Total cost assessment of greenhouse tomato production in Zacatecas, Mexico

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Abstract

Agriculture in the state of Zacatecas, Mexico, consumes 77% of the available groundwater. In this region, the main source of water is 34 aquifers, of which 44% are over exploited. Over extraction of the aquifers damages the environment, increases pumping costs and decreases water quality. Greenhouse tomato production systems have increased considerably in recent years. Besides the environmental problems that agriculture generates, there is also the problem of emissions and solid waste. The objective of this paper is to assess the environmental impact on profitability of protected agriculture systems in the state of Zacatecas. The methodology used was total cost assessment. This study assesses the total cost of four production units in their present situation, as well as in two scenarios: one denominated "sustainable" and the other "unsustainable". Profitability indicators in the "sustainable" and "unsustainable" scenarios show that adopting conservation production practices, besides improving the image of the organization and permitting better access to markets, will maintain profitability and contribute to the conservation of natural resources.

Keywords: sustainability, environmental management, tomato production systems, over-extracted aquifers, water

INTRODUCTION

The state of Zacatecas, located in north-central Mexico, has an arid and semi-arid climate. Its main source of water for carrying out the different activities of the population is groundwater from 34 aquifers, of which 44% are over exploited (CNA, 2011). Agriculture consumes 77% of the available groundwater (CNA, 2008). The high consumption of water for agricultural use is caused by over-irrigation and use of obsolete irrigation systems (Mojarro et al., 2010).

Over-extraction of the aquifers damages the environment (Koundouri, 2004; Wada et al., 2010), increases pumping costs and diminishes water quality (Echavarría-Cháirez et al., 2009; Padilla-Bernal et al., 2012). Less water means greater soil salinity, which in turn reduces crop yields and threatens the sustainability of production systems. In the state of Zacatecas, agriculture is under pressure to improve its water use efficiency and is compelled to become a socially, economically and environmentally sustainable activity.

Protected agriculture is a subsector that has had one of the highest growth rates in Zacatecas in recent years. During the period from 2000 to 2010 it had a mean annual growth rate of 25% in cultivated area (Padilla-Bernal et al., 2010). In 2010, the area was estimated at 277 ha, of which 90% was under tomato cultivation (SEDAGRO, 2010). Given the observed growth rate, it is likely that today the area is larger. The rapid growth of these systems is attributed to their high yield and to the incentives granted by the government for their construction.

The concept of protected agriculture is applied to production systems carried out under any type of cover to protect the crop from unfavourable climate events. Greenhouses are included within this modality. Although not all the production systems analyzed in this study are greenhouses, the term will be used for all the protected agriculture systems included in this study.

All of the greenhouses pump water from the aquifers to irrigate crops. Greenhouses

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require more investment and have higher production costs than field systems. Investment and costs vary in proportion to the level of technology used. The type of structure (macro-tunnel, shade house, Almeria type greenhouse or multi-tunnel), climate control (active or passive) and cultivation technique (soil or hydroponics) are determinants. For the investment to be truly attractive, better prices are required, and therefore, consistency in quality and food safety should be permanent attributes of the system. Sustainable competitive advantage, based on technological, productive and organizational changes, is achieved through the adoption of a quality management system (Fonseca et al., 2011) supplemented with environmental goals (Prando, 1996) that combine efficiency and environmental protection criteria.

The principal environmental problems agriculture generates are those that affect soil quality (degradation and salinization), especially when water is a limited commodity. Moreover, in protected agriculture systems where tomatoes have been mono-cropped for more than eight consecutive years, besides emissions and additional solid waste, abuse in the use of agrochemicals and high irrigation frequency has caused the progressive loss of organic matter and reduction in productivity. The objective of this study is to assess the environmental impact on the profitability of protected agriculture systems in the state of Zacatecas, Mexico. Given the importance of water for the region's agriculture, emphasis is placed on the adoption of practices that contribute to its conservation, those that could lessen environmental degradation and its effects on the productivity of the production system.

