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Development and Application of a Planning Support System to Assess Strategies Related to Land and Water Resources for Adaptation to Climate Change

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ABSTRACT

In this study, development of a planning support system (PSS) was studied as a tool to support the planners for analyzing and choosing the best policy instruments in order to adapt to climate change. In order to carry out this study, different methods for regenerating the time series of climatic variables were assessed and finally, a comprehensive weather generator model was developed which was capable in regeneration of statistical characteristics and also spatial correlation between neighboring stations. After downscaling the monthly outputs of GCM models using the Inverse Distance Weighting (IDW) method, the developed weather generator model was used to generate daily time series for the base and climate change scenarios. In order to simulate the *Taleghan* reservoir daily inflow using the data fusion method, the outputs of the best Artificial Neural Networks and Hammerstein-Wiener models were used and the reservoir daily inflow was simulated under climate change scenarios. The results confirmed the decrease of mean daily inflow in almost all the months. PSS biophysical input coefficients were estimated using the DSSAT crop simulation models under all climate scenarios for 24 land units. The potential production of all studied crops could vary between 86% and 122% of the potential productions in the base scenario. Also, it was revealed that the net irrigation requirement of the crops will decrease by 12% on average. The main goal of the PSS was to maximize the total net income of the entire area. Analyzing the management scenarios using the planning model showed that the best option for climate change adaptation will be the combination of all the instruments in one management scenario. Also, it was concluded that the reduction of interest rate and using two different water prices for surface and pressurized irrigation systems could be the best management scenarios after the combination scenario.

Keywords: Planning support system, climate change, adaptation strategies, management scenarios, DSSAT models, Iran.

1. INTORUDCTION

Agriculture is one of the most important sectors of Iran's economy. A major part of national employment and large share of areas and water demands are related to this sector. More than 17 million hectares of country area are allocated for agriculture and nearly 94% of water demand of the country is consumed by agriculture (Alizadeh and Keshavarz, 2005). Agriculture of Iran supplies required foods for more than 70 million inhabitants. One of the most critical challenges before country's agriculture is using available resources sustainably in order to improve production and living standards. For now, Iran imports a major part of its strategic crops requirements (like wheat, rice, potato, oil seeds and sugar beet). Socially and economically, increasing gross domestic agricultural productions and improving self-sufficiency level is among government's strategic objectives. Current production level of most crops is considerably lower than their potential levels because of limitations of production technologies, water allocation strategies and government policies (Farhadi Bansouleh, 2009).

Despite of vast experiences in global and national planning, designing a planning support system (PSS), which is able to use available data and combine biophysical and socio-economic information in a planning and policy making process, didn't receive enough attention. Taking recent progresses in geo-information technologies into consideration, using regional average values of crop productions or personal judgments in a planning process is not a proper and efficient practice since spatial variations of these values are not taken into consideration and there is possibility for making an unrealistic plan. Therefore, it is necessary to develop a system to combine biophysical and socio-economic information from smaller scales into much larger scales. Such a system can support planning and policy making in agriculture and can also be a basis for analysis at different scales and enables discussion between different stakeholders.

Reviewing the studies on planning process and also the studies in the field of climate changes reveals that these two topics have been seldom addressed together. Taking climate change impacts into consideration in planning process and also assessing and developing strategies in agricultural sectors can results in a better understanding of future climate change impacts on this important sector of economy. Hence, in this study, a spatial planning support system is used to develop and assess some policy instruments for adaptation to climate change in Qazvin irrigation and drainage network which is located near central part of Iran. This system makes use of available biophysical and socio-economic information from different spatial scales.

2. MATERIALS AND METHODS

2.1 Study Area

Study area includes Qazvin irrigation and drainage network, which is located in Qazvin province of Iran (35^{o}-30' to 36 ^{o}-40'N and 49^{o}-10' to 50^{o}-40'E). This area is one of the most important agricultural producing areas in the country. Wheat, barley, corn and tomato are the major irrigated crops cultivated in the area. The whole area of the network has been reported 85000 ha (Ramezani Etedali, 2012) and 20-25% of the whole area is kept fallow each year. The agricultural water requirement of this network is mainly supplied from *Taleghan* reservoir with total capacity of 450 MCM. According to the design plan of this reservoir, 278 MCM is supposed to be allocated to agriculture, 20 MCM to artificial recharge of groundwater resources, 150 MCM to domestic demands of Tehran city and 12 MCM to downstream environmental requirements.

