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Agradecimientos: Son opcionales y tendrán un máximo de tres renglones para expresar agradecimientos a personas e instituciones que hayan contribuido a la realización del trabajo.

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Digestibility of a diet with hydroponic maize (*Zea mays* L.) green fodder and its effect on lamb growth

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ABSTRACT

Objective: Determine the apparent digestibility (AD) of diets with hydroponic maize green fodder (HMGF) (*Zea mays* L.) and evaluate its effect on dry matter (DM) intake and daily weight gain (DWG) in lambs.

Design/methodology/approach: Two experiments were carried out with four inclusion levels of HMGF (0, 20, 40, 60% of DM) in the diet. A total of 16 sheep was used to determine the AD of the diet. Growth testing was carried out in 20 male lambs. Both studies employed a completely randomized design.

Results: The AD of DM and crude protein was higher in diets with 40 and 60% of HMGF ($P \leq 0.05$; $P \leq 0.01$). Lambs fed diets with 0 and 20% of HMGF showed higher DWG ($P \leq 0.05$). Sheep fed diets with 60% of HMGF showed lower DM intake ($P \leq 0.05$).

Study limitations/implications: Although there are currently several methods to supplement sheep during drought periods, few are fully adapted to what the producers need. Hydroponic maize green fodder is a valuable alternative for the rapid and constant production of high nutritional value fodder.

Findings/conclusions: The hydroponic maize green fodder has high digestibility, and thus, it can be used as an excellent source of fodder in the diet of lambs, obtaining adequate weight gains with rations that include up to 40% in the ration in substitution of commercial feed.

Keywords: Hydroponic forage, feeding, digestibility, lambs.

INTRODUCTION

Forage production in the tropical dry is extremely seasonal; the highest volume and quality are obtained during the rainy season (Muñoz *et al*., 2016; Merlo *et al*., 2017), resulting in grazing animals gaining weight during the rainy season and losing it during winter and spring, when forage and nutrient availability decrease (Castro *et al*., 2017; Coleman *et al*., 2018). Therefore, it is important to look for technologies that can provide fodder to animals when they need it and reduce the environmental impact caused by large artificially modified areas. Hydroponic maize green fodder

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(HMGF) represents a valuable alternative for the rapid and constant green fodder production with high nutritional value in extensive livestock farming areas with long drought periods (Morales, 1987). HMGF is cultivated in small areas (greenhouse); therefore, it represents less phytosanitary problems and can be produced throughout the year (FAO, 2002; Müller *et al*., 2005). Hydroponic fodders are highly palatable to livestock and provide optimal protein and energetic levels, vitamins, and minerals, with higher digestibility than fresh pastures (FAO, 2002). The information regarding the use of HMGF in sheep is limited. Some authors suggest substituting between 50 and 70% of the feed ration (Herrera *et al*., 2007); however, high levels of HMGF in the diet could compromise feed efficiency and the productive behavior of animals. This study determined the apparent digestibility (AD) of diets with HMGF and evaluated its effect on dry matter (DM) intake and the daily weight gain (DWG) of lambs.

MATERIALS AND METHODS

The study was carried out in Chiná, Campeche, Mexico (19° 44′ N and 90° 26′ W) at an altitude of 15 masl with tropical savanna climate (AW), based on the Köppen classification modified by García (1973), with 1200 mm of annual precipitation distributed between June and November (Duch, 2002).

Diet apparent digestibility determination

We used a total of 16 Pelibuey male adults with an average live weight ± standard deviation (SD) of 35.2 kg ± 3.4 kg. Sheep were housed in individual metabolic cages made of wood and provided with feeding and drinking troughs and feces and urine collectors. Animals received four treatments consisting of different inclusion levels of HMGF (0, 20, 40, and 60% of DM) in their diet, composed of commercial feed with 15% of crude protein (Table 1). Each treatment had four replicates, each of which consisted of one animal housed in a metabolic cage. Before testing, animals were internally dewormed with ivermectin and subjected to a 14 d-adaptation period to diets and cages. Animals were first fed with the commercial feed in the mornings and then with HMGF at noon. Measurements were performed during a 7-day period in which we recorded the total amount of feces produced per day and the feed and HMGF intake by daily weighing the offered and rejected quantities. Once the total production of feces was determined, feces (10%) and offered and rejected feed and HMGF samples were collected daily to obtain composed samples at the end of the measuring period. Samples were preserved at −20 °C until further processing. We determined the content of dry matter (DM), crude protein (CP), organic matter (OM), neutral detergent fiber (NDF), and acid detergent fiber (ADF) based on the procedures described by the AOAC (2016). We used a completely randomized statistical design (Montgomery, 2004). Results were analyzed with a repeated measures model and using the Proc Mixed procedure of the SAS statistical software (SAS Inst. Inc., 2003).

Table 1. Ingredients and composition of the commercial diet (% of DM).

Ingredients	%
Ground sorghum	46.87
Canola	11.00
Wheat bran	13.00
Soybean hulls	14.00
Cane molasses	5.00
Soybean meal	3.85
Calcium carbonate	2.80
Nutritional additives	0.84
Common table salt	0.80
Urea	0.80
Sodium bicarbonate	0.40
Ammonium sulfate	0.15
Trace minerals	0.43
ADE vitamins	0.06
	100.00
Chemical composition	
Dry matter (%)	88.84
Crude protein (%)	15.48
EM (Mcal/kg of DM)[a]	2.74

[a] Estimated based on NRC (1985).

Lambs growth evaluation

A total of 20 weaned Pelibuey male lambs were used with an average live weight ± SD of 20 ± 2.18 kg. These lambs were randomly assigned (Montgomery, 2004) to the four HMGF treatments (0, 20, 40, and 60% of DM) used in the digestibility testing. Animals were fed a basal diet composed of a commercial feed with 15% crude protein (Table 2). Each treatment had five replicates; each replicate consisted of an animal housed in a feedlot provided with feeding and drinking troughs, concrete floor, and shade. Before testing, lambs were internally dewormed with ivermectin and vaccinated against pneumonic pasteurellosis. Additionally, animals were subjected to a 14 d-adaptation period to diets and cages. Animals were first fed with the commercial feed in the mornings and then with HMGF at noon. Feed daily intake was determined by weighing the offered and rejected amounts of each of the ration ingredients. Animals were weighed before fasting for 16 h, then every 14 days, and finally at the end of the measuring period, which lasted 84 d. We determined the daily weight gain (DWG) and the total weight gain of lambs. DWG results were analyzed using a repeated measures model. The remaining variables were analyzed with a linear model for fixed effects, which considered the effect of the level of inclusion of HMGF in the diet, using the Proc Mixed and Proc GLM procedures of the statistical software SAS (SAS, 2003).

Table 2. Chemical composition of hydroponic maize green fodder.

Component	% Dry basis
Moisture	76.97
Dry matter	23.03
Organic matter	96.2
Crude protein	18.30
Minerals	3.80
Phosphorus	0.44
Calcium	1.20
Neutral detergent fiber	36.92
Acid detergent fiber	15.05

Analyses performed in the Water-Soil-Plant laboratory of ITA Conkal, Mexico.

RESULTS AND DISCUSSION

Table two shows the results for the chemical composition of the HMGF. We observe high moisture, CP, and phosphorus (P) contents, the latter being of greater relevance because they represent approximately double the value reported for other tropical fodders (González *et al*., 2011; Merlo *et al*., 2017; Cuervo *et al*., 2019). These results are of great importance if we consider that the highest contribution of nutrients from the HMGF remains constant all the time and is not subject to a decrease in its content, as happens in traditional fodder (Muñoz *et al*., 2016; Castro *et al*., 2017). It is also worth noting the low concentrations of fiber fractions (NDF and ADF), which indicate that HMGF may be a high-quality fodder. High-quality fodders have high amounts of crude protein, between 12 and 20%, and low fiber levels, approximately 28 to 60% (Linn & Martin, 1991). It is worth mentioning that the contents of CP, NDF, and ADF of HMGF were within the mentioned ranges, highlighting the low proportion of the ADF fraction (15%). Similar values were reported for CP, fiber, and ashes by Naik *et al*. (2014).

Regarding the apparent digestibility of the different diet components (Table 3), we observed higher DM and CP digestibility in the diets with 40 and 60% of HMGF (P≤0.05; P≤0.01). Other authors (Herrera *et al*., 2007) observed a 56% DM digestibility in sheep fed diets with 100% HMGF, below what we found in this study. Similar values were observed by Acosta *et al*. (2016) in goats fed HMGF with DM and CP digestibilities of 77 to 90%. The increase in ruminal function in lambs is probably due to the quality of the HMGF; HMGF inclusion, along with sorghum and canola grains, constitutes a good complement for more efficient use of the diet components. In ruminants, the highest digestive efficiency occurs at higher rumen retention times (Hart & Glimp, 1991). On the contrary, digestibility decreases in diets with high concentrate content due to its lower retention time in the digestive tract of animals (Moore *et al*., 1999; Krämer *et al*., 2013).

There were no significant differences between treatments regarding the apparent digestibility of OM, NDF, and ADF (P>0.05). Naik *et al*. (2016) report a 60% digestibility for HMGF crude fiber; however, this component does not consider the insoluble lignin portion (Van Soest *et al*., 1991). The digestibility values for the NDF of HMGF are higher than those reported for other conventional fodders (Naranjo & Cuartas, 2011; Coblentz *et al*., 2019). The higher apparent digestibility for the NDF of HMGF may be due to the ease of hydrolysis of this fiber, which stimulates its rapid disappearance in the rumen (Allen & Oba, 1996), and to the structure and composition of the cellular wall (Ramírez *et al*., 2002; Valenciaga, 2004). Furthermore, it is important to consider that the HMGF is composed mainly of tender leaves (12 to 14 days of age), making it more digestible.

Table 3. Apparent digestibility of the diet of lambs fed with different inclusion levels of hydroponic maize green fodder (HMGF).

Component	Inclusion level of HMGF (% of DM)				P value	SEM
	0	20	40	60		
Dry matter	89.74b	90.17ab	91.38a	90.98ab	0.022	0.23
Organic matter	87.15	90.32	88.40	89.62	0.820	5.90
Crude protein	75.58b	79.13ab	81.04a	80.04a	0.010	0.69
Neutral detergent fiber	79.6	78.61	82.63	90.40	0.589	3.20
Acid detergent fiber	71.00	72.22	69.20	76.09	0.237	1.62

Different letters in the same row indicate statistical difference (P<0.05; P<0.01). SEM = standard error of the mean

Table 4 shows the results obtained for lamb growth. Animals fed diets with 60% HMGF had a lower total DM intake (22%) than animals fed with 0% of HMGF (P≤0.01). Herrera *et al*. (2007) report DM intake of 564 g (per animal per day) in sheep that received HMGF (19% dry basis) in their cutting grass diet. This intake is below that observed in this study (1000 g per animal per day, on average) with the diets that included HMGF. The higher intake observed in the concentrate-based ration (0% of HMGF) can be explained by the fact that diets with high grain content have a shorter retention time in the digestive tract of animals (Hart & Glimp, 1991; Moore *et al*., 1999), which increases the intake level. There were no significant differences in the total DM intake between treatments with different inclusion levels of HMGF (P>0.05). The DM intake values fall within the ranges established for growing hair sheep (Solís *et al*., 1991; Huerta, 2001).

Lambs treated with 0 and 20% of HMGF showed more significant daily weight gain and total weight than those that received 60% of HMGF (P≤0.01). There were no significant differences between the animals that consumed 20 and 40% of HMGF (P>0.05). Due to their weight gain, lambs fed with 0, 20, and 40% of HMGF consequently had a greater weight at the end of the experiment (P≤0.01). Other authors (Morales, 1987) reported daily weight gains of 240 g in lambs fed with concentrate *ad libitum* and 300 g of dry matter of HMGF. These results are similar to those obtained in the present study with the animals fed with 0 and 20% of HMGF. This author concludes that the inclusion of HMGF allowed to improve the assimilation of the concentrate and decrease the fattening time of animals. Herrera *et al*. (2007), observed higher DWG in sheep supplemented with wheat middling compared to those fed with HMGF (41 *vs* 12 g/animal/day), in which the HMGF represented 19% (dry basis) of the cutting grass diet. The low DWG reported by these authors could be explained by the fact that they did not use a concentrated feed in the rations.

Although lambs fed with 60% of HMGF registered the lowest DWG, the values obtained are much higher than those observed in other studies with animals fed on fodder and supplemented with protein, which report DWG of 50 to 80 g/animal (Gonzalez *et al*., 2011; Holguin *et al*., 2018). The above can be attributed to the higher nutritional content and digestibility of the HMGF, which was reflected in the productive behavior of the animals.

CONCLUSIONS

Hydroponic maize green fodder (HMGF) has a high amount of crude protein and digestibility. By including up to 40% in the diet, substituting the commercial feed, it is possible to obtain adequate weight gains. Therefore, HMGF can be considered as an excellent source of fodder and a viable alternative for feeding lambs.

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Table 4. Dry matter intake and weight gain of lambs fed with different inclusion levels of hydroponic maize green fodder (HMGF).

Variable	Inclusion level of HMGF (% of DM)				P value	SEM
	0	20	40	60		
Feed intake (kg of DM/animal/day)	1.120a	0.968ab	0.865b	0.568c	0.0001	0.05
HMGF intake (kg of DM/animal/day)	0.00	0.122a	0.225b	0.312b	0.0001	0.03
DM total intake (kg/animal/day)	1.125a	1.095ab	1.060ab	0.875b	0.0253	0.03
Final weight (kg)	39.00a	38.60a	35.80a	28.13b	0.0006	3.04
Daily weight gain (g/animal)	255a	246ab	205bc	170c	0.0085	3.74
Total weight gain (kg)	17.56a	15.76a	14.54ab	9.13b	0.0098	2.09

Different letters in the same row indicate statistical difference (P≤0.05; P≤0.01). SEM = standard error of the mean.

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Genuine Mexican cheeses: technological processes and manufacturing parameters

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ABSTRACT

Objective: Provide an overview of the current situation of genuine Mexican cheeses (GMCs), their characteristics, and the conditions of their manufacturing processes (origin of the milk, curdling agent, type of aging, and ripening).

Methodology: We compiled, analyzed, and classified the information available for 20 GMCs in scientific articles, databases, and web pages.

Results: GMCs are mainly classified based on their moisture content in soft or fresh, semi-soft or semi-hard, and hard cheeses. Most of the GMCs are not subjected to ripening processes, which limits their shelf life and large-scale commercialization. Ripened GMCs use their own microbiota, developing characteristic textures and flavors.

Limitations: Few studies have evaluated the manufacturing processes of GMCs and their impact on the physical and sensory properties of the final product. Furthermore, no GMC has a designation of origin, which puts them at a disadvantage in the face of a globalized market.

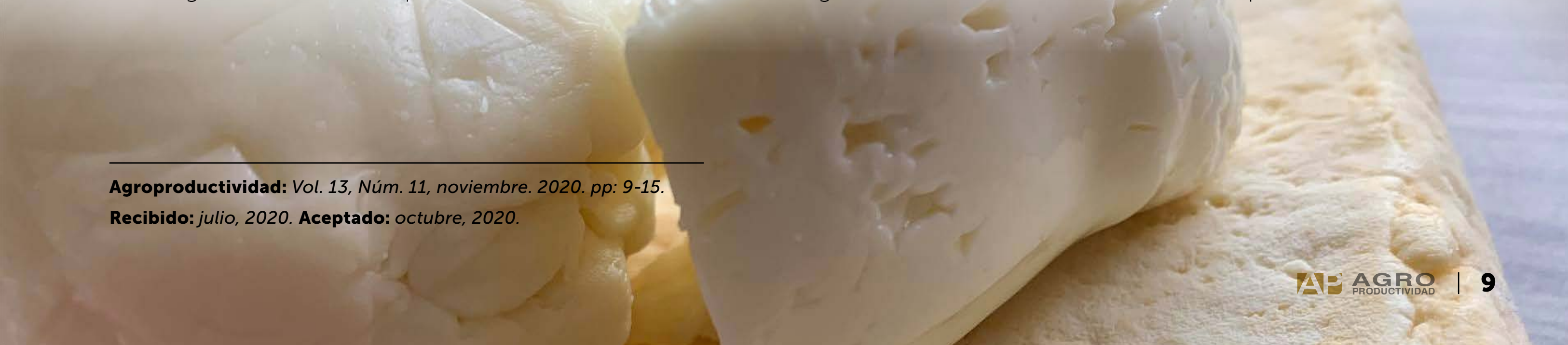
Conclusions: Most GMCs are handmade, and only a few of them are produced on a semi-industrial scale. A standardized production would allow producers to improve and innovate GMCs and increase their shelf life.

Keywords: Mexican dairy products, texture, cheese ripening, curdling agent.

INTRODUCTION

Cheese is a product derived from the coagulation of milk proteins and represents a high-value source of proteins, vitamins, and minerals. Furthermore, the presence of lactic acid bacteria provides a probiotic effect. The coagulated proteins determine the physical, chemical, and organoleptic characteristics of the cheese (González-Córdova *et al*., 2016). After its elaboration, the cheese can be subjected to fermentation, ripening, or both processes, promoting the formation of bioactive peptides with beneficial health properties (Hernández-Galán *et al*., 2016).

Cheese production in Mexico is one of the most important activities in the food industry. In 2019, cheese production amounted to 355 thousand 381 tons, with a market value of more than 18,000 million Mexican pesos (SIAP, 2019). Although most cheese production is concentrated in large national and transnational companies, traditional



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cheesemaking has a remarkable market (Mazorra-Manzano, 2019). However, traditional Mexican cheesemaking is still not very competitive due to the lack of technology and standardization of manufacturing processes and, in some cases, the loss of knowledge of production procedures. Therefore, this review aimed to provide a current overview of the production, classification, and particular characteristics of GMCs, in order to spread knowledge and contribute to its preservation.

Genuine Mexican cheeses and their current situation

GMCs are considered traditional products of origin and agri-food products with significant economic, commercial, and social potential. These cheeses are part of the tradition, culture, and representative heritage of the Mexican town or region where they are made (FAO, 2010). The importance of GMCs lies in the number of existing varieties in the country, the local economic value of their production, and their economic impact in the international market of dairy products (González-Córdova *et al.*, 2016).

The elaboration of GMCs can be homemade, artisanal, or industrial. Small-scale production often has little technology and poorly standardized processes. In general, the production of GMCs uses raw milk, producing distrust in the consumer. However, there are high-quality raw milks in Mexico that, because of their microbiota, can provide cheeses with unique sensory characteristics (Villegas-de Gante *et al.*, 2016). GMCs are differentiated by the origin of milk, type of rennet, ripening, appearance, and other characteristics (Jiménez *et al.*, 2018). The limited production of certain GMCs is due to the lack of knowledge of this type of product by consumers, the strong competition with industrialized cheeses, and the short shelf life that prevents commercialization (Villegas-de Gante *et al.*, 2016). Furthermore, the migration of producers to large cities and the lack of resources have caused the loss of knowledge on the manufacturing of GMCs. Therefore, it is essential to preserve and communicate the knowledge of the manufacturing processes of GMCs, to train producers in the development of standardized processes, the use of technologies to increase the shelf life of their products, and encourage them to obtain quality and safety certifications for the GMCs to maintain the standards that the consumer needs and demands (Vargas, 2016; Cervantes-Escoto *et al.*, 2017; Villegas-de Gante *et al.*, 2016).

Classification of genuine Mexican cheeses

GMCs can be classified by their texture, based on their moisture content. Soft cheeses make up the majority of Latin American cheeses and possess a percentage of moisture in nonfat substance (MNFS) higher than 67%, semi-soft cheeses have a MNFS ranging from 61-69%, semi-hard from 54-63%, hard from 49-56%, and extra-hard less than 51% (NMX-F-713-COFOCALEC-2014). Based on this classification, Figure 1 shows the general manufacturing process of GMCs and the characteristics of each one of them. Table 1 shows the main conditions of the production process of GMCs (origin of milk, curdling agent, type of aging, and ripening) and some final characteristics of these products.

Description of some genuine Mexican cheeses

Soft or fresh cheeses

Queso de Bola de Ocosingo (Chiapas): It consists of a ripened double-cream cheese, lined with a bright yellow rind of cheese made with skim milk to the point of quesillo. It is hard with a spherical form and a diameter between 8 and 12 cm, from 400 g to 1 kg (López *et al.*, 2015; Villegas-de Gante *et al.*, 2014; Sepulveda & Esparza-Chavez, 2016). The core of the cheese has an off-white color and a soft, creamy, spreadable, and crumbly texture with acid aromas and flavors (González-Córdova *et al.*, 2016; Cobo-Monterroza *et al.*, 2019). In 2005, the Instituto Mexicano de la Propiedad Industrial (IMPI) granted the Collective Trademark Registration, thus guaranteeing the consumer the originality of the product (Villegas-de Gante *et al.*, 2014; López *et al.*, 2015). The Bola de Ocosingo cheese was the first Mexican cheese to obtain a Collective Trademark classification and aims for a Protected Designation of Origin (PDO) (López *et al.*, 2015).

