi, T. Sharma and A. Thakkar, *Application of game theory in water resource management*, International Journal of Advance Research and Development, 3(10) (2018) 63-68, Corpus ID: 198926567.

[19] X. Jia, D. Hou, L. Wang, D. O'Connor and J. Luo, *The development of groundwater research in the past 40 years: A burgeoning trend in groundwater depletion and sustainable management*, Journal of Hydrology, 587 (2019) 125006, https://doi.org/10.1016/j.jhydrol.2020.125006.

[20] M. Karamouz, B. Zahraie, R. Kerachian and A. Eslami, *Crop pattern and conjunctive use management: A case study*, Irrigation and Drainage, 59(2) (2010) 161-173, https://doi.org/10.1002/ird.457.

[21] M. Li, Q. Fu, V. P. Singh, D. Liu, T. Li and Y. Zhou, *Managing agricultural water and land resources with tradeoff between economic, environmental, and social considerations: A multi-objective non-linear optimization model under uncertainty*, Agricultural Systems, 178(600), 2020, https://doi.org/10.1016/j.agsy.2019.102685.

[22] M. Löwy, *Ecosocialism A Radical Alternative to Capitalist Catastrophe,* Haymarket Book, ISBN: 978-1-60846-471-5, 2015.

[23] M. Löwy, *Why eco-socialism: For a red-green future*, Ecological Economics, 158 (2018) 88-100, https://greattransition.org/publication/why-ecosocialism-red-green-future.

[24] K. Madani, *Game theory and water resources*, Journal of Hydrology, 381(3-4) (2010) 225-238, https://doi.org/10.1016/j.jhydrol.2009.11.045.

[25] R. Meinzen-Dick, M. A. Janssen, S. Kandikuppa, R. Chaturvedi, K. Rao and S. Theis, *Playing games to save water: Collective action games for groundwater management in Andhra Pradesh, India*, World Development, 107 (2018) 40-53, https://doi.org/10.1016/j.worlddev.2018.02.006.

[26] J. D. Michler, *Agriculture in the process of development: A micro-perspective*, World Development, 129 (2020) 104888, https://doi.org/10.1016/j.worlddev.2020.104888.

[27] M. Mohammadpour and A. Bagheri, *Common pool water resources management considering a regulator inter-*

ference: A game theory approach to derive managerial policies for Urmia Lake, Iran, In Lakes and Reservoirs: Research and Management, 22(1)(2017)85-94, https://doi.org/10.1111/lre.12158.

[28] J. D. Moreno-Ternero and J. E. Roemer,*A common ground for resource and welfare egalitarianism*, Games and Economic Behavior, 75(2) (2013) 832-841., https://doi.org/10.1016/j.geb.2012.03.005.

[29] A. A. Noroozi, *Ministry of Jihad-e-Agriculture. Land cover characterization of Iran*, Data set, Soil Conservation & Watershed Management Research Institute (SCWMRI), Ministry of Jihad-e-Agriculture, Islamic Republic of Iran, 2018.

[30] M. V. Podimata and P. C. Yannopoulos, *Evolution of Game Theory Application in Irrigation Systems*, Agriculture and Agricultural Science Procedia, 4 (2015) 271-281, https://doi.org/10.1016/j.aaspro.2015.03.031.

[31] J. E. Roemer, *Kantian optimization: A microfoundation for cooperative behavior*, Journal of Public Economics, 127 (2014) 45-57, http://dx.doi.org/10.1016/j.jpubeco.2014.03.011.

[32] J. E. Roemer, *A theory of cooperation in games with an application to market socialism*, Review of Social Economy, 77(1) (2019) 1-28, https://doi.org/10.1080/00346764.2018.1555647

[33] I. Sabzzadeh and M. Shourian, *Maximizing crops yield net bene fit in a groundwater-irrigated plain constrained to aquifer stable depletion using a coupled PSO-SWAT- MODFLOW hydro-agronomic model*, Journal of Cleaner Production, 262 (2020) 121349, https://doi.org/10.1016/j.jclepro.2020.121349.

[34] Sazeh Ab Shafagh Consulting Engineers. *The Compiling Plan of Research and Water-Resource (Surface & GW) Atlas Preparation of Karkheh River Basin*, Statistics, Information and Preliminary Survey, Sazeh Ab Shafagh Consulting Engineers Reports, Tehran, Iran, 3, 2013.

[35] A. Shankland and E. Gon alves, *Imagining Agricultural Development in South-South Cooperation: The Contestation and Transformation of ProSAVANA*, World Development, 81 (2017) 35-46, https://doi.org/10.1016/j.worlddev.2016.01.002.

[36] S. Tadelis, *Game Theory: An Introduction*, Princeton University Press; 1, 2013, pp.15-17, ISBN-13: 978-0691129082.

[37] M. Tomasello, *A natural history of human thinking*, Journal of Social Ontology, 2(1) (2016)59-64, https://doi.org/10.1515/jso-2015-0041.

[38] A. Vatn, *Institutions for sustainability-Towards an expanded research program for ecological economics*, Ecological Economics, 168 (2020) 106507, https://doi.org/10.1016/j.ecolecon.2019.106507.

[39] World Bank, *Water Resources Management*, 2017, https://www.worldbank.org/en/topic/waterresourcesmanagement.

[40] A. Zarei, S. F. Mousavi, M. EshaghiGordji and H. Karami, *Optimal reservoir operation using bat and particle swarm algorithm and game theory based on optimal water allocation among consumers*, Water Resources Management, 33 (2019) 3071-309, https://doi.org/10.1007/s11269-019-02286-9.

[41] Y. Zeng, J. Li, y. Cai, Q. Tan and C. Dai, *A hybrid game theory and mathematical programming model for solving trans-boundary water conflicts*, Journal of Hydrology, 570 (2018) 666-681.

[42] Y. Zhang, W. Chen and Y. Mi, *Third-party remanufacturing mode selection for competitive closed-loop supply chain based on evolutionary game theory*, Journal of Cleaner Production, 263 (2020) 121305, https://doi.org/10.1016/j.jclepro.2020.121305.