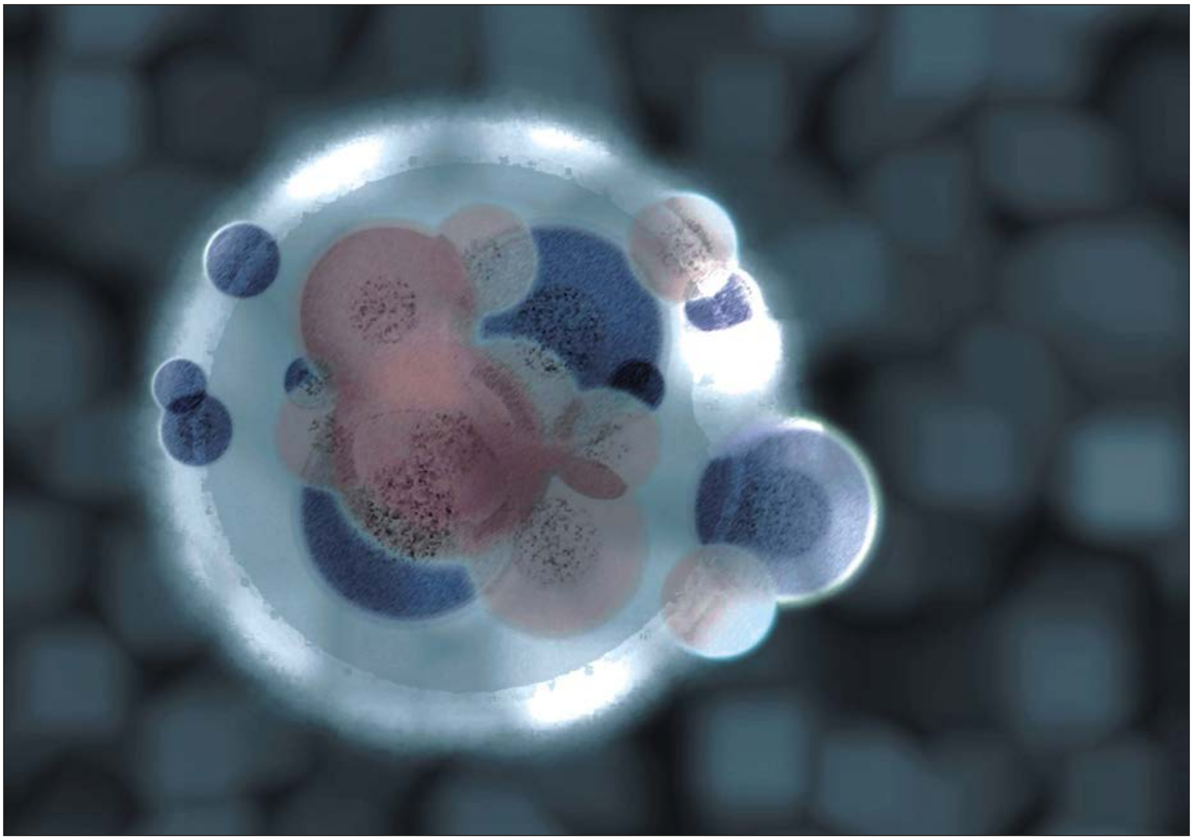

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Monitoring the Agricultural Ecosystem of Paddy Fields Using Modeling Approach (A Case Study: Southern Coast of the Caspian Sea)

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Abstract: Considering the occurrence of economic and environmental problems in the agri-ecosystems of the southern coast of the Caspian Sea, present study was conducted in the paddy fields of one of sub-catchment (Neka Basin) of the Caspian Sea in order to recognize the factors affecting on the agri-ecosystems in the area. Based on this approach, energy approach, energy efficiency as dependent and nine others as independent variables were weighted using the extreme values principle. For modeling the relationship between variables (dependent and independent) regression was applied. The results indicated that input energy was more than output energy. It suggests an agri-ecosystem with negative productivity. Most incremental increase in production was resulted from over-application of chemical fertilizer, pesticides, soil and water loss in expense of loss of the health of the ecosystems.