Queso Jarocho (Veracruz): This cheese is an artisan creation with a cheesemaking tradition of almost 50 years, native to the tropics, manufactured in the municipalities of Tierra Blanca, Tlalixcoyan, and Ignacio de la Llave in the State of Veracruz (Villegas-de Gante *et al.*, 2014). It is a fresh cheese with a soft texture, white color, and slightly acid aroma and flavor. This cheese has a cylindrical shape (26 cm in diameter and 13 cm in height) and its weight varies between 6 and 8 kg (Cervantes-Escoto *et al.*, 2006). Its production process is considered innovative since it uses ice to better preserve the curd and increase its

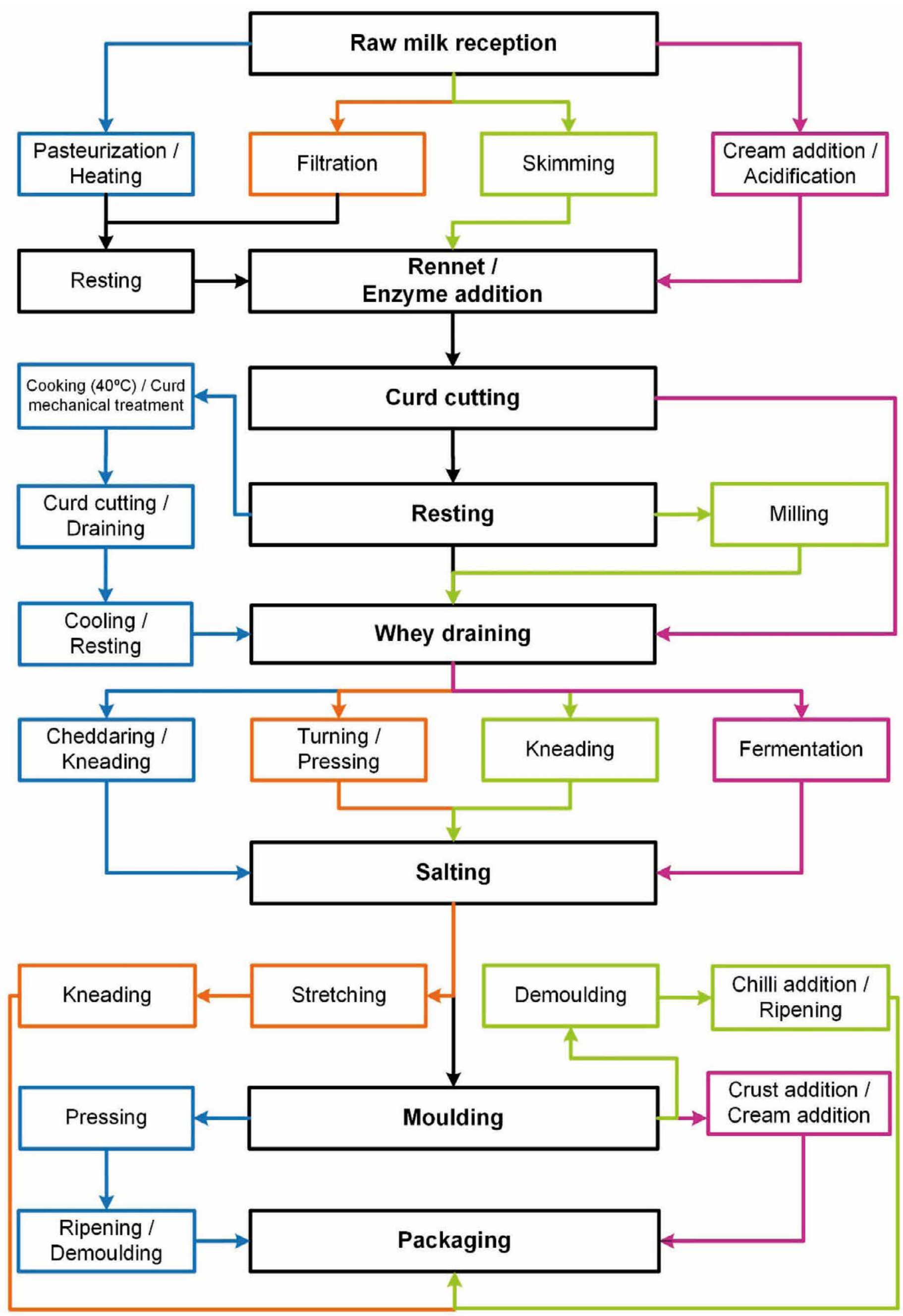

Figure 1. Diagram of the manufacturing process of genuine Mexican cheeses. Overall manufacturing process of cheeses (black) and specific processes for soft (purple), semi-soft (blue), semi-hard (orange), and hard (green) cheeses.

yield (Villegas-de Gante *et al*., 2014). The Comisión Federal para la Protección contra Riesgos Sanitarios (COFEPRIS) is responsible for communicating information and training for improvements in the production of this type of cheese (Villegas-de Gante *et al*., 2016).

Queso Tenate de Tlaxco (Tlaxcala): This cheese is characterized by its peculiar mild milk flavor (Cruz, 2015). It is very similar to the Tenate de Hidalgo cheese, with the difference of having the potential to achieve legal-economic protection (Villegas-de Gante *et al*., 2014). Because of its low commercial demand and the small economic profit margins (Grass-Ramírez *et al*., 2013), in addition to the oral transmission of the production process across generations, Tenate cheese is in danger of extinction (Cruz, 2015).

Semi-soft/ semi-hard cheeses

Queso crema (Chiapas): This is a traditional product from Chiapas, it is manufactured in the Norte, Frailesca, and Costa regions (Rangel-Ortega *et al*., 2012; Villegas-de Gante & Cervantes-Escoto, 2011). It is a unique product, specific and impossible to imitate due to the quality of the milk, its manufacturing process, physicochemical characteristics, salt content, and sensory properties (acidity and strong fruity aromas) that result from fermentation. Shaped as a small flat cylindrical and rectangular prism from 250 g to 1 kg (Agudelo-López, 2015; Cervantes-Escoto *et al*., 2006; Moreno & Villegas-de Gante, 2016). This cheese is protected by the Collective Trademark "Chiapas Centenario" Queso Crema de Chiapas, which grants it national establishment (Pérez, 2014).

Queso de Poro (Tabasco): This is a fresh ripened cheese of semi-hard and pressed paste (Alejo-Martínez *et al*., 2015; Díaz-Ramírez *et al*., 2016) and artisan manufacture in the Ríos region of Tabasco, specifically in the municipalities of Balancán and Tenosique. An important characteristic of this cheese is its 7-day ripening. Due to the microbiota present in the whey used for its manufacture, small holes or pores develop, attributed to the production and accumulation of gas. This cheese has a rectangular shape and its weight ranges from 250 g to 1 kg. It has a characteristic intense aroma, an acid-salty flavor, and a humid texture (Cervantes-

Table 1: Conditions of the manufacturing process of genuine Mexican cheeses and their main characteristics.

CHEESE NAME, ORIGIN	MILK ORIGIN	COAGULATION AGENT	RIPENING TIME	FERMENTATION / RIPENING	PASTE PROPERTIES	FAT CONTENT (FDE %)	MOISTURE CONTENT (MNFS %)	REFERENCE
Adobera de la Sierra de Amula, Jalisco	Brown-Swiss, Simmental, Zebu, and their crosses	Rennet	Fresh	Indigenous raw milk microbiota	Sliceable or crumbly (friable)	Full fat (48.27 %)	Semi-hard (63.63 %)	Villegas-de Gante *et al.*, 2014.
Ahumado de la Joya, Veracruz	Holstein, Jersey, Swiss, Zebu, and Holstein-Swiss crosses	Liquid rennet	Fresh	Indigenous raw milk microbiota	Semi-hard, pressed, and sliceable	NR	Semi-hard (54-63 %)	Villegas-de Gante *et al.*, 2016.
Aro de Etla, Oaxaca	Guernsey, Holstein, Jersey, Swiss and their crosses	Rennet	Fresh	Unfermented	Soft, sliceable, and unpressed	NR	Soft (>67 %)	Cervantes-Escoto *et al.*, 2019; Villegas-de Gante *et al.*, 2014; 2016.
Asadero, Aguascalientes	Holstein and Swiss–Dutch and HolsteinJersey crosses	Renin or microbial rennet and acetic or lactic acid	Fresh	Unfermented	Filata and meltable	Medium fat (29.31 %)	Semi-hard (60.32 %)	Villegas-de Gante *et al.*, 2014.
Bola de Ocosingo, Chiapas	Brown Swiss and Zebu, and Brown Swiss crosses	Mixed: calf rennet and natural acidification	21-30 days	Indigenous raw milk microbiota	Center (spreadable and crumbly), surface (filata)	High fat (71.52 %)	Soft (76.4 %)	López *et al.*, 2015; Vázquez-Velázquez *et al.*, 2018.
Chapingo, Estado de México	Holstein and Jersey-New Zealand	Rennet or microbial enzymes with ripened milk	4-6 weeks	Mesophilic starter culture (*Lactococcus lactis* ssp *lactis* y *Lactococcus lactis* ssp. *cremoris*)	Firm or sliceable	High fat (65.6 %)	Semi-hard (67.77 %)	Villegas-de Gante *et al.*, 2014.
Chihuahua menonita de Cuauhtémoc, Chihuahua	Holstein	Enzymatic	1-6 days	Indigenous raw milk microbiota	Semi-hard and sliceable	Medium fat (26.0 %)	Semi-soft (45 % WB)	Villegas-de Gante *et al.*, 2014
Chipilo, Puebla	Holstein	Enzymatic	1-4 weeks	Indigenous raw milk microbiota	Soft, sliceable, and unpressed	NR	Soft (>67 %)	Villegas-de Gante *et al.*, 2014; 2016.
Crema, Chiapas	Zebu-Brown Swiss and their crosses	Mixed: rennet and natural acidification	Fresh	Indigenous raw milk microbiota	Spreadable and crumbly	Full fat (48.25 %)	Semi-hard (61.70 %)	Villegas-de Gante *et al.*, 2014.
Guaje de Tanquián, San Luis Potosi	Swiss and Zebu-Swiss and Zebu-Dutch crosses	Commercial calf rennet and 3-day whey	Fresh	Unfermented	Filata, unpressed, shaped like a pod (guaje), and with cream filling	Medium fat (38.78 %)	Soft (53.10 % WB)	Villegas-de Gante *et al.*, 2014
Hoja de la Costa Chica, Oaxaca	Zebu	Natural rennet / commercial liquid rennet	Fresh	Unfermented	Soft or semi-hard and sliceable	NR	NR	Villegas-de Gante *et al.*, 2014; 2016.

Table 1: Continues....

CHEESE NAME, ORIGIN	MILK ORIGIN	COAGULATION AGENT	RIPENING TIME	FERMENTATION / RIPENING	PASTE PROPERTIES	FAT CONTENT (FDE %)	MOISTURE CONTENT (MNFS %)	REFERENCE
Jarocho, Veracruz	Zebu and European crosses	Microbial rennet and/or calf rennet	Fresh	Unfermented	High moisture, sliceable, and lightly pressed	Medium fat (29.5 %)	Soft (51.52 % WB)	Villegas-de Gante *et al*., 2014
Poro, Tabasco	Zebu and European crosses	Rennet	7 days	Indigenous raw milk microbiota	Semihard, low moisture, and small pores	Medium fat (27.13 %)	Semi-hard (69 %)	Díaz-Ramírez *et al*., 2016; Alejo-Martínez *et al*., 2015
Quesillo de Reyes Etla, Oaxaca	Holstein	Commercial or natural rennet	Fermented (8-15 h)	Indigenous raw milk microbiota	Filata	Medium fat (29.8 %)	Semi-soft (48 % WB)	Villegas-de Gante *et al*., 2014; 2016.
Cotija región de Origen	Holstein, Zebu-Swiss, and Zebu-Holstein	Rennet	Ripened (3-12 months)	Indigenous raw milk microbiota	Extra-hard, pronounced taste, hard aroma, and crumbly	Low fat (24.8 % WB)	Extra-hard (37.1 % WB)	Villegas-de Gante *et al*., 2014.
Enreatado de Nuevo Morelos, Veracruz	Zebu and Brown Swiss crosses	Rennet	Soft ripened (2-7 days)	Indigenous raw milk microbiota	Semi-hard, sliceable, and gratable	NR	Semi-hard	Villegas-de Gante *et al*., 2014, 2016.
Añejo de Zacazonapan, Estado de México	Zebu Swiss, Zebu American, Gyr, Simmental, and Criollo crosses	Cuerito rennet	Drying (24 weeks) Aging (> 1-12 months)	Indigenous raw milk microbiota	Crumbly (friable)	Full fat (44.55 %)	Hard (49.95 %)	Hernandez *et al*. 2009; Villegas de Gante *et al*., 2011.
Tenate de Tlaxco, Tlaxcala	Holstein (low genetic quality)	Liquid rennet	Fresh or ripened (2 weeks)	Indigenous raw milk microbiota	NR	NR	Soft (>67 %)	Villegas-de Gante *et al*., 2014.
Tenate, Hidalgo	Holstein (low genetic quality)	Enzymatic	Fresh or ripened (2 weeks)	Unripened	NR	NR	Soft (>67 %)	Villegas-de Gante *et al*., 2014.
Tetilla, Nayarit	Zebu and crosses between Brown Swiss and Zebu	Natural rennet	Fresh	Indigenous raw milk microbiota	Soft	NR	Soft (>67 %)	Villegas-de Gante *et al*., 2014.
Seco (añejo) de Chiautla de Tapia, Puebla	Holstein, Zebu-Brown Swiss or Simmental crosses	Cuerito rennet	Ripened (1 week to months)	Indigenous raw milk microbiota	Semi-hard and sliceable	NR	Soft (>67 %)	Villegas-de Gante *et al*., 2014; 2016.

*Cuerito: dry and salty calf abomasum that is soaked in whey or milk to obtain an aqueous extract for curdling; *WB %: Wet basis percentage; *FDE %: Fat in dry extract; * MNFS %: Moisture in nonfat substance. NR: Not reported.

Escoto *et al*., 2006; Díaz-Ramírez *et al*., 2016). Queso de Poro has the Collective Trademark "Queso de Poro de Balancán, Región de Origen", granted by the IMPI (Cervantes-Escoto *et al*., 2017; Díaz-Ramírez *et al*., 2016).

Queso Chihuahua (Chihuahua): This product is of Mennonite origin and has been produced since 1992 in various regions of Chihuahua, being Cuauhtémoc municipality the one with the greatest market presence (Sánchez-Carlos & Bautista-Flores, 2017; Villegas-de Gante *et al*., 2014). Queso Chihuahua, also known as Mennonite or Chester cheese, has a flat cylindrical shape and is characterized by aromas of milk and melted butter (López-Díaz & Martínez-Ruíz, 2018; Villegas-de Gante *et al*., 2016).

Queso Adobera de la Sierra de Amula (Jalisco): This cheese has been manufactured for more than 100 years in the regions of Los Altos (Arandas, Tepatitlán, Lagos de Moreno, and other municipalities) and Sierra de Amula (Atengo, Tenamaxtlán, Tecolotlán, and other municipalitites) in Jalisco (Flores & Villegas-de Gante, 1990). In Sierra de Amula, the queso adobera of Soyatlán is manufactured in two modalities: "adobera de mesa" and "quesadilla". It can be fresh, aired (semi-ripened), or ripened (Flores & Villegas-de Gante, 1990). It is named for its characteristic rustic clay brick (adobe) shape. Its aroma, acidic-salty flavor, and ivory yellow color provide remarkable characteristics to this artisan product (Flores & Villegas-de Gante, 1990).

Queso Chapingo (Estado de México): This product is characterized by its cylindrical shape and weights from 4 to 5 kg (Villegas-de Gante *et al*., 2014). This cheese has a golden-yellow color, is creamy and has a characteristic hazelnut aroma. It is produced by the Universidad Autónoma de Chapingo (Cervantes-Escoto *et al*., 2006).

Hard cheeses

Queso Cotija (Jalisco-Michoacán): It has been made for more than four centuries in Sierra de Jalmich (Villegas de Gante *et al*., 2014). It is recognized as cultural heritage of the region and is protected under the Collective Trademark "Queso Cotija Región de Origen". Being a ripened product, no heat treatments are used in its production, and the physicochemical changes that intervene during its aging give it unique characteristics, which are favored by the environmental conditions of the manufacturing region (Hernández *et al*., 2009; Escobar-Zepeda *et al*., 2016; González-Córdova *et al*., 2016). Several studies have reported that during ripening, this cheese produces peptides with antioxidant and antihypertensive activities, showing its highest activity at the end of this process (Hernández-Galán *et al*., 2016).

Queso Añejo de Zacazonapan (Estado de México): The artisan production of this cheese has been performed for more than 100 years in the Zacazonapan municipality, southwest of Mexico State (Villegas-de Gante *et al*., 2014). This cheese is mainly manufactured during the rainy season because the environmental humidity allows the cheese to air better, and thus avoid the formation of superficial cracks due to a high loss of humidity (Hernández-Morales *et al*., 2011). Queso Añejo can be fresh or aged; the fresh product is consumed after its manufacture and is slightly less salty, while the aged cheese is consumed after 20 days up to one year of maturation, which provides typical features such as strong smell and flavor, attractive red color, and its characteristic consistency (Hernández-Morales *et al*., 2011).

CONCLUSIONS

Most GMCs are handmade. Only a few of them are produced on a semi-industrial scale, such as the Oaxaca, Chapingo, and some fresh cheeses. The standardization of the manufacturing processes would allow improvements and innovations; it would also increase the shelf life of GMCs. Moreover, obtaining a Protected Designation of Origin by the IMPI would contribute to the differentiation of GMCs from imitations, highlighting their identity, quality, and originality. This added value would also benefit local cheese producers, making their products known at a national and international level.

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Evaluation of soil amendments in perennial ryegrass pastures associated with white and red clover in small-scale milk production systems

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ABSTRACT

Objective: Evaluate the effect of agricultural lime and dolomite in a perennial ryegrass cv. Tetragrain pasture associated with white clover cv. Ladino and red clover cv. Kenland.

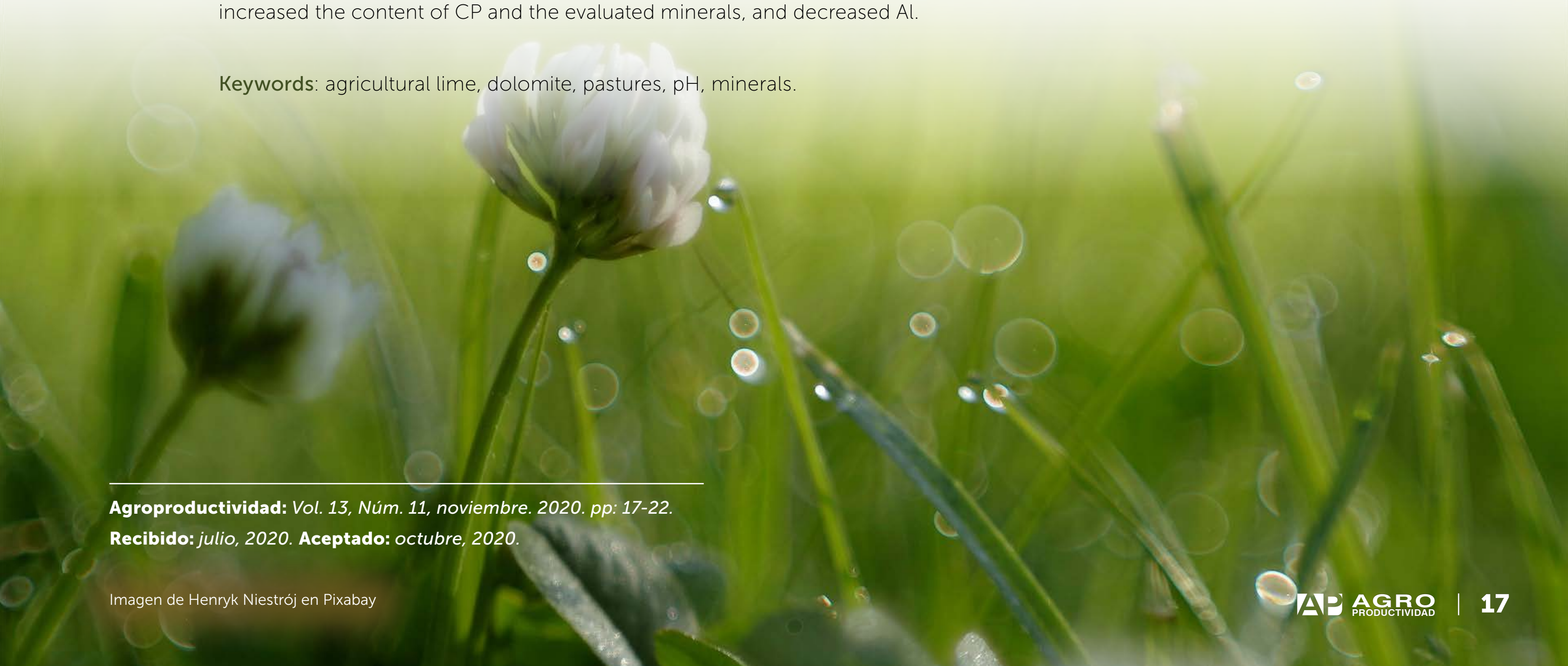
Methodology: Three soil amendment treatments were established in a perennial ryegrass pasture with white and red clover using a split-plot experiment design. The treatments were: T1=control (without soil amendment), T2=agricultural lime, and T3=dolomite. The evaluated variables were pasture height, herbaceous mass (HM), dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), *in vitro* digestibility of dry matter (IVDDM), and metabolizable energy (ME).