2.2 Model Structure

The first stage is to describe the characteristics of Land Utilization Types (LUT). Each LUT is a unique combination of cropping scenarios (crop + planting date + irrigation regime) and irrigation methods (surface or pressurized). Afterward, combining LUTs and Land Units (LUs) results in Land Management Units (LMUs). Next, a planning model is developed for the entire study area in LINGO. Since the farmers are mostly market-oriented in this region, total net income is selected as the goal function of the planning (optimization) process. Decision variables include allocated area to each MLU and also some variables related to *Taleghan* reservoir operation (environmental release) (Figure 1). Each constraint represents the limitation of activities at a specific scale. For instance, limitations on groundwater usage have been considered at the LU level, while limitations on the allocated area to each crop have been considered at the global scale (*i.e.* the entire irrigation and drainage network).

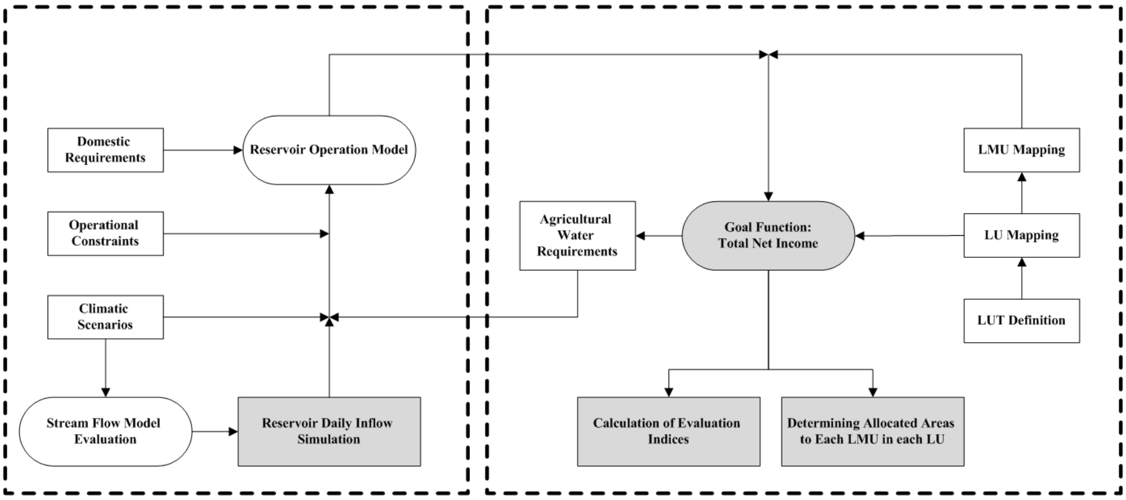

Figure 1. Developed planning model and its reservoir operation sub-model.

2.3 Model Implementation

2.3.1. Estimation of Biophysical Coefficients

Biophysical input-output coefficients (crop yield, water requirement, and nutrient losses) of the model have been generated by spatial application of crop growth simulation models. In this process, DSSAT (Jones *et al.*, 1989, 1994, 2003;

Hoogenboom *et al.*, 2003) models were used. DSSA models were calibrated using available field data for wheat (Golkar, 1998), barley (Farhadi Bansouleh, 1998), corn (Mirlatifi and Sotoudehnia, 2002) and tomato (Farahmand, 2004) as the major cultivated crops in the study area. PEST (Doherty *et al*., 1995) was used to find the target unknown crop parameters to achieve the minimum value of an error function. For silage maize, corn and soybean, ecotype and cultivar coefficients were selected in a way that DSSAT models were capable in simulating (1) reported average yields, (2) seasonal evapotranspiration and number of required irrigation reported by the Ministry of Jihad Agriculture, and (3) The reported growing lengths in the study area.

DSSAT models were run in 24 LUs. These LUs were mapped by overlaying soil maps and weather grid. Daily weather data of four neighboring climatic stations were used and the weather grid was drawn using Thiessen's method. Growth of different crops has been simulated using DSSAT models for 100 years, but only 21 years of these simulations were used as inputs to the PSS (because of computer memory limitations while running LINGO for a very large problem). The potential biophysical coefficients were then scaled into actual values using production efficiency (PE) values. This efficiency values were determined using the method proposed by Nazari (2013) based on the estimation of crop yield for each part of the farm according to assumed distribution uniformity values.

2.3.2. **Estimation of Socio-Economic Coefficients**

Socio-economical coefficients included the water price (per unit volume), production costs and yield price (main yield and by-products) for each studied crop and labor requirements for the production of each studied crop. All required information was obtained from the Ministries of Agriculture and Power, and the Center of Statistics.

