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Sustainability of Rice-Based Agroecosystems in Mazandaran, Iran: Agro-technical Characteristics

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Abstract

In order to evaluate agro-technical characteristics of rice-based agroecosystems in Mazandaran, Northern Iran, a study was conducted in 2007 and 2008. Data relating to agronomic and ecological indicators were collected using questionnaires. Results showed that these systems earned only 22% of the score of production indicators which shows they are not productive systems in term of crop and livestock production. Mean rice yield in these systems was 3129 kg/ha. More than half of farmers apply 200-400 kg/ha N and P chemical fertilizers which is of concern given the demand for rice and the ecological fragility of Mazandaran to environmental pollution due to agrochemicals. In 20% of systems, crop residues are left in the field and, in other cases, residues are removing or burning. Studied agroecosystems earned 73% of score of these indicators which means they are sustainable in terms of applying water and water resources. These agroecosystems earned 39% of the score of mechanization indicators which reveals that they are not sustainable or efficient in terms of mechanization. The survey showed that any progress in crop production management, agrobiodiversity and application of agrochemicals could improve the overall sustainability of these agroecosystems substantially.

Keywords: rice, yield, mechanization, agrochemical, sustainability.

پایداری کشت‌بوم‌های مبتنی بر برنج در استان مازندران: ویژگی‌های زراعی- فنی

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چکیده

با هدف مطالعهٔ ویژگی‌های زراعی- فنی کشت‌بوم‌های مبتنی بر برنج در استان مازندران، پژوهشی در سال‌های ۱۳۸۶ و ۱۳۸۷ انجام شد. داده‌های سنجه‌های زراعی و اکولوژیک با استفاده از پرسش‌نامه جمع‌آوری گردید. نتایج نشان داد این سیستم‌ها تنها ۲۲٪ امتیاز سنجه‌های تولید را کسب کردند که حاکی از ضعف این سیستم‌ها از نظر تولید محصولات زراعی و دامی است. میانگین عملکرد برنج در این کشت‌بوم‌ها۳۲۱۹ کیلوگرم در هکتار بود. بیش از نیمی از کشاورزان، ۲۰۰ تا ۴۰۰ کیلوگرم کود شیمیایی نیتروژن و فسفر در هکتار مصرف می‌کردند که با در نظر گرفتن تقاضای برنج و شکنندگی اکولوژیک مازندران و حساسیت آن به آلودگی‌های محیطی ناشی از نهاده‌های شیمیایی، نگران‌کننده است. در ۲۰٪ سیستم‌ها، بقایای گیاهی در مزرعه باقی مانده و در سایر موارد، این بقایا از مزرعه خارج و سوزانده می‌شود. این سیستم‌ها ۷۳٪ امتیاز سنجه‌های آب و آبیاری را کسب کردند که نشان‌دهندهٔ پایداری نسبی آنها در بهره‌برداری از منابع آب است. کشت‌بوم‌های مورد مطالعه، فقط ۳۹٪ امتیاز سنجه‌های مکانیزاسیون را کسب کردند که نشان می‌دهد در کاربری و بهره‌برداری از این فناوری، کارامد نیستند. این مطالعه نشان داد هر نوع افزایش تولید و بهبود مدیریت گیاه زراعی، تنوع زیستی و نهاده‌های شیمیایی در این کشت‌بوم‌ها موجب بهبود چشمگیر پایداری این سیستم‌های کشاورزی خواهد شد.

کلید واژه‌ها: برنج، عملکرد، مکانیزاسیون، نهاده‌های شیمیایی، پایداری.

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Introduction

Sustainability of agricultural systems can be defined as a set of activities which results in supplying food and fiber demands of current generation, while not limiting future generations' ability to meet such their needs. This definition has its roots in sustainable development and involves the production of enough food with high quality in agroecosystems in a manner which prevents deterioration and depletion of non-renewable natural resources like water, soil and biodiversity as well as the socio-economic structures of rural societies (Rao and Rogers, 2006).

