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Economic and Ecological Factors Affecting Sustainable Use of Agricultural Land and Optimal Sustainable Farm Plans: The Case of Menemen

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Abstract: The starting point of this research was to examine the sustainable use of limited and irresistible resources, the land and investigation of the factors that affects land use. The main aims of the research were to make up farm plans with multi goals regarding sustainability; to determine sustainable cropping patterns which comply with sustainable land use economically and ecologically with least sacrifice possible; suggesting agricultural and environmental policies concerning realization of economic and ecological sustainability of agricultural lands. This research was carried out in the district of Menemen, Izmir, Turkey. Farm plans that were obtained by goal programming models and linear programming in the aspect of sustainability of agricultural lands have given the same results. In the models that minimize fertilizer and pesticide use which effects sustainable use of agricultural lands in a negative way less income was brought by under the existing circumstances. According to the results it might be claimed that when the optimal farm plans are realized the sustainability of the land will be enabled. In the models that do not break sustainable land use but minimize the cost for fertilizers and pesticides; to increase the income and to put unused land in use again new alternative crops should be added to the existing one. Farmers' enthusiasm and belief in this issue are important. It was observed that most farmers were carrying out some rehabilitation activities for their lands and reducing use of fertilizers and pesticides.

Key words: Sustainable land use, farm plan, goal programming

INTRODUCTION

Getting in to the sequence of rapid economic development has made countries especially the developed ones threaten natural resources and the life to a great extent. The pressure of rapid technological development on the environment has increased gradually in 20th century. The increase of environmental problems even more than the self-renewing capacity of the nature in one hand and the limited supply of natural resources on the other hand have turned out to be the facts being admitted by everyone.

Environmental problems that have come up in last 3 decades and discussion on them suggest the necessity of some modifications on the process of agricultural production. Applications towards intensive agriculture such as; use of chemical fertilizers and pesticides; irrigation, mechanization and plant breeding have caused considerable increase in agricultural production. But this development has also turned out to be one of the factors that affect the ecosystem adversely and cause environmental pollution.

As in the world and in Turkey too, the decreasing natural resources and demands of growing population is building up a pressure on limited resources so the sustainability of efforts on protecting these resources is gaining importance. When the sustainability is considered to be based on the equality of generations, the wealth of future generations also depends on the results of current choices of production methods as much as ours does. But unfortunately today's production methods are degrading the land, which is an inevitable resource for agriculture and threatening the wealth of future generations.

Because of its very slow formation rate (100-400 years/cm of topsoil), soil must be considered as a non-renewable resource and must be preserved[1]. Sustainable land use can be defined as the spatial and temporal harmonization of all main uses of soil and land,

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minimizing irreversible effects[1,2]. According to Naveh and Lieberman[3] sustainable land use is the rational continuous use without any serious and constant degradation in the quality of per unit of land.

Inefficient irrigation causes the problems of salinity and waterlogging. The use of heavy machinery also causes soil compaction. Chemical fertilizer and pesticides give rise to decline in soil productivity and deteriorate the environment quality. But, in achieving the sustainable use of agricultural lands, factors affecting the use also have importance. In this study a set of economical and ecological factors were determined in compliance with the objectives of land use assessment. Considering the characteristics of the research area and the data in hand; gross margin as economical; fertilizer and pesticide use, number of irrigation, number of cultivation, as ecological factors were determined as important criteria for sustainability. It is admitted that this chosen set of criteria does not reflect all economical and ecological factors. More parameters may be defined but the set of criteria chosen was accepted suitable for the region in the aspect of sustainable land use.

Objectives of this research includes; to identify economic and ecological factors that affect the sustainable use of agricultural lands in the research area; to make up farm plans with multi goals regarding sustainability; to determine sustainable cropping patterns which comply with sustainable land use economically and ecologically with least sacrifice possible; suggesting agricultural and environmental policies concerning realization of economic and ecological sustainability of agricultural lands.

