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Economic development is an important phenomenon that can positively impact societal problems such as poverty, lack of education, and insufficient infrastructure, among other ills. In this regard, technological advances are essential to making better use of resources. The agricultural sector is no exception. With the passage of time, advances in agriculture have allowed processes to be optimized, improving production practices and minimizing risks, by using innovative technologies (Schenkel, Finley, & Chumney, 2012). For this reason, the adoption and use of approaches to protected agricultural production grew steadily in the State of Sinaloa, Mexico during the last century and until today. Such technology assisted significantly in the economic development of the region. This inquiry sought to understand factors and forces that augmented expansion of protected agriculture, especially regarding tomato production, and its advantages compared to traditional systems, as experienced by producers in Sinaloa. Understanding such a phenomenon may provide important implications for improving the economies of similar contexts in need of economic development where agriculture is a viable sector

Keywords

economic development; protected agriculture; Sinaloa tomato industry; technological innovation

Erratum

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Abstract

Economic development is an important phenomenon that can positively impact societal problems such as poverty, lack of education, and insufficient infrastructure, among other ills. In this regard, technological advances are essential to making better use of resources. The agricultural sector is no exception. With the passage of time, advances in agriculture have allowed processes to be optimized, improving production practices and minimizing risks, by using innovative technologies (Schenkel, Finley, & Chumney, 2012). For this reason, the adoption and use of approaches to protected agricultural production grew steadily in the State of Sinaloa, Mexico during the last century and until today. Such technology assisted significantly in the economic development of the region. This inquiry sought to understand factors and forces that augmented expansion of protected agriculture, especially regarding tomato production, and its advantages compared to traditional systems, as experienced by producers in Sinaloa. Understanding such a phenomenon may provide important implications for improving the economies of similar contexts in need of economic development where agriculture is a viable sector.

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Introduction

Unlike other agroecosystems, protected agricultural schemes such as greenhouses are production systems in which the environment is adapted to the crop to optimize productivity (De Pascale & Maggio, 2005). Greenhouses, for example, have been used as structures to protect plants from the environment, which increases yield and quality. Solbrig and Solbrig (1994) reported that some of the earliest protective structures for growing plants dates to during the time of the European Renaissance. However, Wittwer and Castilla (1995) indicated that the first systematic attempts to adapt the environment for crop production using protective practices or devices occurred in ancient times with the use of such during reign of the Roman Emperor Tiberius Caesar (14 to 37 AD).

Beginning in the 19th century, documents described the first protective structures, such as windbreaks, dedicated to growing various crops in European and Asian countries [see Figure 1] (Castilla, 2007). After the Second World War, greenhouses were established mainly in northern Europe using glass, but the most growth in use was due to the introduction of plastics, with more greenhouses built in Asian and Mediterranean countries as a result (Jaimez, Costa, Araque, Palha, & Salazar, 2015). Greenhouse designs and other protective approaches (see Figure 1) have varied over time and the changes were oriented to structures that minimized production costs and provided optimal environments for growing plants (Jaimez et al., 2015).

Figure 1. A semi-porous windbreak in the Mediterranean region. Screens are placed near the plants to change the environmental conditions affecting the whole plant or part of it. The screen position in relation to the plant determines the type of protection (Comité des Plastiques en Agriculture, 1992). Lateral forms of protection or screens are referred to as windbreaks. Adapted from *Plastic Green Houses Technology and Management* (Castilla, 2007).

As reported in 2001, the total area of protected agriculture in Europe was 247,000 acres, which is the continent with the widest variety of protected crops. The largest production areas were located in Spain (113,667 acres), Italy (61,775 acres), France (23,475 acres), and The Netherlands (20,620 acres) [Cantliffe & Vansickle, 2001]; while in the United States acreage for the same was about 26,000 acres, as reported by the United States Department of Agriculture (USDA) in 2007. Other countries with significant greenhouse coverage included Greece (12,108 acres), Portugal (5,440 acres), and Poland (5,020 acres) [Cantliffe & Vansickle, 2001]. In Europe, two types of greenhouse technology dominate. A highly automated and large investment structure found in the northern countries, e.g., Denmark, Germany, and The Netherlands. And those involving simpler structures and smaller investments, which are less automated or advanced, and used in the Mediterranean countries, including Greece, Portugal, and Spain, where the most acres of covered surface area exists (Cantliffe & Vansickle, 2001).