To understand agroecosystems, the simplification of these natural systems is a necessity. There are several ecological, technical, economic and social processes which control agroecosystems and make the interactions of human, crop, microorganisms, soil and water complex and detailed and their simplification is one way to understand and analyze them (Marten, 1988). There is, however, a critical question of how to simplify these systems without ignoring their key characteristics and interrelations. Integrating several agroecosystem processes as quantitative indicators is a way of simplification which shows us the degree of an ecosystem's health and its ability to meet human needs. So, there is an urgent need to quantify many qualitative aspects of agroecological sustainability. Sustainability, however, is a concept and cannot be evaluated directly (Berroterán and Zinck, 1997) and so suitable indices should be chosen to determine amount and durability of system sustainability. A sustainability index is a set of various indicators which clarify sustainability of an agroecosystem quantitatively (Mahdavi Damghani *et al.*, 2004). A sustainability indicator is quantitative measurement of physical, chemical, biological, social and economic variables that facilitates interpretation of system sustainability (Hess *et al.*, 2000; Kleinman *et al.*, 1995; Pannell and Schilizzi, 1999; Lopez-Ridaura *et al.*, 2002).

Several indices have been suggested for determining the sustainability of agricultural systems which facilitate measuring and monitoring the sustainability of these systems fast and efficiently. For practical application, a sustainability index should be (Camacho-Sandoval and Duque, 2001; Liverman *et al.*, 1988; Nicholls *et al.*, 2004):

- easy-to-handle for farmers,
- highly precise and easy-to-interpret,
- applicable in all scales from a small farm to a landscape,
- sensitive to environmental and management changes, and
- effective in clarifying different ecological relations and processes.

Some studies have been conducted on the sustainability of agroecosystems in Iran during last decade. Sadighi and Rousta (2003) evaluated the sustainability of maize-based agroecosystems in Fars Province, managed by elite farmers of the region. The indicators applied in this study were crop yield, considering crop rotation, applying manure and organic fertilizers as well as legumes, crop residue management, tillage management, water and soil resource conditions and the consumption of agrochemicals (N and P fertilizers and chemical synthetic pesticides). Results of this study showed that 58% of these agroecosystems are non-sustainable or relatively non-sustainable which were attributed to the high consumption of urea and phosphates as well as pesticides. Hayati and Karami (1997), using similar indicators, studied the sustainability of wheat production systems in Fars. A remarkable finding of this study was that the crop yield in sustainable farms was comparable with those who were not sustainably managed; mean wheat yields in sustainable and non-sustainable agroecosystems were 4.2 and 4.3 tonha[1], respectively which indicates that correct management practices would result in good yields as well as the overall sustainability of agroecosystems.

Mahdavi Damghani *et al.* (2006) developed a sustainability index, composed of 82 different indicators to study the sustainability of wheat-cotton agroecosystems in Khorassan. Indicators included information of crop and livestock yield, agrochemicals, crop residue management, water and irrigation data, tillage and machinery, biodiversity of agricultural species, ecological weed management and socio-economic factors. Results of this study showed that only 18.6% of these agroecosystems were sustainable and relatively sustainable. The data indicated that crop and livestock production followed by water and irrigation had the lowest scores among different indicators of sustainability. Stepwise backward analysis showed that acreage, wheat yield, crop residue management, farmers' agronomic income and access to education and extension services were the most important determinants of sustainability in these agricultural systems; while the effect of chemical fertilizers, especially nitrogen, was less determinant on sustainability of the field.

The present study has been performed in rice-based agroecosystems in Mazandaran, Iran, to determine the critical characteristics of sustainability-related points in these agroecosystems in order to improve their ecologic, technical and socio-economic sustainability.