2.3.3. **Weather Generator Models**

Simulation of daily climatic time series is the most important and usual application of Weather Generators (WGs). Sensitivity analysis of crop simulation models revealed that the use of the regional daily average temperature values results in the overestimation of crop production. Therefore, the accurate simulation of crop production requires synthetic data which can mimic the daily variations of climatic variables (Ababaei *et al*., 2010b; Nonhebel, 1994; Semenov and Porter, 1995; Semenov *et al.*, 1998). In current study, six different WG models were assessed, among them a newly proposed semi-parametric algorithm proposed by Ababaei (2012). The best WG model in the study area was selected according to well-known error statistics. This model combines a daily WG model with a monthly WG to better reproduce interannual variations of climatic variables. Also, a correction algorithm is also incorporated into this model to improve the performance of the WG models in relation to the interannual variances (low-frequency variances). Comprehensive explanation of these models can be found in Ababaei (2012). After choosing the best WG model in the study area, a newly proposed algorithm was developed which was capable in preserving spatial correlation between neighboring stations. This algorithm uses an extended Markov model for precipitation occurrence simulation and a semi-parametric algorithm for other climatic variables.

2.3.4. Climate Change Scenarios

In order to describe climate change scenarios (IPCC Emission Scenarios, SRES), the monthly outputs of 25 general circulation models (GCMs) were extracted from PCMDI database for all climate change scenarios (CCSs). The CCSs include 20c3m (twentieth century scenario as the base scenario), Commit (CM), A1b, A2 and B1 (Nakicenovic *et al*,. 2000). The means and standard deviations of monthly mean values were calculated for all scenarios for the periods 1980-1999 (base) and 2040-2069 (CCSs). Two kinds of changes (anomalies) relative to the base scenario were studied: (1) changes in the mean of monthly means and (2) changes in the standard deviation of monthly means (*i.e.* interannual standard deviation). Absolute changes (Eq. 1) were used to calculate temperature anomalies and the relative changes (Eq. 2) for precipitation. Eq. (2) was also used to calculate the anomalies of the interannual standard deviations:

Eq. 1) $\Delta T = T_{GCM,S} - T_{GCM,B}$ Eq. 2) $\Delta V = V_{GCM,S} / V_{GCM,B}$

Where *T*: average temperature means, *V*: mean or standard deviation of precipitation, *S* index: simulated CCS by specific GCM model and *B*: simulated base scenario by the same GCM model. Inverse Distance Weighting (IDW) method was used for removing the discontinuity between the adjacent stations. In this method, the value of desired variable in the target point is calculated by weighted averaging the values in the K nearest GCM grids. The CCSs were classified into five classes. The first class includes all CCSs together (All). The other classes each include one climate change scenario (CM, A1B, A2, and B1). In each class, the anomalies were calculated for 50% percentiles as the CCS representative.

2.3.5. Reservoir Daily Inflow Simulation

In the recent years, Artificial Neural Networks (ANNs) have been widely applied to simulate and forecast the hydrological variables (Ababaei *et al.*, 2012; Razavi and Araghinejad, 2009; Razavi and Karamouz, 2007). In this study, a new type of black-box models, Hammerstein-Wiener models, were also assessed for the first time in hydrologic simulations and for the simulation of *Taleghan* reservoir daily inflows. This structure has been successfully used in order to simulate nonlinear systems in different fields of science (Ceka *et al.*, 2000; Eskinat *et al.*, 1991; Kalafatis *et al.*, 1995; Pearson and Pottmann, 2000), but not in hydrology. Models were tested using available historic data on *Taleghan* reservoir daily inflows. Then, the selected models were also assessed with a 100-year synthetic daily data from a weather generator model.

Data Fusion (DF) is the process of combining information from multiple sensors or data sources to provide a solution to increase accuracy or make more inferences (Dasarathy, 1997). DF method could significantly improve hydrological forecast in comparison with the use of a single model (See and Abrahart, 2001; Abrahart and See, 2002; Shu and Burn, 2004; Azmi *et al.*, 2010).

2.3.6. Constraints

As the planning model is actually an optimization algorithm, it is subjected to several constraints. These constraints were applied on the area allocated to each crop in each LU, maximum fallow area in the study area, underground water balance, maximum volume of water allocated for groundwater recharge, and constraints related to the reservoir operation, including the constraints issued by the domestic water requirements. Each of these constraints was taken into consideration at its relevant scale.

2.4 Adaptation Strategies

The general framework for policy assessment in agriculture and land use sectors is presented in Figure 2. Sometimes the objectives of policy makers are different than the farmers. So, it is necessary to use policy instruments to change farmers' behaviors and eventually to change land uses. In this study, the farmers' responses to a few policy instruments were simulated by the proposed PSS. Proper indices (economic, social and environmental) were estimated to assess the impacts of each instrument using a multi-criteria analysis. Seven management (adaptation) strategies were assessed: (BS) the current management (base management scenario), (S1) expansion of pressurized irrigation systems across the study area, (S2) decreasing bank loan interests for pressurized irrigation systems, (S3) using two different water price for surface and pressurized irrigation systems, (S4) increasing supply and distribution efficiencies of canal networks and also increasing water application efficiencies for surface irrigation (by 5%) and (S5) a combination of all other strategies and (S6) a combination of all other strategies with a 50% cut in domestic water demand from *Taleghan* reservoir

Economic, social and environmental indices must be selected according to the objectives of policy makers in agricultural sector. A list of indices can be found in (Farhadi, 2009; Ababaei, 2012). The division of these indices is quite subjective. For example, employment could be considered as a social or economic index.

