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Assessing Environmental Management of Tomato Production under Protected Agriculture

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Abstract

This study examines the impact of environmental strategies on profitability of protected agriculture production systems in the state of Zacatecas, Mexico using the approach of Total Quality Environmental Management (TQEM) and Total Cost Assessment (TCA). We identified environmental management practices currently used by production units and analyzed the existing situation, plus two hypothetical scenarios. Profitability indicators show that adopting conservation production practices will not only improve the image of the organization but permit better access to markets, maintain positive profitability and contribute to the conservation of natural resources.

Keywords: environmental cost accounting, TCA, Mexico, TQEM, greenhouses.

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Introduction

Zacatecas, is a semi-arid state located in the north-central region of Mexico. The main source of water is 34 aquifers—44 % of which are over exploited (CNA 2011). Agriculture is the primary user of water in the region; 11.8 % of the arable land is irrigated. However, over-irrigation and obsolete irrigation systems (CNA 2007, Mojarro et al. 2010), contribute to water use that is unsustainably high.

Within the agricultural sector, protected agriculture has grown rapidly in recent years, with a mean annual growth rate of 25 % from the year 2000 to 2010 (Padilla-Bernal et al. 2010). The concept of protected agriculture refers to production under cover to protect the crop from adverse climate (García et al. 2011). The rapid growth of these systems is attributed, on the one hand, to technical production factors (higher yields, better quality produce, greater control in the use of inputs, better pest and disease control, and the possibility of cultivating more than one crop per year, or producing during the entire year). On the other are social factors; these systems generate more employment per hectare than conventional agriculture, contributing to regional development and the possibility of increasing social well-being (Padilla-Bernal et al. 2007, García et al. 2011).

Nevertheless, protected agriculture greatly affects the environment. In 2010, the Secretariat of Agricultural Development estimated that, of the 277 hectares under protected agriculture, 90 % is used to cultivate tomatoes (SEDAGRO 2010). Moreover, 70 % has been used for monocropping tomatoes in soil for 8 to 10 consecutive years, leading to progressive reduction of organic matter and loss of productivity. This, in turn, has caused excessive use of chemicals (herbicides, pesticides, fertilizers), and occasionally, the change from soil to inert substrates (Sánchez-del Castillo et al. 2014). In addition, protected agriculture produces large amounts of solid residues: plastics from renovating the structure covering, irrigation tubes and containers, among others, plant residues from the unused part of the crop, and substrates. Added to this, all protected agriculture systems use large quantities of groundwater.

Protected agriculture requires higher investment and production costs than field production. These costs vary in function of the level of technology. The variables structure type (macrotunnel, shade house, Almería-type greenhouse and multi-tunnel greenhouse, among others), climate control (active or passive), cultivation technique (soil or hydroponics) and size are determining. For the investment to be attractive, higher prices are needed. Furthermore, consumers increasingly demand environment-friendly products (Williams 2009). Thus, consistent quality and sustainable production practices must be permanent attributes of the produce.

Under these conditions, gaining a position in the market requires that production units attain sustainable competitive advantages while considering economic, social and environmental aspects. This will require changes in terms of technology, production and organization to achieve sustainable competitiveness, such as the adoption of production practices oriented toward protection of natural resources and public health. These changes involve investment to reduce soil degradation, air pollution and residues and to improve water quality and availability. It is necessary, however, to determine its cost-effectiveness, while considering environmental costs, to support decision-making.

Total Quality Environmental Management (TQEM) and Total Cost Assessment (TCA) are administrative approaches that incorporate aspects of quality into environmental management. While environmental aspects in quality have been discussed by several authors since the early 1990s (Sarkis and Rasheed 1995; Chidiak and Murmis 2003), the agricultural sector has been slow in formally adopting programs and strategies relative to environmental protection. Programs such as environmental management systems (EMS) have been primarily adopted by large agribusinesses (Williams 2009: 59). Environmental management strategies are an essential factor in the competitiveness of the organizations, although introducing them will generate short- and medium-term costs (Puig and Freire 2007). Williams (2009) reported that, in the end, integrating the environmental aspect in total quality management will increase competitiveness.