The possibility of producing certain crops year-round is one of the greatest advantages of production under protected agricultural schemes, which enables producers to grow products out of season and thereby acquire market and price advantages (Agrifood and Fisheries Information Service [*SIAP*], 2017). Pacheco (2006) concluded markets are increasingly demanding quality, safety, presentation and certification of content, and that consumers see the differences between these products and others. However, as Dalrymple (1973) observed, production per unit in greenhouses is almost always more expensive than field agriculture. Regarding productivity, Moghaddam, Feizi, and Mondani (2011) conducted a study in Iran where the total cost of tomato production per hectare in the open field was $3,843.00 USD, significantly less than the cost of greenhouse production at $64,713.00 USD per hectare. Greenhouse production cost, therefore, was 16.84 times higher than in the open field. However, gross value of production per hectare in the open field was only about $8,940.00 USD while production in a greenhouse was approximately $197,894.00 USD per hectare. Therefore, net income from the open field was 26.13 times lower compared to greenhouse production, and the benefit-cost ratio of greenhouses was 3.06 versus 2.33 for the open field (Moghaddam et al., 2011).

As for the future regarding Mexico, Villalobos (2013) concluded that hydroponic greenhouses were also rising as an alternative production system for the agricultural sector, including state-of-the-art technology acquired from Israel and The Netherlands that operates with significant efficiency. Hydroponic greenhouses are gigantic glass vessels by which computerized systems control the temperature, luminosity, water levels, climate, and nutrients the plants receive (Giese, 2015). These systems have drip irrigation, with automated water dispensers and fertilizers, which functions according to the growth and needs of each plant (Giese, 2015). This approach is so efficient that it recycles water the plants do not absorb, treats and reuses it, so 95% of the liquid extracted from the growing media is recycled. As a result, the crop, in terms of yield per square foot, is eight times superior to conventional cultivation techniques; in addition, this controlled environment renders the seasonality of crops irrelevant (Villalobos, 2013). The investment in this type of greenhouse almost guarantees the delivery of products year-round (Villalobos, 2013).

Prevalence of Greenhouses in Mexico

In Mexico, although many *high-tech greenhouses* for flower production, especially in the State of Mexico and State of Morelos, were erected during the 1970s, it was not until the late 1990s that significant development began for the intensive production of fruits and vegetables, which increased from 600 hectares in 1998 to more than 6,475 hectares by 2006 (Díaz, 2016). Regarding greenhouse production in the Mexican States, around 2006 Sonora occupied fourth place with 708 hectares of greenhouses built and 108 hectares under construction, and was surpassed only by the States of Baja California, Jalisco, and Sinaloa (Garza & Molina, 2008). The primary cover materials for protected agriculture in Mexico was 47% with plastic, 50% shade mesh, 2% using glass, and 1% employing other materials. Tomatoes were 70% of the volume produced in greenhouses, cucumbers 10%, peppers 5%, and other crops 15% (Destenave, 2007).

The *Instituto Nacional de Estadísica y Geografía* (*INEGI*, 2007) published the document *Panorama Agropecuario en México*. It defined greenhouses as buildings or installations generally covered with glass or plastic, which allow for control of the temperature, humidity, and nutrients, among other production factors, so that plants can be grown under optimum conditions for commercialization (*INEGI*, 2007). Through the use of greenhouses, the local climate is modified to better meet the needs of crops in any season (*INEGI*, 2007). The 2007 Agricultural Census for Mexico recorded 18,127 production units of greenhouses in the States of Chiapas, Oaxaca, State of México, and Michoacán, with Nayarit having a majority of the facilities. Of the 18,127 greenhouses in these States, 3,173 were one year old, 4,999 were one to two years old, 3,643 were five years old, 2,360 were five to 10 years, 2,409 had been in use for more than 10 years, and 1,543 had no time period of use specified (*INEGI*, 2007). The State of Mexico tended to have the older greenhouses (*INEGI*, 2007).

The use of greenhouses in Mexico nationwide grew from 9,900 hectares of coverage in 2008 to 14,800 hectares in 2010, and it was estimated that by 2020 more than 28,328 hectares of production in greenhouses would exist, according to the NL Agency, a division of the Dutch Ministry of Economy (as cited in Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food [*SAGARPA*], 2010). The State of Sinaloa in particular presents a successful case of economic development based on improved technologies such as protected agriculture. The growth achieved in protected agriculture, especially the use of greenhouses and shade mesh in Sinaloa, reflects the interest and motivation shown by the farmers of Sinaloa to implement improved production methods and models (Robles, 2012). Understanding better the factors that influenced their use of such technologies may inform policies appropriate for regions with similar attributes and constraints also seeking increased economic prosperity (FAO, 2018). This implies opportunities for agricultural educators, including extension agents (Röling & Van De Fliert, 1994), to assist in the technology's adoption, implementation, and continued use.

