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Assessing ecological sustainability of wheat production systems: a regional case study in Khorasan Razavi, Iran

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Abstract

This study was conducted to compile an index for quantifying ecological sustainability of wheat farming system in the Taybad, Khorasan Razavi. Sustainability include social–economical indices, the amount of fertilizer and chemicals, crops and livestock production, crop residue management, the amount of irrigation water, diversity of agricultural species, mechanization level, tillage and weed management**.** Average score of sustainability of the wheat production system was 62. Among the studied indices, the lowest scores were related to livestock production (0.89), weed management (2.63), crop residue management (3.90), and diversity of agricultural species (4.4), respectively. The stepwise regression results showed that the most important determinants of sustainability in the wheat farming system were area under cultivation of wheat, farm income, accessibility to inputs and financial supports, diversity of applied pesticides, diversity of crop species, and accessibility to agricultural experts. The results showed that training of farmers, improved crop managements, water resource management and economic stability of farmers had priority to improve sustainability in wheat cropping systems.

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Introduction

The agricultural improvements in 20th century is an indicator of the effort of several generation of agricultural stakeholders (farmers, advisers, researchers, policy makers). These efforts have caused the increase of the of the global action mean of wheat from 0.9 at the beginning of the 20th century to 2.6 tons in hectares at the end of this century. (Sinclair, 1998). But on the other side, this improvement has lead unpleasant consequences such as soil erosion, being salt, being acidic and declining quantitative and qualitative systems productivity. Furthermore, the high population growth (around 2% annually) further reduces the availability of land for agriculture by creating increased demand for land for settlements, roads, industry, and other nonagricultural uses (FAO., 2000). In view of the scarcity of arable land, emphasis has been given to increasing food production by intensifying the use of off-farm sources. Subsidies are provided for chemical fertilizers, pesticides and irrigation equipment to enable farmers to adopt these technologies for increasing crop yields (Brown *et al.*, 1988). Excessive and unbalanced use of agro-chemicals has led to increased production costs and dependence on off-farms inputs and energy, decline in soil productivity, contamination of surface and ground water, and adverse effects on human and animal health (Koocheki, 1997). Therefore, there is growing emphasis on sustainable agriculture in response to concerns about the adverse environmental and economic impacts of conventional agriculture (Lagerberg *et al.*, 1999).

A different approach from the conventional strategies in agricultural systems should be considered seriously and new systems should be designed which their precedence has long lasting stability while maintaining the production in short time (Beheshti, 1995). We needs new strategies to promote alternative agriculture that emphasizes reduced use of external inputs, including agro-chemicals, and increased use of local and on-farm resources in order to make the system both environmentally and economically sustainable (Kropff, *et al.*, 2001). In the new theory, the agricultural crop production should take place with relying on the biologic and ecological foundations, maintaining the material cycle in soil, comprehending and using the biologic complex relation and mixtures, creating self-reliance systems, economic stability of rural societies and maintaining its social structures (Koocheki *et al.*, 1997).

Despite a broad consensus about the basic features of agricultural sustainability, there are fewer consensuses about which components should be given more importance in the assessment of sustainability. The different researchers emphasize different ecological aspects of farming systems such as maintaining agro-ecological health, biodiversity, integrated nutrient management, energy managements and environment quality, Moreover, others introduce the importance of the economic aspects of sustainability, because farmers will accept this type of agriculture only when it helps to reduce depending on off-farm resources without sacrificing the current level of benefits provided by conventional agriculture (Kleinman *et al.*, 1993). Tools for combined economic and environmental assessment may help organize information to guide appropriate decisions about agricultural policies and extension. Hence for answering the question whether a given system (i.e. a region) is sustainable we often need reference levels, indicators, and benchmarking methods (Kevan *et al.*, 1997). The stability indices are low extents which clarifies our viewpoint in relation to the environmental conditions and the stability of the agricultural systems. Through using these indices, one can evaluate the applicability and the quality of the local agricultural systems and one can use them as instruments for studying the trends, distinguishing and determining the special environmental conditions and assisting huge decision making in managing the environment (Brown *et al.*, 1987).