Materials and Methods

This study evaluated the sustainability of rice production systems in Mazandaran, northern Iran, as an important region of rice production in the country. First, sustainability was defined as the common face of agronomic, ecologic, economic and social factors. The sustainability index in this study is composed of 69 sustainability indicators as follows:

Agronomic-Ecologic Indicators

a) Production indicators: these indicators include cropping acreage area and crop yield as well as production of dairy products (mainly meat and milk);

b) Fertilizers and pesticides: in this part, data relating to the application of different fertilizers (organic vs. chemical) and pesticides (herbicides, insecticides, fungicides) was recorded. The information of consumption of N, F and P as well as micronutrient fertilizers were gathered;

c) Crop residue management: includes indicators of burning residues, feeding residues by livestock, returning residues to soil and, finally, putting them in the soil surface as mulch;

d) Water and irrigation: these indicators are divided into two groups: indicators relating to annual precipitation and its seasonal distribution and the second group, indicators of irrigation amount, source of irrigation water, water will depth and kind (electric or diesel);

e) Tillage and machinery: tillage by animals, mechanical cultivation, applying disc, leveler, ditcher, seeder, fertilizing and pesticide-distributor machines and harvester information were recorded. Data on machinery privacy was also extracted;

f) Biodiversity of agricultural species: consisted of information on crop and livestock species diversity and their density as well as application of crop fallow and forage legumes;

g) Weed management: indicators of this group include mechanical control, hand weeding and biological control of weeds. Although chemical control could also be evaluated in this group, the chemical characteristics of herbicides was more important in this study and so chemical control of weeds was studied under the indicators of fertilizers and pesticides (group b).

From a total score of 100 in sustainability index, 70 points were allocated to agronomic-ecologic indicators. The socio-economic characteristics of these systems are described and evaluated in another paper (Mahdavi Damghani, 2009).

Calculating Sustainability Index, Data Collection and Analysis

The weighing sum method was used to calculate the sustainability index (Andreoli and Tellarini, 2000; Mahdavi Damghani *et al.*, 2006). Each indicator had a score ranging from zero to maximum depending on the scoring system of each indicator. The highest and lowest scores were allocated for the most favorable and the worst conditions of an indicator, respectively. The final value of 100 for the sustainability index was the sum of all the indicators' scores. The indicators used in the study and their weight from final sustainability are presented in Table 1.

Table 1- Agro-technical indicator classification and weight of each class in final sustainability index. Total sustainability index is 100.

Indicator group	Score
Production (crop and livestock)	10.5
Fertilizers and pesticides	14.5
Crop residue management	5.5
Water and irrigation	14.5
Tillage and machinery	15.5
Biodiversity of agricultural species	6.0
Weed management	3.5

The data of indicators gathered from Sari, Ghaemshahr, Neka, Babol, Savadkouh and Juibar counties, using 278 from total 350 questionnaires. The questionnaires passed the validity test and were filled by interview with farmers in the rice-based agroecosystems.

Results and Discussion

Production

On average, rice-based agroecosystems in this study earned only 22% of the score of production indicators which shows they are not productive systems in term of crop and livestock production. Mean rice yield in these systems was 3129 kg/ha and only 19% of them had yields higher than 4,000 kg/ha while in 63% of the farms, rice yield is not more than 3,000 kg/ha (Figure 1). Cropping acreage was another indicator and its results are given in Figure 2. More than 30% of farms were less than one ha and less than one percent of them were greater than 5 ha. Results of livestock production showed that more than 80% of these systems have no livestock (milk and meat) production.

