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Assessing the Impacts of Vegetation-Based Management Scenarios on Hydrologic Responses of North Watershed of Iran

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ABSTRACT: Developing an approach for simulating and assessing vegetation-based management and their effects on land use patterns and hydrological processes at the watershed level is essential in land use and water resource planning and management. Purpose of this study is a assessing the impacts of vegetation-based management scenarios on hydrologic responses in Rammian watershed. For this purpose four biological actions were considered including: agro-forestry, tree plantation, fruit tree growing, and terracing. Combination of these four actions leads to 16 (2n) different management scenarios. Input map layers including sub-watersheds boundary, hypsometry, slope, vegetation cover type and density, soil depth, and hydrologic soil groups were prepared and superimposed within the ArcGIS environment in order to specify the spatial distribution of various management activities considering the scenario development rules. Result showed that scenario 5 (Agro-forestry) have greatest impact on reducing the volume of the flood in Rammian watershed. Results showed that the multiple-criteria decision making serves as a valuable tool to represent the watershed system as a whole, to incorporate output from models and expert-judgments to examine the trade-offs among outcomes necessary to decision making.

***Keywords*:** Integrated watershed management, Vegetation-based scenarios, hydrologic responses, Multiple-criteria decision making.

INTRODUCTION

Globally and particularly in developing countries, population growth and increasing demands for food and other goods resulted in inappropriate use of soil and water resources. Conversions of upland forest areas into croplands have led to accelerated soil degradation and the depletion of soil productivity. Flooding, water pollution, and socio-economic welfare problems are the other negative consequences of inappropriate use of soil and water resources.
Land use change can be characterized by the complex interaction of behavioral and structural factors associated with demand, technological capacity, and social relations, which affect both demand and environmental capacity, as well as the nature of the environment in question (Verburg *et al*., 2005). Evaluating the impact of land use change on water and matter fluxes is a major challenge in hydrological research. Changes inland surface properties ultimately modify the energy and water ex-change of the soil–vegetation–atmosphere system. The impacts of land use changes have received considerable attention from ecologists, particularly with respect to effects on aquatic ecosys-tems and biodiversity (Turner *et al*., 1993). A large number of field studies exist where the influence of land use changes (mainly afforestation and deforestation) is investigated in eitherpaired site studies or single catchment experiments (Bosch and Hewlett, 1982)

The complexity of natural resource management is echoed in the integrated assessment and management-related literature (Heathcote, 1998., Letcher, 2002., Pollard, 2002., Jakeman *et al*., 2005). Integrated watershed management is globally accepted as a sound approach for management of water, land, and related resources which takes care of equilibrium between socio-economic demands of watershed inhabitants and ecosystem sustainability.

Through implementing an integrated watershed management approaches all major factors and events influencing water resources are taken into consideration (Pollard, 2002).

Synthesis of problems, driving factors, biophysical and socio-economic perspectives, watershed-dependent communities, data and models of different scales are elements of integrated watershed assessment and management (Jakeman *et al.,* 2005). Detailed understanding and trade-off analysis of results from implementation of different management scenarios at various spatial and temporal scales will improve decision making. Al weshah and El-Khoury (Al-weshah and El-Khoury, 1999) conducted a regional flood analysis using WMS (Watershed Modelling System) model in Jordan and compared three scenarios of forestation, terracing and check-dams construction. They concluded that the forestation is the best scenario which leads to peak discharge reduction as well as total volume discharge reduction up to 70 percent.

MATERIALS AND METHODS

Methodology

Study area

The Ramian watershed, a sub-basin of the Gorganrood River basin, is located in the eastern part of the Golestan province, Iran. It has an area of about 240 km 2and the geographic position lies between 55◦ 02’ - 55◦ 18’ E longitudes and 36◦ 49’ - 37◦ 02’ N latitudes. Elevation ranges from 220 to 2890 m MSL (fig.1)

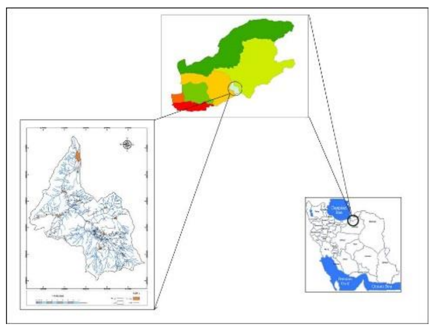

Figure 1. Location of the Ramian watershed in Golestan Province, Iran.Forest is the dominant land cover type in the watershed. However, like most of the Caspian Hyrcanian mixed forest ecoregion, extensive logging and clearing of forests for agriculture are nearly eliminating the forests in this area (Heshmati, 2007). Mean annual precipitation is 898 mm and mean daily temperature is 16.5 oC. According to the de Martonne and Emberger classifications the climate of the study area is humid and cold humid, respectively (Tajiki, 2007)

Considering the high flooding susceptibility of the watershed and socio-economic importance of areas exposed to inundation, flood mitigation measures are necessary to be planned and implemented.