In Iran, there is growing emphasis on sustainable agriculture in response to concerns about the adverse environmental, human health problems and

economic impacts of conventional agriculture. Decision-makers need an evaluation of the sustainability of farming systems in order to how use the concept of sustainability in practical and operational terms to alleviate the pressing problems and production constraints of modern agriculture. This research was motivated by the premise that the concept of sustainability must move from a qualitative state to a quantitative form, in order for sustainability to serve as a guide for agricultural development initiatives. Agro-ecological assessments are frequently carried out with agro-ecological indicators (Kevan *et al*., 1997). These indicators make it possible to draw-up conclusions about the system under analysis, without getting into the large expense of direct measurements. Then, the present research has been performed with the aim of a quantitative survey of the agricultural system stability level of wheat production systems in Iran and by using a systematic approach. The systematic approach is based on the systematic concept that is defined as a connected system of components which act as a universality in reaction to the exterior agents that affect each of them (Stephens *et al*., 1999). This approach analyzes the accomplishment manner of a system (the agricultural system) by considering the coactions of different biological, physical, chemical, social and economic elements (Sharifi Tehrani., 1997). In two recent decades, the systematic approach has been used in designing and managing the agricultural systems widely. The aims of this survey are determining the week and critical point of the studied agricultural systems and presenting suitable method for the stability increase after quantifying a stability index.

Materials and methods

Description of the area and the crops

This study was done in the area of Taybad, Khorasan razavi province, Iran. Taybad located in the eastern part of khorasan razavi conduced to Torbat-e-Jam from the north and to Bakharz from the west and to Khaf from the south and to the abutment of both Afghanistan and Pakistan from the east. The wheat agriculture system was chosen for the present study because of the importance of this crop in the agricultural system of Iran as a staple food. The wheat cultivation is about 18000 ha in selected areas.

Selection of indicators

At first, the stability was considered as a common item of the agricultural, ecological, social and economic elements and stability index was designed based on it. The stability indices are quantitative amount clarifying our viewpoint in relation to the environmental conditions and to the stability of the agricultural systems. An agricultural stability index is a collection of measurements specifying the stability of an agricultural system region quantitatively. Based on the definition, the stability measurement is uttered to the quantitative amount of the physical, chemical, biological, social and economic varies that makes it possible and easy to explicate the current status of the system through quantifying and simplifying the abundant data related to the complex relations ruling the region of the agricultural systems. In fact, every stability index is a numerical amount consisting of the combination of several stability measurements. And it shows the agricultural system stability in from of a unique quantity. By using a stability index, one can assess the applicability and quality of the region of the agricultural systems and one can also benefit it them as the tools for studying the trends, for distinguishing and determining the special environmental conditions and for assisting in the huge decision makings in managing the agricultural systems.

Data categories

In the present study, the stability index has been consisted of 75 measurements (criteria). A dominant portion of these measurements have been extracted from the sources and some of them have also been included in this investigation considering the special characteristics of the systems under study. From among them, one earn point to the existence of the handy industries, tinning carpet, or using the animal fertilizer as the fuel. One can categorize the used

measurements in this survey in two groups: social-economic measurements and agricultural-regional measurements. Weighted sum method was used for computing the stability index, According to this method, a special score is determined for each measurement (Hosseini Araghi, 1997).In addition, an amount scope is considered for each measurement which based on it, the highest score belongs to the best state and zero or lowest score belongs to the worst state, after determining each measurement score, the score sum of the measurements is added up and is considered as the final score. The weighted sum method has been used in many compilation researches of the stability in dice (Brown *et al*., 1987) There is one point relating the manner of determining the score of each measurement. The reason of this criterion has been the priority and the importance of some measurements.

Calculation method

Among the measurements that have taken the highest score (from 100 score of the stability index), one earn point to the level of the university educations related and unrelated to the tillage having the score of 3.15 and 2.7 sequentially, the type of ownership, the farmers in come, the under cultivation area of the crops, and the function of the agricultural crops while a measurement like using the animal fertilizer as a fuel has 0.22 scores. 120 questionnaires were prepared after designing and approring the measurements which were completed by the farmers.

Then these questionnaires data were confirmed and were used. The data analization was done by SPSS, Sigma stat and Excell softwares.

Results and discussion

The score mean of the final stability index was 62 in the wheat tillage system. The highest and the lowest stability scores were 76.6 and 50.2 in the wheat system sequentially. This survey consequence show that this systems is stable to some extent and is not in a weak level in comparison the previous studies since 45 percent of the farmers reached a score equal or higher than 60 and 49.76 percent of them have reached a score equal or higher than 50 (and lower than 60). It have reported the score mean of the stability index as 44 in some cities of Khorasan province and in this survery, only 0.8 percent and 18 percent of the studied farmers have gained the score of 60 to 69 and 50 to 59 sequentially (Mahdavi Damghani, 2005). The reason of this difference can be pointed as the big size of the field pieces Taybad and the high in come because of the big field pieces and also the personal ownership of most fields which simplifies the possibility of the action performance adjusting the stability bases (Mohamadianfar *et al*., 2012).The score of the calculated measurements of this design have been presented in Table 1.

Table 1. The score of different measurements and the stability index.