The selected assessment indices in the current study from the economic viewpoint are presented in Table 1. From social or environmental point of views, the weight of 0.6 will be allocated to the social or environmental general objectives, respectively, and the overall weight of each index is calculated by multiplying the weights of general objectives, sub-objectives and indices. Some indices were just estimated as informative indices and didn't influence the ranking of the scenarios.

As these indices have different units and magnitudes, before comparing them to each other, they must be standardized. In relation with the benefit indices, the standardization was carried out in a way that the highest score was allocated to the index with the highest value. As to the cost indices, this was done in a way that the lowest score was allocated to the index with the highest value. In this study, two different methods were used: (1) Maximum standardization (Eq. 4), and (2) Exponential standardization (Eq. 5):

Eq. 4) $$Benefit: XS_i = W_i \times \frac{X_i}{Max(X)} \qquad Cost: XS_i = W_i \times \frac{1/X_i}{Max(1/X)}$$

Eq. 5) $$Benefit: XS_i = W_i \times e^{\frac{X_i}{Max(X)}} \qquad Cost: XS_i = W_i \times e^{\frac{-X_i}{Max(X)}}$$

Where, W_i: the allocated weight to the ith index, X_i: non-standard value of *i*th index and XS_i: standardized value of *i*th index.

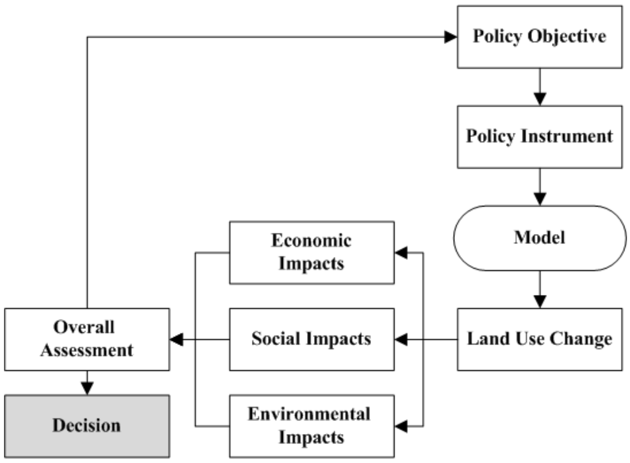

Figure 2. Land use policy development flowchart (Sharifi, 2003).

Table 1. Selected indices for policy assessment (from economic viewpoint).

General Objectives		Sub-Objectives		Indices		Overall Weight
Economic	**0.60**	Total Income	0.30	Total Net Income	1.00	0.1800
				Total Gross Income	0.00	0.0000
		Total Costs	0.20	Total Crop Costs	0.70	0.0840
				Pressurized Irrigation System Costs	0.30	0.0360
		Crop Production	0.30	Total Agricultural Production	0.35	0.0630
				Strategic Crop Production	0.25	0.0450
				Wheat Production	0.20	0.0360
				Silage Maze Production	0.10	0.0180
				Barley Production	0.10	0.0180
		Economic Productivity	0.20	Water Economic Productivity	0.50	0.0600
				Land Economic Productivity	0.25	0.0300
				Labor Economic Productivity	0.25	0.0300
Social	**0.20**	Total Employment	0.60	Total Employment	1.00	0.1200
		Regional Production Self-Sufficiency	0.35	Production per Labor	1.00	0.0700
		Pressurized Irrigation Area	0.05	Pressurized Irrigation Area	1.00	0.0100
Environmental	**0.20**	Water Use	0.60	Total Water Use	0.00	0.0000
				Total Surface Water Use	0.00	0.0000
				Total Groundwater Use	0.00	0.0000
				Total Agricultural Water Demand	0.50	0.0600
				Agricultural Surface Water Demand	0.25	0.0300
				Agricultural Groundwater Demand	0.25	0.0300
		Chemical Fertilizers	0.40	Total Nitrogen Fertilizers	0.25	0.0200
				Total Phosphorus Fertilizers	0.25	0.0200
				Nitrogen Leaching	0.50	0.0400
		Artificial Groundwater Recharge	0.00	Artificial Groundwater Recharge	0.00	0.0000

3. RESULTS AND DISCUSSION

3.1 Crop Model Calibration

The results showed that these crop simulation models were very capable in simulating total biomass, yield and straw (by-product) production. Specifically, the model performances were favorable in simulating nearly-full irrigation scenarios. SRMSE values for barley treatments of 50-100% of crop water requirements were 5.5, 10.9 and 3.6% for yield, straw and total biomass production, respectively. These values were 7.3, 5.1 and 5.9% for wheat treatments of 40-110% of crop water requirements which can be considered as very accurate. For tomato, SRSME and R^2 values were 10% and 98%, respectively, for fresh yield. Without considering two specific treatments with high error values, these values were estimated 6% and 5.3%, respectively.