METHODOLOGY

Total cost assessment of protected agriculture production systems

To examine the environmental impact on the profitability of protected agriculture production systems in the state of Zacatecas, a total cost assessment (TCA) methodology (Constable, 1999; Laurin, 2011), adapted by Curkovic and Sroufe (2007), was used. This methodology was developed by the Centre for Waste Reduction Technologies (CWRT) of the American Institute of Chemical Engineers (AIChE) to quantify environmental and health costs attributed to industrial activity as well as to aid in internal administration and decision-making.

TCA is an integral process aimed to identify, compile and analyze incurred, avoided and saved environmental and health costs, as well as to mitigate future risks and contingent costs of productive processes, products or places (Norris, 2000). The proponents of TCA classify environmental costs into four categories: direct costs, hidden costs, contingent liability costs and less tangible costs (Curkovic and Sroufe, 2007).

To determine the total costs of protected agriculture production systems, budgets were constructed considering technical coefficients, prices and profits for each selected system in their current situation and in two scenarios denominated "sustainable" and "unsustainable". The budgets and net cash flows were projected to ten years in real terms. The profit level was determined through net present value (NPV), internal rate of return (IRR) and the benefit-cost ratio (BCR). In calculating the NPV, net cash flow (NCF) was brought to present value considering a 10 year project life horizon.

The scenario denominated "unsustainable" considered environmental degradation caused by over exploitation of the aquifers, which negatively impacts the productivity of the production system. Budgets and multi-annual net cash flows were generated assuming a 2% reduction in yields (Castellanos and Ojodeagua, 2009; Macías-Duarte et al., 2010). Adjustments to the use of day labour in harvesting and packing were made, and operation costs for pumping water from a well 14 m deeper was considered (CNA-GODEZAC-UAZ, 2008). For the scenario denominated "sustainable" (alternative project), the adoption of sustainable production practices was proposed. In this scenario, constant yields of the production systems were considered over time (10 years). The lower use of water per plant (2 L $plant^{-1}$ day^{-1} in hydroponics and 1.5 L $plant^{-1}$ day^{-1} in soil), rainwater harvesting and storage in cisterns, use of moisture sensors and equipment for recycling water (Kirda et al., 2004; Macías-Duarte et al., 2010; Alaoui et al., 2014) were considered.

Determining the costs of environmental degradation and identifying the benefits of adopting sustainable production practices is not an easy task. Although the area to be studied has quite uniform climatic, topographical and physical production conditions, the quantity of required data is enormous. In areas where conditions are diverse, as in most cases, obtaining sufficient information with some degree of detail is practically and financially impossible. Nevertheless, gross estimations to serve decision-making or formulation of public policy can be made for some produce (Kydd et al., 1997; Pearson et al., 2003). In the case of greenhouse tomatoes, environmental degradation attributed to the excessive use of groundwater is reflected in reduced productivity.

Selection of production systems and information sources

Selection of the production systems included in the study was based on a cluster analysis of 53 units that produced tomato. These production units were identified through a questionnaire given to technicians or owners in 2010. The variables used in the analysis were structure, cultivation technique, climate control and size. Four groups were obtained and one representative system was selected from each group. The main characteristics of the production systems analyzed are presented in Table 1.

Table 1. Principal characteristics of the production systems.

Characteristics	Type of structure			
	Shade house	Multi-tunnel	Almeria type greenhouse	Multi-tunnel
Tomato variety	Saladette	Saladette	Saladette	Tomato on the vine
Cultivation technique	Soil	Soil	Soil	Hydroponics
Climate control	Passive	Passive	Passive	Active
Size	Large	Large	Large	Large
Production period	August-October	June-November	May-November	August-April
Market	Domestic	Domestic	Domestic	Domestic and international
Domestic market destination	Wholesale market, Iztapalapa, D.F.	Wholesale market, Iztapalapa, D.F.	Wholesale market, Iztapalapa, D.F.	Wholesale market, Aguascalientes
Days of growing cycle	155	249	275	332
Yield (t ha^{-1})	130	230	310	637
Number of plants (ha)	20,250	30,000	40,500[1]	28,644
Daily liters water per plant	2	2.5	2	3

[1]The technique of interplanting is used: 1st cycle February-September. 2nd cycle June-November.