One of the fundamental objectives of TQEM is that organizations recognize environmental costs and incorporate them into the capital budgeting process to improve decision-making. Curkovic and Sroufe (2007) suggest that by incorporating Total Cost Assessment (TCA) in each project, environmental proposals will compete successfully with non-environmental alternatives for capital resources in an organization. Since there is little information on the application of TCA in agriculture, a proposal for its use may serve as a useful tool in decision-making.

The objective of this study is to examine the impact of environmental strategies on profitability of protected agriculture production systems in the state of Zacatecas, Mexico using the structure of Total Cost Assessment (TCA). Existing environmental management practices of the production units are also identified, and given the importance of water for agriculture in the state of Zacatecas, emphasis is placed on investment and adoption of practices that contribute to its conservation. The research questions posed are the following. Can protected agriculture production systems maintain profitability with investment in and adoption of sustainable production practices? Are tomato growers aware of the environmental costs generated by their protected agriculture production process?

The results of the study will contribute to closing the information gap in terms of how environmental strategies impact Mexican agriculture. According to SEMARNAT (2006:255), most of the agricultural production units report a huge deficit of information on the topic. The results will be of use to administrators, owners of protected agriculture production units and researchers, as well as to agricultural policy designers.

This study comprises several sections. First, a brief review of literature on TQEM and TCA is presented. The following section describes the methodology of the study, which is a case study of four production units selected through the cluster technique and analysis of data provided by informants. Finally, the results are reported and suggestions are made in terms of environmental and quality management for both government authorities and growers.

Total Quality Environmental Management and Total Cost Assessment

Total Cost Assesment (TCA) was proposed by Curkovic and Sroufe (2007) to assess investment in Total Quality Environmental Management (TQEM) programs. TQEM includes concepts that are partial or totally omitted in a traditional analysis, such as water savings, associated water extraction and treatment costs, and energy savings, among others. 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 (Table 1). Direct costs are easily identified and quantified and can include recurrent and non-recurrent costs (Constable 1999, Laurin et al. 2013). These are found in the data sources used traditionally by most organizations and include concepts such as equipment installation, raw material, labor and residue handling (Table 1).

Table 1. Environmental Cost Categories Applied in Total Cost Assessment.

Category	Description	Cost Type
Direct Costs	Direct costs are directly linked with a project, product, or process.	Capital Expenditures/Depreciation -Buildings -Equipment -Utility connections -Equipment installation -Project engineering Operating and Maintenance Expenses -Materials -Labor -Waste management
Hidden Costs	Regulatory compliance or other costs that are "hidden" or lumped into a general account.	-Compliance reporting -Monitoring -Legal support -Sampling and testing -Education and training -Notification -Utilities
Contingent Liability Costs	Costs associated with liabilities that may result from waste and materials management.	-Costs associated with accidental releases -Lawsuits and settlements for remedial action, personal injury, or property damage.
Less Tangible Costs	Benefits that derive from improved corporate image, customer acceptance, and community goodwill.	-Organization and product image -Community goodwill -Customer acceptance

Source. GEMI 1994. Curkovic and Sroufe 2007.

Hidden costs are regularly found recorded in general overhead, the reason they are difficult to identify and quantify as environmental costs. Under this heading are recorded costs of complying with environmental norms and regulations, such as monitoring, training, legal support, sampling and testing, among others (Constable 1999, Shapiro 2001). Contingent liability costs are those usually associated with liabilities that result from handling residues and materials, for example, costs associated with accidents or those resulting from personal injury or lawsuits (Constable 1999). Unlike other cost categories, contingent liability costs are not easily calculated and so are generally estimated. Many organizations base their estimates on past experience, while others rely on studies of similar production units of the same sector or industry (Curkovic and Sroufe 2007).

Of the cost categories, less tangible costs are the most subjective and controversial. Like contingent liability costs, less tangible costs are difficult to determine. To estimate these costs, some organizations consider the increase in incomes or decrease in expenditures attributed to improved corporate image. These costs can include the level of acceptance of the product on the part of their clients and the community, as well as the positive or negative image of the organization (EPA 1995, Constable 1999).