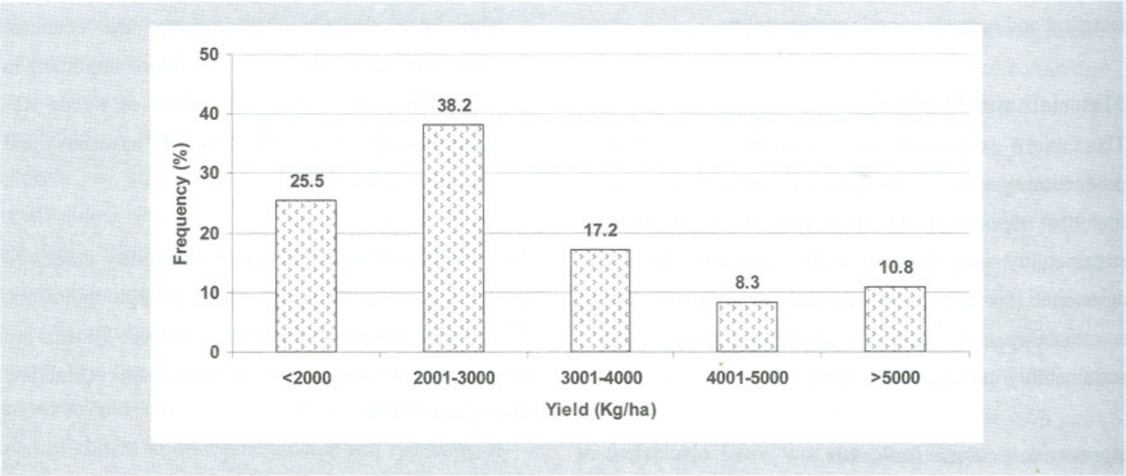

Figure 1. Average rice production in rice-based agroecosystems in Mazandaran.

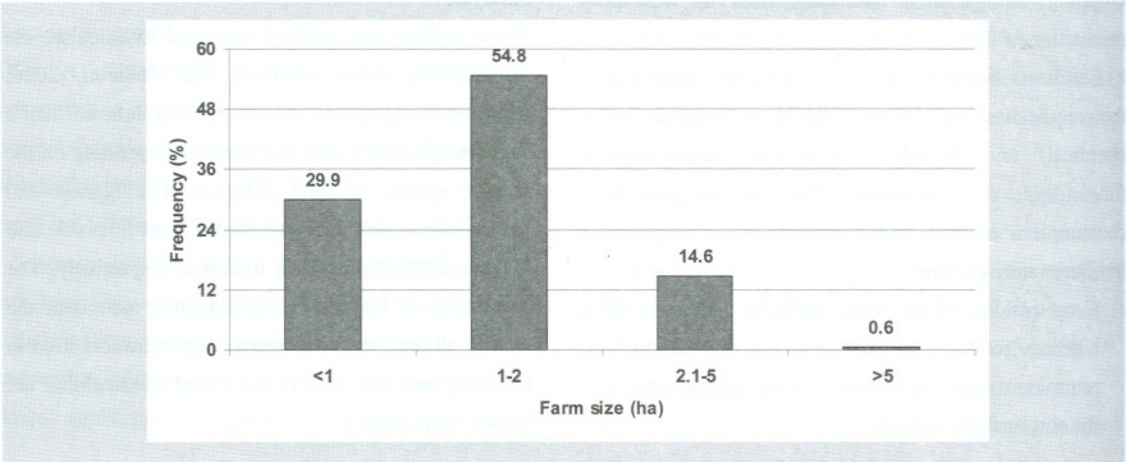

Figure 2. Farm size (cropping acreage) in rice-based agroecosystems in Mazandaran.

Fertilizers and Pesticides

Rice-based agroecosystems in this study earned 42% of the score of these indicators which shows they are not in sustainable status. As shown in Figure 3, more than half of farmers apply 200-400 kg/ha N and P chemical fertilizers which is a cause for concern in view of the demand for rice and the ecological fragility of Mazandaran to environmental pollution due to agrochemicals. Although application of chemical fertilizers prevents increasing the cropping area and improves crop yield, excessive fertilizer use will cause economic loss as well as environmental degradation.

Crop Residue Management

Rice-based agroecosystems earned 55% of the score of crop residue management which indicates they are relatively sustainable in managing crop residues. In 20% of systems, residues are left in the field and, in other cases, residues are removed or burned.

Water and Irrigation

The studied agroecosystems earned 73% of the score for these indicators which means they are sustainable in applying water and water resources. Although Iran is located in an arid and semi-arid area and water is most limiting factor in agricultural production in the country, Mazandaran has a good annual precipitation and so farmers are not forced to utilize non-sustainable methods of water consumption in the systems. However, it should be mentioned that we have not studied water pollution in present research and, therefore, it was not possible to evaluate health of water resources. Figure 4 shows water sources for irrigation of rice in the studied agroecosystems.