3.2 Reservoir Daily Inflow under Climate Change Scenarios

Two different strategies of data fusion were tested for daily inflow simulation of *Taleghan* Reservoir (Ababaei *et al*., 2013). Four artificial neural network models beside two Hammerstein-Wiener models with the best specifications were used as individual simulation models. The results showed that the data fusion method has the capacity to improve substantially the results of individual simulation models and to decrease the bandwidth of errors (Ababaei *et al.*, 2013). The best data fusion algorithm predicted increase of the monthly means only for October. The predicted maximum decreases were in the monthly means 18 (November), 20 (July), 14 (November) and 14% (November) under A1B, A2, B1 and CM scenarios. The mean decreases of the monthly mean inflows under A1B, A2, B1 and CM scenarios were predicted 9, 10, 6 and 5% (AL2), respectively, and 7.4% under all CCSs together (Ababaei *et al.*, 2013).

3.3 Estimation of Biophysical Coefficients

Model biophysical input-output coefficients (crop yield, water requirement, and nutrient losses) have been generated by spatial application of crop growth simulation models. The results revealed that crop yields under different climatic scenarios vary between 86-122% of the yield values in the base period. Crop responses are different under different climate change scenarios. Net irrigation requirements of the studied crops generally decrease under climate change scenarios. The average value of these decreases is expected to be about 12%. Altogether, crop yields and net irrigation requirements showed considerable temporal and spatial variations.

3.4 PSS Validation

In order to validate the accuracy of the developed planning model, it was run for 21 years and then results were compared with the available historic data. Cultivated area of each crop varied between 70-100% of the values in current situation. It can be seen from Figure 3 that if all constraints are taken into consideration for all 10-day simulation periods, it is not possible to cultivate the whole study area without some crops undergoing water stresses (specifically corn and silage maize).

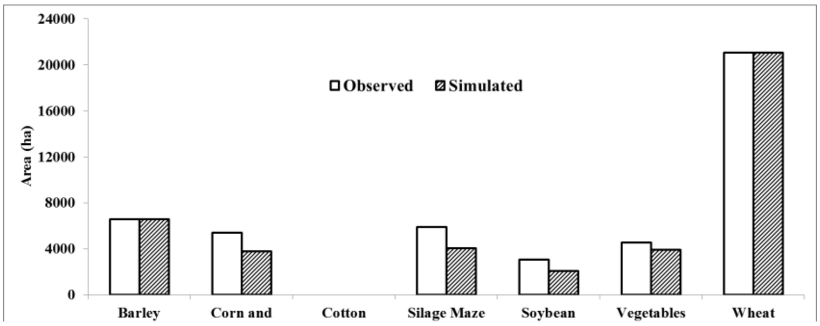

Figure 3. Simulated and observed areas allocated to crop production.

The volumes of water withdrawn from surface (reservoir) and groundwater resources were shown in Figure 4. A part of the differences between simulated and observed volumes from surface resources is related to the withdrawn volumes of water from local rivers which are not considered in the planning model. R^2 value between observed (monthly average) and simulated values is about 95% and between the observed values with the reliance probability of 80% and the simulated values is about 94%.

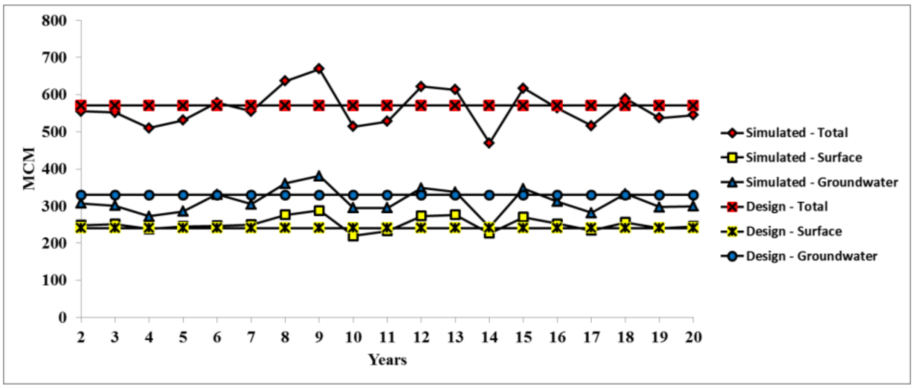

Figure 4. Volume of surface and underground water withdrawn.