Research Methodology

To examine the impact of environmental strategies on profitability of protected agriculture systems and to determine what environmental management practices are being used by the production units, we used the method Total Cost Assessment (TCA) proposed by Curkovic and Sroufe (2007). Because of the type of information required and the difficulty in obtaining it through a representative sample of production units, the study developed as a case study. To obtain the information, following Eisenhardt (1989) for case studies, field data collection methods were used: questionnaires and interviews with owners or technicians of the production units. Information was also obtained from secondary sources.

The disadvantage of the case study research approach is that it is not easy to make inferences and external validity of the study is limited. However, because of the scarce theoretical construction of TQEM and TCA applied to agriculture (Williams 2009), it is important to use the case study approach to describe what is occurring in the area of environmental management in actual production units.

Selection of Production Systems

Selection of the production systems included in the study was based on a cluster analysis of 55 units that produced tomatoes. The clusters were determined using a procedure of hierarchical analysis with the group linking method. The database was constructed in 2010 with data collected through a survey of protected agriculture production units that were larger than or equal to 2,500 m^2 in area. The variables used in the cluster analysis were structure type, cultivation technique, climate control and size. Four groups were obtained (Table 2) and one representative system was selected from each group. The criteria for selecting the production units for the study were a) that they belonged to one of the four groups obtained, b) that they had grown tomatoes in the 2013 growing cycle, c) the market destination of their produce, and d) availability of technicians in the production unit to provide information. The main characteristics of the production systems analyzed are presented in Table 3.

Table 2. Protected agriculture production units in Zacatecas, Mexico, classified by variables and groups obtained with a cluster analysis.

Variable	Type	Group 1	Group 2	Group 3	Group 4	Total
Structure type	Almería type greenhouse		15	15	2	32
	Multi-tunnel		10	3	5	18
	Shade house	2	1			3
	Macro-tunnel	2				2
	Total	**4**	**26**	**18**	**7**	**55**
Climate control	Active		7		7	14
	Passive	4	19	18		41
	Total	**4**	**26**	**18**	**7**	**55**
Type of cultivation	Hydroponics				6	6
	Soil	4	25	17	1	47
	Soil and hydroponics		1	1		2
	Total	**4**	**26**	**18**	**7**	**55**
Size[1]	Small		6			6
	Medium		19		1	20
	Large	4	1	18	6	29
	Total	**4**	**26**	**18**	**7**	**55**

Note. [1]Size was determined by area covered by the production modules, applying the criterion of the Technical Commission of the Greenhouse Program SEDAGRO-SAGARPA: a) small, up to 2,500 m^2; b) medium, 2,500 m^2 to 1.5 ha, and c) large, more than 1.5 ha.

Table 3. Principal Characteristics of the Production Systems.

Characteristics	Group 1	Group 2	Group 3	Group 4
Structure type	Shade house	Multi-tunnel	Almeria type greenhouse	Multi-tunnel
Tomato variety	Saladette	Saladette	Saladette	Round tomato
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/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)	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

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

Data Collection

Primary information was obtained with a questionnaire and structured interviews with technicians or owners of the production units selected during the period from February to April of 2014. The questionnaire was divided into two large sections: 1. Data on the production unit (identification of the production unit, structure type, safety practices, crop variety, planting date, harvest date and yield, type of climate control, type of irrigation system, work areas, machinery and auxiliary equipment, services related to development of crop quality, and employed personnel); 2. Data on crop development and commercialization (input technical coefficients-fertilizers and agrochemicals-and labor, irrigation depth, marketing and shipping). The unit of analysis for the second part of the questionnaire was one hectare cultivated in the 2013 agricultural year. Information on production and environmental production practices was collected through structured interviews, comprising the following sections: a) identification of the production unit, b) costing system, c) identification of activities and practices related to the categories considered in Total Cost Assessment (direct costs, hidden costs, contingent liability costs and less tangible costs), and d) open questions about practices aimed toward care and protection of the environment (water conservation, air quality and soil conservation).

Following suggestions by Eisenhardt (1989) for case studies, after the information was processed, it was checked by the surveyed technicians or owners of the production units and validated by specialists in the field, who had not provided information. 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. Investment in cisterns for rainwater harvesting was determined following indications of 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 are located.