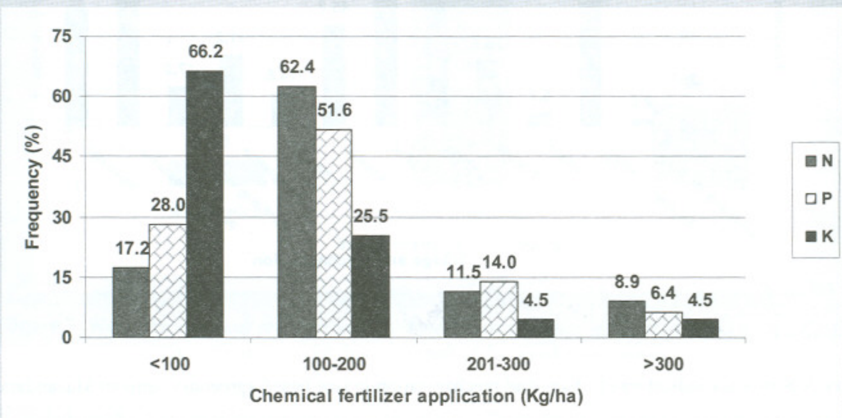

Figure 3. Chemical fertilizer application in rice-based agroecosystems in Mazandaran.

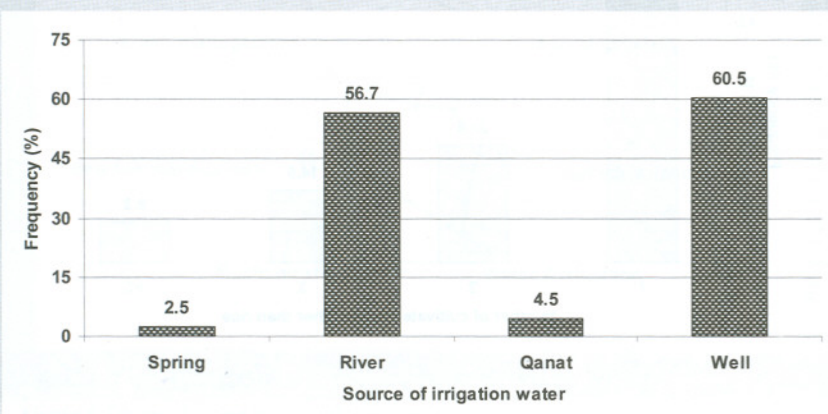

Figure 4. Source of irrigation water in rice-based agroecosystems in Mazandaran.

Mechanization

The results of the mechanization indicators are given in Figure 5. These agroecosystems earned 39% of the score of mechanization indicators which reveals that they are not sustainable and efficient in mechanization. For example, more than 63% of farmers apply more than two tillage practices. Although tillage has clear benefits for soil aeration and facilitates crop establishment and growth, excessive tillage is harmful for soil structure and its aggregates as well as its fauna and flora (Plante and McGill, 2002).

Agrobiodiversity

On average, rice-based agroecosystems in this study earned only 32% of the score of agrobiodiversity indicators which shows they are not productive systems in terms of biodiversity as an important pillar of sustainability. Less than half of farmers cultivated other crops than rice in their fields (Figure 6) which means these agroecosystems are monocultures which is not a sustainable farming system.

Furthermore, among farmers who cultivated other crops than rice, most of them are growing just one or two crops other than rice and two third of them have no livestock in their agroecosystems.

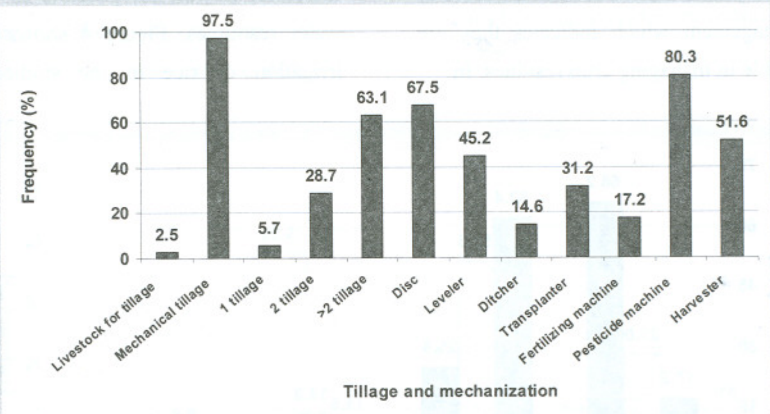

Figure 5. Scores for indicators of tillage and mechanization in rice-based agroecosystems in Mazandaran.

