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Provincial Water Resource Allocation in Agricultural Sector using Conflict Resolution Methods in Atrak Basin

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Introduction: In spite of improving the water productivity due to development in water infrastructure systems, population increasing causing the water withdrawal is triple in the last fifty years. In this situation competition on water consumption especially in the agricultural sector which is the biggest consumer in the world and also in Iran is a severe problem. Water allocation has been assessed widely in the recent past. Additionally, several studies have explored methods to incorporate conflict resolution methods in water allocation. In a general classification, there are two types of methods. One is the method based on game theory, graph theory and general models based oncooperative game into a category that has the ability to consider the stakeholder preferences and assess the several scenarios under specified policy. Although this type of methods iseligible to cooperate the stakeholder in modeling but due to their weakness on considering the information on details and their limitations in adoption with changes caused from uncertainty, they are not popular in practical cases. Another type of conflict resolution method which is eligible to considering more detailed information of systems has the optimization approach basically, has the most interests between researchers. There is namely the Nash bargaining solution, the Kalai-Smorodinesky solution, the Equal loss solution and the area monotonic solution. There are several studies which areapplied these methods to investigate about groundwater (5, 6 and10). There are a few applications of water resource allocation models which is incorporated with conflict resolution methods in Transboundary Rivers nowadays and restricted to game theory related methods (1 and 2). The aim of this study is the assessment of the application of conflict resolution methods such as symmetric and non symmetric Nash solution, non symmetricKalai-Smorodinesky, non symmetric equal loss solution and finally the area monotonic solution in water allocation between beneficiary's provinces in Atrak basin. The performances of these methods are compared with each other and also with the common water allocation model.

Materials and Methods: In the last decades, Atrak river basin located at the eastern north of Iran, shared between three provinces; Razavi Khorasan, northern Khorasan and Golestan, has a tense conflict between upstream and downstream beneficiaries. It is predictable that this conflict will be more tense in the near future due to development of upstream and increasing the water withdrawal. Because of the venial role of the Razavi Khorasan province in the Atrak basin, this province is considered as a coalition with northern Khorasan. Related data for 41 years time series and other information were gathered. Due to Hydrology studies, wet and dry periods in the two regions have not differences. As a fact that the main problem of water allocation belongs to the agricultural sector and it is the biggest consumer in the region, supply of the municipal, industrial and environmental requirement is assumed.To begin, a linear programming model is developed to optimize the agricultural water resource allocation using the LINGO® which is a comprehensive tool designed to make building and solving Linear, Nonlinear (convex &nonconvex/Global), Quadratic, Quadratically Constrained, Second Order Cone, Stochastic, and Integer optimization models faster, easier and more efficient. In the second place, conflict resolution methods such as symmetric Nash, non symmetric Nash, Kalai-Smorodinsky, equal loss, uniform area solutions are applied as an object function of water allocation models one by one. In all of these methods the stakeholder preferences should be defined with their weights in the object function. Moreover, the mentioned models are assessed with performance criteria such as reliability in time and in volume and also the resiliency.

Results and Discussion: Comparison of the results of 4 water allocation models using conflict resolution methods besides the common water allocation model using LP is shown in the figure 3 which shows the differences between models in mean of Agricultural water deficit in both provinces separately.

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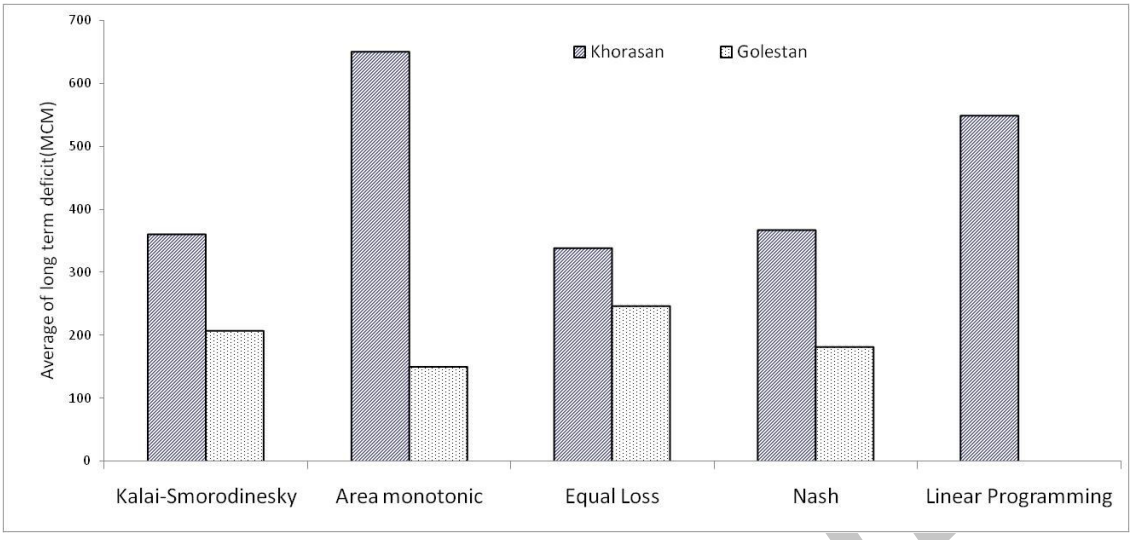

Figure 3- Mean of long term of agricultural deficit in different models

As mentioned before water allocation models are evaluated with performance criteria and the result is revealed in the table3.

Table 3- Comparison of conflict resolution models using the performance criteria

	Reliability in time (%)			Reliability in volume (%)			Resiliency (%)		
	Golestan	Khorasan	Total	Golestan	Khorasan	Total	Golestan	Khorasan	Total
LP	100	20	26	100	31	55	100	18	23
Nash	41	34	36	57	54	55	38	33	42
Kalai	32	37	29	50	54	53	25	38	31
Loss	12	39	34	41	57	52	11	40	37
Area	59	12	8	64	17	34	41	14	9

It is clear that models which have the Nash, Kalai-Smorodinesky, Equal Loss, Area Monotonic solution as the object function produce an equitable allocation between two stakeholders in comparing with the LP.

Conclusion: Without better management in agricultural water in the future which is treated by increasing population and changing the climate, growing conflicts between stakeholders are expected. In this study application of conflict resolution methods in water allocation models in Atrak basin is considered. Comparison of models in terms of their performance to allocate water equitably between two beneficiary provinces is appraised. Results revealed that the conflict resolution methods have the same action in water allocation in general though; the Nash has desirable results than others. All the conflict resolution models have the better performance in general in comparison with the common water allocation model using the linear programming. To conclude, the dependencies of results to provinces weights are appraised. Application of conflict resolution methods are proposed instead of common water allocation models without stakeholder's preference consideration due to water allocation between several stakeholders equitably.

Keywords: Conflict resolutions, Optimization, Water allocation

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