Purpose & Research Questions

The purpose of this historical inquiry was to describe emergence of the commercial agricultural sector and its adoption of protective production technologies in the State of Sinaloa, Mexico over time, especially regarding the tomato industry. In addition, this study sought to identify the related economic impact on the State of Sinaloa. Three research questions guided this study:

R1: Which forces and actors contributed to developing the agricultural sector in Sinaloa over time?

R2: What were tomato producers' primary motives for adopting protected agricultural technologies in Sinaloa, including greenhouses and other protective structures?

R3: What have been the economic benefits of tomato production to the State of Sinaloa?

Methodology

Systematic examinations of the past can enrich our understanding of phenomena because individual memories are usually deficient and fragmentary (McDowell, 2002). With historical research, researchers strive to reconstruct what occurred in some specific period of time with as much accuracy and detail as possible (Marley, 2006). To arrive at conclusions regarding past events and forecast future scenarios, it is necessary to discover and explore facts that support hypotheses and speculations (Key, 1997). Moreover, the investigatory method of historical research is analytic-synthetic. It is essential, therefore, that the issues, events, and actors are analyzed regarding their constitute parts or features to understand the economic, social, political, religious, or ethnographic roots from which such emerged, and from this create a synthesis that reconstructs and explains the phenomenon (Langlois & Seignobos, 1965).

Grajales (2002) described this type of investigative process as actions of the historian that delimit a problem, formulate hypotheses or raise questions to be answered, collect and analyze primary and secondary data, test hypotheses as coherent or not with the evidence, and draw generalizations or conclusions based on the findings. Textbooks, encyclopedias, newspaper articles, chronicles, and literature reviews can be appropriate sources of data for historical inquiries. These were the kinds of sources, traditional and digital, collected and analyzed for this study. Such were collected and examined for *goodness* and *credibility* (Tobin & Begley, 2004), and subjected to external and internal criticism to support the authenticity and accuracy of this investigation's findings (McDowell, 2002). Most of the study's data were retrieved using Internet search engines provided by the main library at Oklahoma State University. The key search terms included greenhouses in the State of Sinaloa, history of greenhouses, history of Sinaloa, protected agriculture, and the tomato industry in Sinaloa, Mexico. More than 80 sources formed the study's corpus of literature.

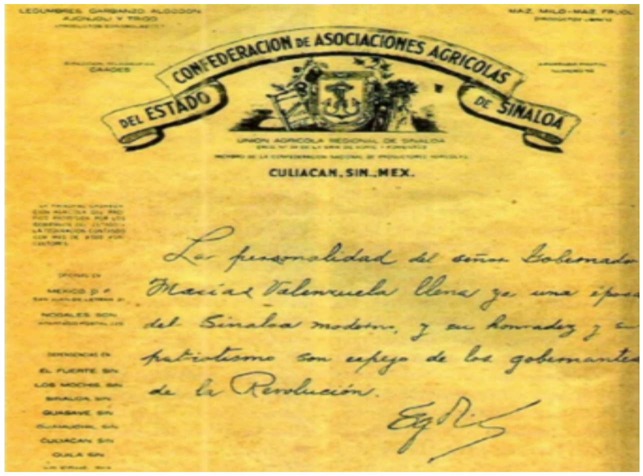
Findings

Commencement of Commercial Agricultural Production in Sinaloa, Mexico

Farmers of Sinaloa, Mexico became major producers and exporters of fruits and vegetables during the 1920s. Their strategic market, from the beginning, was and remains the United States, especially in regard to tomatoes (*SAGARPA*, 2015).

Role of Domestic and International Forces and Provision of Financing and Credit

After the worldwide financial crisis of 1929, agricultural entrepreneurs developed, with the Mexican government's help, enhanced economic and environmental conditions to solve problems of financing and commercialization in Sinaloa (Carrillo & Romero, 2012). In 1932, the Confederation of Agricultural Associations of the State of Sinaloa (*CAADES*) was created (see Figure 2), which supported several projects leading to the resolution of these problems while contributing greatly to developing the region's fruit and vegetable production sector (López, 2012). This activity was encouraged further in 1940 with expansion of the agricultural frontier, the construction of large works for the storage of water, and the establishment of effective irrigation systems in Sinaloa (López, 2012). In 1941, *CAADES* created an agricultural experimental field in Culiacán to find solutions to increasing production through more technical and reliable systems (*SIAP*, 2017). Also, beginning in the 1940s, Mexico had one of its most sustained periods of economic growth as the result of implementing an *import substitution scheme* (Guillén, 2013). This scheme emphasized on accelerating investment for the home market primarily by relying on the government managing market prices which meant replacing foreign imports with domestic production (Uscanga & Edwards, 2016).