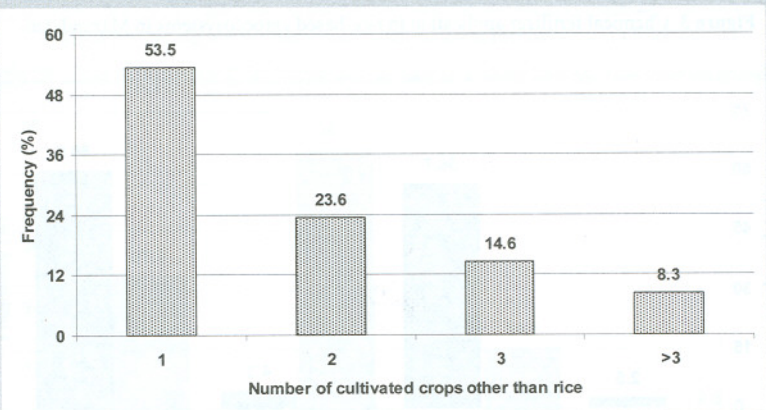

Figure 6. Crop diversity in rice-based agroecosystems in Mazandaran.

Weed Management

On average, rice-based agroecosystems in this study earned 56% of the score of weed management indicators. It seems that as they usually control weeds by hand (Figure 7), they apply less herbicide and, therefore, the methods of weed management in these agroecosystems appear to be more environmentally friendly.

Conclusion

Overall, the picture of the agro-technical characteristics of rice-based agroecosystems of Mazandaran is shown in Figure 8. Results showed that production indicators (including crop and livestock) had the lowest score and these systems should improve their production to attain agroecological sustainability. Production is an important component of sustainability of agroecosystems and many researchers argued that improving agricultural production would result in increasing system sustainability (Marten, 1988; Senanayake, 1991; Mahdavi Damghani *et al.*, 2006). It, however, does not mean that all systems that have a high productivity are sustainable. Some intensive systems have a high level of production while they are not sustainable.

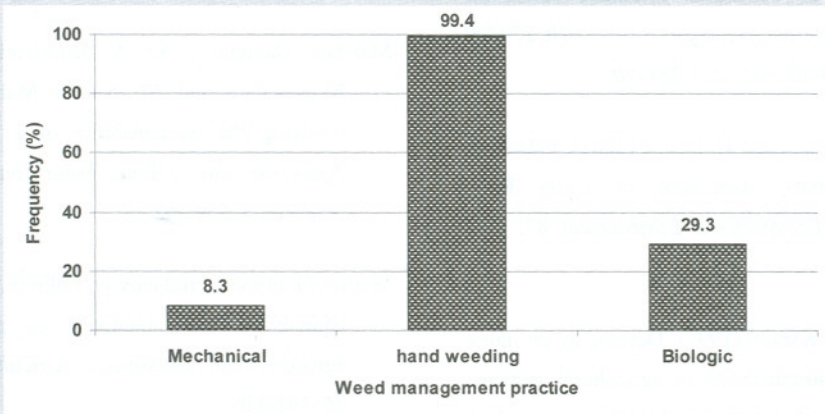

Figure 7. Weed management practices in rice-based agroecosystems in Mazandaran (in some fields, farmers apply more than one method for weed management).