MATERIALS AND METHODS

This research covers the district of Menemen, which has an important agricultural potential within Aegean Region. In the study primary crops as cotton, wheat, grape and corn productions were included in the research.

The data was derived in three ways; the first was obtained by interviews with chosen farmers in the research area. The second was gathered from various institutions in order to determine ecological and agricultural characteristics of the area. The last was gathered from related statistics and previous researches carried out in the same area.

The most important part of data was the one, which was constituted by the original information gathered from a group of farms. During the survey to gather this group a previously prepared questionnaire of 90 questions was applied in face to face interviews with farmers. Before the interviews farmers were informed briefly about what sustainability meant.

The whole Menemen district was examined in order to reflect all problems. To carry out the survey the district was divided in to two banks by using the existing main irrigation canal and named as right and left banks. Three villages out of 15 in the right bank and three from the 15 in the left bank were chosen randomly. They were Hasanlar, Koyundere and Turkeli from the right bank and Musabey, Suzbeyli and Ulucak from the left bank.

To determine how many farmers were to be interviewed, the records of the Water User Associations on the right and left banks in the area were obtained. Sample size was calculated with the proportional sample size formula[4] and the farmers to be interviewed were randomly selected. Later the questionnaire was applied to 98 farms on 125 plots for four main enterprises. By this questionnaire on 125 plots in six villages of both banks the data was gathered for the lands on which primary crops as; wheat, grape, cotton and corn were produced in 1998.

For the plans towards sustainability, linear programming and goal programming methods were used. Goal programming is a modified version of linear programming to meet multi goals. Goal programming is minimizing deviations from the acquired targets according to the given restrictive set instead of maximizing or minimizing the targets in linear programming. Linear programming tries to optimize the target function as much as possible by minimizing or maximizing but goal programming tries to find out closest values to the desired target[5]. In goal programming a specific numerical goal is first established for each of the objectives. Besides, a target formula may be worked out by adding deviation variables to the existing restrictive. When all deviation variables are piled up in target function and minimizing process is carried out all targets are achieved with minimal deviation. A brief goal programming formula is shown below[5-7].

Objective function

$$Z = \sum_{k=1}^{K} (p_k + n_k)$$

Constraints

$$\sum_{j=1}^{n} a_j x_j \leq b_i \qquad i = 1, 2, ..., m$$

Goals

$$\sum_{j=1}^{n} c_{jk} - (p_k - n_k) = g_k$$

Necessity for not being less then zero

$x_j, p_k n_k \geq 0$ j= 1,2,.....n

$x_1, x_2, ...x_n$= decision variables

k = Number of objectives being considered
a_{jk} = x_j's requirement from non-targeted constraint (input/output coefficient)
k = Number of desired goals; C_{jk}= cost-income coefficient of x_j for goal k
g_k= The goal for objective k; p_k= positive deviation from goal k;
n_k= Negative deviation from goal k

In the study, maximizing the income (hereinafter it means gross margin) according to plot's sizes; minimizing the costs of fertilizers and pesticides were made by linear programming on the other hand models minimizing the number of irrigation and cultivation were prepared by goal programming method.

Considering the size of investigated plots they were divided quartiles. The first quartile includes the first group; second and third quartile include second group and fourth quartile includes third group. 1st group of farms ($x \leq 307.5$ ha) were classified as small farms, 2nd group of farms ($307.5 < x \leq 1962.5$ ha) were classified medium size farms, 3rd group of farms ($x > 1962.5$ ha) were classified as large farms.

In the study, various farm models were developed considering size of lands. Initially, linear programs, which can maximize the income and minimize the costs of fertilizers and pesticides within the available conditions, were prepared. Then, goal programming models, which minimize the number of irrigation and cultivation and enable the least deviation from the optimum income in linear programming, were prepared. Results of linear programming and goal programming models were assessed comparatively.