Information on technical coefficients, auxiliary machinery and equipment, cultural practices and environmental protection of each production system studied was obtained through a questionnaire given to technicians of the selected production units during the period from February to April 2014. The unit of analysis was one hectare cultivated in the 2013 growing period. After the information was processed, it was checked by the technicians or owners of the production units and validated by specialists in the field, who had not provided information (Eisenhardt, 1989). Prices of inputs were obtained from suppliers. Information on investment in the structure, auxiliary machinery and equipment, heating system and irrigation equipment was determined with price quotes from manufacturers and suppliers. Investments in cisterns for rain water harvesting were determined following Anaya-Garduño (2010) and Brown et al. (2005), considering the mean rainfall recorded in the period from 2002-2013 in the regions where the production systems studied were located. Following the recommendations of Eisenhardt (1989) for case studies, information on production and environmental production practices was collected through structured interviews with owners or technicians of the production units.

Tomato prices were determined at the farm level considering the months in which the produce was marketed during the year 2013 and the market destination: domestic or international. References prices for domestic and international markets were obtained from the Sistema Nacional de Información e Integración de Mercados (SNIIM) and the United States International Trade Commission (USITC), respectively. The nominal interest rate was 15% and the real discount rate was 11%, considering an inflation rate of 3.57% (INEGI, 2014) and a project life horizon of 10 years.

RESULTS

The results obtained in interviews with technicians and owners of the production enterprises show that the units have established an accounting system with which they can identify the direct costs of production, which include handling some residues such as the plastic greenhouse covering, containers in which inputs are packaged and green organic waste. However, other costs associated with the implementation of a total quality environmental management system were not recorded. That is, no accounting system that includes the measurement of environmental costs was clearly specified.

In their current situation, the four production systems studied register a positive net present value (NPV), an internal rate of return (IRR) above the discount rate, and a cost benefit ratio (CBR) above one, reflecting sufficient financial sustainability. The lowest NPV was obtained in the production system consisting of a shade house, which largely accounts for the harvest and sale period (75 days during August and October). This NPV is lower than that of the system with a multi-tunnel structure and hydroponics (Table 2), which exports 88% of its production during 270 days of the year, including the winter months when tomato prices are higher on the international market.

Table 2. Current investment and profitability indicators of the protected agriculture production systems per hectare.

	Shade house (soil)	Multi-tunnel (soil)	Almeria type greenhouse (soil)	Multi-tunnel (hydroponics)
Initial fixed investment (000/MX pesos)	1,321.6	3,053.2	2,981.2	9,559.4
Re-investment[1] (000/MX pesos)	703.3	1,450.3	1,683.8	3,550.5
Working capital (000/MX pesos)	230.7	300.9	403.6	1,643.5
Total investment (000/MX pesos)	2,255.6	4,804.4	5,068.6	14,753.3
Net present value (NPV) (000/MX pesos)	1,693.9	3,281.2	5,778.5	14,006.0
Internal return rate (IRR) (%)	29.98	29.25	42.42	35.77
Benefit-cost ratio	1.30	1.37	1.52	1.39

[1]Additional investment necessary for replacing the structure covering and equipment.

In the "sustainable" scenario (Table 3), NPV, IRR and BCR are higher than in the "unsustainable" scenario (Table 4) in all of the cases studied. This indicates that the net cash flow that a producer in the "sustainable" scenario would receive would cover the investment in sustainable production practices and would obtain a higher financial return than in the "unsustainable" scenario. In other words, in the "unsustainable" scenario, the income not received due to the loss in productivity, at present value, would be more than the investment needed to adopt sustainable production practices in the "sustainable" scenario. It should be mentioned that in the case of investment in equipment for water recycling for the multi-tunnel hydroponics system, only the part proportional to one hectare was considered since the obtained price quote for the production unit referred to the entire cultivated area in the greenhouse.