CONFEDERACION DE ASOCIACIONES AGRICOLAS DEL ESTADO DE SINALOA

CULIACAN, SIN., MEX.

La personalidad del señor Gobernador Macías Valenzuela llena ya una época del Sinaloa moderno, y su honradez y su patriotismo son espejo de los gobernantes de la Revolución.

Figure 2. Official *CAADES* letter to Governor Macias Valenzuela thanking him for his efforts in pushing into modernity the State of Sinaloa, dated 1948. Retrieved from *Historia Constitutiva de CAADES y sus Presidentes (1932 – 2012). CAADES* was and remains an organization of public interest, autonomous with its own legal nature, made up of 10 agricultural associations, including approximately 15,000 farmers, with the objective of organizing, protecting, and promoting farmers' development in Sinaloa (López, 2012).

In the State of Sinaloa, during the middle of the 20th century, agriculture as a business, and not mainly for subsistence, became a significant driver of the region's economy (Garza & Sobrino, 1989). Both external and internal contexts favored and deepened insertion of the region´s economy into national and world markets as an exporter of primary products, especially fruits and vegetables (Aguilar, 2001). Changes in the world's economy caused by the Second World War expanded this market to the United States given an increase in the per capita income of its citizens (Aguilar, 2001). The competitive advantages of input costs, mainly labor, allowed production to expand more in Mexico than in the United States; another important factor was that, at the beginning of the 1960s, the United States began an economic blockade of Cuba, which stopped its importation of Cuban sugar (Morley, 1984). This geopolitical move stimulated the U.S. state of Florida's agricultural sector to reallocate part of its acreage devoted to fruit and vegetable production, especially tomatoes, to planting sugar cane instead, which impacted the global market for the two products (Morley, 1984).

Foreign investors, for example, Greek immigrants, also participated in the organization of companies in the agriculture sector between 1929 and 1958 (Aguilar, 2006). Of their investments, including large, medium, and small owners/operators, the first was established August 28, 1929 and named Rasura & Davlantes. Its main objective was the production of tomatoes for export using 65 hectares of land leased from the Almada Sugar Company (Aguilar, 2006).

The cultivation and exportation of tomatoes has always required large sums of money (Hernández, 2000). The credit or financing applied to commercial agriculture such as tomato production in Sinaloa was obtained from various sources, including informal credit, foreign investment, self-financing, and local lending institutions (Frias, 2007). Moneylenders who were usually traders, i.e., usurers, also operated, and included people from *high society* or the nation's elites; they lent money based on promissory notes and guarantees of collateral (Frías, 2007).

Before the Mexican revolution of 1910, in Culiacán, the capital of Sinaloa, only two credit institutions existed: a branch of *Banco de Sonora* and a Western Bank agency of Mexico, but the latter disappeared as a result of the Mexican revolution (Aguilar, 1998). In the late 1920s, large farmers and industrialists working in the central and northern parts of Sinaloa, due the scarcity of credit institutions in the region, went to the big national and foreign banks in Mexico City to meet their financing needs (Aguilar, 1998; Carton de Grammont, 1990). After 1940, credit for agriculture became a central element of Mexico's new agrarian policy (Aguilar, 1998; Alvarado, 1998). In Sinaloa, the government had a significant impact on providing credit to develop the region's economy through agriculture; in 1941, the Coordinating Committee of Private Agricultural Credit of the State of Sinaloa was created (Aguilar & Grijalva, 2011). The contribution of credit institutions together with government initiatives supporting agricultural development of the region had great importance by increasing the volume of available credit and assigning almost 80% of the lenders' portfolios to the agricultural sector (Aguilar & Grijalva, 2011).