Characteristics of linear programming models that maximize the income: Income was maximized; enterprises were from the ones, which were grown by the farmers who were interviewed; smallest and largest area of lands to be set-aside for crop types took place within the models; the land, capital, labor and machinery took place in the models as constraint; the cost of hired labor and machinery supplements during labor-full seasons were included in the models; the capital was considered as a constraint factor for production activities and the necessity of capital was accepted equal to variable cost of these activities; it was assumed that when the capital was inadequate for production activities the farmer would be able to get loans. The interest rate was accepted as 70% and was included in target functions.

Characteristics of linear programming models that minimize the costs of fertilizer and pesticide: In minimizing models reduction of fertilizer and pesticide use was taken as the basis in accordance with sustainability principals. For this purpose costs of fertilizers and pesticides were minimized. Values in objective function represent the cost of fertilizers and pesticides per hectare for each crop. Input output coefficients of production activities are all the same as the ones used in maximizing models.

Characteristics of goal programming models that minimize the number of irrigation and cultivation: Objective function was minimized; the optimum plan obtained from goal programming model may provide lesser income than the one obtained from linear programming. For these reason positive and negative variables that can enable the least deviation from the optimum income were used in objective function. It was assumed that more income would be desired and coefficient of positive deviation was taken smaller.

Land, labor and machinery constraints were used. Values on the right hand side of the models are equal to the quantities of resources in linear programming. The capital was accepted to be the total of the amount, which is included in to the plan as the result of linear programming and the loans drawn and used in the models. Values in the target functions of the models represent the minimum values of irrigation and cultivation numbers to enable these binary variables were used.

RESULTS AND DISCUSSION

Socio-economic characteristics of investigated farms: The average age of the farmers in these farms is 47. The average number of family members is 5 and they all have core families. 63.3% of farmers were graduated from primary school and didn't have further education. The ratio of illiterates is 4.1%. The average education period of farmers is around 6 years.

The average size of lands in investigated farms is 1230 ha. This average can be considered higher than national average of farms (560 ha). The average number of plots in each farm was found 6.7 and it shows us that the agricultural lands within the farms are in a fragmented structure.

Apart from cotton, wheat, corn and sultana there are some other crops grown within the investigated farms. Cotton in 56.7% of the lands, corn in 14.8%, wheat in 11.9% and vineyard in 5.9% are produced.

A total 89.6% of the investigated plots are irrigated and the rest of 10.4% are not irrigated. The farmers who actually live on them own 85.6% of the plots; 9.6% are rented land and 4.8% are sharecropper. It was found out that the same crops had been farmed in these plots for the previous ten years.

When we consider the second crops being grown on 24.0% of these lands expecting some problems on these lands won't be wrong. In fact various problems in these plots related to variety of crops grown; different farming methods and some natural factors were identified. The most important problem in these plots is water pollution (76.8% of the plots) followed by low yields (56.0%) and inadequacy of drainage (45.6%).

Some farmers (20.3%) revealed that they had lost some lands because of some various problems. It was observed that farmers took some measures against the problems that led to land losses. In 30.1% of the plots it was observed that farmers had been replacing the crops in order to solve these problems. In addition there has been crop rotation in 64.0% of the investigated plots. Farmers are also considering the use of inputs because of the problems they have been facing. They have been trying to solve the problems by using less fertilizer in 48.3% of the plots and using less pesticide in 45.8% of the plots. They also participated in maintenance and rehabilitation of irrigation and drainage channels to solve one of the most important problems in 45.8% of the plots. And as farmers told in 83.9% of the plots, they have invested on leveling, winter irrigation and soil improvement.

Input use in the crops: 258 kg ha^{-1} of seeds for wheat, 67 kg for cotton and 22 for corn is being used. As for machinery, they use 10 h per hectare for wheat, 50 h for vineyard, 42 h for cotton and 20 h for corn. When distribution of machinery is considered it is seen that the highest machinery use is in vineyard and the least is in wheat.