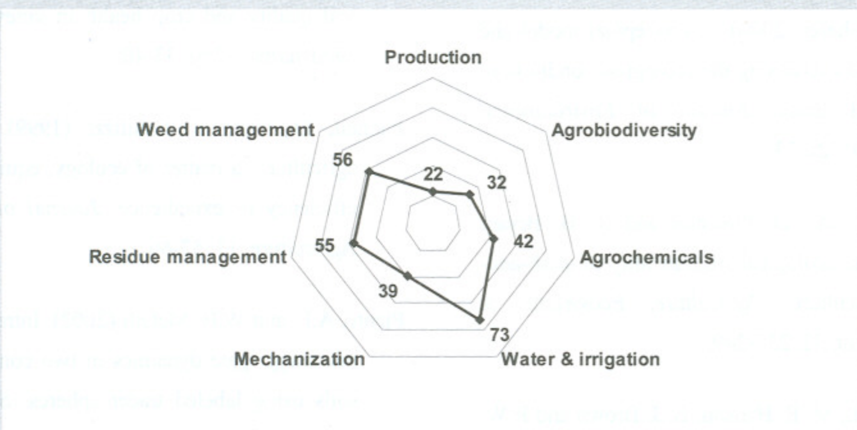

Figure 8. Observed scores (%) of different agro-technical indicators of sustainability index in rice-based agroecosystems in Mazandaran.

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References

Andreoli, M. and V. Tellarini (2000). Farm sustainability evaluation: methodology and practice. *Agriculture, Ecosystems & Environment*, 77: 43-52.

Berroterán, J.L. and J.A. Zinck (1997). Indicators of agricultural sustainability at the national level: a case study of Venezuela. Available online at: *http://ces.iisc.ernet.in/energy /HC270799 /LM/SUSLUP/Thema1/258/258.pdf*.

Camacho-Sandoval, J. and H. Duque (2001). Indicators for biodiversity assessment in Costa Rica. *Agriculture, Ecosystems & Environment*, 87: 141-150.

Hayati, D. and E. Karami (1997). Developing an index to evaluate sustainability of agricultural systems. Proceedings of 1st National Congress on Iran Agricultural Economy. Zahedan. 634-649.

Hess, G.R., C.L. Campbell, D.A. Fiscus, A.S. Hellkamp, B.F. McQuaid, M.J. Munster, S.L. Peck and S.R. Shafer (2000). A conceptual model and indicators for assessing the ecological condition of agricultural lands. *Journal of Environmental Quality*, 29: 728-737.

Kleinman, P. J. A., D. Pimentel and R. B. Bryant (1995). The ecological sustainability of slash-and-burn agriculture. *Agriculture, Ecosystems & Environment*, 52: 235-249.

Liverman, D. M., M. E. Hanson, B. J. Brown and R.W. Merideth Jr. (1988). Global sustainability: toward measurement. *Environmental Management*, 12: 133-143.

Lopez-Ridaura, S., O. Masera and M. Astier (2002). Evaluating the sustainability of complex socio-environmental systems; the MESMIS framework. *Ecological Indicators*, 35: 1–14.

Mahdavi Damghani, A. (2009). Evaluating sustainability of rice-based agroecosystems in Mazandaran, Iran: I. Socioeconomic characteristics. *Green Farming*, 2 (11): 754-757.

Mahdavi Damghani, A., A. Koocheki and P. Rezvani Moghaddam (2004). Sustainability indices: a tool for quantifying concepts of agroecology. *Environmental sciences*, 4: 1-10.

Mahdavi Damghani, A., A. Koocheki, P. Rezvani Moghaddam and M. Nassiri Mahallati (2006). Studying the Sustainability of a Wheat-Cotton Agroecosystem in Iran. *Asian Journal of Plant Sciences*, 5: 559-562.

Marten, G. (1988). Productivity, stability, sustainability, equitability and autonomy as properties for agroecosystem assessment. *Agricultural Systems*, 26: 291-316.

Nicholls, C.I., M.A. Altieri, A. Dezanet, M. Lana, D. Feistauer and M. Ouriques (2004). A rapaid, farmer-friendly agroecological method to estimate soil quality and crop health in vineyard systems. *Biodynamics*, 250: 33-40.

Pannell, D.J. and S. Schilizzi (1999). Sustainable agriculture: a matter of ecology, equity, economic efficiency or expedience. *Journal of Sustainable Agriculture*, 13: 57-66.