Results: Significant differences ($P \leq 0.05$) were observed for experimental periods in pasture height, DM, CP, ADF, OM, IVDDM, and ME. For treatments, there were significant differences ($P \leq 0.05$) in pasture height, DM, CP, and OM. The interaction between experimental periods (P) and treatments (T) was not significant for any variable ($P > 0.05$). Regarding the soil chemical composition results, we observed a decrease in pH at the end of the experiment; however, there was an increase in Ca, Mg, and total N, and a decrease in Al.

Limitations/implications: Given the low impact of the treatments in most of the evaluated variables, it is necessary to expand the study to different doses, type of soil amendments, and handling conditions to control the impact of the producers' practices in pastures.

Conclusions: The use of soil amendments did not increase pH, DM production, NDF and ADF content, IVDDM, or ME, but increased the content of CP and the evaluated minerals, and decreased Al.

Keywords: agricultural lime, dolomite, pastures, pH, minerals.



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INTRODUCTION

Grass-legume mixed pastures usually have improved forage yields due to the different use of resources, complementation of niches, and mutualistic interaction (Ergon *et al*., 2016).

Among the factors that affect soil, pH influences soil microorganisms, plant composition, and its nutrients (Fernández-Calviño & Bååth, 2010). If the pH is lower than 5 it is important to implement practices to increase its value (Ryant *et al*., 2016). Soil acidification frequently occurs in warm and humid climates, with high precipitation levels (Dambrine, 2018).

Besides pH, soil mineral content largely determines plant species and their characteristics. Ca is important for plant structure, as it strengthens the cellular membrane and wall, forming up to 90% of its composition. Mg is essential during photosynthesis, cell division, and protein synthesis (Maathuis & Podar, 2011). Nitrogen is related to increased forage production, as it participates in tissue formation (Flores-Aguirre *et al*., 2018). P is necessary during photosynthesis and root development (Sierra-Alarcón *et al*., 2019). Moreover, K is important for phloem loading, assimilation transport, nitrogen metabolism, and storage processes (Kayser & Isselstein, 2005).

Management of acid soils includes the addition of pH soil amendments (FAO, 2019), such as agricultural lime, which contains calcium carbonate, and dolomite, which besides containing calcium carbonate, provides Mg (Arévalo & Castellano, 2009), both used to increase soil pH, Ca, and Mg (Bambara & Ndakidemi, 2010). When applied in the superficial layers (up to 10 cm), these soil amendments can decrease soil acidity (Corrêa *et al*., 2009).

In subtropical climate pastures, and grasslands in general, soil amendments are rarely used to increase pH and mineral content; furthermore, few studies have evaluated how these soil components affect the physicochemical and agricultural characteristics of pastures. Therefore, this study aimed to evaluate the effect of agricultural lime and dolomite in a perennial ryegrass (*Lolium perenne*) cv. Tetragrain pasture associated with white clover (*Trifolium repens*) cv. Ladino and red clover (*Trifolium pratense*) cv. Kenland.

MATERIALS AND METHODS

Area of study

The study was performed in the Aculco municipality, located at the northwest of Estado de México, at an altitude of 2440 masl, 20° 06′ and 20° 17′ N and 99° 40′ and 100° 00′ W, with a humid subtropical climate (Celis-Álvarez *et al*., 2016), a mean temperature of 16.5 °C during the experiment, and 729.8 mm of precipitation during the experiment. The experiment lasted 336 days, from March 27, 2019, to February 4, 2020.

Pasture establishment

A 1.35 ha pasture was established in August 2018 with 30 kg/ha of perennial ryegrass cv. Tetragrain seeds, 3 kg/ha of white clover cv. Ladino seeds, and 6 kg/ha of red clover cv. Kenland seeds. The pasture was fertilized with 60N-80P_2O_5-60K kg ha^{-1}. Subsequently, it was fertilized every four weeks with 50 kg ha^{-1} of urea. The pasture was under a cut and carry system. Irrigated once a month, from March to June. The pasture was divided into three experimental plots of 0.45 ha. Soil samples were collected at the beginning and at the end of the experiment to determine pH, cation exchange capacity (CEC), Ca, Mg, N, P, K, and Al.

Treatments

Three treatments were established, one in each experimental plot. The first was a control treatment (T1), in which no soil amendments were added; the second and third treatments consisted of applying 400 kg of agricultural lime (T2) and dolomite (T3), respectively.

Agronomic variables

The experiment lasted 336 days, divided into 12 experimental periods of 28 days each. Sampling was performed on day 28, where we also measured the compressed height of the pasture using a rising plate meter, taking 15 measurements per treatment following a "W" pattern (Celis-Álvarez *et al*., 2016). HM (kg DM ha^{-1}) was determined using three randomly distributed 0.5 m^2 (2 m × 0.25 m) quadrants per treatment. Samples were collected by cutting with scissors the forage within the quadrant at ground level. These samples were subsequently processed to determine the chemical composition of the forage in each treatment.

Forage chemical composition

Forage samples were analyzed following standard procedures (Celis-Álvarez *et al*., 2016). The IVDDM was determined using the Ankom-Daisy method. The ME was calculated with the CSIRO (2007) formula:

$$ME = 0.172\ IVDDM\ (\%) - 1.707.$$

Statistical analysis

We used a split-plot experimental design, in which treatments with soil amendments (T1, T2, or T3) are considered fixed effects, and the 12 experimental periods are the random effects. The Minitab V14 statistical software was used to compare results using the Tukey test at a significance level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Soil chemical composition

Table 1 shows the initial and final experimental soil values. The average values of pH, Ca, P, K, and Al decreased in T2 and T3, compared to T1 (control group). N remained the same in T1 and T2; however, the values in T3 were lower.

Pasture variables

The production of HM (Table 2) did not increase linearly with the experimental periods; thus, the treatments with soil amendments did not affect the production of HM. There were significant differences ($P \leq 0.05$) for pasture height between T and P.

Forage chemical composition

There were significant differences ($P \leq 0.05$) between T for DM, CP, and OM (Table 2). Significant differences ($P \leq 0.05$) were found between P for DM, CP, ADF, OM, IVDDM, and ME. The interaction between T and P was not significant for any variable.

Soil chemical composition, height, and plant mass

One of the factors that affect soil is pH, as the changes it induces occur close to the roots, creating a favorable environment for pasture growth (Higgins *et al*., 2012; Minasny *et al*., 2016).

Norton *et al*. (2018) mention that the highest increase in pH occurs in the superficial layer of the soil, from 0 to 2.5 cm in depth. However, in this study, we observed a decrease in pH, which could be explained by the increase of N in the soil, as this element is an important contributor to soil acidification, mainly in T1 and T2, where N concentration increased practically 5.2 times compared to the beginning of the experiment (Table 1).

The most important minerals for soil structure are Ca and Mg; the balance between these two ions is between 5 and 7 (Higgins *et al*., 2012).

With the reduction of pH, Al increases its solubility and, as a result, the ion exchange decreases, causing nutrient deficiencies, mainly of Ca, Mg, and P (Horst *et al*. 2010). At the beginning of the experiment, we observed high levels of Al; at the end, Al levels decreased. These results indicate that both lime and dolomite decrease Al levels in soil, which somehow benefits plant development.

As forage age increases, the concentration of elements with greater solubility decreases, dominating those with less digestibility. DM also depends on cutting age and water availability, since ryegrass requires 48 to 100 mm of water per month (Sierra-Alarcón *et al*., 2019).

The average HM for T1 was 766 kg DM ha^{-1}, with 305.1 g kg^{-1} of DM; this differs from that reported by Muñoz *et al*. (2016), who evaluated perennial ryegrass with heights ranging from 5 to 11 cm, similar to the ones in this study. Moreover, Tiecher *et al*. (2013), 11 months after applying a high dose of lime (3.2 t ha^{-1}), reported a one-point increase in soil pH, which had an initial value of 4.5. They also reported an increase in Ca and Mg, and a decrease in Al.

Table 1. Chemical characteristics of the pasture soil at the beginning and end of the experiment.

Variable	At the beginning of experiment	At the end of experiment			Mean
		Treatments			
		T1	T2	T3	
pH	5.3	5.2	5.1	4.7	5.1
soluble Ca (mg kg^{-1})	28.3	950.3	900.8	823.1	675.6
Mg (mg kg^{-1})	41.3	75.2	173.3	133.2	105.8
Total N (mg kg^{-1})	500.0	2600.0	2600.0	1100.0	1700.0
P (mg kg^{-1})	21.9	191.0	185.5	174.5	143.2
K (ppm)	23.4	43.5	30.1	20.1	29.3
Al (cmol kg^{-1})	38.6	7.0	10.4	1.6	14.4
CIC (cmol kg^{-1})	40.6	25.50	30.9	33.40	40.6

T1, control; T2, agricultural lime; T3, dolomite; CEC, cation exchange capacity; ppm, parts per million; cmol, centimoles.

Table 2. Pasture height (cm), herbaceous mass (HM), chemical composition (g/kg DM), *in vitro* digestibility of dry matter (g kg^{-1} DM), and metabolizable energy (MJ kg^{-1} DM) per treatment and experimental period (28 days).

Treatment	Variable								
	Sward height	HM	DM	CP	NDF	ADF	OM	IVDMD	eEM
T1	6.6^b	1766.0	305.1^a	129.5^b	499.8	281.8	887.0^c	763.8	11.4
T2	6.4^c	1831.0	300.3^b	136.5^a	501.6	284.1	889.0^b	758.1	11.3
T3	6.7^a	1873.0	297.7^c	140.6^a	498.4	285.0	891.0^a	774.5	11.6
SEM_T	0.2	53.7	3.7	5.1	23.6	3.5	2.2	8.3	0.1
Experimental periods									
1	6.0^g	1540.0	233.1^k	131.1^e	446.5	226.0^e	872.0^j	765.7^c	11.5^c
2	8.8^b	1853.0	317.8^d	130.1^e	464.6	225.2^e	882.0^i	729.5^c	10.8^c
3	6.5^f	1959.0	285.4^f	126.3^e	439.2	220.0^e	885.0^g	757.5^c	11.3^c
4	8.4^c	2084.0	488.0^a	91.4^f	478.8	234.9^e	900.0^a	726.1^c	10.8^c
5	6.2^f	1425.0	252.2^j	122.5^e	477.5	359.6^c	894.0^c	803.7^b	12.1^b
6	6.0^g	1514.0	348.2^b	129.5^e	585.6	437.2^a	897.0^b	679.1^d	10.0^d
7	5.8^h	1602.0	287.7^e	144.1^d	517.5	394.0^b	894.0^c	745.2^c	11.1^c
8	6.4^e	1932.0	232.3^l	150.1^c	464.5	352.4^c	892.0^d	771.5^c	11.6^c
9	10.6^a	1927.0	279.3^g	144.7^d	529.7	240.3^e	892.0^d	800.8^b	12.1^b
10	8.8^b	2587.0	338.5^c	124.1^e	569.1	273.1^d	887.0^f	740.2^c	11.0^c
11	5.0^i	1478.0	277.9^h	162.5^b	523.0	224.5^e	890.0^e	837.6^a	12.7^a
12	4.2^j	1977.0	272.4^i	170.0^a	502.8	216.5^e	883.0^h	829.1^a	12.6^a
SEM_P	1.8	333.0	69.3	20.8	42.6	82.5	7.7	46.1	0.4
SEM_{int}	0.1	74.3	5.0	2.1	7.8	3.0	1.0	5.6	0.2

T1, control treatment; T2, lime; T3, dolomite; HM, herbaceuos mass; DM, Dry matter; CP crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; OM, organic matter; IVDMD, *in vitro* dry matter digestibility; SEMT, standard error of the mean for treatments; SEMP, standard error of the mean for experimental periods; SEMint, standard error of the mean for interaction T*P. $^{a, b, c, d, e, f, g, h, i, j, k, l}$ $P \leq 0.05$.

The evaluated soils (Table 1) had optimal P and CEC levels; however, Ca, Mg, N, and K levels were below the adequate levels before establishing the treatments. After the experimental periods, pH, CEC, and Al levels decreased; in T3, K levels also decreased. The soil components that increased in all treatments were Ca, Mg, N, and P; K levels only increased in T1 and T2 (NOM-021-SEMARNAT-2000). The values reported after applying the soil amendments could be explained by their uncertain effects, as well as in soils with high P levels that can be shown at the end of the experiment, there may be an absence of response to the increase in pH (Poozesh *et al*., 2010). The considerable increase of N in the soil could be related to the decrease of Al, which decreases root development (Kumar y Kumar, 2015); therefore, low Al allows correct root development, increasing legume N fixation; thus, it can also increase the availability of P through the release of fusidic acid that mobilizes and increases the availability of P (Bambara & Ndakidemi, 2010).

Forage chemical composition

The content of CP depends on the maturity of forage (Alfonso Ávila *et al*., 2012); CP decreases due to the loss of protein in vegetative structures and the increase of protein in seeds (Haj-Ayed *et al*., 2000). For T1, the average CP was 129.5 g kg^{-1} DM (Table 2), below that reported for the rainy season by Plata-Reyes *et al*. (2018) and Sierra-Alarcón *et al*. (2019).

The NDF and ADF content for T1 was 499.8 and 281.8 g kg^{-1} DM, respectively (Table 2). These results were similar for the rest of the treatments and that reported by Garduño-Castro *et al*. (2009). This arises from the fact that the nutritional value of forage association decreases with time, which reflects in forage digestibility, which on average for T1 was 763.8 g kg^{-1} DM (Table 2), higher than that reported by Plata-Reyes *et al*. (2018). For T1, the ME was 11.4 MJ kg^{-1} DM, higher than that reported by Plata-Reyes *et al*. (2018) for perennial ryegrass.

CONCLUSIONS

The use of soil amendments in pastures did not increase pH, DM production, NDF and ADF content, IVDDM, or ME, but it increased the content of CP and the evaluated minerals, and decreased aluminum, which is a limiting factor for forage growth in acid soils.

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Vulnerability of Citrus Growers to Huanglongbing

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ABSTRACT

Objective: Analyze the vulnerability of citrus growers of San Rafael and Cotaxtla, Veracruz, Mexico, to the presence of HLB.

Methodology: Citrus growers were surveyed on their knowledge, proficiency, and perception of strategies implemented by the Campaign against HLB. Vulnerability was integrated into the Risk Index (IR), which included both the knowledge and perception of citrus growers toward the Campaign's strategies, the actions they perform, and those they are willing to perform. The IR between localities was compared and correlated to the grower's variables, the parcel, and the trust between social actors. Also, the organizational involvement of growers was compared.

Results: Growers of San Rafael and Cotaxtla are at a medium vulnerability level, with no significant difference between their IR ($P=0.48$). The grower IR increases as the degree of trust in social actors decreases ($r=-0.30$). Organizational involvement is equally low in both localities ($P=0.15$).

Study Limitations: The study does not apply to other localities.

Conclusions: Citrus growers may respond adequately and significantly to new vulnerability conditions imposed by HLB, which may endanger actions implemented based on their participation in the Campaign against HLB.

Keywords: social trust, knowledge, HLB, risk index, organization.

INTRODUCTION

Huanglongbing (HLB) is a devastating citrus disease caused by the bacteria *Candidatus Liberibacter* spp. and vectored by the insect *Diaphorina citri*. The disease was detected in 2009 in the State of Yucatan, Mexico (Hernández-Fuentes *et al*., 2012). Sampling, diagnosis, inspection, and monitoring are performed to detect HLB's introduction and dispersion to the national territory. The "National Campaign against HLB" (nowadays "Campaign of Regulated Pests of Citrus Plants") organizes control strategies operated by State Plant Health Committees (CESVVER in Veracruz) under the Federal Law of Plant Health (DOF, 2011).

On the other hand, the vulnerability of social groups to HLB has not been analyzed. The vulnerability has an outer side (the threat) and an inner side (the strategies and overcoming capacities of those affected). Studies have been focused

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on factors that determine the inner side of vulnerability (Coy, 2010). Measuring vulnerability allows to promote corrective measures and limit impacts upon supporting strategies to face and ease society's adaptation (Kelly & Adger, 2000). Vulnerability begins with the notion of risk, a concept not centered on an event's interest, but on how and what actions are generated, and how it influences human behavior (Coy, 2010). Vulnerability refers to the capacity of an individual or a group of people to anticipate, face, withstand, and recover before the effects of danger, either natural or caused by human activity (Sánchez-González & Egea-Jiménez, 2011). Decision-making indicators' are used to perform a qualitative vulnerability assessment. The vulnerability concept refers to "a community's incapacity to adapt to change by a phenomenon that constitutes a risk" (Wilches-Chaux, 1989). Risk refers to "when potential damages are the consequence of conscious decisions" (Luhmann, 1992). In this context, the study's objective was to analyze the vulnerability of citrus growers of San Rafael and Cotaxtla, Veracruz, to HLB's presence through a Risk Index (IR). The hypothesis was that IR would be different between localities and negatively correlate with the grower's trust.

MATERIALS AND METHODS

The study was performed in San Rafael (SR) and Cotaxtla (CO) municipalities, Veracruz, Mexico. At a State level, the municipality of SR represents 10.1% of the citrus-growing area and has an average citrus-growing yield of 69,240 t ha^{-1}. The climate is warm and humid with abundant rains in summer (1400 a 1600 mm, and mean annual temperatures ranging from 24 to 26 °C). CO represents 3.5% of the state citrus-growing area with 23,316 t ha^{-1} of average yield (SIAP, 2020), it has a subhumid warm climate with summer rains (1100 to 1300 mm, mean annual temperatures ranging from 24 to 26 °C). A beta survey test answered by 30 citrus growers estimated the proportion (p) of growers not knowing the disease. The sample size per municipality was estimated with the CESVVER citrus-growing registry (728 growers in SR and 314 in CO), through the formula:

$$n = NZ^2pq / \left(d^2[N-1] + Z^2pq\right)$$

where: n=sample size; N=grower registry per municipality; Z=trust level at 90%; p=70% of citrus growers without knowledge of HLB; q=30% of growers that have heard about HLB; d=random error margin: 10%.

The survey characterized the citrus grower by locality, age, education degree, growing experience, years of residence; also his knowledge on pests, actions by the Campaign against HLB fostered by CESVVER, actions that he performs on his parcel against the vector or the disease; and actions he is willing to perform for the control of *D. citri* and HLB. Citrus orchard (parcel) was characterized by area and plants ha^{-1}. Growers were asked about their knowledge of pests and actions by CESVVER. Citrus grower vulnerability to the presence of HLB was obtained through the Risk Index (IR), which integrated: a) the knowledge of pests and diseases in citrus, b) whether the grower knows the actions of CESVVER; c) what practices he performs to control the vector or disease; d) what he is willing to do; e) perception of CESVVER actions; f) perceptions on practices performed on his parcel, and g) perception of practices that he is willing to implement. IR was calculated by the formula:

$$IR = 70 - \left(a + b + c + d + e + f + g\right)$$

where 70 is the maximum classification of the sum of seven items deemed within a scale of 0 to 10.