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. Reference 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 information was applied in real terms considering a 10-year horizon. The number of years was based on recommendations of the Fideicomisos Instituidos en Relación a la Agricultura (FIRA 2014) for loans for this type of Project. The data considered in the analysis were kept constant during the 10 years, except when a change in the time variable is reported. The real interest rate was obtained in the following manner:

$$1)\quad r=\left(\frac{1+i}{1+\pi}\right)-1,$$

where *i* is the nominal interest rate of 15 %, and π is the annual inflation rate of 3.57 % (INEGI 2014). The nominal interest rate is that applied by Financiera Rural to direct preferential loans in the reference year.

Data Analysis

Because not all of the production units keep a formal systemized costing system, initial work centered on determining actual production, sales and administration costs, identifying and quantifying private and environmental costs under a variable costing system, which included direct inputs, labor and assignment for indirect production costs and administrative expenditures. Assignment for indirect production costs and administrative expenditures helped to determine the cost of production and administration of the product since some costs had been recorded in the general overhead categories. These costs are usually grouped into two categories: indirect production costs, which deal with product costs, and sales and general administrative overhead, which deals with costs of the period. The product costs are those incurred in its production, while the period costs are those that the management considers part of the operation of the agribusiness itself. Both types of costs may include items ranging from equipment to human resources, research and development.

To determine environmental costs, the cost headings used were TCA categories and the costs were expenditures of the production units in their current situation (Table 4). Following Curkovic and Sroufe (2007), once the processes carried out in the production unit were reviewed and the costs classified, processes to be improved were identified and strategies were designed to make the production unit more environment friendly. With this information, two alternative scenarios were constructed: one “unsustainable” and the other “sustainable”. In these scenarios, water management was a basic element of analysis, given the critical situation of water for agriculture in the state of Zacatecas.

The scenario denominated “unsustainable” considered environmental degradation caused by over-exploitation of the aquifers, which affects productivity of the production systems. Budgets and multi-annual net cash flows were generated assuming a 2% reduction in yields (Castellanos and Ojodeagua, 2009; Macías-Duarte et al. 2010) due to poor water management. Adjustments for use of day labor in harvesting and packing and, based on information provided by CNA-GODEZAC-UAZ (2008), operation costs for pumping water from a well 14 m deeper were made.

In the “sustainable” scenario (alternative project), sustainable production practices and water use management are adopted. In this scenario, it was assumed that yields would no longer decrease, and therefore, they were maintained constant during the useful life of the Project (10 years). According to Kirda et al. (2004), Macías-Duarte et al. (2010) and Alaoui et al. (2014), efficient irrigation can sustain greenhouse tomato productivity with 2 L/plant/day in hydroponics and 1.5 L/plant/day in soil, and therefore, these amounts were used. In addition, rainwater harvesting and storage in cisterns, use of moisture sensors, and equipment for recycling water, as proposed by Alaoui et al. (2014) and Anaya-Garduño (2010), were part of this sustainable scenario.

To analyze the “unsustainable” and “sustainable” scenarios and consider all environmental costs included in the production and sales processes, as in the current situation, indirect costs were assigned so that some environmental costs would not be included in general overhead categories. According to Curkovic and Sroufe (2007), identification of all savings and costs associated with a TQEM program is the first and foremost step in TCA. It should be mentioned that TCA is similar to traditional budgeting techniques, except that it includes all associated environmental benefits and costs, which are not frequently considered in a traditional analysis.

Table 4. Classification of Environmental Costs by Structure Type.

Category	Group 1	Group 2	Group3	Group 4
	Shade House (soil)	Multi-Tunnel (soil)	Almeria Type Greenhouse (soil)	Multi-Tunnel (Hydroponics)
Direct Costs	– Infrastructure for reducing risk from use of agrochemicals – Labor – Handling residues	– Infrastructure for reducing risk from use of agrochemicals – Labor – Handling green and solid residues	– Infrastructure for reducing risk from use of agrochemicals – Labor – Handling residues	– Infrastructure and equipment for reducing risk from use of agrochemicals – Labor – Handling green and solid residues
Hidden Costs	– Education and training – Chemical analysis of soil and water – Electricity – Guidelines of Good Agricultural Practices are followed.	– Education and training – Analysis of produce pollutants. – Chemical analysis of irrigation water and soil – Electricity – Certifications of the production unit	– Education and training – Chemical analysis of water and soil – Electricity – Guidelines of Good Agricultural Practices are followed	– Education and training – Analysis of produce pollutants – Chemical analysis of irrigation water and soil. – Electricity – Certifications of the production unit.
Contingent Liability Costs	Not considered	– Increase in job risk premium, IMSS	– Increase in job risk premium, IMSS	– Increase in job risk premium, IMSS
Less Tangible Costs	Not considered	They recognize that the application of environmental protection practices lead to better access to the market, but the effect has not been quantified.	Not considered	They recognize that environmental management practices allow better access to the market and improve the product's image, but the effect has not been quantified.