3.5 Assessing Adaptation Strategies

Finally, the proposed and validated PSS was used to assess a few feasible strategies for adaptation to climate change. The S6 scenario was assessed just under climate change scenarios excluding the Commit scenario and was not considered in the final comparison. Overall scores of each adaptation scenario are presented in Table 2 toTable 4 besides the scores of each general objective independently. The results show that different adaptation strategies could have reciprocal impacts. It is also concluded that some combinations of these strategies may not be the optimum practice (for example from social or environmental viewpoints). Nonetheless, under all climatic scenarios, the combination of all strategies results in the best economical outcomes, although there are sometimes insignificant differences between S2 and S3 scenarios and the combination scenario (S5).

Table 2. Overall and individual scores of economic, social and environmental objectives (Base Scenario).

	Maximum Standardization						Exponential Standardization					
Management Scenarios	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**
Overall: Economic	0.89	0.91	0.92	0.90	0.94	0.95	1.83	1.92	1.94	1.90	1.92	1.97
Overall: Social	0.89	0.94	0.95	0.95	0.92	0.98	1.99	2.10	2.12	2.12	2.06	2.17
Overall: Environmental	0.85	0.90	0.91	0.91	0.91	0.97	1.14	1.21	1.22	1.21	1.20	1.26
Economic Objectives	0.92	0.89	0.91	0.88	0.96	0.92	2.10	2.18	2.22	2.14	2.20	2.24
Social Objectives	0.90	0.97	0.98	0.99	0.93	1.00	2.49	2.64	2.66	2.68	2.57	2.72
Environmental Objectives	0.82	0.87	0.89	0.90	0.88	0.98	0.37	0.41	0.41	0.42	0.41	0.45

Table 3. Overall and individual scores of economic, social and environmental objectives (A1B Scenario).

	Maximum Standardization							Exponential Standardization						
Management Scenarios	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Overall: Economic	0.80	0.82	0.85	0.82	0.84	0.88	0.89	1.65	1.75	1.80	1.74	1.72	1.83	1.95
Overall: Social	0.79	0.83	0.87	0.85	0.82	0.90	0.92	1.79	1.89	1.95	1.91	1.83	1.99	2.13
Overall: Environmental	0.79	0.82	0.86	0.83	0.84	0.93	0.84	1.06	1.12	1.16	1.13	1.10	1.20	1.22
Economic Objectives	0.81	0.81	0.83	0.80	0.86	0.84	0.89	1.87	2.00	2.03	1.97	1.97	2.06	2.22
Social Objectives	0.79	0.85	0.88	0.87	0.80	0.90	0.98	2.22	2.35	2.43	2.39	2.25	2.47	2.67
Environmental Objectives	0.78	0.81	0.87	0.84	0.84	0.97	0.78	0.39	0.42	0.45	0.43	0.43	0.48	0.41

Table 4. Overall and individual scores of economic, social and environmental objectives (All Scenarios).

	Maximum Standardization						Exponential Standardization					
Management Scenarios	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**
Overall: Economic	0.85	0.88	0.91	0.89	0.89	0.94	1.74	1.89	1.95	1.90	1.83	1.97
Overall: Social	0.83	0.91	0.95	0.94	0.87	0.97	1.89	2.06	2.14	2.11	1.96	2.16
Overall: Environmental	0.81	0.87	0.91	0.90	0.86	0.96	1.10	1.19	1.24	1.22	1.15	1.27
Economic Objectives	0.87	0.87	0.90	0.86	0.91	0.90	1.99	2.15	2.21	2.13	2.09	2.23
Social Objectives	0.84	0.94	0.98	0.98	0.87	1.00	2.36	2.58	2.68	2.66	2.44	2.71
Environmental Objectives	0.78	0.85	0.89	0.88	0.84	0.97	0.38	0.41	0.43	0.43	0.41	0.47

Uncertainty analysis (The planning support system proposed for study area helped to assess policy instruments and management scenarios in Qazvin irrigation and drainage network by combining available information from different resources with different formats.

) revealed that the final ranking of the studied scenarios is not sensitive to the allocated weights of the selected indices, since even by considering 50% of uncertainty (error) in these weight values, S5 scenario is always selected as the best management scenario and S2 and S3 scenarios come as the second and third.

Table 5. The probability of allocating ranks 1-6 to adaptation strategies due to uncertainty in weight allocations.