Index	The achieved score wheat	The score from 100 Final stability index	The achieved score percentage wheat
Social-economic	16.3	29.5	55.25
Fertilizer and chemical materials	8.5	14.5	28.81
Management of plant residue	3.9	5.75	13.28
Water and irrigation	7.15	11.2	25.07
Plowing and Mechanization	11.42	16	38.71
Crop production	6.3	7.5	21.35
livestock production	0.88	2.95	2.98
Agricultural typical diversity	4.4	8.75	15.78
Weed management	2.64	4.5	8.94

Considering Table 1, the lowest score belongs to the measurements of the animal production but each measurement score should be compared considering the highest assigned score that is 2.95 for the measurement of the animal productions at last. There are social-economic measurements, fertilizer, chemical and Irrigation materials among the measurements which have attainted low score despite the maximum score devoted them. Considering the present study and the available data, some reasons can be mentioned for it which are the low level of the farmers, education, the extreme use of the chemical fertilizer and the applicability of water consumption. The effective factors in determining the fun the agricultural crops have been distinguished using the retrogressive step by step analysis and the linear multivariate regression of water consumption, the accessibility to the products, the consumption of nitrogen and potassium fertilizers, the consumption of the animal fertilizer, and the management of the herbal remains as the specifying elements of the wheat function. The main point in this relation was the lack of a powerful dependency of the wheat function to the consumption of the nitrogen fertilizers.

In relation to the field area, in this project, 20 percent of the fields have the width of 10 hectares, 8 percent of them are between 10 to 29 hectares, 69 percent of them are between 20 to 100 hectares and 3 percent of them the width of more than 100 hectares in the wheat system.

In this project, the production comparison of different fields shows that the production average of the little fields has been lower than those which have been bigger. Its reason is lower possibility of the use of the mechanized function and the new tillage methods because of the low income of the farmers. And the other reason is the usage possibility of the machinery decreases in little lands due to the little size of the agricultural lands so that that these systems stability decreases too. The anxiety in this relation is that conserving the social structure and the available legal lows, there isn't a bright perspective about the size of the agricultural fields in these systems but it can be predicted that the number of the pieces of the little fields increases by passing the time because the agricultural fields are divided to the number of the family children every several years which causes them to turn into little pieces. As in our country, there is no low for no dividing and for keeping the agricultural fields. At the available size so that it can prevent dividing the lands and making them smaller hence it can be forecasted that the agricultural lands, will be smaller in the future.

The score related to the wheat function has been 4.5 which no score would belong to the wheat if the wheat function was lower than 2 tons and if this function was more than 4 tons, the maximum score would belong to the wheat. If we consider the minimum of the desirable function of the wheat based on providing the costs and guaranteeing minimum income for the farmers and also the technical competency of 4 tons, 28 percent of the farmers have achieved this level of production which is not an acceptable function and is not in a favorable level. In the wheat system, no farmers have had the function lower than 2 tons. It have reported that only 22 percent of the farmers have attained the function of 4 tons per hectare in the wheat system (Mahdavi Damghani., 2005). The matter which should be considered is that the access to the stability of the agricultural systems never means a sheer attention to the environmental and regional aspects and the production should be kept in a desirable extent in it because if the agricultural system is not a favorable level, it will not be possible to access the stability (Dunlap *et al*., 1992).

From 11 score of water and irrigation measurements (of the sum of 100 score), the farmers have attained 7.15 score (66.4 percent) in the wheat systems. This measurement score is not low but one of the reasons of its decrease is the use of a finite number of the farmers from Basin irrigation which has a low competency in a way that 13 percent of the farmers

use the Basin irrigation, 69 percent of them use furrow irrigation and 18 percent of them use sprinkler irrigation. Here, the furrow and sprinkler irrigation has allocated many portions to itself and its one of the reasons of the high score of this measurement while in Basin irrigation, the irrigation waste is in a way that either a dominant part of the irrigation water is out of the plant access or is not used for the crop production.

Though the use of the sprinkler irrigation system increases the tillage system dependency because of the entry of the exotic products and the consumption of high energy in its production and action, In this investigation, 18 percent of the farmers have used this irrigation system which is an acceptable amount but considering the high competency it should be more.

The relation of the function of the agricultural productions and the stability index indicates this reality that in addition to this element, other elements affect the stability index too. Since in a particular function, the stability index score has been completely different and in fluctuation with different farmers. In other words, the function of the agricultural crops are not counted as the most basic and the most exclusive element defining the stability of these two agricultural system but there are also other elements that affect stability index equally or more than the function of the tillage crops.