The greater the individual classification of each item, the lower the risk. Vulnerability level was defined as low (IR<23), medium (from 23 to 47), or high (from 47 to 70); *i.e.*, the more knowledge that growers have on the vector, the more their adherence to CESVVER's indications and the lower their vulnerability. Growers were asked about their trust in several social figures (family, police, government, friends, physicians, "ejido" authorities) to build a social trust index (%). Mean and standard deviation (SD) of variables were calculated. The IR of localities was compared with analysis of variance and correlated to years of growing experience, years of residence in the locality, area, number of plants ha^{-1}, and social trust. The degree of involvement of growers in social organizations, The degree of involvement of growers in social participation is an index based on whether they participated in the association, whether they organized to solve a problem and whether they would participate in an organization. A χ^2 test compared localities in their degree of involvement in organizations.

RESULTS AND DISCUSSION

Citrus growers of San Rafael had an average age of 53 years (SD ± 14), higher than those from Cotaxtla (46 ± 12 years); all respondents in both localities were males. Seventy-four percent of SR citrus growers and 68% of

CO have an elementary education, and even 3% never started school. CONEVAL (2015) reports that the state of Veracruz occupies the 4th position at a national level in educational lag after the states of Chiapas, Michoacán, and Guerrero; being lower in San Rafael (28%), compared to Cotaxtla (40.1%). Pérez (2005) agrees that age and education level (along with gender, family situation, address, employment, and cultural level) allow identifying vulnerable groups. Most (89.7%) CO citrus growers have little experience (<10 years) in the production of citrus, while in SR, 68.2% have a long experience (Table 1).

Table 1. Citrus growers' social characteristics and their parcel attributes in San Rafael and Cotaxtla, Veracruz, Mexico.

Characteristics	San Rafael	Cotaxtla
	Mean ± SD, n = 53	Mean ± SD, n = 48
Education level (years)	6.4 ± 2.7	6.6 ± 3.9
Experience in citrus growing (years)	20.5 ± 14.2	6.8 ± 6.1
Time in locality (years)	47.5 ± 17.5	44.3 ± 18.5
Number of plants per parcel (plants ha^{-1})	347.2 ± 141.6	317 ± 66.7
Grown area (ha)	4.5 ± 3.8	3.4 ± 3.8

Fifty-eight percent of SR growers perceive *D. citri* as a pest of greater risk for citrus. They indicate that red spider [*Panonychus citri* (McGregor)] and other mites, several ant and aphid species [*Aphis spiraecola* Patch, *Toxoptera aurantii* Boyer de Fonscolombe, *Aphis* (*Toxoptera*) *citricidus* (Kirkaldy)], citrus rust mite [*Phyllocoptruta oleivora* (Ashmead)], citrus leafminer (*Phyllocnistis citrella* Stainton), citrus mealybug, [*Planococcus citri* (Risso)], citrus snow scale [*Unaspis citri* (Comstock)] and nematodes are major pests. Among diseases, gummosis (*Phytophthora* spp.) (67%) and HLB (45%) stand out. Also, canker (*Colletotrichum acutatum* J.H. Simmonds), Citrus Tristeza Virus (CTV), and greasy spot (*Mycosphaerella citri* Whiteside) were identified. Even when HLB and *D. citri* are of later introduction, Castillo *et al*. (2004) agreed with the main pests and diseases of citrus in the Central Region of Veracruz (citrus rust mite, citrus mealybug, and ants, as well as gummosis, CTV and anthracnose); although, they also included the Mexican fruit fly (*Anastrepha ludens* (Loew) as a pest of grapefruit. In CO, growers classify *D. citri* en in 4th place (29 %) after the red spider, aphids, and mites; other pests of lesser importance were citrus leafminer and rust mite. Diseases such as gummosis and CTV stood out; HLB appeared in 3rd place (20%), and this suggests that CO citrus growers do not perceive the potential risk of HLB. For Briones (2005), the risk idea is a social construct, as society itself defines what is risky and what is not, according to their history, territory, and institutions, where economic, political, symbolic, and cognitive factors intervene. The CTV case appears in the recent history of the region, which, in the decade of 2000, was deemed to be of high risk for citrus growing, which was not realized to be as damaging as expected. This background may contribute to decreasing the perception of HLB among growers.

Grower Knowledge about CESVVER's Actions

CESVVER establishes sentinel parcels to monitor the arrival of HLB and organizes Control Areas (ARCO), which is the disease control strategy at a broader scale. The campaign name awareness was similarly high in both localities (>80%; Figure 1), while awareness about ARCO and sentinel parcels was similarly low (<13%); these contrasts with the reports of other localities in Veracruz by IICA (2012), where 65% of the population knows about protection strategies. In SR, only 53% of respondents knew that their parcel had been inspected to collect *D. citri* and symptomatic plant tissues to determine HLB's presence, and only 29% were informed about the result of this activity (Figure 1). In CO, although

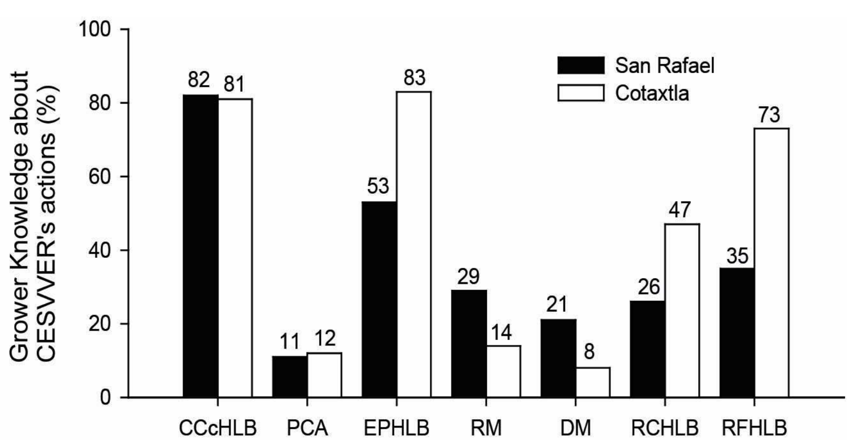

Figure 1. Grower Knowledge about CESVVER's actions: Knows about the Campaign *vs.* HLB (CCcHLB). Knows what a sentinel parcel and ARCO (PCA) are. CESVVER has looked in the grower's parcel for symptoms of HLB (EPHLB). Grower was shown results of *D. citri* or leaves sampled at his parcel (RM). He knows where to send samples to diagnosis by himself (DM). He received training to detect HLB symptoms (RCHLB). He received leaflets to identify symptoms of HLB and *D. citri* (RFHLB).

a greater proportion of growers knew about the actions of inspection and diagnosis (>80%), only 14% were told about the result (Figure 1). In both localities, the percentage of growers that know where to send samples for an official disease identification by technicians is low (21% in SR and 8% in CO; Figure 1). Although training directly influences this threat's perception, it has been the most neglected strategy; when in CO training accounted for almost 50% of respondent growers, it did so for 26% in SR only (Figure 1).

The proportion of CO growers that received leaflets to identify symptoms of HLB and identify *D. citri* was also twice those of SR (Figure 1). Moreover, they were asked whether, after the training, they deemed to have sufficient information to identify *D. citri* on the field, to which 59% in SR and 61% in CO gave an affirmative answer; 53% of trained growers in SR and 54% in CO stated to be able to perform the sampling and recognize symptoms of HLB. Once growers recognize their capacity to perform and be part of the CESVVER strategies *vs*. HLB, it decreases the social group's individual and collective vulnerability. As a counterpart, the population fraction that is not adequately addressed and made aware might decrease the success of self-protection strategies to control HLB. FOESSA (2011) states that the greater vulnerability occurs when social integration is lesser, and segments that do not have adequate integration to campaigns remain disregarded for training. The perception of SR growers toward CESVVER's activities in the Campaign is good; nevertheless, not knowing its objectives and activities contributes to growers lacking risk perception, increasing their vulnerability, and decreasing their capacity to prepare and respond to a contingency. Briones (2005) considers that the perception of risk has consequences in the behavior and management of disasters in society, as persons make rational decisions that do not necessarily meet what authorities expect.

Citrus Grower Actions within his Parcel

More than 50% of growers in both localities performed plant removal, pesticide application, and pesticide rotation (Figure 2). Most actions are made in higher proportion by CO growers compared to those of SR, reflecting more training received by the former. SR growers performed only plant removal practices and received technical advice in a higher proportion than those from CO (Figure 2).

In CO, 54% of growers use certified plants, while 29% do this in SR. Cotaxtla citrus growers participate in programs supported by the Municipality Council, which offers certified plants at reasonable prices. Thus, they would be able to replace plants more frequently than in SR. On the other hand, 94% of SR growers remove sick plants, while 71% does this in CO. This may be related to a lesser experience of growers in this municipality (6.7 ± 3.1 years) compared to that of San Rafael (20.6 ± 14.2 years), and to the fact that, the lesser the cost of non-certified plants *vs*. certified ones, the easier the replacement decision is for the growers. Using certified plants and removing infected plants are baseline strategies in handling HLB, decreasing the potential dispersion of HLB at the parcel. For Pérez (2005), this type of decision-making determines vulnerability in a specific situation, including other relations among persons in different development media.

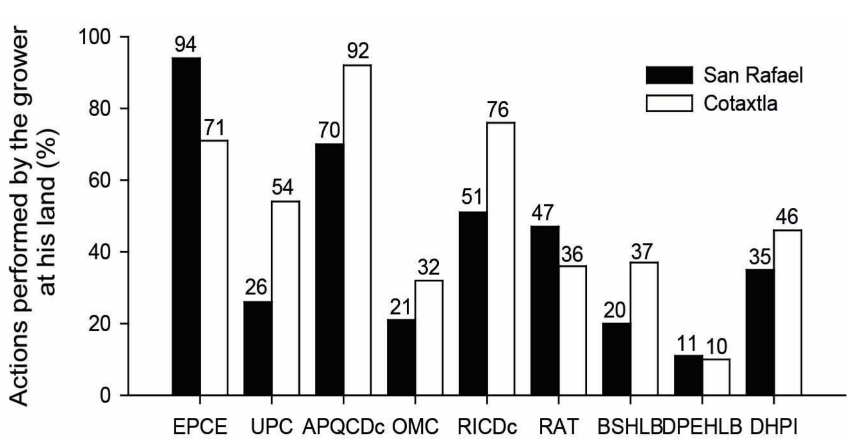

Figure 2. Actions performed by the grower at his parcel to control HLB. Grower removes sick citrus plants (EPCE). He uses certified plants (UPC). He applies chemical products for the control of *D. citri* (APQCDc); another control measure, different than (OMD); rotates pesticides upon controlling *D. citri* (RICDc). He receives technical advice (RAT). He seeks symptoms of HLB at his parcel (BSHLB). He performs an analysis to find sick plants (DPEHLB). He disinfects tools when possible or makes grafts (DHPI).

Only 20% of SR but 37% of CO growers look for HLB symptoms. In SR, 47% had received technical assistance, but only 36% in CO (Figure 2). In SR, technical assistance is provided by agrochemical salesmen (52%), CESVVER (32%), and the packing house they are associated with (16%). In CO, they receive technical assistance from CESVVER (41 %), agrochemical salesmen (35%), personnel from the Municipal Direction of Agricultural Promotion (12%), INIFAP (6%), and from other growers (6%). These numbers beat the 15% of grapefruit growers of Central Veracruz indicated by Castillo *et al.* (2004), who received technical assistance from the private sector, mainly from agrochemical stores.

Actions that Growers Would Be Willing to Perform to Handle HLB

In both localities, the percentage of willingness to perform actions for handling HLB is high, and it is greater in CO than in SR in all items (Figure 3). Most growers in both localities would be willing to remove sick plants (94% in SR and 100% in CO; Figure 3).

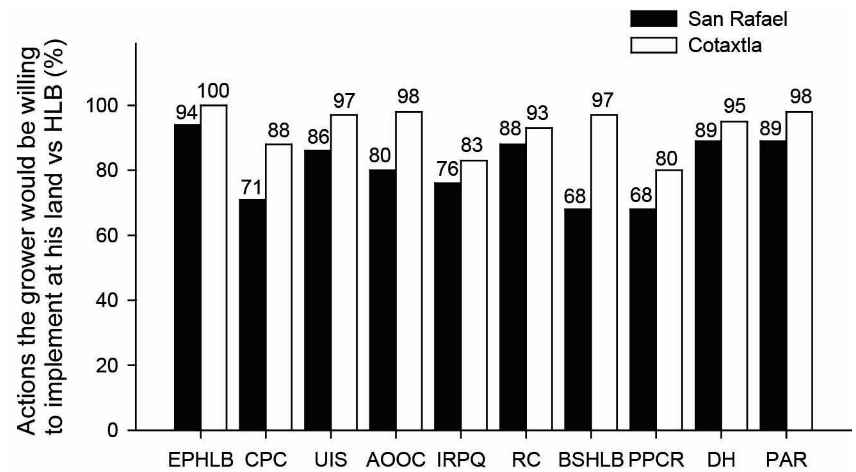

Figure 3. Actions the grower would be willing to implement at his parcel to control HLB (AProImp): Remove sick plants (EPHLB); purchase certified plants (CPC); employ selective pesticides *vs. D. citri* (UIS); adopt other options *vs. D. citri* (AOOC); implement pesticide training in the handling of (IRPQ); obtain training on how to handle HLB and *D. citri* (RC); seek for symptoms of HLB (BSHLB); pay for PCR analysis to find sick plants (PPCR); disinfect trimming and grafting tools to avoid HLB dissemination (DH); take part in regional applications *vs. D. citri* (PAR).

Practices that fewer growers are willing to incorporate are: pay for PCR analysis to find infected plants (68% in SR and 80% in CO), purchase certified plants (71% in SR and 88% in CO), and rotate pesticides (76% SR and 83% CO). The greater contrast between localities concerns the willingness to seek symptoms: only 68% in SR; meanwhile, 97% would do this in CO (Figure 3). Citrus growers' risk conception of the *D. citri* vector and the HLB may differ in the citrus-growing municipalities. Ríos and Murgida (2004) stated that risk perception in growers' groups grants sense to practices directed to face the risk. Also, for growers to adopt certain practices, they would implement these on few trees initially; after seeing results, they might decide whether to apply them to their parcel or not (Almaguer *et al*., 2008). In SR, 89% and 98% in CO would take part in regional applications against *D. citri* (Figure 3), which would not be sufficient from an epidemiological viewpoint, as few untreated parcels would be a weak spot in the Campaign's effectiveness. Briones (2005) mentions that risk perception directly influences attitude and willingness to consider future adjustments in mitigation activities and efforts, the reason why some strategies may not be performed. Lack of inclusion and willingness to include some practices stated by CESVVER, such as using certified plants, visual diagnostics, and PCR, indicate that risk perception is lesser by SR growers than those from CO.

Dimensions that Integrate the Risk Index

The SR and CO municipalities did not show statistical differences in Risk Index (IR for SR = 27.92, CO = 26.92, P = 0.483) (Table 2); vulnerability showed a medium level, similar in both municipalities.

They might pass from a medium vulnerability level to a high one if both neglect activities performed so far. On the contrary, they may decrease their vulnerability by increasing their response to those training actions and activities they would be willing to perform to control HLB. Cutter *et al.* (2003) explain that the information of factors, such as technology and access to resources, may modify persons' vulnerability.

Table 2. Risk Index (IR) for HLB in San Rafael and Cotaxtla, Veracruz, Mexico.

Dimensions	Indexes, Mean ± SD	
	San Rafael n = 53	Cotaxtla n = 48
Grower knowledge about D. citri and HLB	5.1 ± 3.5	2.4 ± 3.4
Grower knowledge about CESVVER's actions	3.5 ± 2.4	4.6 ± 2.1
Actions that the grower performs inside his parcel	6.7 ± 0.6	7.4± 0.7
Actions that he would be willing to implement at his parcel	4.2 ± 1.8	4.9 ± 2.1
Perception of CESVVER by growers	7.0 ± 0.6	7.2 ± 0.7
Perception of actions performed at his parcel	8.2 ± 2.4	9.3 ± 1.1
Perception of actions that would be implemented at his parcel	7.4 ± 0.7	7.4± 0.6
IR =	27.9 ± 8.5	26.9 ± 6.4

Social Trust of Growers, Tool for Decreasing HLB Vulnerability

Most SR (97%) and CO growers

(92%) do not trust their leaders. Therefore, the Campaign decision-makers' actions should be oriented to the social groups' integration, social recognition, and growers' capacity to decrease their vulnerability to this disease. Leaders must be part of the solution. According to Díaz & Díaz (2002), when a leader can disclose risk, conflicts between general and local interests may be solved while generating a trust-generating atmosphere. For Cid *et al*. (2012), the degree of trust is related to an attitude and a state of personal world knowledge, more than an objective vision of the world. In SR and CO, IR, and therefore vulnerability, has an inverse correlation to trust in social actors ($r=-0.302$); *i.e*., if the trust is lost, grower vulnerability increases. Assessing growers' willingness to trust might foster their participation and organization (Yáñez *et al*., 2006). Therefore, generating trust and fostering collective and individual capacities through training and assessment is very needed. Agricultural institutions should conceptualize prevention with equity that allows leveling opportunities for different actors to decrease vulnerability.

Citrus Grower Involvement in Organizations and their Vulnerability to HLB

The degree of involvement in grower organizations was not different between localities ($P=0.154$). In SR, few respondents (15%) take part in grower associations, although 69% are willing to participate in an organization that allows them to set themselves free of the middleman, specifically to obtain pesticides at a better price, training, and advice for marketing. In CO, 52% of growers would be willing to participate in an organization, although 24% do not have any interest and the rest (24%) are already part of some grower association not exclusive for citrus growers. These traits show weakness in the organization of growers. Growers do not perceive HLB as a threat so significant that it compensates problems derived from organizations, as Gonnet (2011) stated about volunteer organizations. In any case, the lack of organizational involvement might prevent an appropriated individual and group response and increase their vulnerability condition to the HLB threat.

CONCLUSIONS

The Risk Index defined a medium vulnerability in San Rafael and Cotaxtla, Veracruz, Mexico, based on the knowledge and perception of the threat, the prevalence of protection actions, and capacities to overcome the issue by growers. Grower vulnerability increases when the degree of trust of social actors' decreases. The low involvement in grower organizations in both municipalities decreases their capacity to respond adequately to the HLB's presence. Their performance might be deficient upon implementing Campaign strategies against HLB and its vector, mainly in actions that demand their participation.

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The Tilapia-Prawn Polyculture: Its Development in Mexico

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ABSTRACT

Objective: To analyze the productive development performed by two aquatic species of recent introduction in Mexico, the giant freshwater prawn (*Macrobrachium rosenbergii*) and tilapia (*Oreochromis niloticus*), arguing their potential under mono- and poly-culture systems.

Design/Methodology/Scope: The bibliographic meta-analysis was developed searching information on the internet, and is presented in a chronological manner with the analysis of the technological, social and political dimensions, visualizing the benefits and advantages of applying the polyculture production system.

Results: A data base on the development of the tilapia-freshwater prawn polyculture in our country was obtained. Mexico presents the required physical characteristics for both species productions. Thus, polyculture allows the use of the same infrastructure, resulting in a better productivity and income.

Limitations of the study/implications: Polyculture information registered on electronic media was scarce.

Findings/Conclusions: The polyculture production of the Malaysian prawn and tilapia is a profitable option for the aquaculture producer in tropical areas of Mexico.

Keywords: integrated management, *Macrobrachium*, *Oreochromis*, profitability increment.

INTRODUCTION

The utilization of aquatic resources dates from pre-historic times to the present. There is sufficient consensus and evidence to confirm that hunting, gathering and fishing sustained human groups since prehistoric times and allowed them to expand globally (Nash, 2011). Just as agriculture and animal domestication became a fundamental step in the development of humanity, aquaculture might have followed a similar process. First, the confinement of species appeared followed by the development of techniques for their reproduction and handling in controlled conditions. This is shown by evidence that dates back before 3000 b. C., mainly in Asian regions (Jones, 1986; Rabanal, 1988; Nash, 2011). A similar process probably occurred in Mesoamerica. The first aquatic organisms that man used came from water bodies (fresh, sea and marsh water), which are still abundant in the territory (CEDERSA, 2007).

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Throughout Mexican history, aquacultural activities were developed and consolidated by Olmecs, Purepecha, Mexica and Chichimeca groups (Gutiérrez-Yurrutia, 1999). Following the conquest, use of natural resources underwent important changes. Notwithstanding, it was not until the time of Mexican Independence, in particular the Porfirian period, that the Mexican State took the first steps to incorporate aquaculture in the national agenda (Gutiérrez-Yurrutia, 2000; Contreras-Alvarado, 2012; Cupul-Magaña and Cifuentes-Lemus, 2016). Thus, by order of the Office of President Porfirio Díaz, the first pisciculture treatise was prepared and published in Mexico (Cházari, 1884). Since then, the establishment of aquaculture centers was promoted to foster the development of trout and carp (Cupul-Magaña and Cifuentes-Lemus, 2016). During the last five decades, aquaculture has enjoyed significant support; this sector that produces food of animal origin is the one with more rapid growth in the primary sector (FAO, 2016). The productive development that two aquatic species of recent introduction to the country, giant river tilapia (*Macrobrachium rosenbergii*) and tilapia (*Oreochromis niloticus*), have exhibited their potential for mono- and polyculture systems.