Key words: Regression modeling, systemic analysis, rice, energy efficiency, North of Iran

INTRODUCTION

Ecological conditions of agri-ecosystems of the southern coast of the Caspian Sea are accounted for suitable lands for cultivation of rice. At present, because of over utilization of these ecosystems, there many evidence indicating that they are endangered in spite of high level of production. Then concepts for assessing agroecosystem health including productivity, efficiency and effectiveness appear very useful for assessing the functional performance of agroecosystems (Xu and Mage, 2001).

Based on the fore-mentioned approach, understanding the realities governing on these ecosystems, is necessitated for achieving the sustainable development. Considering the complexity of agri-ecosystems, ecological modeling was considered for paying attention the present realities and then forecasting the future conditions.

In this research, a continuous modeling approach under titled biophysical or energy approach was applied. By definition, economical, ecological and environmental approach standpoint of energy is linked using these kinds of the models. Altieri (2002) emphasised which Agroecology provides the scientific basis to address the production by a biodiverse agroecosystem able to sponsor its own functioning.

In present study, ratio of out put energy to input energy was employed as an indicator for assessing independent variable. Sing *et al*. (1997) considered that agri-ecosystem the more agricultural diversity, the higher economic efficiency based on their study on assessing the energy and economic efficiencies.

Based on the findings of Sing *et al*. (1997), energy and economic efficiencies for wheat were more than potato. Also for example, Thankappan *et al*. (2006) expressed although traditional cultivators are both economically rational and the guardians of ecological wisdom, in terms of done study, it suggest broad reasons for the divergence between current practice and the activity patterns potentially required for overall energy efficiency and net revenue maximisation. Achrock *et al*. (1985) and Nguyen and Haynes (1995) suggested that although production of conventional agri-ecosystems are high, energy efficiency of the organic agri-ecosystems is higher than those of conventional agri-ecosystems. Socio-economic and ecological problems of agri-ecosystems are of global importance. Nevertheless, for dealing with the local and regional-scale problems, endeavors of local experts are of considerable significant.

MATERIALS AND METHODS

Neka sub-catchment has area of 2800 km^2 and constitutes 6.7% of whole catchments of the southern

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coast of the Caspian Sea. Mainstream has been originating from the highest parts of the Alborz Mount (3000-4000 m from sea level). The study area has a semi-Mediterranean to Mediterranean climate.

Methods: The catchment boundaries of the southern coast of the Caspian Sea were delineated using topographical map (1/250 000). Neka catchment was chosen as a study area for conducting the present study.

The study was classified into three hypsometric classes (less than 0-500, 501-1500, more than 1500 m from sea level) considering the elevation is varied from 20-3000 m.

The dominant cultivation was specified in each elevation class and agricultural land-use map was generated using the available land use map and fieldwork.

Paddy fields were randomly sampled in each elevation class and geographical coordinates were determined using GPS (Garmin, Etrex) for using it on Geographical Information System. For map generation and input-output analysis, ArcView 3.1 was applied.

Indicator of productivity was calculated based on input-output relationship and energy efficiency as dependent variable. The task was carried out using filling out the questionnaire, which was prepared based on Koocheki and Hosseini (1995), Pimental (1993) and Zare Feizabadi and Koocheki (1999).

Intensity of ecological factors, as dependent variables were weighted as the Extreme Value Principle (Jabbarian Amiri, 1996; Safaian *et al*., 2004). Accordingly, as ecological factor approaches its critical value, productivity of ecosystem decreases. It was done by determining the value of ecological factors from one to five.

For expressing the eco-factors affecting on under-studying ecosystems, modeling approach was applied as follows:

- Preparing the affecting factors in each sub-catchment as impact unit based on the fieldwork.
- Determining the intensity of the affecting factors based on object-oriented determination of ecological factors (Jabbarian Amiri, 1996; Safaian *et al*., 2004).
- The effecting factor was indicated in each impact unit, compiling the code and intensity of values were integrated and was expressed in a linear model.