Plante, A.F. and W.B. McGill (2002). Intraseasonal soil macroaggregate dynamics in two contrasting field soils using labeled tracer spheres. *Soil Sci. Soc. Am. J.*, 66: 1285– 1295.

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The authors thank the Vice Presidency for Research and Technology of Shahid Beheshti University for providing financial support.

References

Andreoli, M. and V. Tellarini (2000). Farm sustainability evaluation: methodology and practice. *Agriculture, Ecosystems & Environment*, 77: 43-52.

Berroterán, J.L. and J.A. Zinck (1997). Indicators of agricultural sustainability at the national level: a case study of Venezuela. Available online at: *http://ces.iisc.ernet.in/energy /HC270799 /LM/SUSLUP/Thema 1/258/258.pdf.*

Camacho-Sandoval, J. and H. Duque (2001). Indicators for biodiversity assessment in Costa Rica. *Agriculture, Ecosystems & Environment*, 87: 141-150.

Hayati, D. and E. Karami (1997). Developing an index to evaluate sustainability of agricultural systems. Proceedings of 1st National Congress on Iran Agricultural Economy. Zahedan. 634-649.

Hess, G.R., C.L. Campbell, D.A. Fiscus, A.S. Hellkamp, B.F. McQuaid, M.J. Munster, S.L. Peck and S.R. Shafer (2000). A conceptual model and indicators for assessing the ecological condition of agricultural lands. *Journal of Environmental Quality*, 29: 728-737.

Kleinman, P. J. A., D. Pimentel and R. B. Bryant (1995). The ecological sustainability of slash-and-burn agriculture. *Agriculture, Ecosystems & Environment*, 52: 235-249.

Liverman, D. M., M. E. Hanson, B. J. Brown and R.W. Merideth Jr. (1988). Global sustainability: toward measurement. *Environmental Management*, 12: 133-143.

Lopez-Ridaura, S., O. Masera and M. Astier (2002). Evaluating the sustainability of complex socio-environmental systems; the MESMIS framework. *Ecological Indicators*, 35: 1–14.

Mahdavi Damghani, A. (2009). Evaluating sustainability of rice-based agroecosystems in Mazandaran, Iran: I. Socioeconomic characteristics. *Green Farming*, 2 (11): 754-757.

Mahdavi Damghani, A., A. Koocheki and P. Rezvani Moghaddam (2004). Sustainability indices: a tool for quantifying concepts of agroecology. *Environmental sciences*, 4: 1-10.

Mahdavi Damghani, A., A. Koocheki, P. Rezvani Moghaddam and M. Nassiri Mahallati (2006). Studying the Sustainability of a Wheat-Cotton Agroecosystem in Iran. *Asian Journal of Plant Sciences*, 5: 559-562.

Marten, G. (1988). Productivity, stability, sustainability, equitability and autonomy as properties for agroecosystem assessment. *Agricultural Systems*, 26: 291-316.

Nicholls, C.I., M.A. Altieri, A. Dezanet, M. Lana, D. Feistauer and M. Ouriques (2004). A rapaid, farmer-friendly agroecological method to estimate soil quality and crop health in vineyard systems. *Biodynamics*, 250: 33-40.

Pannell, D.J. and S. Schilizzi (1999). Sustainable agriculture: a matter of ecology, equity, economic efficiency or expedience. *Journal of Sustainable Agriculture*, 13: 57-66.

Plante, A.F. and W.B. McGill (2002). Intraseasonal soil macroaggregate dynamics in two contrasting field soils using labeled tracer spheres. *Soil Sci. Soc. Am. J.*, 66: 1285– 1295.

Rao, N. H. and P.P. Rogers (2006). Assessment of agricultural sustainability. *Current Science*, 9: 439-448.

Sadighi, H. and K. Rousta (2003). Factors affecting sustainable agricultural knowledge of exemplary corn growers in the Province of Fars, Iran. *Iranian J. Agric. Sci.*, 34: 913-924.

Senanayake, R. (1991). Sustainable agriculture: definitions and parameters for measurement. *Journal of Sustainable Agriculture*, 1: 7-28.