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Identifying Indicators of Environmentally Sustainable Agriculture in Paddy Fields of Guilan Province

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Abstract

In recent years, agriculture has become the prime polluter of natural resources. It is therefore essential to make assessments based on reliable indicators to ensure that an agricultural system remains not only productive, but also ecologically sound. A large area of arable land in Guilan province is devoted to rice cultivation so the transition to environmentally sound agricultural practice in paddy fields of the province is an important strategy. The main purpose of this study was to present a new and comprehensive framework for assessing environmentally sound agricultural practice applicable to the paddy fields in Guilan Province. A review of the relevant literature identified environmentally sound indicators that had been used by researchers in recent years. Then some parameters were introduced for examination and prioritization. The proposed structural model includes seven factors and 21 indicators. The target population included university faculty members and researchers who were familiar with the concepts of agricultural sustainability and that were familiar with the Guilan paddy fields. A structural on-line questionnaire was the main instrument used to gather information. Based on experts' points of view, the coefficient of significance for each of the selected indicators was measured using the Yager fuzzy screening method. The results obtained from structured questionnaires showed that 20 of the 21 indicators were appropriate for assessing environmentally sustainable agriculture.

Keywords:
Sustainable agriculture, Environmentally sound agriculture, Paddy fields, Experts, Yager fuzzy screening method

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INTRODUCTION

The decline of public extension services is one of the most striking changes in the agricultural landscape over the past decade. This has been brought about as farming systems worldwide have been going through dramatic changs as a result of globalization, liberalization and rapid urbanization. Economic growth, population dynamics (growth, urbanization, migration) and industrial development over the past 50 years have resulted in changes in the natural environment, and agricultural systems have become responsible for the persistence, emergence and re-emergence of infectious diseases in many developing countries. Agricultural practices, including intensive use of fertilizers, pesticides and other industrial inputs, degrade the natural resources in an environment that contributes to a slowdown or even a decline in agricultural growth, such conditions also have a negative impact on human health, biodiversity and ecosystems (Settle and Garba, 2011; Yang *et al*., 2013). The concept of sustainability was first introduced in the early 80's by Lester Brown, founder of the World Watch Institute. He defined a sustainable society as one that is "able to satisfy its needs without diminishing the chances of future generations." (Adrian, 2008). Sustainable agriculture is a way of raising food production that is healthy for men and animals, does not harm the environment, is humanitarian for workers, respects animals, and provides a fair wage for farmers (Faroque, 2011). Indicators for making assessments of sustainability should have multidimensional attributes that include economic, environmental and social considerations. Sustainability, in terms of these three dimensions may be difficult to reconcile because usually each one has a different time-scale implication and takes a different perspective within each given context. It is now widely understood that agriculture can have a destructive affect on the environment through overuse of natural resources as inputs or through their use as a sink for waste and pollution, such effects are called negative externalities because they impose costs that are not reflected in market prices. What has also become clear in recent years is that the apparent success of some modern agricultural systems has masked significant negative externalities now becoming clear, with environmental and health problems documented and recently costed for many countries (Rao and Rogers, 2006; Pretty *et al.*, 2011; Zhen and Routray, 2003). In Iran, like other developing countries, agriculture is an important economic sector and comprises a considerably high percentage of production and employment. The Iranian agriculture sector provides employment to about 25% of the labor force, accounts for 25% of the Gross National Product (GNP), contributes over 4.5 of total domestic food supply, 1.3% of non-oil exports (excluding carpet exports), and provides 9.10% of the raw material demand of national industries (Allahyari, 2009). This paper is an effort to identify indicators that constitute our concept of environmentally sound sustainable agriculture and suggests a pattern for assessing environmental sustainability of agricultural activities in the Guilan paddy fields that will be appropriate for moving toward sustainable agriculture.

Sustainability is an issue being addressed all over the world in response to the rapid changes taking place, and safe agriculture is key to sustainability. Various scholars and organizations have attempted to assess environmental sustainability at farm level. And these frameworks for assessment have indicators based on specific conditions in terms of populations. Table 1 summarizes some environmental sustainability indicators at farm level, proposed by researchers over the past 10 years.

This study was designed to address the following research questions:

• What are the key factors and indicators for environmental sustainability assessment in the paddy fields of Guilan Province?

• What are the priority factors of environmental sustainability assessment in the paddy fields of Guilan Province?

• What is an applicable framework of environmental sustainability assessment in the paddy fields of Guilan Province?

