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ASSESSING SUSTAINABILITY IN AGRICULTURE: A MULTICRITERIA APPROACH

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1. INTRODUCTION

This paper presents the results of a study on sustainability of alternative corn farming systems. The aim of this study is to select indicators for sustainability analysis, and to set up a methodological path.

While talking about sustainable agriculture is increasing in the academic, technical, extension, farmers association communities, it is still difficult to determine if and how much an agricultural system is really sustainable. It is really difficult to determine at what point does philosophy end and science begins. Vernon W. Ruttan, in closing his paper "Sustainable Growth in Agricultural Production: Poetry, Policy and Science", asserts: <<At present, there is no package of technology available to transfer to producers that can assure the sustainability of growth in agricultural production at a rate that will enable agriculture, particularly in the developing countries, to meet the demands being placed on them. At present, sustainability is appropriately viewed as a guide to future agricultural research agendas rather than as a guide to practice>>. (V.W.Ruttan, 1991). Now, after seven years, the situation is not very much changed, but subsidies that governments, particularly in the EU, are providing to the farmers for lower input agriculture, call for appropriate methodologies to measure sustainability of agricultural production.

2. THE CASE-STUDY

The selected area for this study is the watershed of Trasimeno Lake that is the largest lake of Central Italy. It is a very important area from the environmental point of view, and very high is the risk of environmental contamination from agriculture, because of the type of soils, especially those just around the lake. Most of them are sandy, and farmers use to grow crops almost as far as the lake shore.

Beside the concerns for nitrogen and pesticide leaching, phosphorus and pesticide runoff and soil erosion, many people are discussing about the use of lake water for irrigation, and the influence of it on the lake water level. Some restrictions in water pumping are imposed by local government, but still a large amount of water is drawn from the lake.

The lake is easily subject to pollution because it only has an artificial effluent built by Romans, so it is a close basin and the average depth of the lake is only m. 4.7. The theoretical time for complete exchange of water is 21.6 years, very high for only 124 square km of area surface and 53.7 km of perimeter. In addition, in the area there is a very important and varied vegetation, as well as the fauna. Both vegetation and fauna are rare in some cases.

Most of the farmers in this watershed grow wheat, burley, sunflowers, sugar beet and corn. Some of them are also growing olive trees and vine. The most important crop is wheat, and second is corn. Most of the farmers growing corn use high input. As a matter of fact, they use much water for irrigation, pesticides mainly for weeds, and large amounts of nitrogen. Another behavior that may generate environmental impacts, is that some farmers do not rotate crops for several years, so that they can grow corn on the same field for years.

For all the reasons above, this area and this crop are particularly suitable to try to set up a way for measuring sustainability of different farming systems. The starting point is to understand what is the standard farming system for corn in the Trasimeno area. After that, it is possible to check for other farming systems, and to take in consideration other low input farming systems, even though not really adopted there.

The study of the standard farming system has been done through a survey on a representative sample of farms. The resulting data have been compared and checked with other source of information, such as farmers' associations, or extension services.

To get the representative sample first a data bank on all conventional farms growing corn has been set up. Only conventional farms have been considered because most of the farms in the Trasimeno area don't use low input or organic farming systems, so the standard farming system must be conventional. However, there are some farms using different cropping systems, and they were taken into account in the phase of setting up the alternatives to the standard farming system. The data bank has been built getting information on farms from two big Plants for corn grain drying. All the farmers sell corn there, so they have the complete list of all farmers growing corn.

The second step was to fix a threshold in terms of total production, under which the farms have not been considered. The threshold adopted was 10 t of total production. In this way, 90 farms were excluded from the list, because they are under this threshold. They represent the 44.4% of the farms growing corn, but only the 4.5% of the total production. After that, the remaining list counted 113 farms.

Once got this list, the third step was to extract the sample using the statistical method of random sampling without repetition. The sampling rate used is 20%, so that 22 farms have been extracted.