A linear model was compiled using the afore-mentioned model as follows:

X_1 : Environmental conditions (derivation from a desirable cultivation, to meet scientific standards).
X_2 : Economic aspects (sustainable income).
X_3 : Social aspects (employment, public agri-techniques knowledge, food supply).
X_4 : Environmental aspects (conversing natural environment, pollution, degradation or threatening the biodiversity).
X_5 : Degrading the resources (changing the land use, flooding, land sliding and soil erosion).
X_6 : History of cultivation pattern (very old farming pattern 5, old farming pattern 4, relatively new farming pattern 3, new farming pattern 2, very new farming pattern 1).
X_7 : Water resources- related aspects (threatening the groundwater resources, over-use of the water resources).
X_8 : Soil resources-related aspect (soil erosion, soil pollution, loss of fertility).
X_9 : Risk ability (minimum risk, low risk, medium risk, high risk, very risk).
X_{10}: Public opinion.

Considering the above-mentioned, from proposed regression models, beta coefficients were used to specify the effectiveness of each independent variable. It would indicate the effectiveness of each independent variable on variation in dependent variable. Significant level of β regression was not considered. In general, the following regression model was applied:

$$y = \alpha X_1 + \beta X_2 + \lambda X_3 + ... + \theta X_n$$

Where, α, β and λ indicate the effect of independent variable (β coefficient) and X_1, X_2,..., X_n stand for independent variables itself. For statistical prediction, beta coefficients would be applied. Those independent variables, whose significant values were less than critical values of significance, might be introduced in the model.

Regression equation was, in general, defined as follows:

$$y = C + \alpha X_1 + \beta X_2 + \lambda X_3 + ... + \theta X_n$$

Where, α, β and θ are coefficient of the variables and C stands for constant. SPSS software was used for conducting the statistical analysis.

RESULTS

The following results (Table 1-3) were obtained in hypsometric class (less than 500 m) as:

High correlated relationship was observed between independent and dependent variables. The results indicated that 96.3% of total variations of dependent variable could be explained by independent variables.

Table 1: Calculation of coefficients of the registration

Model 1	R	R^2	Adjusted R^2	SEE
	0.980[a]	0.961	0.865	0.1507

[a]:Predicates:(Constant), People hypothezie, Economic, Riskability, Damageable, Soil, Environment, Environmental condition, Old, Social, Water

Table 2: Matrix of comparison of ANOVA relating to the significant level of regression analysis

Model 1	SS	df	MS	F-value	Significant
Regression	2.258	10	0.226	9.947	0.020[a]
Residual	9.081E-02	40	2.270E-02		
Total	2.349	14			

[a]:Predicates: (Constant), People hypothezie, Economic, Riskability, Damageable, Soil, Environment, Environmental condition, Old, Social, Water

Table 3: Determination of the coefficient of regression model

	Unstandardized coefficients		Standardized coefficients		
Model 1	β	SE	β	t-value	Significant
(Constant)	-2.882	0.723		-3.986	0.016
Environmental Condition	0.113	0.110	0.214	1.032	0.360
Economic	9.273E-02	0.072	1.168	1.291	0.266
Social	0.546	0.118	1.064	4.638	0.010
Environment	-0.239	0.084	-0.619	-2.838	0.047
Damageable	2.768E-02	0.062	0.073	0.443	0.681
Old	0.199	0.067	0.709	2.966	0.041
Water	-0.314	0.127	-0.760	-2.473	0.069
Soil	0.185	1.101	0.360	1.835	0.140
Riskability	0.183	0.100	0.265	1.829	0.141
People hypothezie	0.155	0.152	0.326	1.023	0.364

Fisher value is significant ($p<0.05$) indicating independent variables would be able to significantly predict the dependent variables.