Uncertainty	**10%**	**30%**	**50%**

Levels	Rank	Scenarios						Scenarios						Scenarios					
	Rank	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**
Economic Viewpoint	**1**	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100
	2	0	0	100	0	0	0	0	0	100	0	0	0	0	0	95.5	0	4.5	0
	3	0	0	0	75.7	24.3	0	0	0	0	61.4	38.6	0	0	0	4.5	54.7	40.8	0
	4	0	0	0	24.3	75.7	0	0	16.8	0	38.6	44.6	0	0	26.2	0	45.3	28.5	0
	5	0	100	0	0	0	0	0	83.2	0	0	16.8	0	0.1	73.7	0	0	26.2	0
	6	100	0	0	0	0	0	100	0	0	0	0	0	99.9	0.1	0	0	0	0
		Scenarios						Scenarios						Scenarios					
	Rank	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**
Social Viewpoint	**1**	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100
	2	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0
	3	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0
	4	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0
	5	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0
	6	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0
		Scenarios						Scenarios						Scenarios					
	Rank	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**	**BS**	**S1**	**S2**	**S3**	**S4**	**S5**
Environmental Viewpoint	**1**	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100
	2	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0
	3	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0
	4	0	100	0	0	0	0	0	100	0	0	0	0	0	98.3	0	0	1.7	0
	5	0	0	0	0	100	0	0	0	0	0	100	0	0	1.7	0	0	98.3	0
	6	100	0	0	0	0	0	100	0	0	0	0	0	100	0	0	0	0	0

4. CONCLUSION

The planning support system proposed for study area helped to assess policy instruments and management scenarios in Qazvin irrigation and drainage network by combining available information from different resources with different formats.

Spatial and temporal variations of biophysical potentials and their impacts on potential production and required production inputs were taken into consideration in this model. Application of crop simulation models for estimating potential yields and determining crop irrigation requirements in each land unit is one of the advantages on this study. Determining and mapping analysis units is a critical step in combining biophysical and socio-economic information because different data come from different spatial scales. The analysis unit in this study was Land Management Units (MLUs) which were mapped with the combination of Land Utilization Types (LUTs) and Land Units (LUs). These units are homogeneous from the socio-economic and biophysical viewpoints.

In policy assessment, biophysical and socio-economic information were used to simulate farmers' responses. Biophysical information can be used in each LU to simulated potential crop yields or crop yields under deficit irrigation. Since crop simulation models don't take the impacts of applied management into consideration, in this study, the concept of Production Efficiency (PE) was used to change potential biophysical coefficients into actual coefficients in each LMU.

The main objective of this planning model was the maximization of total net income in the study area. Since the relative importance of different objectives is different between beneficiary sectors, weighting the objectives was done from three different viewpoints: economic, social and environmental. But, it is better to consult all beneficiary sectors while determining these weight values. Four climate change scenarios were assessed besides the base scenario. The inclusion of these scenarios showed the wide uncertainty range of climate change scenarios. Although similar management scenarios were selected for all climatic scenarios, but the evaluation indices have different values under each climatic scenario.

In this study, a multi-criteria evaluation technique was used to assess proposed policy instruments and management scenarios from different viewpoints. The most critical issue is the selecting of indices and determining their relative importance (*i.e.* weights). It can be expected that policy makers and other beneficiary sectors know exactly the weights of different objectives (indices) before doing the analysis. Therefore, the uncertainty analysis was performed to assess the impacts of this kind of uncertainties on the selection of the best adaptation scenarios.

The results of this study showed that it is possible to incorporate a policy-making process with climate change impact assessment studies using a planning support system. This leads to a better understanding of the integrated system taking into consideration temporal and spatial variations of biophysical potentials under different climatic scenarios.

5. REFERENCES

Ababaei, B. 2012. Development and application of a planning support system to assess strategies related to land and water resources for adaptation to climate change. PhD Dissertation, University of Tehran, 327 pp (in Farsi).

Ababaei, B, Mirzaei, F., Sohrabi T. M. and Araghinejad S. 2013. Reservoir Daily Inflow Simulation using Data Fusion Method. Journal of Irrigation and Drainage. DOI: 10.1002/ird.1740.

Ababaei, B., Sohrabi T.M., Mirzaei F, Araghinejad, S., and Ahmadizadeh, M. (2012) Suitability of different neural networks in daily reservoir inflow simulation. The First International Conference on Dams and Hydropower in Iran, Tehran. Feb. 8-9, 2012.

Abrahart, R.J., and See, L. 2002. Multi-model data fusion for river flow forecasting: en evaluation of six alternative methods based on two contrasting catchments. Hydrology and Earth System Sciences. 6(4): 655-670.

Alizadeh, A., and Keshavarz, A. 2005. Status of agricultural water use in Iran. Water Conservation, Reuse, and Recycling: Proceedings of an Iranian- American Workshop. The National Academic Press, Washington D.C., USA, pp. 94-105.

Azmi, M., Araghinejad, S., and Kholghi, M. 2010. Multi-model data fusion for hydrological forecasting using K-nearest neighbor method. Iranian Journal of Science and Technology, Transaction B, Engineering. 34(B1): 81-92.

Doherty, J., Brebber, L., and Whyte, P. 1995. PEST: Model Independent Parameter Estimation. Australian Centre for Tropical Freshwater Research, James Cooke University, Townsville, Australia, 140 pp.