With 77.2% wheat is the crop that requires the highest family labor. In contrast with wheat cotton, vineyard and corn mostly requires hired labor. Cotton uses the highest hired labor with 84.3%. 62.4% of the total labor in vineyard and 68.9% in corn are covered by hired labor.

Natural fertilizers are mostly used in vineyard but never used in corn. It was found out that chemical fertilizers were used at the highest rate but natural and green fertilizers were used very little.

When number of irrigation in regard with enterprises was investigated; wheat was irrigated 1.3 times vineyard 2.6 times; cotton 3.4 times and the corn was irrigated 4.6 times. Farmers reported that water consumption in these plots were normal. Only 6.1% of the plots were excessively irrigated and 5.3% were insufficiently irrigated.

Table 1: Output and costs of the crops in the investigated plots ($/ha)

	Wheat	Vineyard	Cotton	Corn
Gross output	1462.97	3759.83	3435.40	2546.50
Variable costs	453.37	1038.55	835.33	570.47
Gross margin	1009.60	2721.28	2600.06	1976.03

(1$=151 425 Turkish Liras in 1997)

Income and variable costs regarding the crops investigated: When the variable costs were examined; vineyard had the highest variable costs and wheat had the least variable costs. Fertilizer costs among variable costs were the highest with 40.3% in wheat, 29.7% in corn, 39.3% in vineyard and 41.0% in cotton. Considering the pesticides costs the highest pesticide cost was in vineyard and the least was in wheat.

The average yield for wheat in the plots was 4228 kg ha^{-1}; for sultana 3374 kg ha^{-1}, for cotton 3585 kg ha^{-1} and was 9459 kg ha^{-1} for corn. The crop type with the highest gross output is vineyard followed by cotton, corn and wheat, respectively. It is similar in gross margin too; the gross margin for vineyard is 2721.28 $/ha but is 1009.60 $/ha for wheat (Table 1).

Linear and goal programming towards sustainability: In this section, the linear programming that maximizes the income and minimizes the costs for fertilizers and pesticides and goal programming that minimizes the numbers of irrigation and cultivation were given in comparison. As a result of optimal farm planning, 352 ha of wheat, 1264 ha vineyard, 551 ha of cotton and 13 ha of corn were suggested to be grown in small farms. Existing labor and machinery were used completely. To realize this plan 13397 h of labor, 535 h of machinery and 13366.4 $ of are loan needed (Table 2). The income expectation at the end of planning is 422937.6 $. Optimal crop patterns of medium sized farms are of 1443 ha wheat; 1636 ha vineyard; 6377 ha cotton and 2589 ha corn. 113946 h of labor, 7379 h of machinery and approximately 98471.7 $ of loan are needed. As a result of optimal planning all restrictive were used. The expected income is around 2336142.0 $.

In large farms optimal cropping pattern that was included in the plan is; 2658 ha of wheat; 1203 ha vineyard; 4502 ha cotton and 4268 ha of corn. 75092 h of labor; 3565 h of machinery and approximately 65993.8 $ of loan are needed. As the result of optimal planning, approximately 3081716.4 $ is expected.

In small farms while the suggestion for vineyard was 1264 ha in the model that maximizes the income, the suggested area of vineyard decreased to 286 ha in models that minimize both the costs of fertilizer and pesticide. But in Goal Programming models 1215 ha of vineyard farming was suggested. In linear programming models the land of