This close alliance began in 1932, as established between the new private farmers and the post-revolutionary Mexican State; in 1984, the same alliance would be redefined due to increased political and organizational autonomy of the agricultural sector vis-à-vis the State (Carton de Grammont, 1990). By provision of Mexico's National Banking Commission, the Bank of Sinaloa (*BANSIN*) [see Figure 3] was authorized and founded in 1933 at Culiacán, as the only institution empowered to support producers of tomato, chili, eggplant, cucumber, chickpea, cotton, sugar cane, and sesame in the region at that time. Thereafter, this private banking institution served the credit needs of Sinaloa´s producers. Prominent farmers put up almost one-half of the founding capital with a contribution of $493,000.00 Mexican pesos (approximately $246,500.00 USD at that time), and the Monetary Commission provided $500,000.00 Mexican pesos or about $250,000.00 USD (Aguilar, 1998). The bank was established to strengthen the more profitable production activities conducted by the agricultural elite of the State, and, in particular, to solve the financing needs of horticulturists (Frias, 2007), including tomato growers.

Another important phase this industry underwent was the founding of *BANPROSIN* (Provincial Bank of Sinaloa) in 1940, which represented the lending flexibility needed by the government banks (Aguilar, 2002). According to William Patton Glade, an economics scholar, this institution, designed to contribute to the development of northwestern Mexico beginning in 1943, was dedicated to actively promoting the economic development of Sinaloa through the private credit institutions operating there (as cited in Aguilar, 2002).

Figure 3. Bank of Sinaloa's original building used from its inception until the 1950s. The bank began operation on July 3, 1933, in accordance with the authorization granted by the Secretariat of Finance and Public Credit (*SHCP*) on April 5 of that same year (Aguilar, 1998). (Copyright by Mexicoenfotos, 2011.)

Organizing Sinaloa´s Agricultural Producers and Supporting Factors

From 1942 and until 1950, four important events occurred in the Sinaloa region supporting its agricultural development. The first was formation of the Association of Farmers of the San Lorenzo River on August 8 of 1942 with an initial capitalization of $10,000.00 Mexican pesos (approximately $5,000.00 USD), which promoted water conservation and irrigation infrastructure in the region (Aguilar, 2001). On September 3 of the same year, the second significant event was creation of the Association of Farmers of the Eastern Area of the Sinaloa River (Herrera, 1962). Next, after creation of the agricultural experimentation fields of *CAADES*, a main building was erected at a cost of $800,000.00 Mexican pesos (approximately $400,000.00 USD), the third important event of this period. *CAADES* continues to dominate the content and application of agricultural policy in Sinaloa (Aguilar & Romero, 2011) to this day.

The fourth major event occurred April 10 of 1950, when formation of the Association of Farmers of Baluarte's River was announced (López, 2012). The objective of this agribusiness network was to create an organizational structure to apply the norms of agricultural production and commercialization to the most important crops of the region, to monitor producers, and to penalize those who may violate the prescribed expectations. An important step in bringing scientific research to the farmers of Sinaloa was creation of the Agricultural Research Institute of the State of Sinaloa in 1955, which was established by staff members of the Culiacan Agricultural Experimental Field Station to address technical problems associated with irrigation in the region (*SAGARPA*, 2013). The Permanent Commission for Agricultural Research and Experimentation of the State of Sinaloa (*CPIEAES*) was also created (Carton de Grammont, 1990). This commission was the work of *CAADES,* in collaboration with the Association of Agrarian Communities and Farmers Unions, and with support from the Center for Forest and Agricultural Research of the State of Sinaloa (*CIFAES*), as responsible for providing economic resources to improve, conserve, and expand agricultural production (Cañes, 2016).

During the 1960s and through the mid-1970s, tomato production experienced significant growth in Sinaloa. Among the factors explaining this were the effects of ending the *Bracero* Program (see Figure 4) in 1964, which meant a surplus of farm labor was readily available, and the commercial blockade of Cuba by the United States beginning in 1962 (Losman, 1974). The *Bracero* program grew out of a series of bi-lateral agreements between Mexico and the United States that allowed millions of Mexican men to migrate to the United States to work on short-term, primarily agricultural labor contracts (Uribe, Cuellar, & Alvarado, 2013). From 1942 to 1964, almost 5 million contracts were signed, with many individuals returning several times on different contracts, making it the largest U.S. contract labor program (Uribe et al., 2013).

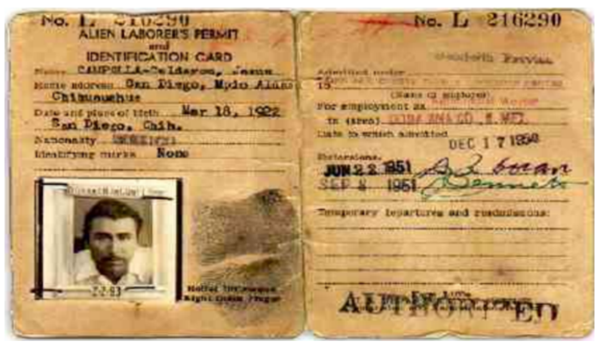


Figure 4. Bracero card issued to Jesús Campoya in 1951 at El Paso, Texas (Center for History and New Media, 2019).