The questionnaire used was divided in three parts: the first one includes general information on the farm; in the second one, specific information on the corn farming system is requested; the third part contains questions to understand if the farmer is informed about environmental problems, and what precautions, if any, they use to reduce environmental and human health risks.

The survey shows that most of the farms are small size farms, growing some only corn, some corn and other crops. The more farms are small, the more they do not use rotation, so that it is possible to find several cases of continuous corn cropping. The average is 12 years, but in some fields corn is grown for 20 years. This especially happens in the smallest farms, due to the need of simplifying the farming system to reduce costs. However, even if the farmers think that they can reduce costs in this way, in the long term they may increase them, because without rotation, weeds and plant disease tend to increase, and more technical and financial efforts are required to fight them. This also means that farmers have to use more chemicals, increasing in this way the environmental impact.

Farming system for corn is very similar in all the farms, the only one significant difference is that big farms use rotation.

From the questionnaires it was possible to get all information about tillage, fertilizers and pesticides use, irrigation. In this way the existing most common farming system was well described.

3. THE ALTERNATIVE CORN FARMING SYSTEMS

Following, very shortly each alternative farming system considered to be assessed will be presented. They are four farming alternatives, called from Alternative 0 to 3.

3.1. Alternative 0

This is the existing situation that is the standard corn farming system resulting from the questionnaires. Some technical information:

Previous crop:	normally corn is continuously grown for years. Rare rotation with wheat.
Field operations:	plowing, 40-45 cm; disk harrowing; sweep; cultivator.
Main fertilization:	rarely manure used. Normally fertilizers are incorporated while plowing. Average quantities are 220 kg/ha nitrogen, 170 kg/ha phosphorus, 100 kg/ha potash. Distribution by centrifugal fertilizer spreader.
Seeding::	75,000 treated seeds/Ha distributed using drill presswheel. Rarely soil disinfesting is used. Sometimes there is a need for rolling.
Weeding:	normally done before seeds sprouting, using very high quantities of chemicals with sprayers.
Late fertilization:	only nitrogen is used, about 100 kg/Ha incorporated during cultivator use.
Irrigation:	mainly sprinklers are used. Average water amounts used yearly is 4,000 m^3.
Yield:	average 10 t/Ha.

3.2. Alternative 1
This alternative comes from a long experimentation of different corn crossbreeds that is part of a broader research done in central Italy. By reducing the life cycle of the plant, it is also possible to reduce the quantity of water and chemicals. Using the results of this experimentation, it has been assumed that this alternative farming system follows the EU Reg. 2078/92, in particular the measure A, action 1.1 "considerable reduction of fertilizers". If a farmer applies for this action, he has to reduce of a 40% the standard quantity of nitrogen, that is established for corn to be 280 kg/Ha. The loss of the yield is compensated by a subsidy.
The other aim of this alternative is to optimize water efficiency, by using less water but in the appropriate growing stages of the plants.

Some technical information:

Previous crop:	normally corn is continuously grown for years. Rare rotation with wheat.
Field operations:	plowing, 40 cm; disk harrowing; sweep; cultivator.
Main fertilization:	fertilizers are incorporated while plowing. Average quantities are 100 kg/ha nitrogen, 90 kg/ha phosphorus. Distribution by centrifugal fertilizer spreader.
Seeding::	using a class 500 crossbreed, seeding is done 15-20 days before the normal time, to get 6 plants/m^2. Sometimes there is a need for rolling.
Weeding:	normally done before seeds sprouting, using suggested quantities of chemicals with sprayers.
Late fertilization:	only nitrogen is used, about 70 kg/Ha incorporated during
Irrigation:	sprinklers are used only two times during the life cycle.
Yield:	average 9 t/Ha.

3.3. Alternative 2

This alternative comes from the experimentation of drip irrigation for corn. Three years experimentations showed that drip irrigation is not very effective for corn from the economic point of view, but it is very good from the environmental point of view. As a matter of fact, water quantities are in this way reduced to 1,200 m^3, and drip irrigation makes it possible to add fertilizers to water, so that quantities can be reduced due to the local application. Using this system, corn increases very much production. The problem from the economic point of view is irrigation system cost and maintenance.