Once all costs and savings of each of the scenarios are identified, tools are applied for financial assessment of the investment in each project. According to GEMI (1994) and Curkovic and Sroufe (2007), when applying TCA, standard financial indicators can be used to compare investments. The financial assessment techniques applied were net present value (NPV), internal rate of return (IRR) and profitability index (PI), also known as the benefit-cost ratio (BCR).

Net present value is used to assess capital projects. This technique "discounts" to a present value the dollars received in future periods by the rate of return that a production unit could obtain on an investment with comparable risk. NPV was obtained with the following equation:

$$2)\ NPV = \sum_{J=0}^{J=n} \frac{NCF_j}{(1+r)_j} \ ,$$

where NCF is the annual net cash flow from $j = 0$ to $j = 10$; r is the real interest rate and n is the useful life of the project. If $NPV \geq 0$, the net cash flows cover the inversion; otherwise, the project does not provide sufficient retribution to obtain positive profitability. In the case of IRR, the discount rate that makes the project NPV null is calculated in the following way:

$$3)\ NPV = \sum_{j=0}^{j=n} \frac{NCF_j}{(1+r)^j} = 0\ ,$$

where r is IRR in real terms. PI or BCR is determined as a relationship between incomes and costs at current values. It is calculated with the following equation:

$$4)\ BCR = \frac{\sum_{j=0}^{n} \frac{B_j}{(1+r)}}{\sum_{j=0}^{n} \frac{I_j}{(1+r)} + \sum_{j=0}^{n} \frac{OC_j}{(1+r)}}$$

where B is income or benefits, OC is operation costs, I is the investment, r is the real interest rate, and n is the useful life of the project. To be an acceptable investment, BCR must be greater than 1. Based on the proposal of Curkovic and Sroufe (2007), in TCA both normal savings and costs related to the project and environmental savings and costs associated with the project are incorporated.

Results

Environmental Management-Related Activities

The information obtained from the interviews enabled us to identify the activities related to environmental management in each of the production units analyzed. It should be mentioned that none of the production units has a formally established environmental management system, such as ISO 14001. Carruthers (2005) and Williams (2009) point out that adoption of a formal environmental management system has been slow in the agricultural sector. Nevertheless, the soil multi-tunnel and hydroponics multi-tunnel production systems (groups 2 and 4) carry out activities aimed at reducing residues, conserving water and detaining soil erosion. All of the production units declare that they have established an accounting system with which they can identify direct costs, which include management of some residues, such as plastic coverings, input containers and green residues. However, only the production systems of groups 2 and 4 had a formal system of costs, and only in group 4 did they declare having certificates of quality. This is the only production unit that exports. None of the production units has an accounting system that includes measurement of environmental costs.

Although the interviewees recognize that certification or recognition for having participated in environment-related programs facilitates access to markets and generates competitive advantages, in this sphere of action the production units have been driven basically by national and international norms and legislation (Table 5, see Appendix). As has been pointed out by Curkovic and Sroufe (2007), this is a reactive attitude in which growers deal with environmental problems only when they occur, rather than planning for their prevention. The interviewees from only two production units stated having plans or having begun other actions aimed at applying strategies of environmental quality management (Table 5, see Appendix), in addition to recycling structure covering, containers and green waste.

Environmental planning entails several possibilities. Bello et al. (2000) point out that there are biological alternatives for plant health management in a protected agriculture production system, implicating different ways of managing soil and crop health (Bello et al. 2003; Bautista-Calles et al. 2008). Moreover, several authors indicate sustainable practices for irrigation water management in protected agriculture that reduce its use and better care, as pointed out by Macías-Duarte et al. (2010) and Alaoui et al. (2014). They also suggest harvesting rainwater from the plastic coverings (Anaya-Garduño 2010) and storing it for use in crop irrigation, as well as water recycling systems and soil moisture sensors at different depths (Alaoui et al. 2014).

