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Greenhouse Production System Choices: Is Modern Technology Better for Environment? Case Study from Turkey

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Abstract
Tomato is one of the most widely cultivated crops in the world. Turkey produces on average almost 10 million tons of tomatoes annually. Greenhouse tomato production in Turkey has been significantly increasing in the last decade. However, environmental concerns are increasing especially about greenhouse production. There is also a misunderstanding among people that if a greenhouse is equipped with sophisticated technological systems of production, this will lead an environmentally friendly production because of more awareness, more certification, etc. However, studies show that there is not a significant correlation between technological investments and environmentally friendly practices. The empirical data used in this article was gathered by a research project which was granted by TUBITAK (Science and Technological Research Council of Turkey). A survey and observation techniques were used as a data collection method. Meanwhile, "*Life Cycle Assessment*" method was used to measure the impact of conventional farming and modern farming on the environment. The significant finding of the research is that even though profit obtained from unit area in a greenhouse which is equipped with a sophisticated technology is higher than a low technology greenhouse, there is a significant difference between high and low tech greenhouse systems in terms of environmental pollution.

Keywords: Agriculture and ecology, life cycle assessment, technology, modern and conventional production, Turkey.

INTRODUCTION

On the one hand, technological applications used in greenhouses increases productivity and efficiency, on the other hand; some of the applications have raised many ethical, moral and societal issues about giving irreversible damage to natural environment for decades. Whether technology is useful or not is difficult to answer. Why is it important for producers to analyze the benefits and risk when deciding to use technology? Sometimes, it is easier to calculate and analyze the benefits of technology in the short run for individuals, but difficult calculate and analyze the social losses in the long run. It has been believed in "Classical Economics Theory" that producer and consumer welfare will be increased by reaching the highest profit level with the lowest cost per unit area. Therefore, in a free-market system where prices are set by supply and demand, natural resources can be used in an unbounded way.

"Green Revolution" is a milestone for realizing how to get higher yield from soil which is thought as a scarce factor of production. Since fertilizers and irrigation are significantly what made the "Green Revolution" possible, they changed agricultural production techniques because more productive varieties developed during the revolution period cannot grow successfully without the help of fertilizers and irrigation potentials.

Greenhouses are common structures of production in Mediterranean countries. Parallel to advancement in technology, they have been developed for the last ten years. A precise control of inputs and climate in greenhouses has become crucial to maximize the profit during the production period. Therefore, the modern greenhouses in the region have become widespread. These greenhouses are capital intensive and based on an advanced automated system. The output in these greenhouses is higher compare to low tech technology greenhouses. For example, the average output per hectare for tomato is up to 30-35 ton per year. Higher output makes producer invest on sophisticated production systems. On the other hand, public concerns about health, safety and sustainability issues in the modern greenhouses have been questioned since the year 2000 [1] (Mencet and Sayin 2010).

Major environmental impacts have been associated mainly with high-input high-output intensive systems in greenhouses. The direct or indirect negative impacts of intensive input usage (chemical fertilizers, pesticides, irrigation, mechanization, fuel, hormones) on natural resources are the main problem for environment. Especially, the nitrogen density has been the most discussed and most abundant input among the other inputs [2] (Loizou et.al. 2000). As well, by the washing of nitrogen and phosphorus fertilizers, the contamination of base and surface water is occurred and by the nitrogen oxides (NO, N2O, NO2) emission air pollution is emerged and this situation is affecting the environment negatively [3] (Guler 2004).

This article is about small part of the project titled as "Ecologic, Economic and Policy Analysis of Greenhouse Tomato Production Systems: Antalya Province Case". The objective of the article is to present the impacts of greenhouse production systems in terms of ecological indicators. The data used in the article was collected by face to face survey which was conducted with greenhouse producers and managers in the city of Antalya which is the center of greenhouse production in Turkey. The significant finding of the research is that even though profit obtained from unit area in a greenhouse which is equipped with a sophisticated technology is higher than a low technology greenhouse, there is a significant difference between high and low tech greenhouse systems in terms of environmental pollution.

MATERIAL and METHODS

Field survey

The data gathered by the research is based on a face to face survey with greenhouse tomato producers and observations about their agricultural practices. "*Neyman Allocation*" Methodology is used to determine the number of greenhouse producers in the sample. Homogenous classes are needed to be allocated in terms of the size of greenhouses. The purpose of the method is to maximize survey precision to predict the population value. The method is one of the best to raise the level of precision for estimating a population mean given a fixed total sample size. The suitable sampling size is set by using "*Neyman Equality*" The process of the determining sampling size is given below in the classified order [4] (Yamane 2004).

The first step is to evaluate whether the data is distributed normally or not. The skewness and the kurtosis of the distribution curve are examined for each population. Furthermore, Kolmogorov-Smirnov normalization test is applied to the data. According to Neyman Allocation Method, 148 conventional low-tech (small scale) greenhouse producers and 25 high-tech (big scale) greenhouse producers are included in the sample. The total numbers of producers surveyed are 169 in the research.