MATERIALS AND METHODS

The province of Guilan, in the northern part of

Table 1: Overview of environmentally sustainable assessment indicators

Benchmark source	Indicators
Asadi *et al.* (2013)	Topography slop, Soil feature and quality
Bosshaq *et al.* (2012)	Rate of share s land for agriculture, Rate of sufficiency for water resources, Rate of soil fertility, Ratio of farming logged lands to total lands
Urutyan and Thalmann (2011)	Energy (environmental effect on the used energy carrier), Water (water quantity and availability, water quality and stability of the quality), Soil (soil PH, salinization, water logging, soil sampling, erosion index), Biodiversity (biodiversity promoting farming system)
Rieg *et al.* (2010)	Rice ecosystem, Water quality, Air quality, Effect on nearby ecosystems
Oliviera *et al.* (2010)	Current soil condition, Water source protection, Thermal comfort at the AFS, Production and use of firewood, Presence of fauna, Extractivism in secondary forest areas, Extractivism in bordering wooded areas, Appearance of pests and diseases in AFS areas, Pest and disease control, Conservation of agro-ecosystems fauna and flora
Ramroop and Ragbier (2009)	Knowledge of field environment, Knowledge of pesticide toxicity, Use of safer chemicals, Use of toxic chemicals, Pesticide Safety, Reduction in water pollution, Reduction in air pollution, Reduction in land pollution
Bos *et al.* (2007)	Water and consumption (water availability, crop yield (productivity), drainage of water from field to downstream environment), Fertilizer use (potential pollution of ground water and the downstream environment, depletion of soil fertility, crop yield), Pesticide (environmental risk downstream of agricultural area, potential pollution of ground water in relation to drinking water safety, crop yield)
Van calker *et al.* (2005)	Eutrophication, Groundwater Pollution, Dehydration of the soil, Acidification, Biodiversity

Iran covers an area of 14711 km^2 and has a population of 2403716 residents.

This province has 400000 ha agricultural land, of which 60% is allocated to rice cultivation. Guilan province has 230000 ha paddy fields with annual production of 700000 tons white rice. This amount is equivalent to 30% of the country's rice production. This research was designed as a descriptive study. The target population of this study was 24 university faculty members that were experts in the field of Agricultural Organization and researchers familiar with the status of the paddy fields of Guilan, particularly with regard to the concept of sustainability. They were selected by using convenience sampling method. Data was collected using a self-made questionnaire designed for the purpose. Questions were generated from a review of related literature. The questionnaire had two sections. The first section investigated personal characteristics of the experts, and the second section investigated their opinions on importance of the selected indicators for assessing environmental sustainability in agriculture. Questionnaires were administered using Google doc and sent as emails. For data analysis, determinations were made on the Importance Coefficient, giving linguistic variables on a seven-level Liker scale (outstanding importance = 7, very high importance = 6, high importance = 5, medium importance = 4, low importance = 3, very low importance = 2, no importance = 1). At first, based on the literature review, a set of indicators was introduced for examination and prioritization. This model included seven main factors and 21 indicators (Table 2). As mentioned earlier, in the second step, Yager fuzzy screening method was used to determine degree of importance for each of the research indicators.

FINDINGS

Population profile

Distribution of respondents' personal characteristics is shown in Table 3. This shows that

Table 2: ecological factors and indicators

Factors	Indicators
Knowledge and Skills	1- Farmer's knowledge about conservation of natural resources
	2- Rate of Farmer's participation in promotional and training curses about sustainable agriculture
	3- youth interest in innovative systems of sustainable agriculture
	4- Attempt to Protection and improvement of biodiversity and natural
Air Quality	resources by related organizations and farmers
	5- Minimizing use and destruction to forest areas
Water Quality	6- Air quality (SO2 and NO particulate)
Farming system characteristics	7- Rate of greenhouse gas emission
	8- Surface water and groundwater quality
	9- Rate of lands under double cultivation
	10- Rate of lands under continuous cultivation to total lands ratio
	11- Rate of lands under fallow to total lands ratio
	12- Rate of lands under intercropping to total lands ratio
	13- Rate of lands under crop rotation to total lands ratio
Soil Quality	14- Plowing perpendicular to the slop in order to prevent erosion on
Chemical inputs	sleep lands
	15- Soil quality (physical, chemical and biological condition)
	16- Use of organic, green and micronutrients fertilizers
	17- The amount of fertilizer per hectare (intensive agriculture)
Area characteristics	18- Minimizing use agricultural chemical inputs
	19- use of crop residue as green manure
	20- Appropriate population density in rural areas
	21- Rate of flood risk

58.3% of the experts were within the age range of 20– 39 and 41.7% of them were within the age range ≥ 40 and the average age of respondents was 41.76 years. Respondents with 5-9 years' experience had the highest prevalence and those with 20 years and above had the lowest prevalence, also the mean number of years of workers' experience was 16.67 years. The majority of workers in the agricultural organization were male. It was found that respondents with a PHD degree level of education had the highest prevalence (54.17%).