Eskinat, E., Johnson, S.H., and Luybean, W.L. 1991. Use of Hammerstein models in identification of nonlinear systems. AICHE Journal. 37(2): 255-268.

Farahmand, A. 2004. Assessing the impacts of different irrigation and nitrogen fertilizer application on quantity and quality of tomato yield under deficit irrigation and determination of production function. M. Sc. Thesis, University of Tehran.

Farhadi Bansouleh, B. 1998. Effects of deficit Irrigation on yield (production) of barley in Karaj region and determination of production function. M. Sc. Thesis, University of Tehran.

Farhadi Bansouleh, B. 2009. Development of a spatial planning support system for agricultural policy formulation related to land and water resources in Borkhar & Meymeh district, Iran. Ph.D Dissertation. International Institute for Geo-information Science & Earth Observation (ITC), Enschede, the Netherlands.

Golkar Hamzei Yazd, H. 1998. Determination of wheat production function and assessing the impacts of water stress on wheat yield in Karaj region, Iran. M.Sc. Thesis, University of Tehran.

Hoogenboom, G., Jones, J.W., Porter, C.H., Wilkens, P.W., Boote, K.J., Batchelor, W.D., Hunt, L.A. and Tsuji, G.Y. 2003. Decision Support System for Agrotechnology Transfer Version 4.0. Volume 1: Overview. University of Hawaii, Honolulu, HI.

Jones, J. W., K. J. Boote, G. Hoogenboom, S. S. Jagtap, and Wilkerson, G.G. 1989. SOYGRO V5.42, Soybean Crop Growth Simulation Model. User's Guide. Fl. Agric. Exp. Sta., Journal No. 8304. Univ. of Florida, Gainesville. 53 pp.

Jones, J.W., Hoogenboom, G., Porter, C.H., Boote, K.J., Batchelor, W.D., Hunt, L.A., Wilkens, P.W, Singh, U., Gijsman, A.J., and Ritchie, J.T. 2003. The DSSAT cropping system model. Europ. J. Agronomy 18: 235-265.

Jones, J.W., Hunt, L.A., Hoogenboom, G., Godwin, D.C., Singh, U., Tsuji, G.Y., Pickering, N.B., Thornton, P.K., Bowen, W.T., Boote, K.. J., and Ritchie, J.T., 1994. Input and output files. In: Tsuji, G.Y., Uehara, G., Balas, S. (Eds.), Decision Support System for Agrotechnology Transfer (DSSAT) Version 3, vol. 2. University of Hawaii, Honolulu, HI, pp. 1-94.

Kalafatis, A.D., Arifin, N., Wang, L., and Cluett, W.R. 1995. A new approach to the identification of pH processes based on the Wiener model. Chemical Engineering Science. 50(23): 3693-3701.

Mirlatifi, S.M.,and Sotoudehnia, A. 2001. Simulation of deficit irrigation impacts on maize yield. Final Report of Research Project, the Ministry of Power, Iran. 221pp.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., Jung, T.Y., Kram, T., La Rovere, E.L., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, W.H., Price, L., Raihi, K., Roehrl, A., Rogner, H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N. and Dadi, Z., 2000. Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, 599 pp.

Nonhebel, S. 1994. The effects of use of average instead of daily weather data in crop growth simulation models. Agricultural Systems. 44: 377–96.

Pearson, R.K., and Pottmann, M. 2000. Graybox identification of block-oriented nonlinear models. Journal of Process Control. 10: 301-315.

Razavi, S., and Araghinejad, S. 2009. Reservoir Inflow Modeling Using Temporal Neural Networks with Forgetting Factor Approach. Water Resour Manage. 23(1): 39–55.

Razavi, S., and Karamouz, M. 2007. Adaptive neural networks for flood routing in river systems. Water Int 32 (3):360–375.

See, L., Abrahart, R.J. 2001. Multi-model data fusion for hydrological forecasting. Comput. Geosci., 27: 987-994.

Semenov, M.A. and Porter, J.R. 1995. Climatic variability and the modelling of crop yields.Agricultural and Forest Meteorology. 73: 265–83.

Semenov, M.A., Brooks, R.J., Barrow, E.M. and C.W. Richardson. 1998. Comparison of the WGEN and LARS-WG stochastic weather generators for diverse climates. Clim. Res. 10 (2):95–107.

Shahkarami, N., Morid, S., Massah Bavani, A., and Fahmi, H. 2008. Assessing the impact of AOGCM models uncertainty on the risk of agricultural water demand caused by climate change in Zayandeh-Rud irrigataion networks. Iranian Journal of Irrigation and Drainage. 2(2):1-10.

Shu, C., and Burn, D.H. 2004. Artificial neural network ensembles and their application in pooled flood frequency analysis. Water Resour. Res. Vol 40, W09301.