MATERIALS AND METHODS

For this analysis, a literature review in electronic meta engines available at the Digital Library of Colegio de Postgraduados for 2019 (http://www.biblio.colpos.mx/portal/index.php/colpos-digital.html), such as Academia.edu, Science Research, Jurn, Redalyc and Scielo was developed. The information is submitted in chronological order, from basic literature on aquaculture in Mexico to our days. The conclusion is reached based on the technological, social and political dimensions of the tilapia (*O. niloticus*) and giant river prawn (*M. rosenbergii*) cultures in order to finally bring an insight on the application and benefits attained by the polyculture of both species in Mexico.

RESULTS AND DISCUSSION

Prawn Culture Background

Utilization aspects of both cultures and that of prawn as a natural resource are submitted; public policies, infrastructure, social organization and places with forseeable productive potential are included. Table 1 shows a timeline for both cultures in Mexico and their international development.

Currently, the Mexican fishery of river prawn is based on the utilization of four main species, all of the *Macrobrachium* genus: two in the Gulf of Mexico region (*M. carcinus* and *M. acanthurus*) and two in the Pacific region (*M. tenellum* and *M. americanum*) (Cifuentes-Lemus *et al.*, 1997). These organisms live in tropical and subtropical places, in fresh and braquish water, they are omnivorous, detritophages, saprophages and cannibals and accept artificial food (Mayorga-Castañeda, 2011).

In December 1972, the General Directorate of Fisheries Planning and Promotion of the Ministry of Industry and Trade suggested a visit to the states of Michoacán and Guerrero by a group of persons from the Food and Agriculture Organization of the United Nations (FAO) and the National Community Development Institute (INDECO) by the Mexican Government (Balbuena, 2014). Since this visit, the river prawn (*M. rosenbergii*) was introduced to Mexico in 1973 and then again in 1978 (Figure 1). The Fisheries Department built three aquaculture centers: "El Real" in Veracruz, "El Carrizal"

Table 1. Timeline per decade of evolution for tilapia and prawn in Mexico and internationally.

Decade	River prawn	Tilapia
1950	The controlled culture of *M. rosenbergii* began in Maysia	Species studied by the academy in different parts of the world
1960	In Hawaii, USA, the productive foundations for its cultivation were established	A prawn species was introduced in Mexico in order to repopulate big basins
1970	The river prawn was introduced in Mexico and the infrastructure for its development was built	Its culture begins as a social support species; the species is studied in academic institutions
1980	International congresses are organized and it is included in educational programs	It is consolidated as one of the most important species in Mexico and the world
1990	Production and fattening units are operated in Mexico and Latin American countries	One of the species of greater production at an international level; congresses are organized in Mexico and abroad.
2010	Monoculture production. The polyculture of tilapia begins	It is the culture fish with most economic importance in Mexico
2020	New post-larva production units are established and its production is encouraged	Species of great importance, with social culture and industrial organizations

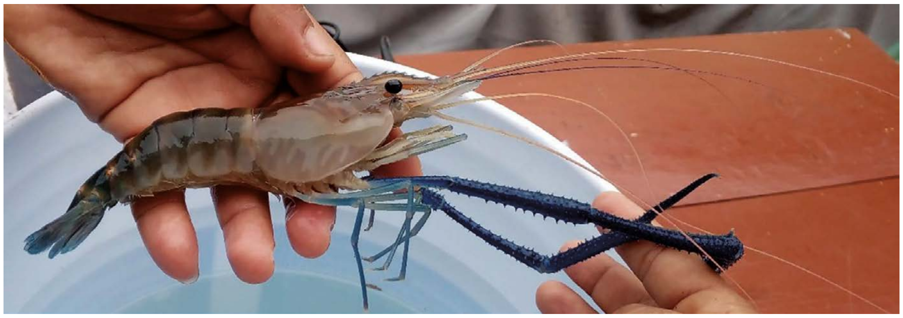

Figure 1. Male river prawn (*Macrobrachium rosenbergii*) breeder.

in Coyuca de Benítez, Guerrero, and "Chamela" in Sinaloa. Its objective was to produce post-larvae with a technique named "green water". In that same decade, the Papaloapan Commission, an instance of the Federal Government, boosted the first attempts to cultivate one of the most important species in the zone in Veracruz: freshwater prawns (*Macrobrachium acanthurus*); for this, it built an aquaculture station on the side of the Los Amates lagoon, on the riverside of the Papaloapan River, in Tacotalpan, Veracruz (Cabrera-Cano, 1977).

Since its introduction in 1973 to present, the river prawn has attained good productive results. However, it has not attained the expected ones (New, 2009). Experiments have been made on native prawns such as freshwater prawn (*M. Acanthurs*) and freshwater prawn *M. carcinus* (Cabrera-Cano, 1977), although results have not been encouraging either. The national fishery of fresh water crustacean species that occupy the same market niche as *M. rosenbergii* is almost depleted (Espinosa and Rodríguez, 1986; Lorún-Núñez, 2017). The available information for native species of Latin America includes biological, ecological and sometimes controlled culture aspects, but little is known about the fishery utilization or the actual state of populations (García-Guerrero *et al.*, 2013; Lorún-Núñez, 2017). Traditionally, the fishing art used to capture prawns are traps; the best capture opportunities happen during the mating period as it is then that mostly females migrate to release larvae near the cost (García-Guerrero *et al.*, 2013). As these carry eggs adhered between the pleopods, their extraction implies a loss of the offspring.

In contrast, the river prawn *M. rosenbergii* is a studied domesticated species cultured successfully in several parts of the world (New, 1995; Cifuentes-Lemus *et al.*, 1997). Therefore, the development of its culture is an alternative to meet the demand and decrease the pressure that fishing exerts on prawns as a natural resource. (Asiain-Hoyos *et al.*, 2013). Since 2014, the river prawn offspring production, which is the first link in the agri-food chain, is addressed in the state of Veracruz by organized producer groups (Acuacultores Veracruzanos A.C., AVAC), and research institutions (Tecnológico Nacional de México-Instituto Tecnológico de Boca del Río and Colegio de Postgraduados, Veracruz Campus) (Benítez-Hernández *et al.*, 2016). Currently, there is a post-larvae production unit for river prawn in the state of Oaxaca. Another unit in the state of Guerrero supplies post-larvae intermittently to the state of Morelos (Figure 2). Currently, the limited offer of post larvae endangers the entire industry.

Tilapia Culture Background

Tilapia is the name for several species of African species belonging to the *Oreochromis* genus; most of them inhabit tropical regions in the planet where environmental conditions are favorable for their reproduction and growth (Morales-Díaz, 1991). By initiative of the Papaloapan Commission and as an option to detonate development, tilapia was introduced in Mexico to consolidate fisheries in great basins (Asiain-Hoyos, 2009). As of 1965, broods were cultured in the Miguel Alemán dam in Temascal, Oaxaca and other water bodies of the same type throughout the country. From 1972 to 2014, it is estimated that more than one million tons of tilapia have been captured in national basins. In 1999, the General Directorate of Aquaculture had 27 aquaculture centers for the reproduction of tilapia broods in the states of Aguascalientes, Coahuila, Colima, Chiapas, Chihuahua,

Figure 2. Harvest of river prawn *M. rosenbergii* in Jojutla, Morelos, Mexico.

Durango, Guanajuato, Guerrero, Jalisco, Michoacán, Morelos, Nayarit, Oaxaca, Querétaro, Sinaloa, Tabasco, Tamaulipas, Veracruz, and Zacatecas. Today, tilapia *O. niloticus* is the main aquaculture species cultured in the country, with presence nationwide and a production of more than 100 000 t per year (CONAPESCA, 2014; Ventura *et al*., 2014).

The Tilapia-Prawn Culture

Aquaculture is a productive activity oriented to producing food. As a strategy for attaining yields and the use of infrastructure, diverse production technologies have been developed (Navarrete-Salgado *et al*., 2000). Polyculture consists in culturing a main species, generally with greater population density or dominance, and the inclusion of one or more additional species to the existing one in order to use resources available in the pond with greater efficiency (García-Guerrero *et al*., 2013). The use of several trophic niches is the reason why the polyculture has been successful. The tilapia-prawn polyculture has a net yield above the tilapia monoculture (Alvarez-Torres *et al*., 1999; Asiain-Hoyos *et al*., 2013). Because of its capacity to improve water quality, tilapia sets a control on the flourishing of phytoplankton and the accumulation of organic matter (Massaut *et al*., 2004; Flores, 2010). Income obtained from the production if tilapia may cover operational expenses of polyculture, as well as providing an earning margin in income from the culture of shrimp which represents the net profits of culture (Espinosa-Chaurand *et al*., 2011), which allows performing the production, as each species occupies different ecological niches. Tilapia-Prawn polyculture organisms help each other: the level of dissolved oxygen is stabilized, predators are reduced, there is greater total productivity of the pond, fish and crustaceans perform cross coprophagy, produce greater financial value per culture, among others (Hernández-Barraza, 2011). Hishamunda (2003) and Navarrete-Salgado (2017) describe some advantages offered by integrated pisciculture: the cost per organism is reduced; allows establishing preservation methods for the later sale in neighboring markets; ponds use lands not suitable for agricultural activities; the production may be calculated according to needs; growth and the fattening of fish and crustaceans is controlled; this is adequate for genetic handling; only species cultured in ponds are developed; the presence of predators and competitors is avoided; last, natural mortality is minimized.

Although there are different polyculture models with different species (Tafur-Gonzales *et al*., 2009), in all cases, the different strata and pond resources are utilized with more efficiency (Sanabria, 2016). In the 1980s, different aquaculture farm models with catfish, trout, tilapia and carp were developed in Mexico. Also, smaller fish were used and the cage strategy was implemented to assure and control the population. All sorts of studies were performed. However, as no polyculture projects were implemented, the system's advantages were not utilized (Ventura *et al*., 2014). This way, the polyculture of these two species is feasible and recommended to elevate yield per surface unit and hence profitability. An example of a polyculture is found in Tezonapa, Veracruz, México (Figure 3). It does not increase operating costs or infrastructure significantly. Work with the same labor and energy requirements or aeration equipment is used (Ponce *et al*., 2005).

CONCLUSIONS

Mexico has been a fishing and aquacultural country since pre-Hispanic times. Tilapia was introduced to the country more than 50 years ago and river prawn more than 40 years ago. Currently, the production of both species as a mono- and polyculture is a reality. Increases in production volumes will depend on the sufficient supply of broods of both species, as the market

Figure 3. Tilapia-Prawn polyculture pond in Tezonapa, Veracruz, Mexico.

is well established. In polycultures, both species benefit from their mutual relationship, which results in greater yield and profits per productive cycle. The tilapia culture tradition already overcame a generation of producers in the tropical region of Mexico. In contrast, river prawn did not have the same luck; notwithstanding, its market and current boost of new production units of post-larvae generates a new perspective. In the infrastructure installed for the production of tilapia, developing the polyculture with both species is feasible. This activity overcomes monoculture income. Therefore, it has the potential to increase the wellbeing of aquaculturists in the tropical regions of Mexico.

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AP AGRO PRODUCTIVIDAD

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Agroecosystem and rural tourism: Bibliometric analysis and its conceptual relationship from 2014 to 2020

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ABSTRACT

Objective: To analyze scientific papers close linked to the concepts of agroecosystems, rural tourism and its conceptual relationship.

Design/methodology/approach: A search of papers published from 2014 up to 2020 in Science Direct (https://www.sciencedirect.com) was conducted, using key words related to the agroecosystem concept and rural tourism. After that, a bibliometric and text analysis was performed.

Results: The concept of agroecosystems has been dynamic through time and related to other disciplines. However, research relating this concept with rural tourism is scarce.

Limitations of the study/implication: Research proposals on agroecosystems associated to rural tourism are limited.

Findings/Conclusions: Papers with the conceptual evolution of agroecosystems integrating rural tourism are few. So, it is suggested to study the agroecosystem in its different aspects, but considering their cultural and historical basis.

Keywords: Bibliometric analysis, culture, ecosystem transformed.

RESUMEN

Objetivo: Analizar las publicaciones científicas relacionadas con los conceptos de agroecosistemas, turismo rural, así como su relación conceptual.

Diseño/metodología/aproximación: Se hizo una búsqueda de artículos publicados del 2014 al 2020 en Science Direct (https://www.sciencedirect.com), con palabras clave relacionados con el concepto de agroecosistemas y el turismo rural. Posteriormente se realizó un análisis bibliométrico y de texto.

Resultados: El concepto de agroecosistemas ha sido dinámico en el tiempo y respecto a otras disciplinas. Sin embargo, la investigación que relaciona este concepto con turismo rural es escasa.

Limitaciones del estudio/implicaciones: Son limitadas las propuestas de investigación en agroecosistemas desde el turismo rural.

Hallazgos/conclusiones: Son escasas las publicaciones con la evolución conceptual de agroecosistemas que integran al turismo rural. Se sugiere estudiar al agroecosistema en sus diferentes vertientes, pero considerando sus bases culturales e históricas.

Palabras clave: Análisis bibliométrico, cultura, ecosistema transformado.

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INTRODUCCIÓN

Se le han asignado diversos conceptos a la investigación de la agricultura o de los espacios transformados para producir alimentos y otros satisfactores sociales, los que reflejan una intención y enfoque de abordaje. A estos ecosistemas transformados se les denomina sistemas agrícolas o agroecosistemas (Hernández X., 1977). La operacionalización de estos conceptos ha permitido el abordaje de la agricultura en su sentido amplio y como un todo. Es así que los conceptos o sinonimias de lo que se concibe como agroecosistemas, han pasado por una evolución, particularmente con la emergencia de conceptos como agroecología, sustentabilidad y complejidad (Cuadro 3).

Por otro lado, el turismo rural es una actividad que está teniendo auge en comunidades rurales de todo el mundo. De hecho, esta actividad surge en los países desarrollados en el siglo XIX, con la expansión de las ciudades industriales (OECD, 2005). Sin embargo, el concepto de turismo rural, aunque aparentemente reciente, se remonta a finales del siglo XIX en el Reino Unido (Tang, 2017). El turismo rural tiene su fundamento y justificación en su potencial para impulsar el desarrollo económico regional, particularmente de comunidades que están en una condición social y económica deprimida (Blaine y Golan, 1993; Dernoi, 1991; Fleischer y Felsenstein, 2000); aspecto ampliamente documentado por los efectos positivos, e incluso negativos en el bienestar económico de la gente (Belisle y Hoy, 1980; Liu *et al*., 1987; Tosun, 2002; Um y Crompton, 1990; Weaver y Lawton, 2001). Por tanto, el presente ensayo tiene como objetivo analizar las publicaciones científicas relacionadas con los conceptos de agroecosistemas, turismo rural, así como su relación conceptual.

METODOLOGÍA

La investigación bibliográfica se realizó en tres fases, de enero 2014 a febrero 2020. Se seleccionaron los artículos científicos y de revisión en Science Direct (https://www.sciencedirect.com). En la primera fase se identificaron los conceptos y las palabras más frecuentes que los investigadores consideran como "Agroecosistema". Para ello, se realizó una búsqueda mediante las palabras clave "*Agroecosystem*" y "*agro-ecosystems*". En la segunda fase se identificaron los conceptos y características del turismo rural, para lo cual se realizó una búsqueda mediante la palabra clave "*rural tourism*". Finalmente, se identificaron las investigaciones que se han realizado en agroecosistemas desde el punto de vista de turismo rural, para lo cual se hizo una búsqueda de las palabras clave conjuntas "*agroecosystem*" and "*rural tourism*". En los documentos obtenidos se identificó el país en donde se publicó, el año de publicación, los autores, títulos, revista y tema general del mismo. En las búsquedas se realizó un análisis bibliométrico y análisis de texto; se identificó la co-ocurrencia de palabras clave de los artículos, mediante el software VosViewer.1.6.14 (Van Eck y Waltman, 2010).

RESULTADOS Y DISCUSIÓN

Análisis bibliométrico para "agroecosistema" y para "turismo rural"

Para el periodo indicado 2014-2020, se identificaron 4185 publicaciones que refieren la palabra clave "*agroecosystem*" y 702 que se refieren a "*rural tourism*"; para la combinación "*agroecosystem*" and "*rural tourism*", se registraron solo seis publicaciones. La Figura 1 evidencia que existe una tendencia de aumento en el número de publicaciones de "agroecosistemas", mientras que la de "turismo rural" se mantiene prácticamente constante; también son escasas las publicaciones sobre "*agroecosystem*" and "*rural tourism*", las cuales han declinado. Esto indica la escasa pertinencia bibliográfica de investigaciones en agroecosistemas y turismo rural. Sin embargo, los autores consideran necesario retomar el turismo rural y revalorar su importancia en el seno de los agroecosistemas y de una agricultura multifuncional.

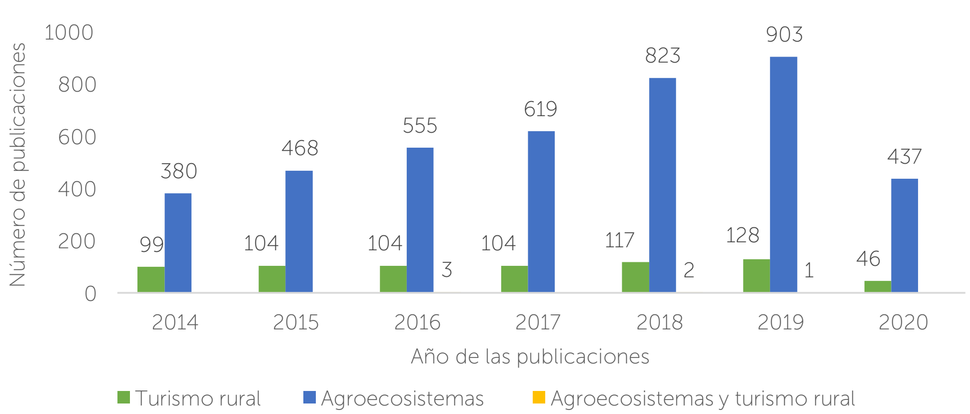

Figura 1. Número de artículo sobre los temas "turismo rural", "agroecosistema" y "agroecosietemas y turismo rural" publicados de 2014 a 2020, consultados en la base de datos Science Direct.

La revista que mayor número de artículos ha publicado sobre "agroecosistemas" es *Agriculture, Ecosystems and Environment*, seguida de *Science of the Total Environment* y *Applied Soil Ecology*. Mientras que para "turismo rural", las revistas con mayor número de referencias fueron *Tourism Management*, seguida de *Land Use Policy* y *Procedia-Social and Behavioral Sciences* (Cuadro 1).

Se agruparon las palabras clave de cada artículo; al relacionarlas, se identificaron 229 palabras correspondientes a la palabra clave "*agroecosystem*"; las palabras clave de mayor presencia fueron "agroecosistemas" y "sustentabilidad". Las palabras mayormente relacionadas con "*rural tourism*" fueron 304, siendo las de mayor frecuencia "turismo" y "turismo cultural".

Las investigaciones de "agrocosystem" and "rural tourism", se identificación únicamente 30 palabras, de la cuales "adaptación", "desarrollo alternativo", "servicio ecosistémico", "reconstrucción" y "resiliencia" fueron las de mayor frecuencia. Al agrupar las palabras clave, se formaron tres grupos, "agroecosistemas", "turismo rural" y "turismo". Las interconexiones de estos tres grupos fueron con "desarrollo sustentable", "sustentabilidad", "desarrollo rural" y "resiliencia" (Figura 2).

Para "*agroecosystem*" and "*rural tourism*", los países con más publicaciones son China (14), España (13) e Italia (7), los dos primeros con la mayor frecuencia (Figura 3). El país que más publica temas de agroecosistemas es Estados Unidos (EUA), y en turismo rural son: Romania (12), Reino Unido (7) y Malasia (11). En el marco de la celebración del Año del Turismo Unión Europea-China 2018, la UNWTO (2018) analizó el informe del turismo internacional de China, en el que destaca la economía asiática como la más importante, junto con los 28 países de la Unión Europea. Además, China es considerado uno de los principales emisores de turistas, y no sorprendería que China predomine en el futuro, en investigaciones sobre agroecosistemas y turismo rural (Figura 3).