Impact of Environmental Strategies on Profitability

In their current situation, the four production systems studied register a positive net present value (NPV), an internal return rate (IRR) above the discount rate, and a benefit-cost ratio (BCR) above one, reflecting sufficient financial sustainability. The lowest NPV was obtained in the production system consisting of a shade house, largely due to the harvest and selling period (75 days during August and October). This contrasts with the system with a multi-tunnel structure and hydroponics (Table 6), which exports 88% of its production 270 days of the year, including the winter months when international tomato prices are higher.

Table 6. Current investment and profitability indicators of the protected agriculture production systems per hectare.

	Group 1	**Group 2**	**Group3**	**Group 4**
	Shade House (soil)	**Multi-Tunnel (soil)**	**Almeria Type Greenhouse (soil)**	**Multi-Tunnel (Hydroponics)**
Initial fixed investment [1]	103.48	239.05	233.41	748.45
Re-investment [1, 2]	55.06	113.55	131.83	277.98
Working capital[1]	18.06	23.56	31.60	128.68
Total investment (000/USD)	176.61	376.16	396.84	1,155.12
Net present value[1] (NPV)	132.62	256.90	452.43	1,096.60
Internal return rate (IRR) (%)	29.98	29.25	42.42	35.77
Benefit-cost ratio	1.30	1.37	1.52	1.39

Note. [1] (000/USD) [2]Additional investment necessary for replacing the structure covering and equipment.

With the savings and costs assigned to the "sustainable" and "unsustainable" scenarios, the financial indicators of each scenario were determined. In the "sustainable" scenario (Table 7), NPV, IRR and BCR are higher than in the "unsustainable" scenario (Table 8) in all of the cases studied. This indicates that the net cash flow that the producer in the "sustainable" scenario would receive would cover the investment made in sustainable production practices, and the financial return would be higher than in the "unsustainable" scenario. In other words, in the "unsustainable" scenario the income not received due to loss of productivity, at present value, would be more than the investment needed for adoption of sustainable production practices. It should be mentioned that in the case of investment in equipment for water recycling in the multi-tunnel-hydroponics system, only the part proportional to one hectare was considered, even though the price quote obtained for the production unit referred to the entire cultivated area.

Table 7. Investment and profitability indicators of the protected agriculture production systems: "sustainable" scenario (one hectare).

	Shade House[1] (soil)	**Multi-Tunnel[1] (soil)**	**Almeria Type Greenhouse[1] (soil)**	**Multi-Tunnel[2] (Hydroponics)**
Initial fixed investment [4]	103.48	239.05	233.41	748.45
Re-investment[3,4]	55.06	113.55	131.83	277.98
Working capital[4]	18.54	23.99	32.06	131.70
Investment in cistern, moisture sensors & water recycling system [4]	16.44	16.44	16.44	103.26
Scenario total investment[4]	193.52	393.03	413.74	1,261.40
Net present value[4] (NPV)	117.47	242.61	437.61	1,001.34
Internal return rate (%)	26.19	27.38	39.83	31.53
Benefit cost ratio	1.26	1.35	1.50	1.35

Notes. [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 hectares). [3] Additional investment necessary for replacing the structure covering and equipment. [4] (000/USD).

Table 8. Investment and profitability indicators of the protected agriculture production systems: "unsustainable" scenario (one hectare).

	Shade House (soil)	**Multi-Tunnel (soil)**	**Almeria Type Greenhouse (soil)**	**Multi-Tunnel (Hydroponics)**
Initial fixed investment[1]	103.48	239.05	233.41	748.45
Re-investment[2](000/USD)	55.06	113.55	131.83	277.98
Working capital [1]	18.05	23.54	31.58	128.65
Scenario total investment [1]	176.59	376.14	396.82	1,155.09
Net present value (NPV) [1]	87.02	182.98	350.12	787.24
Internal return rate (%)	24.75	25.10	37.69	30.79
Benefit cost ratio	1.20	1.28	1.42	1.37

Note. [1] (000/USD). [2] Additional investment necessary for replacing the structure covering and equipment.

