

Sustainability Assessment and Land Use Priority in an Arid Region: A Case Study

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Abstract: To assess the sustainability and to determine the land use priority of the main irrigated crops in Darab (south-east of Iran), an arid region with water scarcity, growing corn, cotton, wheat and citrus was selected for evaluation as a case study. Seven sustainable indices; water use efficiency, water requirement, economic return, soil erosion, environmental impacts, compatibility to new irrigation systems and labor requirements were used to evaluate the agricultural sustainability and sustainable land use. The effects of cultivation and land use on the sustainable indices were examined. The indices were given a score based on variation increment. Each crop finally received a weight corresponding to the sustainable indices. The results showed that citrus received the highest score of 29, corn a score of 8, wheat a score of 7 and cotton received the lowest score of 3. This study could be an introduction to develop a mathematical model for sustainable land use of the irrigated crops in the region with water scarcity. However, the conclusions of this study cannot be generalized.

Key words: Sustainable development, land use priority, irrigated crop evaluation

According to the World Commission on Environment and Development (1987) sustainable development is the development that meets the needs of the present generation without jeopardizing the ability of future generations to meet their needs. Yark (1993) believes a distinction should be made between sustainability and productivity. Gains in productivity required to achieve in short-term may often not be sustainable, and efforts to achieve sustainability goals must take into account long-term implications and needs. From an agricultural point of view, sustainable development deals with how our natural resources, including water and soil, may be used without jeopardizing needs of the next generation (Chizary and Mirzai, 2000). Many researchers believe that we are compromising the ability of future

generations to meet their food needs by our current misuse of the natural resources on which agriculture depends, particularly in the arid and semi-arid regions. The rapid destruction of forests, depletion and contamination of water supplies, soil erosion, global warming, salinization and water logging are some examples. Ecological systems are being destroyed throughout the world. It is necessary to impose controls to practice sustainable resource management and to protect the environment (Faris and Khan, 1993).

Mollison (1988) and Mollison and Slay (1991) believe that to achieve sustainable environment, first we need to identify and maintain the necessary physicochemical, bioecological, and sociocultural resources. Bastlanoni *et al.* (2001) used emerge analysis introduced by Odum (1988) to obtain

sustainability indicators and to assess the efficiency of complex agricultural system of a farm in the Chianti area (Italy). They concluded that the Chianti farm had good long-term sustainability, considering the low environmental loading ratio of the whole system.

The objective of this study was to evaluate the agricultural sustainability and try to develop an approach to estimate a sustainable agricultural cropland use policy for an arid and semi-arid region with scarce water.

Materials and Methods

The study was carried out in Darab, south-east of Iran, located between 27°, 17' and 29°, 50' north latitude and between 53°, 17' and 44° east longitude in a semi-arid region, 1100 m above sea level with annual precipitation of 264 mm and evapotranspiration of 2700 mm. All cost analysis are based on Iranian official currency (Rials) for the year 1999 (7900 Rials equal to 1 US \$).

The main annual crops of the region are wheat, cotton and corn irrigated with furrow irrigation, and citrus irrigated with drip system. The study area suffers from inadequate water resources. The groundwater is the only source of irrigation and is over exploited. The general tendency of the farmers is to shift from crop cultivation to citrus orchards. This gradual change in land use is carried out by either clearing lands with natural vegetation cover or by swapping with irrigated crop lands. A key question always arises whether this type of land use change is sustainable and how it could be possible to reach an equilibrium

state. Seven indices were used to assess the sustainability of the irrigated land in the region. The agronomic, environmental and social indices included: water-use efficiency (WUE), water requirements, economic returns, compatibility to modern irrigation systems, soil erosion, environmental impacts, and employment capability. The crops studied were wheat, corn, cotton and citrus. The index values were scored and each crop was assigned a weight. The priority for the land use of crops and citrus was determined based on the weights obtained. Net water requirement was determined based on the weights obtained by the Penman-Monteith method modified by FAO in 1993, as CROPWAT computer program (Smith, 1993). Gross water requirement was estimated using 80% irrigation efficiency for drip and 60% for furrow systems (Doorrenbos and Pruitt, 1975; Keller and Bliesner, 1990). Average yield was obtained based on a simple survey of 300 farmers involved with crops and citrus. A simple procedure was used to rank the crops based on their weight of indices (Fig. 1).