Watershed management using scenario analysis approach

Contrary to mathematical optimization models, scenario-based approaches increase the insight of watershed inhabitants regarding watershed system Scenario-based approaches allow the users to choose different management scenarios and evaluate their possible positive and/or negative outcomes. Using a scenario-based approach in this study is consistent with the intention of supporting decision makers rather than making decision for them (Cain, 2001).. This procedure improves our knowledge about watershed system and its behavior and helps to identify the best management scenario.

Developing of mutually exclusive vegetation-based management scenarios

First the sources of surface runoff and sediment problems over the Ramian watershed system and their relative importance are identified. Then a list of all feasible solutions for mitigation or elimination of these problems is prepared. Maintaining the current condition can sometimes be a solution for a watershed to recover itself through natural evolution particularly once the watershed disturbance is not extended in a large scale (Heathcote, 1998). Furthermore it can be used as a base case scenario to evaluate the other scenarios. After identifying the contemporary management activities in the study area, the possible management actions were defined considering the existing constraints in the watershed. For the Ramian watershed four biological actions were considered including: agro-forestry, tree plantation, fruit tree growing, and terracing. Combination of these four actions leads to 16 (2n) different management scenarios (Table 1).

Table 1. Vegetation-based management scenarios for the Ramian watershed

Scenario	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
terracing	-	+	-	-	-	+	-	-	+	+	-	+	-	+	+	+
tree plantation	-	-	+	-	-	+	+	-	-	-	+	+	+	+	-	+
fruit tree growing	-	-	-	+	-	-	+	+	+	-	-	+	+	-	+	+
agro-forestry	-	-	-	-	+	-	-	+	-	+	+	-	+	+	+	+

It should be mentioned that the management scenarios should be exclusive. In other words, admission of one scenario leads to refusal of other scenarios. Regarding the fact that most croplands of the study area are cultivated with wheat and there is a tendency among the watershed community for establishing fruit trees, a walnut-wheat agro-forestry system has been proposed as an action.

Input map layers including sub-watersheds boundary, hypsometry, slope, vegetation cover type and density, soil depth, and hydrologic soil groups were prepared and superimposed within the ArcGIS environment in order to specify the spatial distribution of various management activities considering the scenario development rules shown in Table 2. In developing the scenarios, 100% of suitable areas for each vegetation-based activity have been allocated for it.

Table 2. Scenario rules for vegetation-based management of the Ramian watershed.

Biological actions	Suitable areas
Agro-forestry	Croplands with slope 30-65% and semi-deep to deep soils
Tree planting	1) barren lands, shallow soils, low density vegetation, slopes less than 60%, elevations up to 1600 m above MSL 2) forests, semi-deep soils, moderate vegetation density, slope less than 60% elevation up to 1600 m above MSL
fruit tree growing	Croplands with slope 30-65 % and semi-deep to deep soils, elevations 1600 -1800 MSL
terracing	Croplands with slope 12-15 % and deep soils

Modeling the hydrologic impacts of vegetation-based scenarios

The SCS model was used to simulate the effects of vegetation cover changes on hydrological characteristics. This method can relate the watershed characteristics to the flow parameters. The Curve Number (CN) is calculated based on hydrologic soil group, antecedent soil moisture condition, and the land use type. The outputs of the model are rainfall excess depth, peak discharge, and time to peak over the watershed with spatial resolution of sub-watershed unit. The initial abstraction and surface runoff depth are calculated with equations 1 and 2, respectively.

$$s = \frac{2540}{CN} - 2.54 \qquad (1)$$

$$R = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (2)$$

Where, S is initial abstraction in mm; CN is curve number; P is rainfall in mm and R is rainfall excess in mm. Peak discharge is calculated with equations 3 and 4.

$$Q_p = \frac{2.083AR}{t_p} \qquad (3)$$

$$t_p = \frac{D}{2} + t_1 \qquad (4)$$

Where, Q_p is peak discharge in m3.s-1. A is watershed area in ha; R is rainfall excess in mm; t_p is time to peak in hour; D is duration of rainfall excess in hour and t l is watershed lag time in hour. The 50 years discharge volume for each sub-watershed was calculated by multiplying the 50 years peak discharge and the respective time to peak.