Table 2: Linear programming solutions by land size

	Income maximization			Fertilizer cost minimization			Pesticide cost minimization		
	Small farm	Medium farm	Large farm	Small farm	Medium farm	Large farm	Small farm	Medium farm	Large farm
Enterprise	**Optimal solutions**								
Wheat (ha)	352	1443	2658	352	1443	2658	352	1443	2658
Vineyard (ha)	1264	1636	1203	286	1115	137	286	1115	137
Cotton (ha)	551	6377	4502	512	2686	2358	512	2686	2358
Corn (ha)	13	2589	4268	13	2589	2888	13	2589	2888
Hired labor (h)	13397	113946	75092	0	0	0	0	0	0
Hired machinery (h)	535	7379	3565	0	0	0	0	0	0
Credit ($)	13366.4	98471.7	65993.8	0	0	0	0	0	0
Constraints	**Surplus**								
Land (ha)	0	0	0	1017	4212	4589	1017	4212	4589
Operating capital ($)	0	0	0	80110.8	269215.8	286985.2	80110.8	269215.8	286985.2
Labor (h)	0	0	0	43993	106654	92949	43993	106654	92949
Machinery (h)	0	0	0	4519	13157	7444	4519	13157	7444
Maximum income ($)	422937.6	2336142.0	3081716.4	207925.0	1438267.1	1741993.1	207925.0	1438267.1	1741993.1
Minimum fertilizer /pesticde cost ($)	-	-	-	16713.9	113954.1	145646.0	10115.9	62364.9	40467.8

Table 3: Income maximization linear programming solutions by land size and goal programming plans with minimum irrigation and cultivation

	Income maximization linear programming			Goal programming with minimum irrigation			Goal programming with minimum cultivation		
	Small farm	Medium farm	Large farm	Small farm	Medium farm	Large farm	Small farm	Medium farm	Large farm
Enterprises	**Optimal solutions**								
Wheat (ha)	352	1443	2658	440	1443	2658	440	1443	2658
Vineyard (ha)	1264	1636	1203	1215	1114	1203	1215	1114	1203
Cotton (ha)	551	6377	4502	512	5915	4502	512	5915	4502
Corn (ha)	13	2589	4268	13	3573	4069	13	3573	4069
Hired labor (h)	13397	113946	75092	6916	64832	72915	6916	64832	72915
Hired machinery (h)	535	7379	3565	0	4501	3267	0	4501	3267
Credit ($)	13366.4	98471.7	65993.8	-	-	-	-	-	-
Income positive ($)	-	-	-	0	0	0	0	0	0
Income negative ($)	-	-	-	0	0	0	0	0	0
Constraints	**Surplus**								
Land (ha)	0	0	0	0	0	19.8	0	0	19.8
Operating capital ($)	0	0	0	5119.1	45101.3	12067.7	5119.1	45101.3	12067.7
Labor (h)	0	0	0	0	0	0	0	0	0
Machinery (h)	0	0	0	1.2	0	0	1.2	0	0
Maximum Income ($)	422937.6	2336142.0	3081716.4	-	-	-	-	-	-

wheat did not change (352 ha) but in Goal Programming models that minimize the number of irrigation and cultivation it increased to 440 ha. The corn lands remained the same in all models (Table 2 and 3).

While the hired labor activity was included in the linear programming model that maximizes the income, it didn't take place in the linear programming model that minimizes the cost of fertilizers and pesticides. In other two models that minimize the number of irrigation and cultivation the hired labor took place at the same levels. Hired machinery was only included in the model that maximizes the income but this wasn't needed in other models. A part of the land was not used in models that minimize the costs of fertilizer and pesticide but in other models all of the land was used (Table 2 and 3).

The total income obtained from income maximizing model was 422937.6 $. The total income of other two models together that minimize the cost of fertilizers and pesticides was only 207925.0 $. In the models that minimize the number of irrigation and cultivation the income had no deviation from the income that was gained as a result of linear programming.

In medium size farms, wheat land remained some in all models. In income maximizing models the vineyard land was 1636 ha but in all other models a decrease was observed in vineyard land. While the cotton land was 6377 ha in income maximizing models a decrease was observed in the models that minimize the cost of fertilizers and pesticides. In Goal Programming models the cotton land was 5915 ha.

While the hired labor of 113946 h was included in the model that maximizes the income, there was no need for hiring labor in the models that minimize the cost of fertilizers and pesticides. The existing labor was suggested. Hiring machinery was suggested in income maximizing model but the existing machinery was adequate in cost minimizing models, some part of the land remained unused. While the income resulting from the income maximizing model, was 2336142.0 $. It was 1438267.1 $ in cost minimizing models. The income expected from goal programming models was same as the income of linear programming.