Promotion of Greenhouse Production of Tomatoes in Mexico

In the late 1970s, *COPLAMAR* (Commission for the Development of Marginalized Areas) promoted the construction and use of greenhouses in Mexico (Loredo, 2015; Pacheco, 2006). All were wooden structures and covered with plastic films; in addition, new machinery was also introduced to automate certain agricultural tasks and the modernization of packaging occurred to better care for the harvested product, as well as the cooling and gassing of tomatoes to a ripening point (Pacheco, 2006).

In the 1980s, U.S. horticulture producers greatly outperformed their counterparts in Mexico by incorporating plastic protection systems, by gassing to ripen green tomatoes after harvest, and by expanding greenhouse production overall (Massieu, 2009). "Freshly harvested tomato fruit are highly perishable, with losses occurring during harvesting due to uncontrolled ripening" (Khaira, Sandhu, & Singh, 2014, p. 90). However, "considerable evidence at the physiological, biochemical, and molecular levels have been accumulated which indicated ethylene mediated regulation of ripening at various levels" (Bapat et al., 2010, p. 95) was an effective post-harvest practice. Over time, this approach to controlled ripening became an industry standard (Bapat et al., 2010). In addition, problems associated with the production of fruits and vegetables in the open, such as inclement weather and pest control, including sucking insects and virus vectors, as well as the need for more efficient and productive agriculture contributed to the rapid development of protected agriculture in Mexico (Moreno, Aguilar, & Luévano, 2011).

Before the end of the 1980s, Mexican tomato producers, as a response to their U.S. competitors' advances, also began to orient toward the use of less polluting technologies and inputs that improved productivity (Carrillo, 2015). This growth in tomato production did not occur much as the result of *territorial expansion of production*, but rather through the *intensification of production*. The technological changes made to production practices were reflected in horticultural crops, especially regarding use of fertigation together with plastic mulching (Carrillo, 2015; Pacheco, 2006; *SAGARPA*, 2010). The start of greenhouse production and the implementation of hydroponic technologies allowed horticultural farmers to take better advantage of inputs, reduce risks of diseases and pests, and positively impact productivity and quality of the tomatoes grown (Martínez, 2006).

During the 21st century, tomato production in Mexico grew at an average annual rate of 3.3% from 2005 to 2015 (*FIRA*, 2016). The total land area dedicated to this crop decreased at an annual average rate of 3.8% (*FIRA, 2016*) at about the same time. The downward trend in the surface area sown is derived from a decrease in the cultivated area under the open sky versus cultivation in protected conditions, which continued to expand (Gomeiro, 2016). Thus, the volume of red tomato grown in Mexico using the latest technologies, including protective shade houses and greenhouses, went from 2.9% in 2005 to 32.2% in 2010, and to 59.6% of all production in 2015 (*FIRA*, 2016) [see Figure 5]. More than one-half of the area with protected agriculture is concentrated in four Mexican States: Sinaloa (20.4%), Jalisco (14.2%), Baja California (11.4%), and the State of Mexico (7.0%). The national average is 0.9 hectares / production unit (PU); in Sinaloa and in Baja California, however, the average is 28.8 and 13.1 ha / PU, respectively (Amarillas, 2018).

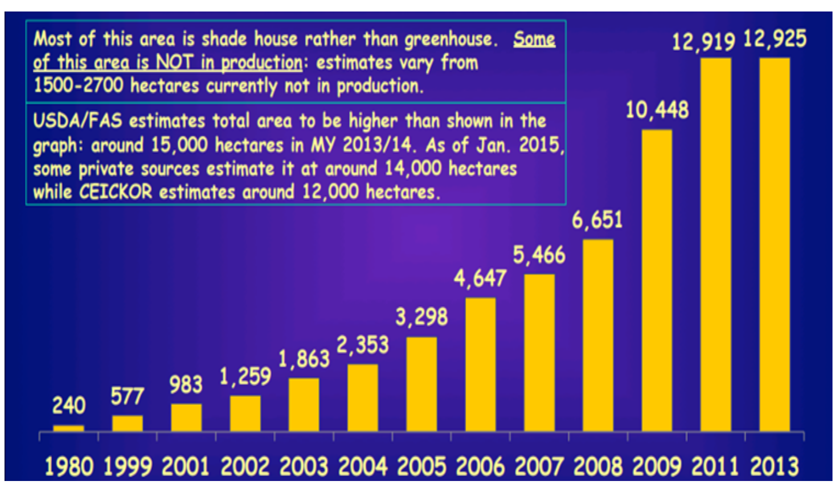


Figure 5. Estimated area of protected tomato production in Mexico from 1980 to 2013; numbers are expressed in hectares (1 hectare = 2.47 acres). The increase in the area with protected agriculture infrastructure is attributed mainly to success in the tomato harvest of export quality destined for the U.S. market. Adapted from *Fresh Tomato Production and Marketing Trends in the N. American Market* (Cook, 2015).