Some technical information:

Previous crop:	normally corn is continuously grown for years. Rare rotation with wheat.
Field operations:	plowing, 40-45 cm; disk harrowing; sweep; cultivator.
Main fertilization:	fertilizers are incorporated while plowing. Average quantities are 120 kg/ha nitrogen, 120 kg/ha phosphorus, 60 kg/Ha potash. Distribution by centrifugal fertilizer spreader.
Seeding::	class 600-700 crossbreed used, to get 7 plants/m^2. Sometimes there is a need for rolling.
Weeding:	normally done before seeds sprouting, using very high quantities of chemicals with sprayers.
Late fertilization:	only nitrogen is used, 100 kg/Ha dissolved in irrigation water.
Irrigation:	drip irrigation.
Yield:	average 13 t/Ha.

3.4. Alternative 3
In this alternative, it is assumed that some principles of organic agriculture are applied to corn growing. The most important techniques used are:
- rotation;
- tillage reduction;
- manure and previous crop leftovers used as fertilizers;
- no use of chemicals.
This alternative is better feasible if farms have livestock to get manure, and also to rotate corn with forages, especially legumes. In this case is also possible to apply for subsidies, adopting measure A/3 of EU Reg. 2078/92.
Some technical information:

Previous crop:	Rotation with wheat and alfalfa.
Field operations:	plowing, 25-30 cm; harrowing.
Main fertilization:	Application of 35 t of solid manure incorporated while plowing.
Seeding::	class 500 crossbreed used, to get 6 plants/m^2. Sometimes there is a need for rolling.
Weeding:	no chemical weeding, only one or two cultivator uses.
Irrigation:	sprinklers are used only two times during the life cycle.
Yield:	average 6 t /Ha.

4. THE INDICATORS

Indicators are the tools that allow to carry out a multicriteria analysis, because they make it possible to describe and sum up the multiple features of each alternative. In this case, the choice of indicators comes from several selections and tests. The result is that four groups of indicators have been selected:
-economic indicators to represent the economic efficiency of each alternative;
-energy indicators to find the input-output ratio and understand cost and benefits in terms of energy consumption. Energy could be a good bridge for a better understanding of both economic and environmental effect;
-farming indicators to stress some technical results got using different farming systems;
-environmental indicators to assess the environmental impact of each alternative.

4.1. Economic indicators
For each of the alternatives a balance sheet was done. The balances are reported in Tables 1, 2, 3 and 4. From the balance results, two indicators were selected: *Gross Income and Return Over Direct Expense,* both per Hectare. In this way it is possible first understand the effect of different farming systems on production capacity, and second how the different techniques contribute to increase the direct expense, compared to the increased or decreased production. All values are in Italian Lire.

Gross Income	
corn grain	3,200,000
subside Reg. 1765/92	1,068,000
Total	**4,268,000**
Direct expense	
fuel and lubricants	727,000
custom hire	280,000
irrigation	400,000
seeds	198,000
herbicides	100,000
fertilizers	458,000
grain drying	494,000
Total	**2,657,000**
Return over direct expense	**1,611,000**

Tab.1: A0, economic balance

Gross Income	
corn grain	2,880,000
subside Reg. 1765/92	1,068,000
subside Reg. 2078/92	330,000
Total	**4,278,000**
Direct expense	
fuel and lubricants	450,000
custom hire	280,000
irrigation	258,000
seeds	198,000
herbicides	100,000
fertilizers	227,000
grain drying	275,000
Total	**1,788,000**
Return over direct expense	**2,490,000**

Tab.2: A1, economic balance

Gross Income	
corn grain	4,160,000
subside Reg. 1765/92	1,068,000
Total	**5,228,000**
Direct expense	
fuel and lubricants	340,000
custom hire	280,000
irrigation	980,000
seeds	198,000
herbicides	100,000
fertilizers	333,000
grain drying	635,000
Total	**2,866,000**
Return over direct expense	**2,362,000**