Yager fuzzy screening method

Based on experts' points of view, after implementing the Yager fuzzy screening method, a coefficient of significance evaluation was made for each of the selected indicators based on Linguistic Variables. In the Yager fuzzy screening method, each indicator was given a score after evaluating the negative of indicator s, importance and aggregation values were determined according to degree of satisfaction based on experts' points of view and calculations were made to give a score to each indicator; Aggregation Function (Q) was determined for decision making. This function expressed how many s values were needed to determine agreement for acceptance of an indicator.

$$Q_A(K)=Sb_{(K)} \qquad K= 1,2,3,\ldots..,24$$

$$b(K) = Int[1+\frac{q-1}{r}] \qquad (1)$$

In the above formula q is expressed as number of selected points in qualitative space (q=7), r is expressed as the number of expert group (r=24) and Int is defined as correct number. Using the expert s Aggregation Function and unit score of each of the experts for each of the indicators, scores integration and aggregation was done and a separate score was identified for each indicator. Therefore, based on Yager OWA operator, expert scores for each indicator presented in descending order and final assessment was

Table 3: Frequency of distribution of respondents' personal characteristics

Characteristics	Frequency	Percent	Cumulative percent	M	SD
Age					
20-29	5	20.8	20.8	38.62	8.66
30-39	9	37.5	58.3		
40-49	7	29.2	87.5		
50-59	3	12.5	100		
Work Experience					
Less than 5 years	4	16.7	16.7	10.79	6.42
5-9	8	33.3	50		
10-14	6	25	75		
15-19	4	16.7	91.7		
20 years and above	2	8.3	100		
Gender					
Male	23	95.8	95.8		
Female	1	4.2	100		
Level of education					
Master	11	45.83	45.83		
PHD	13	54.17	100		

Table 4: Importance degrees of 21 indicators

Indicators	importance degrees	Acceptance ☺
1- Rate of Farmer's participation in promotional and training curses about sustainable agriculture	Outstanding	☺
2- Rate of lands under continuous cultivation to total lands ratio	Outstanding	☺
3- Rate of lands under intercropping to total lands ratio	Outstanding	☺
4- Minimizing use and destruction to forest areas	very high	☺
5- Rate of lands under crop rotation to total lands ratio	very high	☺
6-Appropriate population density in rural areas	very high	☺
7- Use of organic, green and micronutrients fertilizers	very high	☺
8- The amount of fertilizer per hectare (intensive agriculture)	very high	☺
9- use of crop residue as green manure	very high	☺
10- Farmer's knowledge about conservation of natural resources	high	☺
11- Attempt to Protection and improvement of biodiversity and natural resources by related organizations and farmers	high	☺
12- Air quality (SO_2 and NO particulate)	high	☺
13- Rate of greenhouse gas emission	high	☺
14- Rate of lands under double cultivation	high	☺
15- Rate of lands under fallow to total lands ratio	high	☺
16- Soil quality (physical, chemical and biological condition)	high	☺
17- Minimizing use agricultural chemical inputs	high	☺
18- Surface water and groundwater quality	medium	☺
19- Plowing perpendicular to the slop in order to prevent erosion on sleep lands	medium	☺
20- Rate of flood risk	medium	☺
21- youth interest in innovative systems of sustainable agriculture	Low	☠

determined for each indicator using the following formula.

Ui =maxj{Qj ^Bij} (2)

In the above formula *Qj* indicates that decision maker to what extent feels support and confirmation of at least j expert is necessary. *Bij* is expressed as the value of J-th well score of I indicator. {Q(j) ^ *Bij*} can express as weighting of J-th well score of I indicator (*Bij)*, based on decision makers' points of view who calls necessary support of j expert (*Qj*).

According to selected threshold value 1 indicator out of 21 indicators with less than medium score was be removed from final model. This one indicator is youth interest in innovative systems of sustainable agriculture among knowledge and skills factor. So that the final model of this assessment of environmental sustainability in agriculture was designed with 20 indicators in seven factors.

DISCUSSION

Industrialization is the inevitable process of modernization. So a country that supports its agriculture should change to develop environmental-friendly agriculture in modern times in order to meet people's needs (Jikong and Jing, 2011). Agricultural activities have a destructive impact on the environment that effect climate change, contribute to soil degradation and produce waste and pollutants. Environmentally sound agriculture is a system that, while increasing prosperity and quality of life, reduces waste and harmful environmental impacts of agricultural activities. In designing a conceptual pattern of environmentally sound agricultural assessment a set of indicators needs to be selected according to an appropriate reality. Accordingly, validation of 21 research proposed indicators was examined based on experts' points of view. The assessed ecological indicators by Gomes-Limon and Riesgo (2010) in Spain, Ramroop and Ragbir (2009) and Oliveira *et al.,* (2010) in Amazon can be compared to the most important ecological indicators determined in this assessment.

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