Tomatoes contributed 22% of the national volume of vegetable crops, including fruits such as tomatoes, produced in Mexico, and the average annual yield from 2006 to 2016 was 2.4 million tons (*FIRA*, 2016). The sale of tomatoes increased by more than $200 million USD during this time period, which placed it second among Mexico's top 20 agricultural products, only after beer (*SADER*, 2017b). Tomato is the country's largest export crop, with revenues between January and October of 2016 reaching $742 million USD, and an annual growth rate of 15% (*SADER*, 2017b). "Tomato production for marketing year 2017/18 is estimated at 3.4 million metric tons (MMT), similar to the previous marketing year" (USDA, 2017, p. 2). Further, according to the USDA (2017), "[p]rotected agriculture is growing in Mexico, as producers increasingly become aware of the benefits in production, quality, pest control, and reduced risk exposure to climate change" (p. 3).

Tomato Production in Sinaloa

Sinaloa includes 2% of Mexico's population and contributes 2.1% of the national GDP (Amarillas, 2018). The main economic activities are commerce (22.4%); real estate services and rental of movable and intangible goods (13.9%); agriculture, animal husbandry and exploitation, forestry, fishing and hunting (10.3%); construction (8.8%); and the food industry (6.9%). Together these sectors represent 62.3% of state´s GDP (Amarillas, 2018).

The State of Sinaloa is the largest overall agricultural producer in Mexico among its 32 states. The best cultivated areas are in the dry and semi-dry climates, which are mostly irrigated, and the main crops other than tomato are beans, chickpea, cotton, maize, potatoes, safflower, sorghum, and soybean (Amarillas, 2018; *SAGARPA*, 2015). In this region that has a warm, sub-humid climate, tomato, melon, watermelon, and vegetables are grown, and most of the production occurs under protected conditions with the use of organic fertilizers; improvements in irrigation systems are also found, with the intention of further increasing productivity (Amarillas, 2018; *SAGARPA*, 2015).

Large-scale agriculture under controlled environments has become a realistic alternative for developing some regions of the world, including Sinaloa, which resulted in its producers growing fruits and vegetables during seasonal periods not possible before, such as tomatoes. These production systems also strengthened environmental conservation by reducing excess exploitation of land and water (Zaragoza, Buchholz, Jochum, & Pérez-Parra, 2007).

The adoption of protected agricultural schemes was accelerated in the State of Sinaloa, as supported the Mexican government's agricultural strategy, in response to a financial crisis caused by devaluation of the nation's currency in 1995 (Pacheco, 2006). Thereafter, strong growth occurred in the installation of shade mesh and greenhouses in Sinaloa (*FIRA*, 2007). This was also due to producers acquiring access to financing from suppliers in France, Israel, Spain, and The Netherlands (*FIRA*, 2007). As a result, the practice of horticulture under protected growing conditions continued to gain economic importance in Sinaloa (Amarillas, 2017). The largest growth was reached during the first decade of the 21st century; approximately 20 years earlier the adoption of greenhouse technology began with 350 hectares, and by the 2011-2012 growing season the area dedicated to protected production in the State of Sinaloa was about 5,000 hectares (Robles, 2012). This economic activity generated more employment per hectare than conventional agriculture, contributing to regional development and the possibility of increasing the prosperity of many Sinaloans (Bernal et al. 2010; Victoria et al., 2011). Thus, by the early 2000s the tomato industry in the State of Sinaloa supported about 180,000 jobs either directly or by association with the sector (Sánchez, 2008).