Tab.3: A2, economic balance

Gross Income	
corn grain	1,920,000
subside Reg. 1765/92	1,068,000
subside Reg. 2078/92	330,000
Total	**3,318,000**
Direct expense	
fuel and lubricants	420,000
custom hire	250,000
irrigation	258,000
seeds	198,000
herbicides	0
fertilizers	0
grain drying	183,000
Total	**1,309,000**
Return over direct expense	**2,009,000**

Tab.4: A3, economic balance

4.2. Energy indicators

For each of the alternatives an energy balance was calculated, including energy inputs and outputs, using conversion factors from existing publications (see references). Tables 5, 6, 7 and 8 show the energy balances.

The selected indicators are:

-Net energy efficiency

It comes from the ratio output/input, where the output is only the grain of corn, not residues.

-Net economic productivity of the non renewable energy

This is an indicator got crossing economic and energy information.This indicator gives information on the net (no residue) production got, in monetary terms, per each energy unit put in the production process.

-Net energy productivity of money for non renewable energy

This indicator too crosses economic and energy information. It gives information on the net (no residue) quantity of energy produced per each unit of money (Italian Lire) put in the production process.

INPUT	Kg/Ha	MJ/Kg	MJ/Ha
1.*Machinery operation*			
1.1.Fuel	182	44.4	8,080.8
1.2.Lubricant	1.14	80	91.2
2.Irrigation			
2.1.Fuel	750	44.4	33,300
2.2.Lubricant	5	80	400
3.*Fertilizers*			
3.1.Nitrogen	320	75.3	24,096
3.2.Phosphorus	170	12.6	2,142
3.3.Potash	100	9.6	960
4.Seeds	25	28.9	722.5
5.Herbicides	4	91.3	365.2
6.Machinery			5,610
7.Grain drying	458	44.4	20,335.2
Total input			**96,102.9**
OUTPUT			
1.Corn grain	10,000	14.7	147,000
2.Residue	12,000	18.8	225,600
Total output			**372,600**

Tab. 5: A0, energy balance

INPUT	Kg/Ha	MJ/Kg	MJ/Ha
1.*Machinery operation*			
1.1.Fuel	182	44.4	8,080.8
1.2.Lubricant	1.14	80	91.2
2.Irrigation			0
2.1.Fuel	400	44.4	17,760
2.2.Lubricant	2.5	80	200
3.*Fertilizers*			0
3.1.Nitrogen	170	75.3	12,801
3.2.Phosphorus	90	12.6	1,134
3.3.Potash	0	9.6	0
4.Seeds	22	28.9	635.8
5.Herbicides	4	91.3	365.2
6.Machinery			4,772
7.Grain drying	188	44.4	8,347.2
Total input			**54,187.2**
OUTPUT			
1.Corn grain	9,000	14.7	132,300
2.Residue	10,800	18.8	203,040
Total output			**335,340**

Tab. 6: A1, energy balance

INPUT	Kg/Ha	MJ/Kg	MJ/Ha
1.*Machinery operation*			
1.1.Fuel	174	44.4	7,725.6
1.2.Lubricant	1	80	80
2.Irrigation			0
2.1.Fuel	260	44.4	11,544
2.2.Lubricant	2	80	160
3.*Fertilizers*			0
3.1.Nitrogen	220	75.3	16,566
3.2.Phosphorus	120	12.6	1,512
3.3.Potash	60	9.6	576
4.Seeds	25	28.9	722.5
5.Herbicides	4	91.3	365.2
6.Machinery			7,048
7.Grain drying	587	44.4	26,062.8
Total input			**72,362.1**
OUTPUT			
1.Corn grain	13,000	14.7	191,100
2.Residue	15,600	18.8	293,280
Total output			**484,380**