Análisis conjunto de las palabras clave "*agroecosystem*" and "*rural tourism*"

En las investigaciones que conjuntan las palabras clave

Cuadro 1. Relación de publicaciones sobre temas de agroecosistemas y turismo rural derivadas de Science Direct: enero 2014 a febrero 2020.

Tema	Revista	Número de publicaciones	Factor de Impacto	Cite Score
AGROECOSISTEMAS	Agriculture, Ecosystems and Environment	523	3.954	4.42
	Science of the Total Environment	286	5.589	5.92
	Applied Soil Ecology	201	3.445	3.81
	Soil Biology and Biochemistry	165	5.29	6.24
	Journal of Integrative Agriculture	148	1.337	1.71
	Soil and Tillage Research	135	4.675	5.24
	Geoderma	135	4.336	4.55
	Ecological Indicators	117	4.49	5.06
	Biological Control	115	2.607	2.88
	Agricultural Systems	92	4.131	4.33
TURISMO RURAL	Tourism Management	105	6.012	8.2
	Land Use Policy	78	3.573	4.22
	Procedia-Social and Behavioral Sciences	54	*	
	Tourism Management Perspectives	49	2.485	3.42
	Journal of Rural Studies	43	3.301	3.73
	Annals of Tourism Research	38	5.493	4.55
	Journal of Destination Marketing and Management	29	3.8	4.78
	International Journal of Hospitality Management	26	4.465	5.56
	Procedia Economics and Finance	26	**	
	Journal of Cleaner Production	19	6.395	7.32

CiteScore=Mide el promedio de citas recibido por documento publicado en la revista. *Descontinuado desde el 2019, **Descontinuado desde el 2017.

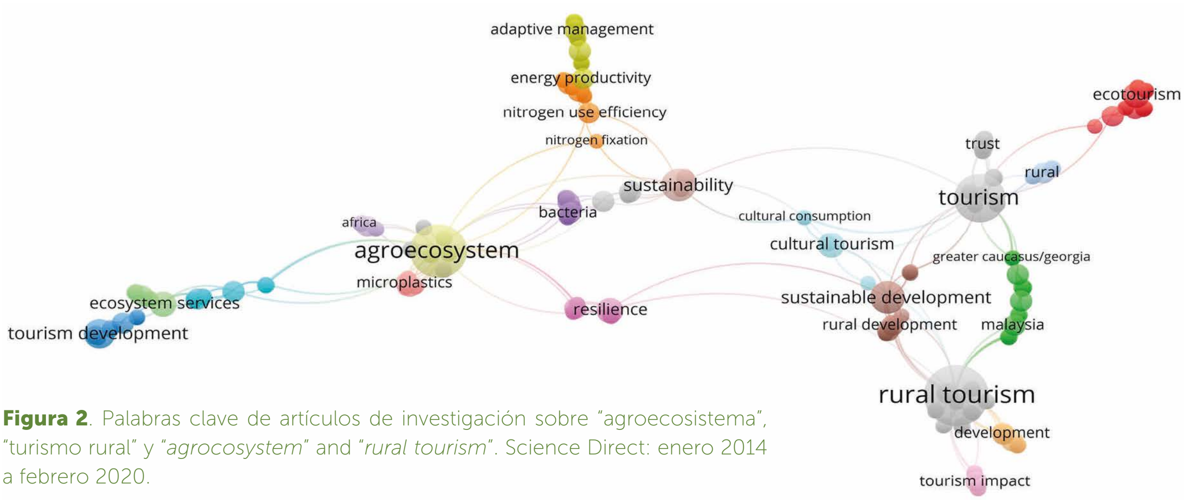

Figura 2. Palabras clave de artículos de investigación sobre "agroecosistema", "turismo rural" y "*agrocosystem*" and "*rural tourism*". Science Direct: enero 2014 a febrero 2020.

"*agroecosystem*" and "*rural tourism*", España, China e Italia vuelven a ser los países con mayor frecuencia. Sin embargo, no existieron publicaciones entre los años 2014 y 2015 (Cuadro 2). Entre los años 2002 y 2010 se incrementó el número de citas, ya que posiblemente, al existir escasas investigaciones, se incrementó la necesidad de información del pasado.

A partir de las palabras clave, se puede inferir que las nuevas vertientes de investigación son las de adaptación

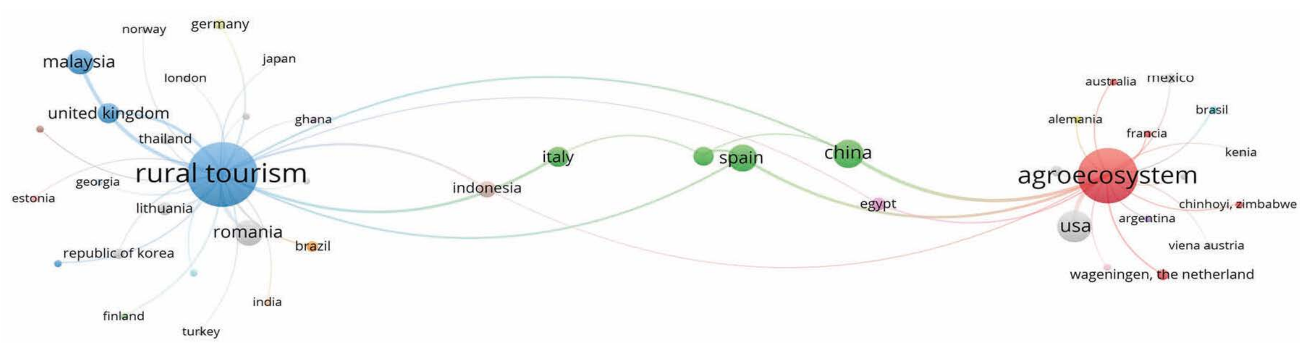

Figura 3. Países que realizan investigaciones en "agroecosistemas", "turismo rural" y "*agrocosystem*" and "*rural tourism*".

Cuadro 2. Relación de publicaciones con los temas "*agrocosystem* and *rural tourism*". Science Direct: enero 2014 a febrero 2020.

País	Año	Autores	Título	Veces citada	Revista	Tema
España	2019	Martínez-Paz *et al.*	Assessment of management measures for the conservation of traditional irrigated lands: The case of the Huerta of Murcia	4	Land Use Policy	Cambio de uso del suelo
España	2018	Hanaček y Rodríguez-Labajos	Impacts of land-use and management changes on cultural agroecosystem services and environmental conflicts-A global review	8	Global Environmental Change	Servicios ecosistemas culturales
España	2018	Roces-Díaz *et al.*	Assessing the distribution of forest ecosystem services in a highly populated Mediterranean region	8	Ecological Indicators	Indicadores ecológicos
España	2016	Bernués *et al.*	Agricultural practices, ecosystem services and sustainability in High Nature Value farmland: Unraveling the perceptions of farmers and nonfarmers	22	Land Use Policy	Servicios ecosis-témicos
Italia	2016	Ottomano *et al.*	Greenways for rural sustainable development: An integration between geographic information systems and group analytic hierarchy process	33	Land Use Policy	Desarrollo sustentable
China	2016	Abramson	Periurbanization and the politics of development-as-city-building in China	11	Cities	Política

y resiliencia. El turismo rural se ha considerado como una de las estrategias de desarrollo económico rural, que, en conjunto con los agroecosistemas, forman servicios ecosistémicos que promueven cultura, recreación y desarrollo rural.

Análisis de contenido de "agroecosistema"

Los agroecosistemas han sido estudiados desde la teoría de sucesión ecológica, la teoría de interacciones biológicas y la teoría general de sistemas. Se han estudiado desde las disciplinas de agronomía, ecología, agroecología, biología, física, sociología, economía, tecnología, biogeoquímica, geoinformática y genética. El concepto de agroecosistemas ha sido cambiante en el tiempo, y se ha tratado de adecuar al contexto y sus transformaciones (Cuadro 3).

El estudio de los agroecosistemas en las diferentes ciencias funcionó debido al contexto histórico. Sin embargo, otros investigadores cuestionaron y propusieron otras formas de investigar a través del tiempo. En la actualidad, los asuntos de complejidad han fomentado que se adopten estos conceptos (Figura 4).

Desde el enfoque de sustentabilidad, el agroecosistema se ha estudiado con las dimensiones de este enfoque, en conjunto o por separado (Sainju, 2017; Pant *et al.*, 2017; Sánchez-Moreno *et al.*, 2018; Marín-Castro *et al.*, 2017; Lal, 2018). Desde el enfoque económico-ambiental, sus dimensiones se estudian respecto a los servicios ambientales que brindan, su productividad y rentabilidad (Novikova *et al.*, 2017; Lazzaro *et al.*, 2017).

Además, se sugiere considerar elementos como cultura e historia (Tittonell, 2014), con la finalidad de comprender el funcionamiento y la estructura de los agroecosistemas, para implementar estrategias para su desarrollo.

Por otra parte, Gómez (2012) indica que se está produciendo un cambio de tendencia en los motivos por los que la población se acerca al medio rural. Ha aumentado el número de alojamientos e infraestructuras que contribuyen a reforzar los servicios culturales de los agroecosistemas; este autor considera que debe aumentar el número de centros de interpretación, de la oferta de ac-

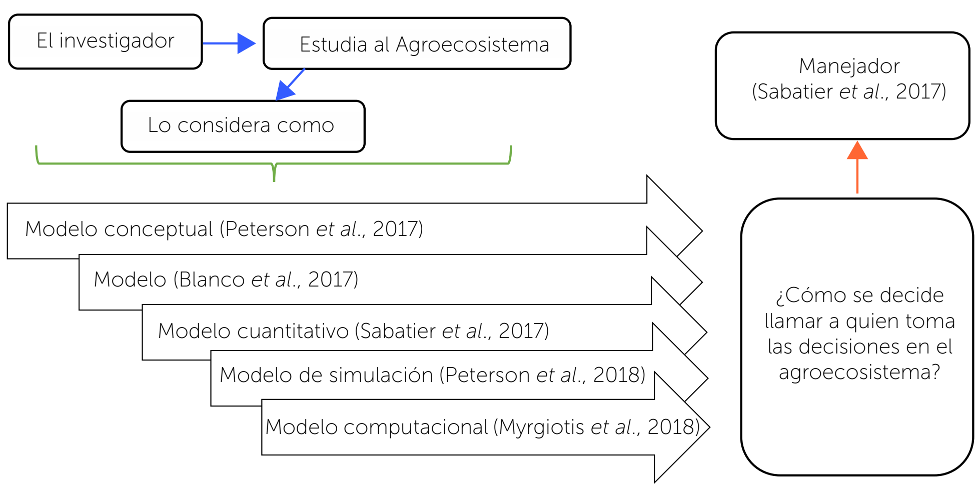

Figura 4. Identificación de la palabra más frecuente respecto a la pregunta ¿Qué es un agroecosistema?

Cuadro 3. Conceptos de agroecosistema.

Año	Autores	Concepto de agroecosistema
2017	Blanco *et al.*	Modelo basado en la movilidad y manejado de acuerdo a la variabilidad de sus funciones. En su análisis consideran la estructura y la función como resultado de la adaptación.
2017	Peterson *et al.*	Modelo conceptual determinado desde la gestión ambiental a una escala múltiple-espacial y temporal, y análisis metodológico acorde a su desarrollo.
2017	Sabatier *et al.*	Sistema real, diseñado desde un modelo cuantitativo que considera los eventos agro-climáticos y manejado por el productor (controlador) por ser quien define los elementos con base a las condiciones socio-económicas, aunque estas difieran de las condiciones ecológicas.
2017	Smith *et al.*	Requiere para su medición de indicadores y medidas de sustentabilidad del ambiente, considerando la medición del cambio climático y medidas sociales.
2018	Peterson *et al.*	Modelo de simulación, donde la resiliencia social, ecológica y económica es resultado de una agricultura resiliente con una máxima productividad.
2018	Myrgiotis *et al.*	Modelo que sirve como una herramienta computacional para simular procesos, tales como los flujos de nutrientes a través de los ecosistemas agrícolas, sus interacciones y el ambiente; para ello incluyen información del clima, tipo de vegetación, propiedades del suelo, entre otros.

tividades, en específico las deportivas y de conocimiento de los recursos naturales, como la observación de aves (Figura 5).

Si al estudiar los agroecosistemas no se considera su cultura, entonces no se puede entender por qué la sociedad se comporta de una manera específica.

Por otra parte, desde el año 2017, las investigaciones en torno a los agroecosistemas se han dirigido a los servicios ambientales, a estudiar las propiedades del suelo, y a trabajar el enfoque industrial, dado que la economía ejerce un papel importante en los sistemas agrícolas. Sin embargo, han sido escasas las investigaciones asociadas a turismo rural. El concepto de agroecosistemas ha permeado en la sociedad consumidora; se demandan productos saludables y que provengan de agroecosistemas sustentables o que promuevan la sustentabilidad. Entonces, si el manejador es quien decide qué acciones van a implementarse en el agroecosistema, la pregunta sería: ¿Hasta qué punto el manejador compartirá su cultura, e influirá en desarrollar agroecosistemas similares?

CONCLUSIONES

Pocas publicaciones dan cuenta de la evolución conceptual de agroecosistemas que integran al turismo rural. Algunos autores sugieren estudiar al agroecosistema en sus vertientes histórica y cultural. Se propone el concepto de agroecosistema como modelo sistémico-dinámico, que representa una realidad determinada en un espacio de tiempo, y que se interrelaciona entre los sistemas político, económico, social, ambiental y cultural, y entre otros factores que el controlador considere relevante para la obtención de productos y servicios, acordes a la función y estructura del sistema, por ejemplo, al sistema del turismo rural. Se requiere un concepto de agroecosistemas que integre al turismo rural, en el contexto de la agricultura multifuncional.

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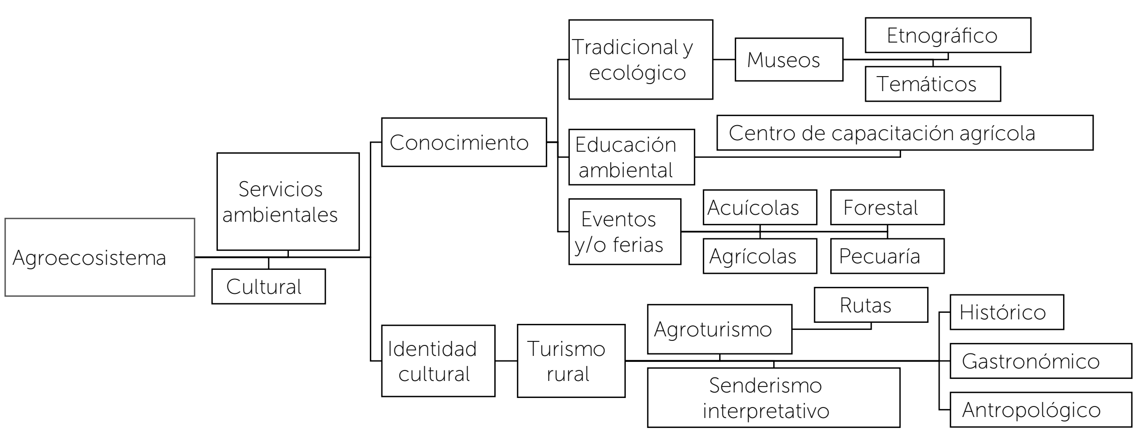

Figura 5. Servicios de los agroecosistemas de tipo cultural (Gómez, 2012).

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The Coffee Agroforestry System in Mexico

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ABSTRACT

Objective: To identify the current coffee knowledge as agroforestry systems, with emphasis on Mexico.

Design/Methodology/Scope: A search for documentary information was performed on the Internet based on Google®, with the keywords "agroforestry and coffee plantations" and "coffee systems in Mexico".

Results: 88 documents were found; 91% of publications were in Spanish, 40% were from Colombia, 24% from Mexico, 7% from Costa Rica and the remaining 29% of other countries.

Study Limitations/Implications: This topic is studied in several institutions, although it does not constitute a systematized study line.

Findings/Conclusions: Most research works are centered on the importance of the coffee agroforestry system as provider of environmental services, among which the carbon and water intake, biodiversity reserve and erosion buffering stand out.

Keywords: coffee industry, water capture, *Coffea arabica*, carbon sequestration, environmental services.

INTRODUCTION

The word agroforestry is associated to silviculture, although it refers more commonly to an agroforestry system (SAF). This production focus has been used worldwide and is as ancient as agriculture itself. Nevertheless, barely in the 1970s, the first formal research on agroforestry was obtained. It tried to clarify the concept of agroforestry and differentiate it from other production systems (CONAFOR-UACH, 2013; Farfán, 2014). Agroforestry or an agroforestry system comprise those systems where there is a combination of arboreous species with shrubby or herbaceous species generally grown. This term is wide; it includes from the simple presence of some trees in combination with vegetation crops or cereals, to complex systems with multiple species in several strata (FAO, 1999). According to Farfán (2012), agroforestry objectives are: diversifying production, improve migration agriculture, increase organic soil matter levels, set atmospheric nitrogen, recycle nutrients, modify microclimate and optimize the system's productivity always respecting the concept of sustainable production. According to Noscue (2014), agroforestry objectives may also be applied to the growing of coffee (*Coffea arabica* L.).

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Due to the elevated level of components that constitute them and the interaction dynamic between them, agroforestry systems with coffee (SAFC) may be catalogued as complex systems, as they comprise interconnected parts, the links of which generate information for the observer and, as a result of interactions, properties that may not be explained from properties of isolated or separate elements appear. In SAF, the interaction of their components generate an adequate microclimate, in particular in suboptimal areas for coffee-growing (Farfán, 2014). The SAFC is usually compared with a forest as a similar ecological value may be attained (Manson *et al*., 2008). Forests are recognized as important systems due to the environmental services that they provide, such as carbon storage and capture, oxygen production, scenic beauty, habitat for diverse animal species; also, forests are indirect providers of water supply for urban life, fauna, medicinal plants and, in general, major elements of wild life (CEDERSSA, 2011; Moraga *et al*., 2011).

According to Londoño *et al*. (2014) "state-of-the-art means studying a substantial portion of relevant literature and sources of information in an area and develops an understanding process that converges in a global and integrating vision and a communication of this result for others." Therefore, the objective of this work was to identify the current coffee-growing knowledge of coffee as agroforestry systems, with emphasis on Mexico.

METHODOLOGY

A search and review of literature was made on the Internet via Google®, for documents published between 1984 and 2017, that were obtained through keywords "agroforestry and coffee plantations" and "coffee agroforestry systems in Mexico." The central subject were agroforestry systems and coffee. The search threw documents with other subject that contained keywords, although there were not deemed to be of interest for our research. Each document was analyzed to know what, how, where and why studies have been performed in subjects that comprise the previously mentioned concepts.

RESULTS

A total of 88 documents in the form of technical note, books written in Spanish and English, scientific papers in Spanish and English, guidelines, monographs and theses were found. Documents were made in Puerto Rico, Nicaragua, Peru, Honduras, Colombia, Costa Rica, and other countries in Latin America, and even from institutional agreements by Mexico-Nicaragua-Bolivia-Spain-Italy. The greater number of studies published in Colombia by CENICAFÉ (*Centro Nacional de Investigaciones de Café*) stands out with 27 documents, followed by CATIE (*Centro Agronómico Tropical de Investigación y Enseñanza*) of Costa Rica. 20 documents related to agroforestry were found in Mexico, but only 11 were specific of coffee under the shade or SAFC (Table 1).

Overview of SAF Agroforestry Systems

Agroforestry Systems (SAF) are quoted for their forms of use and handling of natural resources, in which wood species of trees and multiuse trees (fruit, timber, foraging or living fences) are used in a sustainable domain. Also, this is referred to due to agricultural crops and/or animals of financial value and ecological and economic interactions between components. These interactions may be simultaneous and directly (synchronic) of components in the land or with a temporary sequence (diachronic) with a chronological interaction, without being present at the same time in the same land unit. Also, these refer to the application of handling practices compatible with cultural practices of the local population (Nair, 1993; FAO, 1999; Farfán, 2014; Noscue, 2014; López, S/F).

SAFs have been developed as an option for the handling and preservation of natural resources of the tropic that are found within a rapid degradation process. With the introduction of trees to these ecosystems, a greater total yield may be obtained as the diversity is kept and sustainable use of resources is promoted or the degradation of the land and loss in biodiversity is avoided at least (Farfán, 2012). Villavicencio-Enríquez (2013) recommended performing the social-economic analysis on the handling of SAF, based on sustainability, the preservation of resources and their biodiversity; income and outcomes of the system in form of inputs and products are to be identified together with processes generated between them to determine the SAF functionality.