Based on this, the stability index was computed based on the whole used measurements of the project in the wheat system. The general form of the regression equation $Y=f(x_1,x_2,...x_n)$ was used for used for the stability index calculation. And based on it, the general linear multi variable regression equation was fitted which consists of $Y= (b_0+b_1x_1+b_2x_2+...b_nx_n)$ and b_1 to b_n are the coefficients of the independent variables, b_0 is the fixed amount of the equation and y is the dependent variables. Then by using the retrogressive step by step analysis method, the elision process of the dispensable variables was followed. Accordingly, the primary model which has been calculated by 82 measurement and 100 variables was abbreviated to a simpler model of the dependent variable significantly. For calculating the stability index of the wheat system, this model consists of:

S.I.=35.057+(0.015*A)+(0/944*B)+(1.42*C)+(1.1*D *)+(1.20*E)+ (0/02 *F)+(1.50 *G)+(1.82 *H)+ (0.98 *I)+(0.834 *J)- (0.008 *K)- (1.29*L)

In which the symbols indicate:
SI: the stability index, A: the wheat function, B= the under harvest level of the wheat,
C= the agricultural type variety, D=the herbicide variety, E:the fungicide variety, F: the wheat income, G:returning the left over to the soil, H: access to the products, I: access to the financial support ,J: access to the experts and the propagators, K: the farm distance to the dwelling place, L: selling the wheat remains.

As it can be observed in the formula, the numerical amount of the stability index decreases by increasing the farm distance to the dwelling place and selling the remains which is the confirmer of the negative effect of the before mentioned factors on the stability of this agricultural systems. The considerable point in this formula is that the factors such as the consumption amount of the chemical fertilizers has not an appointing effect on the stability index and the measurement as agricultural type variety, the herbicide and the fungicide varieties, managing the herbal remains and the access to the products had a considerable effect on the final amount of the stability index.

Conclusion

High irrigation water use, high consumption of chemical fertilizers and pesticides and low organic matter in soils are the main factors affecting suitability index in wheat farming system. The results showed that the improvement of farmer's knowledge will accompany producers to help transition from a conventional to a more sustainable farming system.

Suggestions

1-The farmers level of education is one of the important factors from among the social-economic factors. Because the acceptance expectation of the operations adjusting to the stability does not seen so much logistic by these farmers. In an accomplished investigation in Taybad, the number of the farmers with university education was 19 percent and the number of the illiterate farmers or those who had a degree lower than diploma was 47 percent. In this study, the farmers level of education is in a rather eligible level, but what is more considerable is the educations related to the agriculture that considering the high number of the graduated students in agriculture, providing the suitable conditions for their employment in the agricultural part can help the elimination of this tension.

2- one of the very important problems is the high expenditure of the chemical fertilizers by the farmers. As for the high expenses of providing and consuming these chemical fertilizers and the negligible effect which it has on the action increase in comparison to these high expenses, the irregular use of these fertilizers should be avoided so that it can be prevented both from the expenses and the time spending and from polluting the environment and the agricultural fields to the chemical fertilizers. But what is more important is the consumer's health of the tillage crops which should be noticed by the organic and healthy productions.

3- This research consequences are confirmation on the previous continual reports that these is on the low competency of water consumption. This problem exists in the agricultural systems of Khorasan province, from one side, the yearly low rainfall and the low level of the underground waters have encountered the farmers with a serious restriction of water sources. From the other hand, the low competency of efficiency is an additional reason from the same limited water sources. One way of increasing water efficiency is through using the impact irrigation systems. If one can provide the efficiency context of these systems by presenting the financial facilities, a huge part of the problem has been solved surely. It seems that a choice between the available traditional irrigation systems contain a low competency and a score energy consumption and the new irrigation systems having a maximum competency and a high energy consumption mean while choosing the second option provides the stability aims idealistically in the present conditions.

4- The function of the agricultural products has not been satisfactory in this survey, meaning that 60 percent of the farmers have attained a function between 3-4 tons in the wheat system. Considering this issue that the production increase causes the farmers income enhancement, each technique that helps the production enhancement while regarding the stability principles and the environmental health will increase the stability of these systems finally.

5- Most farmers do not use the green fertilizer, biologic control and also the feedstuff legume. This fact causes the biologic diversity decrease in two ways. From one side, the biologic variety of the agricultural plants and the insects or other elements of the biologic elements decrease and from the other hand, plenty of the goal and not goal types are destroyed by the chemical pesticides. One cannot consider this issue for the sake of the farmers lack of familiarity with these operations but the delinquency of the domestic researchers is also effective in the study and in the introduction of compatible species with the regional conditions of the tillage systems of Iran, whether in the section of the green fertilizer and the legume or in the section of biologic control factors. Of course, wide researches might have taken place in this regard and there might also be noticeable data, but the knowledge production chain work to its transition to the farmers seems discrete.

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