RESULTS AND DISCUSSION

Results

The SCS model was used to investigate hydrological response to different scenarios of land use management. To achieve this objective, the Curve Number Map (CN) prepared, and then CN weighting of each scenario was calculated (fig.2). CN weighting obtained 77.01 for watershed. CN value of each biological action presented in table (3).

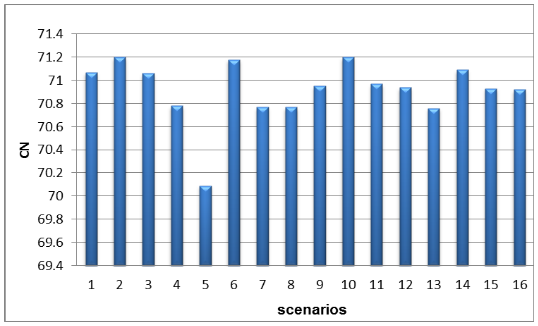

Figure 2. CN weighting of scenarios

Table 3. CN value of each biological action

Biological actions	hydro group		
	B	C	D
terracing	71	78	81
fruit tree growing	64	78	85
Tree planting	60	73	79
Agro-forestry	64	77	

Vaziri method was used to calculate the rainfall Plan. For this purpose, table of rainfall distributed with duration and different return period Based on the average maximum daily rainfall and time of concentration prepared and rainfall plan with return period of 2, 5, 10, 25, 50, 100 and 200 years have been calculated (table 4).

Table 4. rainfall plan of Ramian watershed calculated by Vaziri method

Return period (years)					
2	5	10	25	50	100
46.28	65.04	78.01	94.73	107.14	119.48

The SCS model was used to simulate the effects of vegetation cover changes on hydrological characteristics. Volume flood of the rainfall plan in different return period have been calculated for each scenario (Figure 3).

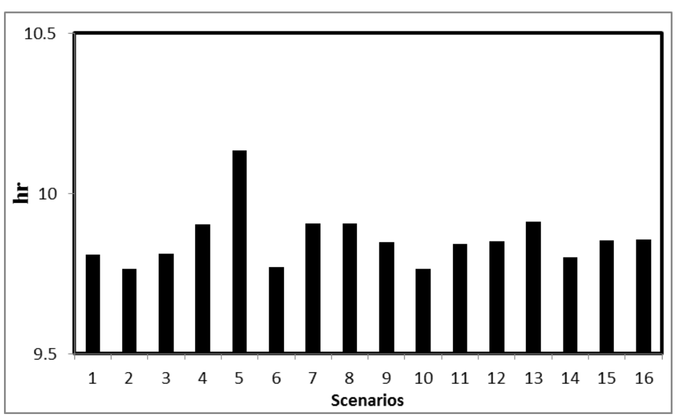

Figure 3. Lag time of each scenario

Result showed that scenario 5 (Agro-forestry) have greatest impact on reducing the volume of the flood in Rammian watershed. Scenarios of 7, 8, 13 and 14 have reducing impact on volume of flood, respectively.

CONCLUSION

In using a scenario-based approach for watershed management, it is necessary to use models which are able to predict the impacts of implementing different scenarios on watershed scale. The results of this study indicate that SCS models are capable of predicting the impacts of vegetation changes on total discharge. In case of encountering a difficulty in identifying a preferred criterion, the best scenario is derived based on the equal weights for all criteria. Trade-off analysis of the results shows that when social criteria are emphasized, in most sub-watersheds scenario 1 gets the highest score followed by scenario 2 (agro-forestry). This indicates that the communities of the Ramian watershed are unwilling to extend forest areas. Choosing criteria depends directly on the national and regional strategies. Therefore, to use the findings of this study, these strategies should be considered. This warranties the feasibility and suitability of the results.

The approach used in this study allows decision makers and/or stakeholders of the Ramian watershed to reach their own conclusions on the basis of their improved understanding of the system and of the trade-offs among various outcomes arising from implementing management scenarios. This approach occurs with the fact that watershed systems are dynamic and complex and it is a difficult task to capture all of the disciplinary components involved in management of natural resources watershed-wide. Result showed that fruit tree growing and Agro-forestry have a special place in people. Because of these actions provide sustenance and income through horticulture and job security. Another reason can be considered that in fruit tree growing and Agro-forestry, peoples are landowner and attempt to maintain their.

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