Tab. 7: A2, energy balance

INPUT	Kg/Ha	MJ/Kg	MJ/Ha
1.*Machinery operation*			
1.1.Fuel	145	44.4	6,438
1.2.Lubricant	1	80	80
2.Irrigation			0
2.1.Fuel	400	44.4	17,760
2.2.Lubricant	2.5	80	200
3.Fertilizers			0
3.1.Nitrogen	0	75.3	0
3.2.Phosphorus	0	12.6	0
3.3.Potash	0	9.6	0
4.Seeds	22	28.9	635.8
5.Herbicides	0	91.3	0
6.Machinery			3,078
7.Grain drying	125	44.4	5,550
Total input			**33,741.8**
OUTPUT			
1.Corn grain	6,000	14.7	88,200
2.Residue	7,200	18.8	135,360
Total output			**223,560**

Tab. 8: A3, energy balance

4.3. Farming indicators
Relating to main environmental issues of the Trasimeno area, two indicators have been selected in this group:
-Nitrogen fertilizers productivity
It is the ratio yield (kg/Ha)/nitrogen quantity (kg/Ha). In other words, it indicates the quantity of the product got per each nitrogen unit.
-Irrigation water productivity
It is the ratio yield (kg/Ha)/irrigation water quantity (m^3/Ha). In other words, it indicates the quantity of the product got per each water m^3.

4.4. Environmental indicators
The environmental indicators used are those included in Planetor. Planetor is a computer program designed by the Center for Farm Financial Management, University of Minnesota, to help farmers evaluate the impact of implementing sustainable farming practices. The environmental impacts are evaluated using a system of high, medium and low ratings. In addition to the high, medium and low ratings, each environmental factor has additional detailed information available. To get this result, Planetor program has been run, using available data of Trasimeno area. Indicators are:

-Soil Water Erosion
This indicator estimates soil losses due to rainfall and surface runoff; it comes from the application

of the Revised Universal Soil Loss Equation (RUSLE), incorporated into Planetor.
-Nitrogen Leaching
This is to calculate the potential nitrogen leaching. For this purpose, Planetor uses the Nitrogen Leaching and Economic Analysis Package (NLEAP), developed by ARS (Agricultural Research Service).
-Phosphorus Runoff
The aim of this indicator is to assess the potential risk of phosphorus movement to water bodies based on site specific characteristics and management practices. Potential phosphorus runoff is estimated using the Phosphorus Index, developed by a National Soil Conservation Service Phosphorus Task Force.
-Pesticide Leaching and Runoff
The potential for pesticide leaching and runoff problems are evaluated using a screening level methodology developed to evaluate pesticide-soil interactions (Hornsby, 1992).

5. ASSESSMENT OF THE ALTERNATIVES

Following, main steps of the assessment of the alternatives are described.

5.1. Analysis development
Several multicriteria methodologies are available in literature. In this study two different methods have been used, to compare the results, and test the consistency. An evaluation method can generate a complete ranking of the alternatives, the best alternative, or a set of acceptable alternatives. In this case, the methods used can present a complete ranking. Methods used are of course discrete evaluation methods, since a finite set of alternatives has to be evaluated. Discrete methods differ with respect to the measurement scale of the attributes; the attribute scale can be quantitative or qualitative. Most evaluation methods are designed to process quantitative information on attributes. These methods require quantitative information both on the attribute values (indicators), and on the priorities. In this study, most of the indicators are quantitative. Only the environmental indicators are qualitative, based on rating scores. However, several procedures can be applied to produce quantitative weights from qualitative rating scores. In this case, the three rating levels (High, Medium, Low), have been just turned into numbers 1, 2 and 3, where H=3, M=2, L=1.
To prepare the analysis development, available data have to be ordered in an evaluation matrix, in which alternatives are on the columns, and indicators on

the rows. In this way, for each of the alternatives the value of each of the indicators is represented, and the matrix includes all information on the performance of the alternatives. The evaluation matrix is shown in Table 9. In this case the result is a 12 rows (indicators) x 4 columns (alternatives) matrix.