In the large farms; in all models the wheat land was equally allocated in the plans. In income maximizing model the areas for vineyard and cotton were equal to the ones that were the results of goal programming models. While the corn land was 4268 ha in income maximizing model, it decreased to 4069 ha in goal programming models.

According to process results of income maximizing and goal programming models hiring labor and machinery were included in the plans. However there was no need for hired labor and machinery in cost minimizing models. In income maximizing model the land was used completely but in cost minimizing and goal programming models some part of the land remained unused (Table 3).

While the income was 3081716.4 $ as the result of income maximizing model, it was 1741993.1 $ in east minimizing models. The income resulting from the models that minimize the cost for fertilizers and pesticides is 76.9% less than the income that occurred from maximization (Table 2). The income results of goal programming models are at the same level with the results of maximization.

Plans obtained by linear programming have given quite good results in the aspect of sustainability of agricultural lands. In other words, when the optimum cropping pattern is realized, sustainability of the lands will be possible as well. Farm plans that were obtained by goal programming models and linear programming in the aspect of sustainability of agricultural lands have given the same results. In the models that minimize fertilizer and pesticide use which effects sustainable use of agricultural lands in a negative way less income was brought by under the existing circumstances. Apart from less profit some of the land remained unused as well. New suitable alternative crops that does not effect the sustainable use of lands and in which there is less need for chemical fertilizers and pesticides; should be determined and adopted to the area by advertising among the farmers. Adding new alternative crops to the existing cropping pattern that do not affect sustainable land use; a suitable production planning will be realized.

The starting point of this research was based on the fact that the sustainable use of agricultural lands is necessary and economical and ecological factors affect this land use. The primary objective of this research was to establish goal programming plans towards sustainability and to determine crop patterns for Menemen that are possible to realize with least sacrifice in economical and ecological aspects. In doing so the criteria for sustainable use of agricultural lands was benefited from.

Optimal plans towards sustainable use of agricultural lands were obtained by using linear programming method. According to the results it might be claimed that when the optimal plans are realized the sustainability of the land will be enabled. In the models that do not break sustainable land use but minimize the cost for fertilizers and pesticides; to increase the income and to put unused land in use again new alternative crops should be added to the existing one.

It was detected that a considerable majority of the farmers were aware of sustainable use of agricultural lands and were taking some precautions although they were unfamiliar with the general concept of sustainability. It was observed that most farmers were carrying out some rehabilitation activities for their lands and reducing use of fertilizers and pesticides.

These results that are reached in the research have proven that some precautions should be taken considering the issue. Some policy suggestions are listed below.

It is not enough to make some decisions alone towards sustainable use of agricultural lands. Primarily farmers' enthusiasm and belief in this issue are important. The participation of the farmers will play an important role in making political decisions towards sustainable use of agro-lands and their implementations.

In protecting natural resources such as land, taking necessary steps to raise knowledge among the farmers; having them participated in implications regarding the issue and getting NGOs to contribute to the efforts are important. Raising awareness among the farmers especially about using fertilizers, pesticides machinery and irrigation together with their effects an agricultural lands is also important.

It is believed that some precautions should be taken for those activities that are considered to be an obstacle for sustainable use of agricultural lands. Encouragement on using inputs should comply with the objective of land protection. The production policies should aim at land protection as well. In regard with the implications of production policies both deterrent and incentive tools that help protect the agro-lands should be used.

In the research areas, there is a need for additional measures to be taken concerning the inadequacy of drainage system. In this respect existing drainage system should be improved and the missing parts should be completed.

Without ignoring the demands of rapid growing population, acceptance of farming methods, that are environment friendly and resource-protecting, by the farmers such as: ecologic and integrated farming should be enabled.

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