To examine the effect of crops on soil erosion and nutrient losses a randomized complete block design experiment with three treatments, each with three replications, was designed. The treatments included 2 x 1.8 m plots covered by wheat crop and plots covered with the corn and cotton residues. Plots were enclosed by a sheet-metal wall. A simulated rainfall was applied at an intensity of 75 mm hr⁻¹ for 10, 15, 20, 25 and 30 minutes. The runoff was collected from plots into separate containers installed at the end of the plots. A number of samples were taken from the containers and analyzed

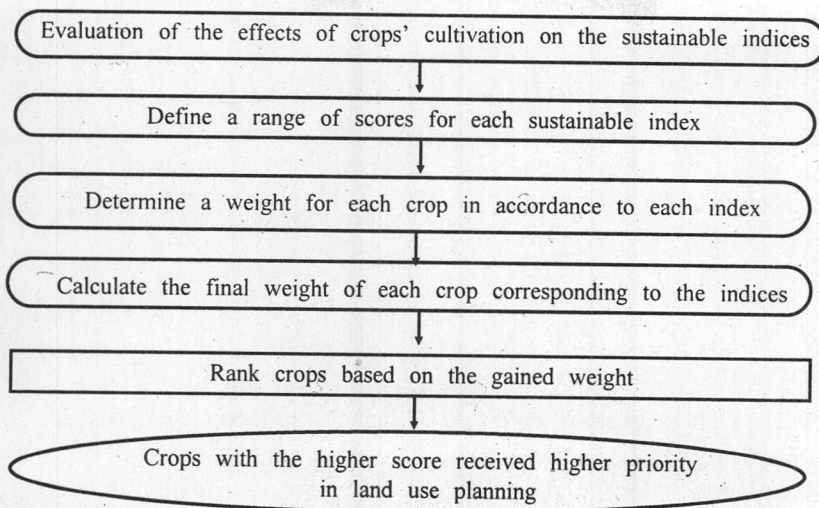


Fig. 1. The procedure used for ranking the crops based on the received weight

in the laboratory. Soil erosion and soil nutrient losses were measured.

Results and Discussion

Water requirement and WUE

Citrus raised with drip irrigation had the highest WUE. The field crops received furrow irrigation and cotton consumed the highest amount of water (Table 1).

In the study region, the limited ground water resources are used for irrigation at an unsustainable rate. The over use of ground water and rapid depletion of aquifers in more than 168 regions of Iran caused annual

decline in water level by 1 m (Keshavarz and Sadeghzadeh, 2000). That is not consistent with the sustainability in the region. Gross water requirements were calculated following Farshi *et al.* (1998) considering the irrigation efficiency of 60% and 80% for furrow and drip systems, respectively. Accordingly, crops consuming less water received higher score. Total water depleted annually from ground water aquifers by citrus and field crops is 620335100 m³.

Compatibility to modern irrigation systems

In Iran, micro-irrigation systems are mainly used for trees and wide spaced plants.

Table 1. Water-use efficiency of citrus, wheat, corn and cotton

Crops	Average yield (kg ha ⁻¹)	Water used (m ³ ha ⁻¹)	WUE (kg m ⁻³)
Citrus	18000	13250	1.36
Wheat	5500	7133	0.77
Corn	7800	11537	0.68
Cotton	2650	18030	0.15

Table 2. Net income per year (economic return) in the study region

Crops	Citrus	Corn	Cotton	Wheat
Average yield (ton ha ⁻¹)	18	7.9	2.65	5.5
Unit price (Rials ton ⁻¹)	1200000	8000000	22500000	770000
Gross income (Rials)	19767198	6261760	5984260	4256760
Production cost (Rials ha ⁻¹)	80477457	3287998	5232535	2998553
Net income (Rials ha ⁻¹)	11719451	2973762	751725	1258207

Although, corn and cotton could also be irrigated with micro-irrigation systems, these systems are not yet adapted for these crops. However, wheat crop is cultivated intensively, but drip-irrigation is not feasible and economically viable for this crop. Based on the compatibility to new irrigation systems a weight was given to each crop as shown in Table 7.

Total production cost including the capital cost and the annual operational costs with the annual interest rate of 20% was calculated. The net economic return was obtained by subtracting the total production cost from the total gross income. Results are summarized in Table 2. The priority of land use base is denoted to the crops with the higher economic returns.

Soil erosion control

Soil erosion affects soil productivity by changing soil properties, particularly destroying topsoil structure, reducing infiltration, increasing runoff and washing away plant nutrients such as nitrogen,

phosphorous and organic matter. Frager *et al.*, (2000) believe larger canopy, larger root structure and higher vegetation cover of crops reduce soil erosion considerably. Citrus with the large canopy throughout the year and with the large root system and minimum tillage requirement prevents soil erosion to some extent.

The soil erosion from wheat plots, because of good vegetation cover, is less than that from the other plots (Table 3). On the other hand, erosion from plots having cotton residue is much more than that from plots having wheat and corn residue. The designed rainfall simulator could not work in citrus plots due to the large canopy and dykes around the trees. However, the large root structure, the large canopy and dykes around the citrus prevent runoff and soil erosion. The nutrients and organic matter losses from plots having cotton residue were highest compared to plots having corn residue, and wheat plants were more effective than the corn residues and cotton and corn residue plots, respectively

Table 3. Soil erosion (kg ha⁻¹) from different land use plots with 75 mm hr⁻¹ artificial rainfall

Treatments	Duration (minutes)					Average erosion
	10	15	20	25	30	
Wheat plant plot	69.3 ^{a*}	119.5 ^a	136.5 ^a	176.5 ^a	212.1 ^a	142.78
Corn residue plots	58.7 ^b	96.8 ^b	167.5 ^b	237.2 ^b	290.6 ^b	170.16
Cotton residue plots	144.1 ^c	235.4 ^c	495.9 ^c	595.9 ^c	768.6 ^c	447.98

* Single letters show significant difference at P<= 0.05 on Duncan test.