Indicators	A0	A1	A2	A3
1. Return over direct expense	1,611,000	2,490,000	2,362,000	2,009,000
2. Gross income	4,268,000	4,278,000	5,228,000	3,318,000
3. Net energy efficiency	1.52	2.44	2.64	2.61
4. Net econ. prod. of non renewable energy	44.41	78.94	72.24	0.067
5. Net energy prod.of money for non ren.energy	0.055	0.073	0.066	50
6. Nitrogen fertilizers productivity	31.25	52.94	59.09	3.75
7. Irrigation water productivity	2.5	5.62	11.8	1
8. Soil water erosion	3	2	2	1
9. Pesticide leaching	3	1	1	1
10. Pesticide runoff	3	2	1	1
11. Nitrogen leaching	3	1	1	1
12. Phosphorus runoff	2	1	1	1

Tab 9: Evaluation matrix

Since indicators values are expressed in different measurement units, to make them comparable it has been necessary to transform the original values into a common dimensionless unit. Values have been transformed in utility indices by defining utility functions for each indicator. Utility functions can relate different measurement scale values to an index reflecting the utility or disutility of these values. In this study, depending on the type of measurement scale, linear increasing or decreasing functions have been used. The resulting indexes are included in the 0-1 range, where 0 is max disutility and 1 is max utility.

In particular, increasing function was used for economic, energy and farming indicators, and decreasing for environmental indicators.

Next step is the assignment of priorities to the indicators. As a matter of fact, different indicators can contribute with different weight to the final result. A weight vector has to be set up. Taking into account the aims of this study, to find a set of significant indicators and to set up a methodological path to assess sustainability in agricultural production, same weights should be attributed to environmental and economic indicators, to stress the concept of sustainability. However, this is not a rule always applicable. It depends upon the socioeconomic conditions of the area, but also upon the environmental vulnerability. In this case, since Trasimeno area is considered a high environmental risk area, just little more importance has been attributed to the environmental indicators, as well as to the farming ones, because they give an

idea of the water consumption and nitrogen level of use, so are strongly related to the environmental ones.

5.2. Multicriteria methodologies used

To get the results, it was used a computer program [13], that allows to guide the user through the steps described above, and to assess alternatives using several different multicriteria methodologies. In this study only two multicriteria methods were used: a.Weighted Summation; b. ELECTRE Method.

a. Weighted Summation

Consider i(i=1,....I) alternatives and j(j=1,....J) indicators. x_{ji} denotes the effect of alternative i according to indicator j. The priorities assigned to indicators are denoted in terms of weights w_j (j=1,....J).

Weight summation method consists in an appraisal score calculated for each alternative by first multiplying each value by its weight, followed by summing of the weighted scores for all indicators.

Alternatives ranking is got by using:

$$\text{maximize} \quad \sum_{j=1}^{J} \quad (w_j \, x_{ji})$$
$$i= 1,....I$$

b. ELECTRE Method

The program uses a variant of this method, known as Electre 2. It is based on a pairwise comparison of alternatives. To establish a dominance relationship for each pair of alternatives both an index of concordance and an index of discordance are used. The first one, shows how much alternative i is better than alternative i'. This index is got by summing the weights of the indicators included in the concordance set C_{ii}' that is the set of indicators for which alternative i is at least equal to alternative i':

$$c_{ii'} = \sum_{j \, \in \, Cii'} w_j$$

The discordance index shows how much alternative i is worse than alternative i'. For each indicator from the discordance set D_{ii}' (that is the set of indicators for which alternative i is worse than alternative i') the difference between the values of both alternatives is calculated. The largest of these differences is the discordance index:

$$d_{ii'} = \max_{j \, \in \, D_{ii'}} / x_{ji} - x_{ji'} /$$

5.3. Results

Both methodologies used gave the same results. And Electre method gives the same result both for concordance and discordance indexes. Rankings are shown in Tables 10 and 11.