Based on Table 3, the following regression is proposed:

$$Y = 1.06X_3 - 0.76X_7 + 0.70X_6 + 0.70X_5 - 0.61X_4 + 0.36X_8 + 0.32X_{10} + 0.26X_9 + 0.21X_1 + 0.16X_2$$

The regression indicates X_3 (social aspect), X_7 (ware resources-related aspects), X_6 (history of cultivation) had high effect on energy efficiency. It means that farmers are consciousness to social aspects. It was integrated by water resources-related aspects and history of cultivation. However, farmers were cautious to the incurred damage to their farms as much as the historical aspect of cultivation. In spite of farmers' consciousness to increase the risk ability, environmental aspects (X_1) and sustainable income, (X_2) are not considered very much by farmers. Little attention to environmental aspects and sustainable income might be originated from extensive land and work force resources. Moreover, imbalance output-input might be indicated by the findings of the present study.

Table 4: Calculation of coefficients of the regression

Model 1	R	R^2	Adjusted R^2	SEE
	0.619[a]	0.383	-1.161	0.5666

[a]:Predicates:(Constant), People hypothezie, Old, Riskability, Environment, Water, Environmental condition, Damageable, Social, Economic, Soil

Table 5: Matrix of comparison of ANOVA relating to the significant level of regression analysis

Model 1	SS	df	MS	F-value	Significant
Regression	0.766	10	7.961E-02	0.248	0.966[a]
Residual	1.284	40	0.321		
Total	2.080	14			

[a]: Predicates: (Constant), People hypothezie, Old, Riskability, Environment, Water, Environmental condition, Damageable, Social, Economic, Soil

Table 6: Determination of the coefficient of regression model

	Unstandardized coefficients		Standardized coefficients		
Model 1	β	SE	β	t-value	Significant
(Constant)	0.597	2.004		0.298	0.780
Environmental Condition	0.911	1.208	1.198	0.754	0.493
Economic	-0.341	0.523	-0.545	-0.651	0.550
Social	-0.349	0.527	-0.637	-0.662	0.544
Environment	-0.343	0.427	-0.550	-0.803	0.467
Damageable	0.249	0.433	0.295	0.574	0.597
Old	0.390	0.611	1.280	0.639	0.558
Water	-4.74E-02	0.270	-0.079	-0.176	0.869
Soil	-0.511	0.859	-0.959	-0.595	0.584
Riskability	2.571E-02	0.322	0.042	0.080	0.940
People hypothezie	0.158	0.578	0.263	0.274	0.798

The following results (Table 4-6) were obtained in hypsometric class (500-1500 m) in Neka sub-catchment as follows:

High correlation (61%) was observed between independent and dependent variables. The results indicated that 38.3% of total variations of dependent variable could be explained by independent variables.

Fisher value is not significant ($p<0.05$) indicating independent variables would not be able to significantly predict the dependent variables. Nevertheless, using the β coefficients, contribution of each independent variable might be deducted.

Based on Table 6, the following regression is proposed:

$$Y = 1.28X_6 + 1.19X_1 - 0.96X_8 - 0.63X_3 - 0.55X_4 - 0.54X_2 + 0.29X_4 + 0.26X_{10} - 0.07X_7 - 0.04X_9$$

X_6 (historical aspect) and X_1 (social aspect) indicated high effectiveness on energy efficiency, respectively. Whereas X_7 (water resources-related aspect), X_9 (risk ability) were associated by low effectiveness on energy efficiency. Based on the results, subsistence farming was observed by increasing the elevation from sea level because of problem in access to chemical fertilizer, pesticides. That was why water and soil pollution were less observed in this part of the study area. Land use change had indicated very distinctive effects (flooding, soil erosion, run-off, degrading the habitat) on the environment comparing other parts of study area. In spite of less production rather than plateau, it should be noted that this part of the study area recorded a high-energy efficiency.

The following results (Table 7-9) were obtained in hypsometric class (more than 1500 m) as follows:

There is a high correlation coefficient (81%) between independent and dependent variables. The results indicated that 66% of total variations of dependent variable could be explained by independent variables.

In spite of high correlation coefficient, Fisher value is not significant ($p<0.05$) indicating independent variables would be able to significantly predict the dependent variables.