Table 4. Nutrients and organic matter losses by runoff from different landuse (kg ha⁻¹)

Different land use	Rainall duration minutes							
	N		P		K		Organic matter	
	15	30	15	30	15	30	15	30
Wheat plant plots	0.01	0.015	0.001	0.002	0.039	0.067	0.12	0.19
Corn residue plots	0.019	0.054	0.002	0.006	0.021	0.063	0.19	0.58
Cotton residue plots	0.029	0.084	0.003	0.007	0.06	0.137	0.033	0.87

(Table 4). Crops were scored according to their effects on erosion as shown in Tables 5 and 6. Considering the adverse impacts of soil erosion on sustainability, a negative weight was given to each crop and citrus corresponding to the extent of erosion that resulted from the experiment.

2000) as shown in Table 7. Based on a field survey of 300 farmers the amounts of fertilizers used currently with a specified percentage of net nutrients were determined. The results are shown in Table 8. The amount of herbicides and pesticides currently used was also determined (Table 8). Based on

Table 5. The required net nutrients supplied by the commercial fertilizers in terms of weight percentage of production

Crop	N (%)	P (%)	K (%)
Wheat	2.80	0.30	1.8
Corn	3.05	0.33	2.4
Cotton	3.30	0.50	2.9
Citrus	3.00	0.22	1.6

Environmental impacts

Overuse of chemicals for higher yields is very common in the experimental region, which is not conducive for sustainability. To examine the extent of excess use of fertilizers and other chemical pollutants by farmers for the arable crops and citrus, the amounts of nutrients required were determined based on the literature (Malakooti,

the excess chemicals used for the evaluated crops and considering the inverse impacts on the environment a negative weight was found for each crop from the environmental point of view.

Employment capability

One of the main social problems in Iran is the rate of unemployment (about

Table 6. The excess nutrient and other chemical pollutants used by farmers (kg ha⁻¹)

Crop	N	P	K	Pesticides and herbicides	Total chemical pollutants
Wheat	142.4	33.9	34.0	3.0	213.3
Corn	71.9	35.5	0.0	5.5	112.9
Cotton	295.6	53.5	84.3	6.5	429.9
Citrus	34.25	60.8	64.5	6.3	165.8

Table 7. The range of sustainable index variations and the corresponding weights

WUE (kg ha ⁻¹)		Water requirements (m ³ ha ⁻¹ x 1000)		Economic return (Rials ha ⁻¹ x 1000)		Soil erosion (kg ha ⁻¹)		Environ- mental impacts (kg ha ⁻¹)		Compatibility to micro- irrigation		Labor requirements (labor day ha ⁻¹)	
Sc	VI (0.3)	Score	VI (0.3)	Sc	VI (0.3)	Sc	VI (0.3)	Sc	VI (0.3)	Sc	VI (0.3)	Sc	VI (0.3)
5	1.3-1.6	5	5-8	12	11100- 12100	0	NS	-1	100-170	5	very high	5	80-10 0
4	1.0-1.3	4	8-11	4	3100- 4100	-1	50-100	-2	170-240	4	high	4	60-80
3	0.7-1.0	3	11-14	3	2100- 3100	-2	100-150	-3	240-310	3	mean	3	40-60
2	0.4-0.7	2	14-17	2	1100- 2100	-3	150-200	-4	310-380	2	low	2	20-40
1	0.1-0.4	1	17-20	1	100- 1100	-8	400-450	-5	380-450	1	very low	1	00-20

Sc = score; VI = variation increment; NS = not significant.

25%). Unemployment is not consistent with the sustainability goals from social and economical point of view. Based on the survey in the region, plantation of citrus requires 92, cultivation of cotton 68, corn 26 and wheat 18 labor-days per year per ha. The crops that require more labor, generate greater employment and hence they receive a higher score as shown in Tables 5 and 6.

The weight obtained for citrus is much higher than that of three other crops. It means expansion of area under citrus is desirable for sustainability of this dry region.

In contrast, cotton has the lowest priority. This approach could be applied to the regions with any number of crops and with different sustainable indices. However, this model needs further evaluation so as to generalize the conclusion to other regions.

Acknowledgements

This research was partially financed by University of Shiraz, Iran. This cooperation is appreciated. The comments of Professor Soltani and Professor Karami and also cooperation of Mr. Salmani and Mrs. Rashidfar are appreciated.

Table 8. The weight of the crops based on their effects on the sustainability

Crops	WUE	Water require- ments	Economic return	Soil erosion	Environ- mental impact	Compati- bility to micro- irrigation	Labor require- ments	Total weight	Priority of land use
Citrus	5	3	12	0	-1	5	5	29	1
Corn	2	3	3	-3	-1	2	2	8	2
Cotton	1	1	1	-8	-5	3	4	-3	4
Wheat	3	2	2	-2	-2	0	1	7	3

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