Tomato production is the most prefered vegetable for the greenhouses in the region because of many economic advantages. It has better marketing opportunities and higher profit margin. On the other hand, Tomato poduction in greenhouses requires more fertilizers and pesticides than any other vegetables. Therefore, the quantity of production increases, the amount of input used increases as well. The city of Antalya and its districs are the largest tomato producer in Turkey (1.712.000 tones and 18% of total tomato production in Turkey). Tomato production creates an income for many families and it is an important source of employment in the city.

The research field as indicated in Figure 1 covers the total size of land allocated to greenhouse and open field tomato production. The reason behind to choose the tomato production as a research subject is that while tomato among vegetables has higher output level, its production process needs more inputs to be used. There are trade-offs between steady rate of income growth and sustainable standards of environmental quality for tomato producers. Growing production activities on natural resources requires more input uses. This results in the degradation of environmental quality. The target group surveyed was tomato producers in the research. Producers were divided into two main groups in order to comparing their production activities. While one group was using low-tech conventional techniques, the other was high-tech (intensive) modern agricultural techniques. The research was done by using the data for the period of 2009-2010 greenhouse tomato production [5] (Sayin et. al. 2013).

Figure 1: Antalya Province and Its Counties

Method of the study

Life Cycle Assessment (LCA) method is used to measure and evaluate the potential environmental impacts of a production system throughout its life cycle. LCA principles provide a holistic approach that takes into the consideration of all production stages. The analysis begins with the land use and input usage and ends up with consumption stage. LCA has four different steps such as goal and scope, inventory analysis (life cycle inventory), life cycle impact assessment and interpretation [6]. Its goal and its scope for all scientific studies should be clear and understandable for its readers. One of the key issues at this stage is to determine which functional unit should be used in the study. Functional unit is subject to change the product itself and the characteristics of production processes. The second important issue is to establish the framework of the system boundaries. This gives elasticity for the project manager because each study may differ from each other according to its aim, scope, data availability and variability [7,8] .

The second step of LCA is to determine life cycle inventory. This step covers all the fixed and variable inputs e.g. water, fertilizer, pesticides. The third step is to evaluate the environmental impacts of all the inputs used in production stage. It is important to know and choose the right software for LCA analysis. The results of analysis can be depicted by supplementary visual tools (graphs, charts, tables etc.) [9].

RESULTS

In this study we examined the environmental impacts originated from greenhouse tomato production in the region where the city of Antalya is located. This project was initiated to find out whether a modern or conventional greenhouse in the region has greater impact on the environment and human health [5].

The application of fertilizers per hectare is calculated for both conventional and modern greenhouses. They are shown in Table 1. There is a significant difference in the use of fertilizer between conventional (low-tech) and modern (high-tech) greenhouses.

Table 1: The ingredients of fertilizer application in research area (Sayin et.al. 2013)

	Fertilizers (kg/ ha^{-1})					
	N	P2O5	K2O	CaO	S	B
Conventional	6702,89	5420,86	9452,76	63,39	197,75	1,41
Modern	108314,54	97546	197776	3,19	218,1	0,44

The main finding of the project is that agricultural practices used in modern greenhouses are less harmful to human health and the environment. The 65 percent of producers who have a high-tech greenhouses stated that they prefer an automated monitoring system because of more precession for using inputs and controlling the atmosphere in their greenhouses. According to LCA analysis conducted in the research, input usage is in modern (high-tech) greenhouses more than the conventional ones per decare (ha^{-1}) [5].

Excessively or improperly applied fertilizers and pesticides can wash into underground water, lake, sea and streams. Accumulated chemical residues can cause irreversible damage to the environment and human health. When collected conventional and modern agriculture data compared to each other, Figure 2 shows that the highest difference is in marine aquatic Eco toxicity [5].