Based on Table 9, the following regression is proposed:

$$Y = 0.76X_8 - 0.37X_5 - 0.36X_7 - 0.36X_4 + 0.29X_3 + 0.23X_9 + 0.06X_{10} - 0.02X_2 - 0.01X_1$$

X_8 (soil), X_5 (sustainable negative effect) indicated high effect on energy efficiency whereas X_2(economic aspect), X_1 (environmental aspect) had lowest effects on energy efficiency in this part of the study area.

Table 7: Calculation of coefficients of the regression

Model 1	R	R^2	Adjusted R^2	SEE
	0.813[a]	0.661	-0.187	0.1696

[a]: Predicates: (Constant), People hypothezie, Damageable, Riskability, Economic, Water, Soil, Environment, Social, Environmental condition, Old

Table 8: Matrix of comparison of ANOVA[b] relating to the significant level of regression analysis

Model 1	SS	df	MS	F-value	Significant
Regression	0.224	10	2.2E-0241	0.779	0.660[a]
Residual	0.155	4	2.877E-02		
Total	0.339	14			

[a]:Predicates: (Constant), People hypothezie, Damageable, Riskability, Economic, Water, Soil, Environment, Social, Environmental condition, Old, [b]: Dependent Variable: Efficiency

Table 9: Determination of the coefficient of regression model

	Unstandardized coefficients		Standardized coefficients		
Model 1	β	SE	β	t-value	Significant
(Constant)	0.776			0.667	0.542
Environmental Condition	-2.75E-03	0.102	-0.017	-0.027	0.980
Economic	-6.86E-03	0.111	-0.026	-0.062	0.954
Social	7.074E-02	0.114	0.291	0.620	0.569
Environment	-6.89E-02	0.080	-0.361	-0.866	0.435
Damageable	-7.99E-02	0.089	-0.371	-0.899	0.420
Old	-6.46E-03	0.101	-0.041	-0.064	0.952
Water	-8.83E-02	0.140	-0.363	-0.633	0.561
Soil	0.149	0.130	0.765	1.147	0.316
Riskability	5.307E-02	0.150	0.231	0.355	0.741
People hypothezie	0.158	0.578	0.263	0.274	0.798

[a]: Dependent Variable: Efficiency

DISCUSSION

Based on the findings of this study, it could be stated that technology, innovation and those policies, which had caused to increase the production, endangered the bases of production. This view is nearly similar to finding of Thankappan *et al*. (2006) that stated the nature and direction of interventions required to make smallholder agriculture more sustainable, in terms of both energy conservation and farmer livelihoods. It also using of technology, innovation and those policies has caused to over-utilization and in turn, degradation of natural resources (soil, water resources and genetic diversity). Altieri (2002) also believe that resource conserving technologies, that uses labor efficiently and on diversified farming systems based on natural ecosystem processes will be essential. Then it is necessary that practices changing of yield and productivity be done based on knowledge of agroecosystem health. This finding confirm Xu and Mage (2001) that expressed investigation simultaneously different aspects of agroecosystem health can be better understood land uses patterns.

In present study, for understanding the relationship between ecological factors and production in agri-ecosystems of the southern coast of the Caspian Sea and its future, continuous modeling approach was applies. It could be accepted that application of the model is suitable way to understanding the real world (Odum, 1983). Other findings of the present study indicated that the trade-off between incompatible environmental and economic criteria is unavoidable, if decision-makers' attention were focused on socio-economic pressures. This fact was confirmed by Costanza (1993) but contradicted by pre-defined principles for achieving a sustainable agriculture.

Based on the findings of this study, it would be acceptable that models could be applied for setting a detailed scenario. An input-output scenario could describe the total environmental changes, regional development or management of ecosystems. The findings, the same as Sing *et al*. (1997), indicated that there was a relationship between energy efficiency and economic output. The results revealed that production was decreased by increasing the elevation from sea level and change in agricultural inputs. It was confirmed by Achrock *et al*. (1985), Nguyen and Haynes (1995) and Zare Faizabadi and Koocheki (1999). In spite of interaction and existence of ample of biotic and abiotic factors in agri-ecosystems, it seems dynamics of ecological modeling are to be able to create the understanding the potential of the agri-ecosystems and framework for sustainable utilization of resources.

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