Based on the structure developed by Curkovic and Sroufe (2007) for implementation of TCA, the results of this study provide the owners of the production units information on which to base their decisions regarding investment alternatives that contribute to their sustainability.

Conclusions

All of the production units have an accounting system that allows them to determine direct costs of handling plastic coverings, input packaging and green organic waste. However, on the part of technicians or owners of the production units, there is no clear understanding of what is involved in environmental accounting or in total cost assessment of the production process. They were nevertheless open to adopting techniques that would improve production processes and give them better access to information for their decision-making.

The technicians or owners of the production units also manifested that their actions relative to the adoption of environmental production practices are those required by environmental regulation. None of the production units has established a formal environmental management system even though they recognize that having been certified (México Calidad Suprema, 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.

TCA can give production units more precise information for decision-making in the administration of environmental projects. This information would include implementation of a water savings strategy: normal costs and those associated with loss of productivity due to environmental degradation, as well as savings and investment in rainwater harvesting or water recycling. Profitability indicators obtained in the "sustainable" and "unsustainable" scenarios illustrate how an enterprise, by adopting sustainable production practices, can not only have better access to markets, but also maintain positive profitability while helping to conserve the natural resources soil and water.

For implementation of environmental and quality management strategies in administrative systems of the agricultural sector, we recommend that the government: a) Hold workshops to inform growers of the critical situation of water in the region and of the importance of protecting the environment to make the production units sustainable. b) Design an environmental management framework for the agricultural sector aiming for ISO 14001 certification. c) Promote the adoption of TCA as a form of assessing production unit environmental projects.
At the level of the production unit, we suggest: a) Implementation of a costing system in which identifies product costs and period costs. b) Establishing strategies for addressing aspects of quality and environmental management in the administrative system, prioritizing environmental costs in decision-making.

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Appendix

Table 5. Production Unit Practices Oriented Toward Establishing an Environmental Management System.

Table 5. Production Unit Practices Oriented Toward Establishing an Environmental Management System.

	Group 1	**Group 2**	**Group3**	**Group 4**
Concept	**Shade House (soil)**	**Multi-Tunnel (soil)**	**Almería-Type Greenhouse (soil)**	**Multi-Tunnel (Hydroponics)**
Good agricultural practices and adequate use and management of inputs for pest control	Yes, those indicated by government programs	Yes, those indicated by government programs	Yes, those indicated by government programs	Yes, those indicated by government programs
Recognitions or certification for participating in environmental management programs	No	Good use and management of agrochemicals (BUMA) in tomato production and packing	No	▪ Primus GFS Global Food Safety Initiative ▪ SENASICA (BPA and BPM) ▪ Mexico Supreme Quality ▪ Global G.A.P. ▪ Ministry of Labor and Welfare. Agricultural Enterprise Free of Child Labor ▪ Good use and management of agrochemicals (BUMA)
Destination of plastic residues from renovation of coverings	They have been dumped in the garbage, but in the last change of covering, the old plastic was sold to a recycling company	It is sold to a recycling company	They have been dumped in the garbage, but in the last change of covering, the old plastic was sold to a recycling company	It is sold to a recycling company
Has personnel or consultants specialized in the area of food safety	No	Training courses given by the state Committees for Plant Health	Training courses given by the state Committees for Plant Health	Yes, a trained technician
Accidents in the production unit caused by misuse of agrochemicals	No	No	One worker affected	No
Fines for misuse of inputs, or product contamination	No	No	No	No
Benefits for the production unit from having recognition for participating in environmental management programs	Not applicable	Access to markets, increased competitiveness	Not applicable	Better access to markets and government subsidies
Actions directed toward establishing a Total Quality Environmental Management system (TQEM) to reduce environmental impact of residues or agrochemicals on water, soil, air and health.	Guidelines of Good Agricultural Practices manuals are followed.	▪ Contamination Risk Reduction Program of SENASICA and Good Agricultural Practices manuals are followed. ▪ Integral management of pests and diseases initiated.	Guidelines of Good Agricultural Practices manuals are followed.	▪ Good agricultural practices and vegetable handling are applied. ▪ Recognition and certifications indicated. ▪ A system for recycling water is planned.