The results obtained suggest that the adoption of conservation practices in production, as part of an environmental management strategy, can maintain a positive financial position and contribute to reducing environmental degradation.

Table 3. Investment and profitability indicators of the protected agriculture production systems: "sustainable" scenario (per ha).

	Shade house[1] (soil)	Multi-tunnel[1] (soil)	Almeria type greenhouse[1] (soil)	Multi-tunnel[2] (hydroponics)
Initial fixed investment (000/MX pesos)	1,321.6	3,053.2	2,981.2	9,559.4
Re-investment[3] (000/MX pesos)	703.3	1,450.3	1,683.8	3,550.5
Working capital (000/MX pesos)	236.8	306.4	409.4	1,682.0
Investment in cistern, moisture sensors, water recycling system (000/MX pesos)	209.9	209.9	209.9	1,318.9
Scenario total investment (000/MX pesos)	2,471.7	5,019.8	5,284.4	16,110.7
Net present value (NPV) (000/MX pesos)	1,500.3	3,098.7	5,589.2	12,789.3
Internal return rate (%)	26.19	27.38	39.83	31.53
Benefit cost ratio	1.26	1.35	1.50	1.35

[1]Includes geomembrane cistern.

[2]Considers water recycling system. The amount allotted to investment for the recycling system was determined by prorating the total budget estimated for the production unit by number of hectares (9.12 ha).

[3]Additional investment necessary for replacing the structure covering and equipment.

Table 4. Investment and profitability indicators of the protected agriculture production systems: "unsustainable" scenario (per ha).

	Shade house (soil)	Multi-tunnel (soil)	Almeria type greenhouse (soil)	Multi-tunnel (hydroponics)
Initial fixed investment (000/MX pesos)	1,321.6	3,053.2	2,981.2	9,559.4
Re-investment[1] (000/MX pesos)	703.3	1,450.3	1,683.8	3,550.5
Working capital (000/MX pesos)	230.5	300.7	403.3	1,643.2
Scenario total investment (000/MX pesos)	2,255.5	4,804.2	5,068.3	14,753.0
Net present value (NPV) (000/MX pesos)	1,111.4	2,337.1	4,471.7	10,054.8
Internal return rate (%)	24.75	25.10	37.69	30.79
Benefit cost ratio	1.20	1.28	1.42	1.29

[1]Additional investment necessary for replacing the structure covering and equipment.

CONCLUSIONS

In all of the production units, there is an accounting system that allows owners and managers to determine the direct costs of handling plastic coverings, input packages and green organic waste. However, there is no clear understanding of what is required in environmental accounting or in assessing the total costs of the production process, although they were open to adopting techniques that would improve production processes and give them better access to information for decision-making.

The owners and managers of the production units indicated that the actions they take relative to the adoption of environmental production practices were those required by societies' norms and laws on environmental protection. However, they recognize that having been certified (good agricultural practices, good handling of fruit and vegetables, and good use and management of agrochemicals) allows them to access markets, improve their image and sell at higher prices.

By applying TCA in the implementation of a water saving strategy, including normal costs and those associated with the loss of productivity, due to environmental degradation as well as savings and investment in rainwater harvesting or water recycling, production units could have more precise information for decision-making in the administration of environmental projects. The profitability indicators obtained in the "sustainable" and "unsustainable" scenarios show that by adopting sustainable production practices not only can the enterprises have better access to markets, but they can also be more profitable while helping to conserve natural resources (soil and water).

In the production units, only some internal environmental costs were identified. Complete information on environmental costs in protected agriculture systems requires studies to identify external, or social costs, as well as internal costs, which would permit a holistic assessment of this expanding sector. Moreover, it will contribute to avoiding future environmental risks and better support decision-making.

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