General Definition of the Coffee Agroforestry System

Farfán (2012) defines that coffee agroforestry system (SAFC) as the "set of handling practices where tree species in association with (sic) coffee or tree planting of farms; the objective of which is the handling and preservation

Table 1. Research works performed in Mexico on coffee agroforestry systems from 1999 to 2017.

Title	Author	Year	Type of Material
Definition of shade-grown coffee with biophysical criteria	Instituto de Ecología, A. C.	1999	Workshop Results Report
Handling of tree species for agroforestry systems in the Maya Tzotzil-Tetzal region in northern Chiapas	María Lorena Soto Pinto	2000	Project final report
Coffee Agroforestry Systems. Production of more than a beverage	Lissette Rodríguez Rubí	2001	Abstract
Analysis of the Tree Structure of the Rustican Agroforestry System of Coffee in San Miguel, Veracruz, Mexico	Luis Villavicencio-Enríquez & Juan I. Valdez-Hernández	2003	Scientific Paper
Agroforestry Experience for Carbon Capture in Indigenous Communities in Mexico	Lorena Soto-Pinto, Guillermo Jiménez-Ferrer, Adalberto Vargas Guillén, Ben de Jong Bergsma, Elsa Esquivel-Bazán	2005	Scientific Paper
Agroforestry Characterization in Traditional and Rural Coffee Systems in San Miguel, Veracruz, Mexico	Luis Villavicencio-Enríquez	2013	Scientific Paper
Timber Agroforestry System in Mexico	National Forest Commission and Universidad Autónoma Chapingo (CONAFOR-UACH)	2013	Literature Review
Tree Structure and Diversity in Agroforestry Systems of Coffee in the Atoyac Mountains, Veracruz	Luis E. García Mayoral, Juan I. Valdez Hernández, Mario Luna Cavazos and Rosalío López Morgado	2015	Scientific Paper
Innovation with pink cedar; (*Acrocarpus fraxinifolius*) as a coffee-growing agroecosystem in central Veracruz	Sergio Sánchez Hernández	2016	M.Sc. Dissertation
Characterization of the Shade-Grown Coffee Agroecosystem in the Copalita River Basin	María Estela García Alvarado; Gustavo Omar Díaz Zorrilla; Ernesto Castañeda Hidalgo; Salvador Lozano Trejo; María Isabel Pérez León	2017	Scientific Paper
Diversification of Traditional Shade of Coffee Plantations in Veracruz through Timber Species	Sergio Sánchez Hernández; Martín Alfonso Mendoza Briseño and Raúl Vidal García Hernández	2017	Scientific Paper

of land and water, the increase and maintenance of production to guarantee sustainability and the strengthening of the socioeconomic development of coffee-growing families." Also, the "tree planting" term is defined as the capacity to establish trees in the coffee-growing farm without using space destined to the establishment of crops and without affecting coffee production. Rodríguez (2001) quotes SAF in coffee defined as "a set of land utilization techniques that combine the use of forest trees with coffee seeding."

The use of trees as a shade in coffee plantations began as a growing practice by growers in Asia and Africa. Shading was chosen and lay down without further analysis, by using any species; the result thereof was disadvantageous for coffee growers and, as a consequence thereof, the practice lost legitimacy (Farfán, 2014). The natural adaptation of coffee to underwood of shade trees is a strong argument for agroforestry practices in coffee production. *Inga* genus species are shade trees of greater use for coffee and cocoa (*Theobroma cacao* L.) in Mesoamerica, except for Costa Rica where *Erythrina poepigiana* (Walp.) O. F. Cook, is the most abundant species in coffee agroforestry systems (SAFC) (Cannavo *et al.*, 2011). For Farfán (2012) a tree employed for coffee plantation shade has to gather the following characteristics: a) being a legume on account of its potential to fix atmospheric nitrogen; b) adapting well to coffee climate; c) being of rapid growth and long life; d) having abundant branches and good height; e) the conformation of its foliage should not interfere with the passage of the sun; f) developing deep roots; g) being timber and withstand winds; and h) being immune to plagues that may affect the coffee plant.

Examples of Studies Performed in SAFC in Mexico

Sánchez *et al.* (2017) studied the diversification of traditional shade of coffee plantations in Veracruz through timber species. Interviews documented the existence of timber utilization forms and the economic inputs of tree species introduced in shade-grown coffee farms in central Veracruz. They visited farms to recognize the species and evidence the producer's knowledge on these species and the traditional and commercial growing of coffee. Producers prefer the Spanish cedar (*Cedrela odorata* L.) and encino (*Quercus oleoides* Schltdl. & Cham.), known locally as timber tezmol; at the same time, encino (*Quercus laurina* Bonpl.), pink cedar (*Acrocarpus fraxinifolius* Wight *et* Arn.), achiotillo (*Alchornea latifolia* Sw.) and ice cream bean (*Inga edulis* Mart.) as a shade for coffee trees.

In 2015, García and his collaborators characterized the structure and diversity of arboreous vegetation in three coffee agroforestry systems: rural, simple polyculture, complex polyculture and semi-deciduous of the Atoyac mountains, Veracruz. They sampled 917 individuals distributed in 90 taxa. Identified species identified were distributed in 32 families and 65 genera. The complex polyculture shows more richness in species than the rural system and simple polyculture. The most important species in the SAFC structure was *Cordia alliodora* Cham.; and, for the semi-deciduous forest were *Bursera simaruba* (L.) Sarg. and *Myriocarpa longypes* Liebm., with no significant statistics between it and the complex polyculture.

In order to perform an agroforestry characterization of the traditional coffee-growing system (STC) and the rural coffee system (SRC) in San Miguel, Amatlán de los Reyes, Veracruz, México, Villavicencio-Enríquez (2013) performed an inventory of canopy species as an experiment as well as obtaining information for the functional and socioeconomic analysis by means of interviews to community producers. STC considers a lower number of canopy species, which only meets the shade option for coffee, while the SRC employs the natural canopy of the tropical rainforest, which preserves a greater number of native species based on their structures, composition of species and use of canopy trees. Both systems obtain similar financial benefits, although the composition of canopy species and obtained products are different. The main economic product are timber trees, followed by coffee and palm trees *Chamaedorae tepejilote* Liebm. and *Chamaedorae elegans* Mart. The sale of forest and agricultural products gave 2.5 times as much financial gain for SRC than STC. Both production systems may be profitable when handled in a sustainable manner and with the sale of coffee and other organic-type products.

Soto-Pinto *et al*. (2005) studied the carbon capture in the northern zone, the border zone and the Chiapas jungle, where growers were involved in a project that began in 1994; by means of participative methodologies, they exchanged information with technicians in a process of mutual learning. They laid down agroforestry systems in individual lands, in agricultural areas susceptible of enriching with trees: shade-grown coffee, fallow corn systems, continuous use corn (without fallow), with silvopasture systems, diversified plantations and natural forest regeneration systems. They consider that the sale of environmental services is an activity complementary to productive activities for each family, as agroforestry systems allow greater income in the medium and short terms.

Villavicencio-Enríquez & Valdez-Hernández (2003) proposed analyzing the vegetation structure of the rural coffee agroforestry system (SAF) (*Coffea arabica* L., *Coffea canephora* Pierre ex A. Froehner) and comparing it with the semi-deciduous forest with little disturbance (SMSP), through the determination of importance value indexes and species diversity, and performing the taxonomic identification of all tree components. The prepared a species-area curve that consists in charting the number of vegetation species found for a sampling surface and they obtained the Jaccard coefficient (*Cj*), to know the floristic similarity between studied systems. They found a total of 81 tree species that belong to a native, secondary and exotic vegetations, of which 62 were present in the rural coffee SAF and 66 in the semi-deciduous forest. The Jaccard coefficient (*Cj*) for both studied systems was 0.58, which indicates a floristic similarity of 58% and 42% of different species between both systems. Diversity and equity values were greater in the SMSP system compared to the rural coffee SAF, which shows greater richness of species and a more equitable distribution in sampled jungle units.

DISCUSSION

Agroforestry may be deemed to be more than a single and finished technology. Although several finished systems have been conceived and tested, such technology may require an adjustment for particular situations. The flexibility that the agroforestry focus is one of its advantages. Agroforestry systems limit risks and increase agriculture sustainability, both at a small and big scale. Also, they may be deemed to be main parts of the agricultural system itself, as it contains other subsystems that define a way of life. In order to plan on the use of trees in agroforestry systems, it is necessary to have a considerable knowledge of its properties. Information desirable for each species includes its benefits, its adaptability to local conditions (weather, soil and stress), the size and shape of the canopy, root system and the suitability of several agroforestry practices (Martin *et al.*, 2007). It is also recommended that the potential shown by each agroforestry plantation has to be foreseen as a shelter for the preservation of biodiversity, both in vegetables and animals. Although CEDERSSA (2011) reports that the contribution of 1% to the gross domestic product (PIB) from forest activity in Mexico has little significance, its presence in national life has great importance, as its spaces are environmental service suppliers.

The combination of trees and crops is an association between different beings that coexist and commonly differ in economic yields. As for coffee plantations in agroforestry systems, the combination has to be made with trees of which lesser profits would be expected. Therefore, the introduction thereof in crops should no cause losses in productivity, no matter how valuable the environmental service is. The task is to know, identify and integrate forest and agronomic technologies both to silviculture and agriculture. For this, the knowledge of rural social traditions and the abilities in human relations should be supported (Farfán, 2014). If this is established under the shade of an adequate species and distance, coffee may produce the same as if it were under free exposure, depending on the variety of used clones. In productivity terms, there are contrasting results. Lymbaeck *et al*. (2001) found that the productivity average in organic coffee farms is 23% lower than the production of conventional farms. While Villarreal *et al*. (2002), state that the production average in organic production systems of the Mesa de los Santos farm in Santander, Colombia was 20% greater than the production of technical conventional farms.

Research performed by Farfán (2010) that compare organic coffee grown under the sun and organic under the shade in environmental conditions of Colombia indicate that it had a greater harvest in the first century under the handling under full sun; nevertheless, after the plantation cycle, the production is similar, except for seeding densities in the growing process. The handling of organic coffee under the shadow recommends the installation of densities greater than 4,000 plants ha^{-1}; also, it does not recommend growing coffee under full sun with organic handling. There are no sufficient studies that allow comparing results of other countries with Mexico or even perform comparisons between Mexican coffee regions and states. For this, in order to preserve biotic resources of the central Veracruz coffee region, it is necessary to assess the environmental impact of the entire removal in order to grow coffee at full solar exposure or to introduce yearly crops. The shades of traditional polycultures, in combination with banana, ice cream bean or citrus, contribute to maintaining soil fertility, as well as reducing erosion, supplying organic matter produced by litter and fixing atmospheric nitrogen. In the short term, the full sun coffee growth may produce satisfactory results for the economy; nevertheless, the suppression of the tree stratum in a fog zone, just like the central part of Veracruz, may have terrible consequences in the long run (Barradas & Fanjul, 1984) (Figure 1). In turn, Contreras & Osorio (2015) recognize that the coffee-growing regions in Veracruz were defined decades ago and, currently, the manner in which the coffee crisis modified this production zones is not known. Therefore, it is pertinent to analyze the evolution of coffee-growing regions and redefine those regions known for their new characteristics. Interdisciplinary studies supported by conceptual agroecology frameworks, social anthropology and rural sociology that help actors

Figure. 1. Example of current situation of land with the coffee agroforestry system in the municipality of Tlacotepec de Mejía, Veracruz, Mexico. November 2018.

involved in the production to identify and overcome challenges associated to the development of sustainable handling strategies in the agricultural sector are required.

There is little information related to functions, structure and benefits of the coffee-growing agroforestry system, reason why the performance of studies that reveal the influence of tree species used as a shade in coffee plantations is justified. Even when institutions that do research to this respect have international reputation, the information obtained in Colombia and Costa Rica, which also attains the first places in biodiversity shelter may not be compared. Tree species that exist in combination with coffee plants in some coffee-growing zones in the states of Chiapas and Veracruz in are known in studies performed by Colegio de Postgraduados, ECOSUR, Instituto de Ecología A. C., Colegio de Veracruz, Universidad Veracruzana, Universidad Nacional Autónoma de México and Universidad Autónoma Chapingo. What happens to other coffee-growing states in Mexico?

CONCLUSIONS

Forest specialists both in agronomy and agroecology recognize that polycultures, agroforestry and other diversification methods imitate the natural ecological processes and that the sustainability of complex agroecosystems is based on the ecological models that are followed by these production methods. It is recognized that, depending on variety, coffee has greater yields in monoculture or plantations without employing shade; although these systems are not favorable for the preservation of the environment and biota, as its modernization considers an indiscriminate use of agrochemicals. The employment of shade in the coffee-grown area has been documented and the biodiversity, absorption of water and nutritious contribution of trees in the coffee plantation, contribute with other products such as timber, wood or fruits, necessary for the agroecosystem's self-supply. It is suggested to do further research related to agroforestry systems in general with the coffee-growing agroforestry system in Mexico, as the information available is scarce, as even the contribution of the coffee agroforestry system to the Mexican coffee-growing industry is known.

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The Postgraduate Course in Tropical Agroecosystems: Facing the Challenges for Mexican Agriculture in the 21st Century

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ABSTRACT

Objective: To analyze the contemporary scientific contributions of the Postgraduate Course in Tropical Agroecosystems (PTA), both in Master's and PhD Degree, of Colegio de Postgraduados, Veracruz Campus, before the current challenges facing the Mexican agriculture.

Design/Methodology/Scope: A search was made in SCOPUS and Web of Science for publications between 2014 and 2019 (N = 92) by PTA researcher scholars. A text analysis was performed by using the Nvivo software in order to identify scientific contributions based on the problem categories suggested by FAO for Mexico.

Results: Scientific contributions are more prolific in relation to the increase of agricultural productivity (66%), have lesser presence in sustainable practices (14.9%) and the articulation of public policies (10.6%) and begin to appear in the adaptation and mitigation of climatic risks (8.5%).

Limitations/Implications: The findings excluded publications that do not appear in SCOPUS or Web of Science or outside the analyzed period.

Findings/Conclusions: The PTA shows social relevance when generating knowledge, with scientific contributions to the current challenges of Mexican agriculture. Nevertheless, they have been oriented mainly to increasing agricultural productivity without attaining the risks of PTA toward transdisciplinary research processes. This suggests a new role of research that addresses disciplinary interfaces.

Keywords: Mexican agriculture, scientific contributions, system approach, institutional impact, social significance of the postgraduate course.

INTRODUCTION

Society expects that postgraduate courses perform complex functions, such as the generation of knowledge, training of creators, thinkers, professionals, researchers and leaders for social, economic and political development (Cardoso & Cerecedo, 2011). They are a strategic element for

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the development of scientific competences, reason why an indicator of their quality are the scientific contributions published in high-impact magazines with useful knowledge (Ortega *et al*., 2017). In Mexico, these contributions have a high weight in order to belong to the National Quality Postgraduate Program (Programa Nacional de Posgrados de Calidad, PNPC), of the National Committee of Science and Technology (Consejo Nacional de Ciencia y Tecnología, Conacyt); for the agricultural and rural sectors, the postgraduate courses are aimed at providing guidelines that allow the government to set the public agricultural policy to cooperate in the solution for its problems (Reyes & Reyes, 2018). In this context, the objective of this work was to analyze the contemporary scientific contributions of the Postgraduate Course in Tropical Agroecosystems (PTA) both at Master's degree and PhD.

Origin and Evolution of the Postgraduate Course in Tropical Agroecosystems

In 1993, the Veracruz Campus began the Master's Degree in Tropical Agroecosystem Sciences, based on a diagnosis, forecast and prospective for tropical agriculture in Mexico; the PhD in Sciences was incorporated in 1994. Before the program, there were research lines, some of which were addressed individually by the researchers. In 2001, research lines that were aligned with social and scientific trends on the handling of natural resources and production of foodstuffs were implemented, and this resulted in a robust program development. The educational scopes of students should be both national and international; the PTA has fostered the agroecological focus for the analysis of agroecosystems (AES) and an integrated agricultural perspective. In 2014, their knowledge generation and/or application lines (Lineas de Generación y Aplicación del Conocimiento, LGAC) were addressed at three levels: a) agroecosystems and their relationships with the territory, b) processes and interactions in the handling of AES and c) self-regulated ecological processes. Today there are three lines: 1) Assessment and Re-Design of Agroecosystems (ARAES), 2) Tropical Agroalimentary and Agroindustrial Chains (TAAC), and 3) Natural Resources, Agroecosystems and Climate Change (NRACC). The postgraduate course seeks to develop capacities under the competence focus in order to apply and transfer knowledge in productive units, under an integrated focus of agricultural and natural resources use, with interdisciplinary participation (CP, 2017).

Agroecology: Disciplinary Framework of Agroecosystems

Since the beginning, PTA professors considered the agroecosystem to be their unit of study and as a scientific discipline of agroecology (Martínez *et al*., 2011; Ruíz, 2006). Agroecology is an approach for understanding the ecological principles of traditional agricultural systems and to define, classify and study these systems from an ecological and socioeconomic perspective (Altieri, 1989; Méndez *et al*., 2013). Agroecology stopped seeing the field or plot scale (1930-1960) and began the perception of an agroecosystem (1970-2000) (Wezel *et al*., 2009; Wezel & Jauneau, 2011); the PTA was consolidated in this last period. The study of agroecosystems initially considered the components and functions of natural ecosystems, including local knowledge and production strategies based on ecological principles (ecological handling of plagues, association of crops and agroforestry systems (Altieri *et al*., 1999; Argüello, 2015; Gliessman, 2011). Currently the agroecosystem is studied as a unit of analysis from the systems approach; it considers both ecology, social and political aspects in the context of decision-makers (farmers) (Gallardo *et al*., 2018); together with this growth in intention (qualitative) and extension (qualitative) of agroecology and its unit of study, the PTA has co-evolved as a response to the complexity of social demands.

MATERIALS AND METHODS

A query was made on the SCOPUS and Web of Science databases in February 2020, with the name of each PTA researcher; the last 5 years were considered (2014-2019). SCOPUS gave 138 scientific papers and Web of Science gave 101; upon suppressing repeated papers there were 92 papers left. In both databases information on 23 researchers was found from a total of 28 PTA professors. The final database had the name of the author, the publication, the magazine, volume, issue and publishing year. A Word file with the title, year, abstract, keywords and conclusions was created for each document. A text analysis of these documents (Gallardo *et al*., 2018; Gallardo *et al*., 2019) was made by analysis category of challenges for Mexican agriculture set in advance according to FAO's classification (2018): 1) effective alternatives to adapt and mitigate climate risks, 2) sustainable practices in the handling of natural resources, 3) knowledge and practice of indigenous communities and 4) articulation of public social protection and economic development policies that leverage an integrated human development. The NVivo

12 Pro for Windows was used for the analysis of contents (Kaefer *et al.*, 2015). An emergent category named "increase in agricultural productivity" was identified.

RESULTS AND DISCUSSION

The queried publications (N = 92) show an intensification in the last two years: 2014 (5.4%), 2015 (12%), 2016 (16.3%), 2017 (16.3%), 2018 (28.3%) and 2019 (21.7%). The text analysis found scientific contributions in the following categories: effective alternatives for adapting and mitigating climate risks (8.5%), sustainable practices in the handling of natural resources (14.9%), articulation of public social protection and economic policies that intensify an integrated human development of rural population (10.6%) and increase in agricultural productivity (66%), a more prolific category. No contributions of "knowledge and practices of indigenous communities" were found. The orientation of publications is related to the increase in production and is supported by their text contents (Figure 1).

Effective alternatives for adapting and mitigating climate risks

This category showed both renewable energies and the adaptation of flora and fauna and social and cultural responses to attain the adaptation and mitigation of climate risks until reaching the design of strategies by farmers (Ávila *et al.*, 2018; Casanova *et al.*, 2016, 2018; Casanova *et al.*, 2019; Castellanos *et al.*, 2017; Pérez *et al.*, 2016; Torres *et al.*, 2016; Vilaboa *et al.*, 2019).

Sustainable practices in the handling of natural resources

These contributions are oriented toward the preservation of flora and fauna (handling and consumption), soil improvement practices, organic fertilizers for the sustainable production of crops, handling of natural resources and adequate use and handling of pesticides (Avendaño *et al.*, 2018; Candelaria *et al.*, 2014; Cisneros *et al.*, 2015; Cruz *et al.*, 2019; Chontal *et al.*, 2019; De Farias *et al.*, 2015; García *et al.*, 2015; Jacinto *et al.*, 2017; Linares *et al.*, 2018; Linares *et al.*, 2017; Llarena *et al.*, 2019; Nikolskii *et al.*, 2019; Ramirez *et al.*, 2016; Vandepitte *et al.*, 2019).