	Alternatives	Weighted Sum
1.	A2	0.901
2.	A1	0.768
3.	A3	0.716
4.	A0	0.031

Tab.10: Weighted Summation

	Alternatives	Concordance	Alternatives	Discordance
1.	A2	1.437	A2	-1.915
2.	A1	1.062	A1	-0.671
3.	A3	0.375	A3	0.084
4.	A0	-2.875	A0	2.503

Tab.11: Concordance and Discordance Analysis

Alternative 2 better than the other ones can accomplish the different objectives represented by the indicators. As a matter of fact, this alternative reconciles in a very good way production with a reduction of nitrogen and irrigation water. However, this is also the most theoretical alternative, due to the use of drip irrigation, that is able to give good economic results if only short term and return over direct expense are taken into account, but as soon as depreciation, maintenance and long term are considered, the economic results could fall. Drip irrigation is good for high income crops, such as fruit trees, or some type of vegetables, but for corn it seems to be mostly experimentation matter, than real farming system.

Looking at the alternative ranking, much more interesting is the second place of alternative 1, because it makes chemical inputs considerably reduced, and even though production is reduced too, the EU subsidies for low input agriculture help to keep good the economic results. In this way, sustainability accomplishment is much closer. It could be observed that if subsidies will be no longer distributed, this alternative will fall from the economic point of view. Agenda 2000, the EU orientation document for the Common Policy in the 21st Century, underlines the importance of the subsidies to farmers for low input agriculture, so that it is reasonable to expect the subsidies increasing, instead

of suspension. The EU in this way acknowledges that sustainable agriculture cannot be only a farmers responsibility, but there is the need for a public participation.

Finally, it is interesting that the existing situation, that is alternative 0, is the last in the ranking. This is because economic results are good, but too many chemical inputs are used and too much water for irrigation. The risk for environmental pollution is too high.

Table 12 shows sensitivity analysis that is a simulation of the stability of the weighted summation ranking, increasing or decreasing each of the weights, while all the others are kept. To get a different ranking, weights need to be changed so much, that it is possible to say that the ranking is very stable, and well reflects the objectives and the conditions established with the analysis.

Indicators	Weights	Dec. Sensitivity	Inc. Sensitivity
1. Return over direct expense	0.094	-	1.006>A1
2. Gross income	0.063	-	-
3. Net energy efficiency	0.031	-	-
4. Net econ. prod. of non renewable energy	0.063	-	0.445>A3
5. Net energy prod.of money for non ren.energy	0.063	-	0.404>A1
6. Nitrogen fertilizers productivity	0.125	-	-
7. Irrigation water productivity	0.125	-	-
8. Soil water erosion	0.063	-	0.433>A3
9. Pesticide leaching	0.125	-	-
10. Pesticide runoff	0.063	-	-
11. Nitrogen leaching	0.125	-	-
12. Phosphorus runoff	0.063	-	-

Tab.12: Sensitivity Analysis

6. CONCLUSIONS

It is not easy to make conclusions for this study. It is just a beginning, since several tests, for different crops and eventually for the whole farm level should be done. It is only possible to do some considerations and remarks.

First of all, about the methodology. Since there is no way, at the moment, to include in monetary terms in the balance sheet of farms the environmental impacts, both positive and negative, multicriteria analysis seems to be a good method to assess the level of sustainability of different farming systems or

different farms. Of course other multicriteria methodologies than the two used in this study can be used. However, several other tests have to be done.

The other point of discussion is the indicators choice. The indicators used in this study are just some proposals, but several other indicators can be included in the set to better assess the different aspects of the farming systems. There is the need to keep studying indicators and to try other ones.

Besides this study, there is the need in any other way, to get methodologies to assess and compare different level of sustainability in agricultural production. This is becoming particularly urgent in the EU, due to the increasing in the near future of grants and subsidies for several forms of environmentally sound agricultural production techniques.

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