It is necessary to highlight the importance of foreign markets for this industry, because for both open field and protected production almost 88% of the profit resulted from exporting and only 12% was attributed to domestic consumption in the early 2000s (*FIRA*, 2007). Sinaloa stands out as the Mexican State that uses the most protected horticulture, where it is estimated more than 8,000 hectares of protected area were under production in 2017 (*SADER*, 2017a). Sinaloa has established itself as the leading tomato producer in Mexico, with the production of 1,039,367 tons, and a value of slightly more than 4 billion pesos or $200 million USD in 2017; therefore, tomatoes are a very important source of jobs and foreign exchange for the region and nation (Amarillas, 2018). As such, tomato is one of the most important horticultural products of Mexico due to the monetary value the sector generates and its demand for labor (Sañudo et al., 2013). According to *Asociación Mexicana de Horticultura Protegida A.C.* (*AMHPAC*), i.e., the Mexican Association of Protected Horticulture, tomato is the crop most produced in protected environments, for which shaded meshes prevail, a coverage technique that has given Sinaloa's producers a huge advantage in managing solar radiation to promote photosynthesis and plant development (Goldense, 2016). Of the 25,000 hectares of tomatoes grown under protected agricultural systems in Mexico, more than 8,000 hectares are in Sinaloa, making it the leading Mexican State for this production system (*SADER*, 2017a).

Conclusions, Implications, & Recommendations

Tomato production in Sinaloa contributes to the economic livelihood of thousands of people in its rural areas (FAO, 2013; *FIRA*, 2016). Mexico's tomato exports remain among the top three places at the international level due to its growers' adopting modern production practices, and the sector applying accredited packaging standards, which supports its year-over-year, high trade volume with the United States (*FIRA*, 2016).

The use of protected agriculture in the State of Sinaloa was augmented by the global trend of increasing demand for higher quality products, the opportunities that different government programs created in the region, (Cook & Calvin, 2005), and geo-political forces (Aguilar & Grijalva, 2011). Reasons also include growing consumer demand for select product presentation standards and certification of origin, content, and quality, as well as producers' competitiveness (Porter, 2011). Most of the tomato producers in Sinaloa have invested large sums in protective technologies, organized and became well-structured in entrepreneurial ways, created a strategic vision, established corporate offices, and devised financial development schemes and a marketing infrastructure (Robleño, 2006). Efficient use of inputs helped increase growers' productivity, which contributed to the economic sustainability and competitiveness of rural communities regarding their agricultural sectors and supported the implementation of innovations (Porter & Kramer, 2018) such as protective growing systems.

The Mexican government played an important role in Sinaloa's agricultural development by designing policies to support producers that provided financial assistance (Aguilar, 2002; Aguilar & Alvarado, 1998; Aguilar & Grijalva, 2011;

Carrillo & Romero, 2012; Carton de Grammont, 1990; Cook & Calvin, 2005; Frias, 2007), and having as a main objective to mitigate asymmetries and thereby improve the sector's competitiveness in international markets (Porter, 2011). Investments in credit-lending institutions, irrigation infrastructure, and agricultural research capacity are but three significant examples of government support (Aguilar & Grijalva, 2011). This strategy also improved the *economic spill* in the State of Sinaloa, reaching $200 million USD, as based on the sale of tomatoes in 2017 (Amarillas, 2018). It is expected that because cultivation through forms of protected agriculture is still increasing in Sinaloa, various industry actors will continue to reap significant benefits from their use of these technologies and other innovations in the future (Amarillas, 2017).

"Good practices are successful experiences that have been tested and replicated in different contexts and can therefore be recommended as a model. It deserves to be shared so that a great number of people can adapt and adopt it" (FAO, 2018, p. 4). To that point, Röling and Van de Fliert (1994) identified Extension as the delivery of technology- and knowledge-based systems. Moreover, facilitating the implementation of product *and* process innovation by farmers within the agro-industrial model is an essential role played by agricultural extension services (Hellin, 2012; Sæther, 2010).

Rivera and Sulaiman (2009) and Rogers (2003) reinforced the importance of Extension and the vital role it serves in the *diffusion of innovation* as a mechanism for transferring new technologies intended for adoption by farmers. However, before diffusing these innovations and practices, change agents, including extension and advisory service professionals, must be convinced of the necessity and importance of such (Tiraieyari, Hamzah, Samah, & Uli, 2013). In addition, the contributions of extension educators regarding their facilitation of farmer interest groups, as especially related to the adoption of agricultural innovations, warrants more research.

The case of the emergence, growth, and successful use of protected agriculture for tomato production in Sinaloa, Mexico could serve as a guiding template or framework to be followed in other developing contexts with similar needs, opportunities, and constraints. Therefore, it is recommended to further explore Sinaloa's rise as a leading tomato producer on the international stage, which may lead to developing a model for use by policymakers and practitioners of agricultural and rural development worldwide.

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