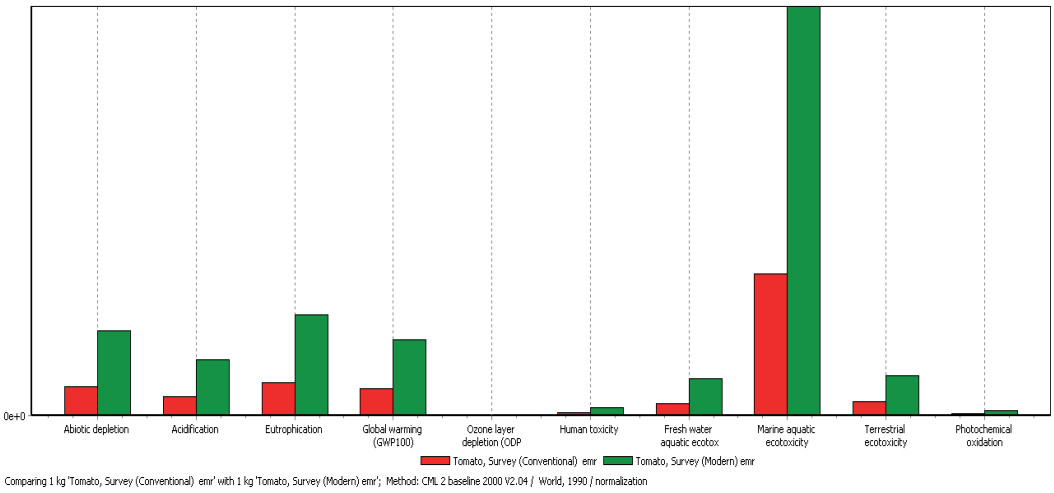
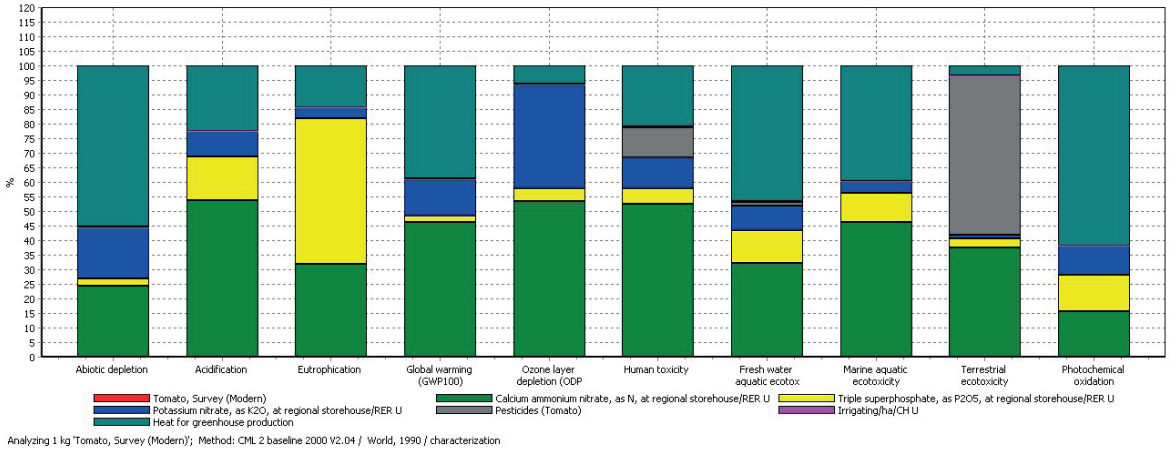


Figure 2: LCA analysis of conventional and modern greenhouses in Antalya (Sayin et.al. 2013)

Clean air is essential to life and good health. But the combustion of fossil fuels threatens the natural environment in which all creatures live. Most of this air pollution mainly results from the burning of fossil fuels. Although agriculture production process in greenhouses is not a potentially important contributor for air pollution, it is necessary to pay attention and evaluate to its contribution (Fig.3). First of all, the consumption of coal for heating purposes needed to be evaluated for modern greenhouses in the region. The climate is moderate and convenient for tomato production but heating for greenhouses necessary for several months. The greenhouses in the region are heated for 12 hours in a day except for five months. There are three main impact categories related with the usage of coal for heating purposes. They are photochemical oxidation, abiotic depletion and global warming. Those are shown in Figure 3 [5].



On the other hand; the usage of coal or wood for heating purposes in conventional greenhouses are minimal because of their cost. Therefore, producers prefer crop rotation instead of heating. Transportation is also another cause of air pollution but it has to be excluded from analysis due to system boundaries of the study.

DISCUSSION

Modern (high-tech) greenhouses have some advantages and disadvantages for the market they operate in. They can achieve higher output levels and greater productivity from their workers through specialization and division of labor. Intensive and repetitive cultivation of tomatoes in modern greenhouses on the same soil generally results in a degradation of soil properties and fertility. This modern and commercial greenhouse production creates stiff competitive market for conventional and small-scale greenhouse production. Small-scale greenhouse producers can create and maintain the knowledge and biodiversity through their production practices. They are better motivated to protect their land and inherit to their children but they cannot lower a long run average of cost and marginal cost because of their size disadvantages. The key factor to sustain the production in modern or conventional greenhouses is the capital intensity. Greenhouse tomato producer in the region must take full advantage of technology to produce the highest quality in adequate quantity.

According to Burkett (2004), maximizing the processing of raw materials and energy depletes resources quickly. How fast getting the raw materials and making the products ready for customers increases the possibility of profit maximization as well. Sophisticated technological system with selectively

focusing on the minimization of the labor input expands the energy usage. Therefore, the expanded energy usage results in the depletion of scarce natural resources and pollution in the environment [8,9].

The ecologically friendly agricultural practices should be encouraged by agricultural policies in the areas where bio-diversity is under a risk.

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