Articulation of Public Social Protection and Economic Development Policies that Intensify an Integrated Human Development of the Rural Population

Forms of implementation of public policies, the main role of actors and performed strategies, agroecology as emergent production forms, which has evolved together with science, farmer practices and social movements appear in this category (Arroniz *et al.*, 2015; Casanova *et al.*, 2015; Cruz *et al.*, 2019; Figueroa *et al.*, 2019; Gallardo *et al.*, 2018; Gallardo *et al.*, 2019; Guerrero *et al.*, 2016; Ireta *et al.*, 2018; Platas *et al.*, 2017; Quintero *et al.*, 2017).

Increase in Agricultural Productivity

The contributions propose an increase in animal, forestry and crop productivity. The livestock part does research on ovines, bovines, birds, bees and rabbits, byproducts thereof and factors that limit production (Arce *et al.*, 2017; Dominguez *et al.*, 2015; Fraire *et al.*, 2018a; Fraire *et al.*, 2018b; González *et al.*, 2016; Herman *et al.*, 2019; Hernández *et al.*, 2017; Hernández *et al.*, 2018; Hernández *et al.*, 2016; Huerta *et al.*, 2018; Juárez *et al.*, 2016; Ramírez *et al.*, 2018a; Ramírez *et al.*, 2018b; Ramírez *et al.*, 2017a; Ramírez *et al.*, 2017b; Ramírez *et al.*, 2017c; Rivera *et al.*, 2016; Rodríguez *et al.*, 2017; Romero *et al.*, 2018; Rosales *et al.*, 2018; Sosa *et al.*, 2014; Yáñez *et al.*, 2018). Within the factors that limit or improve the production, sociocultural, technological and productive aspects that suggest fostering the use of technology to improve productive indexes are identified (Juárez *et al.*, 2015; López *et al.*, 2017; Maldonado *et al.*; Purroy *et al.*, 2015). In the forestry part, the availability of nutrients in the production of commercial forest species is addressed (Montero *et al.*, 2019; Rodríguez *et al.*, 2014; Santiago *et al.*, 2016). The contributions on the production of crops are more prolific and include basic crops, fruits, grass

Figure 1. Conceptual superlatives in scientific contributions of the Tropical Agroecosystem Program.

and forage, citrus fruits and energy crops (Aguas *et al.*, 2014; Alamilla *et al.*, 2016; Andrés *et al.*, 2017; Calzada *et al.*, 2014; Espinosa *et al.*, 2018; García *et al.*, 2016; García *et al.*, 2019; Grifaldo *et al.*, 2019; Guillén *et al.*, 2018; Gutiérrez *et al.*, 2018; Hernández *et al.*, 2015; Hernández *et al.*, 2016; Hernández *et al.*, 2018; Hernández *et al.*, 2019; Ibarra *et al.*, 2018a; Ibarra *et al.*, 2018b; Jaimez *et al.*, 2015; José *et al.*, 2017; Mendoza *et al.*, 2019; Mendoza *et al.*, 2015; Pérez *et al.*, 2016; Rueda *et al.*, 2016; Rueda *et al.*, 2018; Sánchez *et al.*, 2018; Valdes and Pérez, 2019; Villanueva *et al.*, 2019.

The current PTA challenges suggest that the subject matter of the study and generation of knowledge integrate experiences of stakeholders in a transdisciplinary research process (CP, 2017). Nevertheless, the results show scientific contributions oriented to increasing productivity, in congruency with the development of scientific research in the last 60 years that fosters a highly productive and profitable agriculture, although with environmental and social consequences (Sarandón, 2019). Similar studies are centered under the perspective of social relevance without considering scientific contributions like this work does, although with similar results, reflections and conclusions. Garrocho & Lazcano (2012) explored the social relevance of scientific research projects of Universidad Autónoma del Estado de México; these evidence the need of a more integrated academic structure centered on social relevance criteria that guarantee a sustained progress of knowledge areas, but which mainly contribute to reaffirming the commitment of scientific communities with their social environment. In the state of Chihuahua, Hernández *et al.* (2017) suggested orienting the training of researchers in a curriculum design that is congruent with the context in order to respond to real needs. As for postgraduate degrees in Universidad Autónoma de Nuevo León, Duéñez *et al.* (2018) considered that the relevance in education should be reviewed constantly and this allows changes in policies toward a contemporary education, such as reinforcing research competences for the design and implementation of innovative projects. This analysis on the scientific contributions of PTA and its contribution before the challenges of Mexican agriculture are the background for re-thinking our research, as the current administration points to a development model that prioritizes emergent social and economic issues to attain human wellbeing and development (Muñoz, 2019).

CONCLUSIONS

Publications generated from 2014 to 2019 by postgraduate course Tropical Agroecosystems researchers show that the research is oriented mainly to an increase in agricultural productivity, with low social relevance, according to the main challenges identified by FAO. This shows contributions with respect to sustainable practices and the articulation of public policies; initial contributions to the adaptation and mitigation of climate risks, although there were no contributions from the knowledge and practice of indigenous communities. This also suggests laying down a new role for the research of the program to address complex contemporary challenges and disciplinary interfaces with a transdisciplinary trend.

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Resilience as an Adaptation Strategy of Agroecosystems in the light of Climate Change

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ABSTRACT

Objective: To analyze the resilience concept as a property of agroecosystems to face potential climate change scenarios.

Methodology: The literature related to concepts such as resilience, vulnerability, climate change scenarios and resilience in agroecosystems was analyzed.

Results: Resilience is an upcoming property and it is part of the trajectory of agroecosystems and it is also closely related to the capacity of adaptation and self-learning.

Limits: Weak elements should be strengthened and feedback for the agroecosystem controller should be fostered in order to increase adaptation capacities.

Conclusions: The promotion of agroecosystem resilience should start from the integration of indicators in environmental dimensions, governance, risk assessment, knowledge and education, risk management and vulnerability reduction, disaster preparation and response.

Keywords: Exposure, natural disasters, temperature.

INTRODUCTION

Natural disasters have been experienced throughout history in different human civilizations. In Mexico, the oldest disaster reports go back to pre-Hispanic times, which were recorded in codices (Therrell *et al*., 2004). The impact of natural disasters on society is significant to the degree of making it prone to collapse, as it happened in lowland Mayan cities, where the cause for their collapse could have been due to the incapacity of the government system to maintain social and cultural balance in the light of a great draught caused by strong climate changes and an intense solar cycle (De la Garza, 2018). Due to natural disasters from 1998 to 2017 in poor countries, 130 individuals out of one million inhabitants have died as opposed to rich countries where only 18 out of one million individuals die. This means that citizens of poor countries are more exposed to natural disasters and that the likelihood of dying in these nations is seven times greater compared to persons inhabiting rich countries. Human losses happen frequently in environments exposed to natural dangers and problems caused by man, such as poverty, lack of ecosystems, protectors and institutional incapacity to prepare for and respond to extreme natural phenomena (Wallemacq & House, 2018).

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As for Mexico, in the last 30 years the yearly average of natural disasters has increased to more than twice. According to CENAPRED (2014), the catastrophes that have increased more are weather events (tropical storms, winter storms, droughts and tornadoes), water events (flash floods, tidal waves and landslides) and weather events (heatwaves, frosts, forest fires and droughts). Between 2000 and 2014, the country showed losses accounting for US$2 147 million caused by disasters of natural origin (CENAPRED, 2015). In poor and emergent economies, a natural disaster also means greater attachment to the financial poverty of their citizens, due to material losses amplified by the effects of natural phenomena. With anticipated changes in the global climate system and the vulnerability of systems, it is possible that the frequency and impact of extreme events will increase in the future. As a result of climate change, it is likely that coastal cities will be affected by the increase in sea levels. As for natural systems (ecosystems) and agricultural production systems (agroecosystems), the increase of temperature and the decrease in rain will affect their current distribution and productivity (IPCC, 2015). Within the agroecosystem context, it is important to ensure the production of foodstuffs for humanity, reason why the development of robust agroecosystems with high resilience capacity, that allow minimizing losses caused by extreme weather phenomena is necessary. The aim of this study was to analyze the resilience concept as a property of agroecosystems to face potential climate change scenarios.

MATERIALS AND METHODS

A literature review was made with the keyword "resilience"; the association thereof with the words "vulnerability", "agroecosystems" and "climate change" was used as selection criterion in academic search engines (SciELO, Redalyc, Google Scholar, ISI Web) and the CENAPRED database. Then the clearing of results followed. Once the articles that addressed resilience as an emergent property of agroecosystems were identified, concepts and methods were reviewed and identified. Municipal vulnerability and resilience data found in the CENAPRED database were analyzed through the Qgis software, version 3.6.

RESULTS AND DISCUSSION

Vulnerability

Within the context of agroecosystems, vulnerability may be defined as the susceptibility or tendency that the exposed systems have to being affected or damaged by the effect of a disturbing phenomenon. In general terms, two types of vulnerability may be distinguished: physical and social. The quantification of the former is more feasible. For example, in the number of resistant plants against the forces of wind produced by hurricanes,

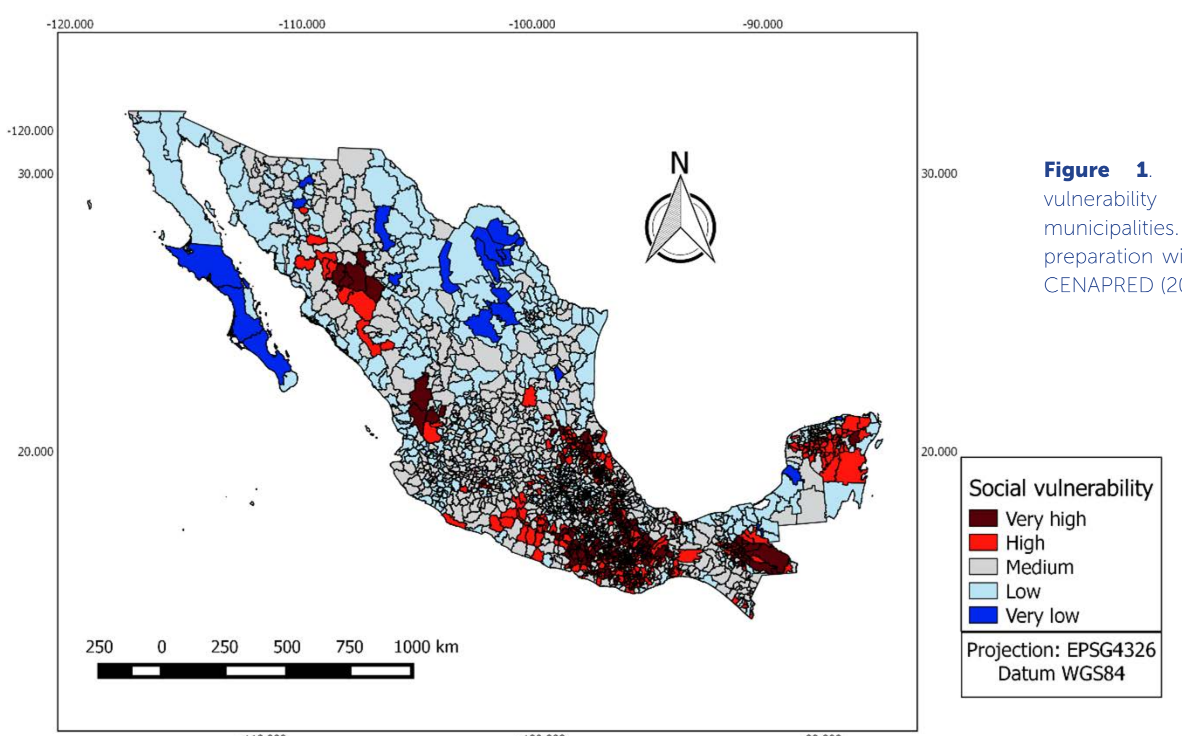

Figure 1. National social vulnerability classification of municipalities. Source: Self preparation with information of CENAPRED (2015).

which is different to the latter, which should be appraised in quality and which is relative, as it is related to economic, educational, and cultural aspects and the degree of preparation of persons (Zepeda *et al*., 2014). For Mexico, most of the municipalities classified as "high" and "very high" social vulnerability are located in the southeast (Figure 1) and associated to marginalization and "high" and "very high" poverty (CONAPO, 2013).

It is likely that agroecosystems distributed in municipalities with greater vulnerability are also vulnerable to the effects of climate change. The European Environment Agency (EEA, 2004) defines vulnerability as "the fact that citizens may be subjects of negative effects of climate change; either as individuals, members of a community, citizens of a country or part of humanity in general." The Intergovernmental Panel on Climate Change (IPCC, 2015) defines vulnerability as the "degree at which a system is susceptible or incapable of facing adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of character, magnitude and rapidness of climate change and the variation at which a system exposes its sensitiveness and adaptation capacity."

Table 1. General characteristics of scenarios used to study climate change (IPPC, 2015).

Scenarios	Description
A1	A quick economic growth and introduction of new, more efficient technology.
A2	A socially heterogeneous world with emphasis in family values and local traditions.
B1	A world with de-materialization and introduction of clean technologies.
B2	A world with emphasis on local solutions for economic and environmental sustainability.

Climate Change and its Scenarios

Climate change scenarios are a plausible and often simplified representation of the future climate, based on a set of weather relations which are constructed to be used in the research of potential consequences of human-generated climate change and that serve as an input for impact simulation (IPCC, 2015). Climate change scenarios are not weather forecasts, as each scenario is an alternative to how the future weather may behave depending on anthropogenic emissions of greenhouse gases (GEI). These emissions depend mainly on the size of the population, economic activity, lifestyle, use of energy, land use patterns, technology and climate policy. Due to the foregoing, the scenarios allow decision-makers to face potential future conditions and analyze the availability and usefulness of options to face an unknown future; they also allow implementing mitigation measures in the present to avoid an undesired future (INECC, 2017).

Table 1 shows four emission scenarios that have been published in the Special Report on Emissions Scenarios) developed by economists and social science researchers for the third assessment report of IPCC (2015).

The Impact of Climate Change in Agroecosystems

The increase in global temperature (Table 2) will increase the frequency of extreme weather phenomena that will have direct and indirect effects on ecosystems, biodiversity, the productivity of crops, livestock breeding, forestry, fishing and aquaculture in the years to come (IPCC, 2015). Projected impacts vary in different adaptation, crop and regional scenarios. Around 10% of projections for the 2030-2049 period show gains of more than 10% in the performance of crops and performance losses above 25%, compared to what occurred by the end of the 20th century. The most severe impact risk increases after 2050 and it depends on the warming level.

There is also a risk of violent conflict derived from the deterioration of subsistence means, which depend on agricultural and grazing resources. Water access will be lesser for poor persons in rural and urban areas due to the scarcity and greater competition for the obtainment of such resource. Due to the above, under a context of increase in temperature and decrease in rain, the southeastern states of Mexico that currently show a greater population in poverty, among which Veracruz (Figure 2) stands out as it has a greater cultivated agricultural

Table 2. Mean global temperature increase between 2081-2100 (IPCC, 2015), based on different scenarios.

Scenario	Increase in temperature (°C)
RCP 2.6	0.3 – 1.7
RCP 4.5	1.1 – 2.6
RCP 6.0	1.4 – 3.1
RCP 8.5	2.6 – 4.8

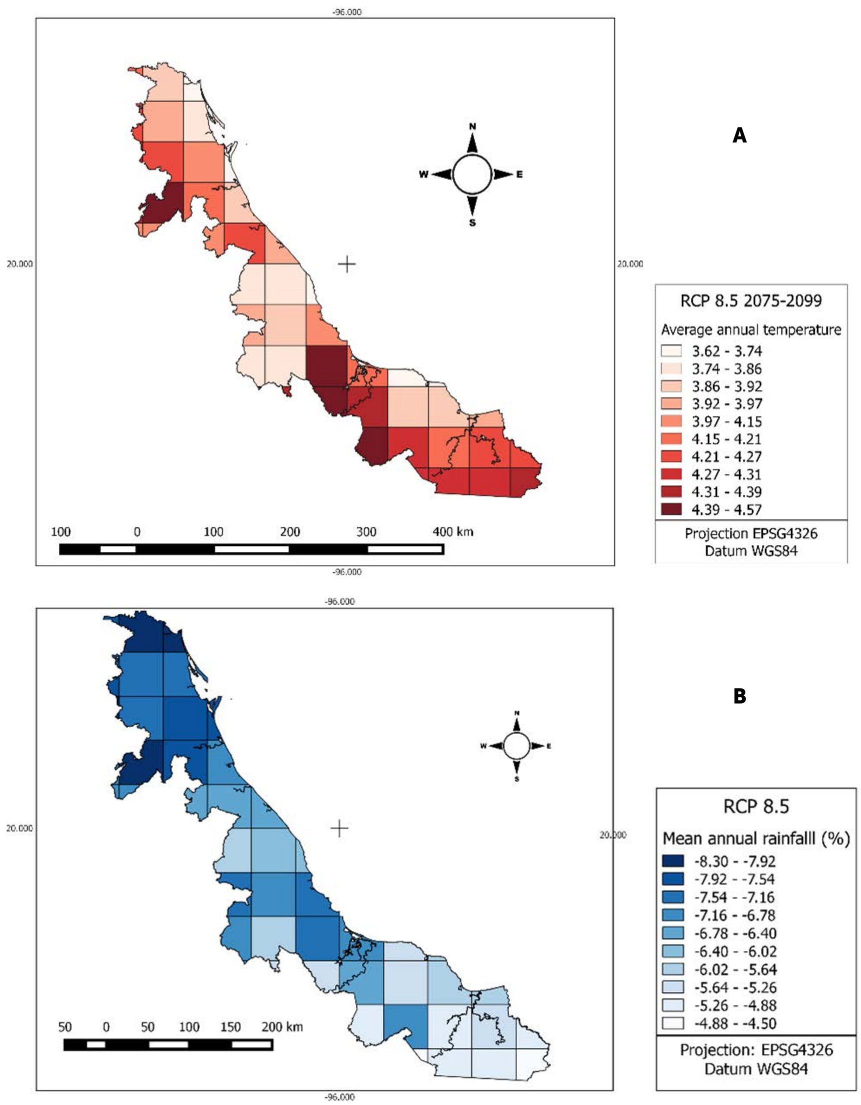

Figure 2. Veracruz state area, according to scenario 8.5, during the 2075-2099 period: A) Increase of mean annual temperature B) Decrease of mean annual temperature. Self preparation with information of INECC (2017).

area, may be considered to be at risk of conflict (CONEVAL, 2018; SIAP, 2020).

Thus, it is foreseen that the more vulnerable areas face great impacts with respect to food security, infrastructure and agricultural income, including changes in food and non-food crops around the world (IPCC, 2015).

¿What is Agroecosystem Resilience?

The word resilience comes from the latin *resi-lire* and it was used initially by physicists to describe the stability of materials and their resistance to external impacts (Davoudi *et al*., 2012; Reid & Botterill, 2013). In the 1960s, with the growth of systemic thinking, the concept was used in ecology, and its definition underlines the recovery and return to an initial state of an ecosystem after an impact (Masterson *et al*., 2014). Currently, the term resilience is used in areas such as psychology, geography, psychiatry, public health and economics, to mention a few. A resilient system is that which has a capacity to absorb or withstand impacts and its ability to maintain or return to its original structure, shape, functions or qualitative state (Miller *et al*., 2010). For the purpose of this work, the resilient agroecosystem is considered to be a set of social, economic, technological, and environmental components, the robustness, feedback and adaptation capacity of which allows the expression of resilience as an emergent property (Figure 3) (Masterson *et al*., 2014). Due to the foregoing, in agroecosystem design, farmers and technicians should establish characteristics that foster the reduction of future vulnerabilities through adaptation and innovation strategies to ensure that agroecosystems do not return the level before the impact, due to the fact that the risk of suffering the same damage would exist in case that a similar extreme event occurred. This is why a disturbance should be an opportunity for gaining experience through feedback and increasing agroecosystem robustness (Helfgott, 2018).

There are important factors for the development of agroecosystem resilience, one of which is the ability of farmers to access and use their capital (natural, financial and human) better after an extreme natural phenomenon, which would allow them to improve the economic, political and civil state and begin their accelerated recovery (Alfani *et al*., 2015). Other important factors of resilience dimensions are autonomy, food security, adequate nutrition levels, health, and education, to mention a few, as well as the versatility of modifying their system's structure, as required, in light of disaster scenarios (Akter and Mallick, 2013). In Mexico, the National Disaster Prevention Center assessed resilience at a municipal level, depending on the adaptability capacity before disruptive phenomena; it determined that the greater part of municipalities with "low" and "very low" resilience are in southeast Mexico (Figure 4). These municipalities also show low values

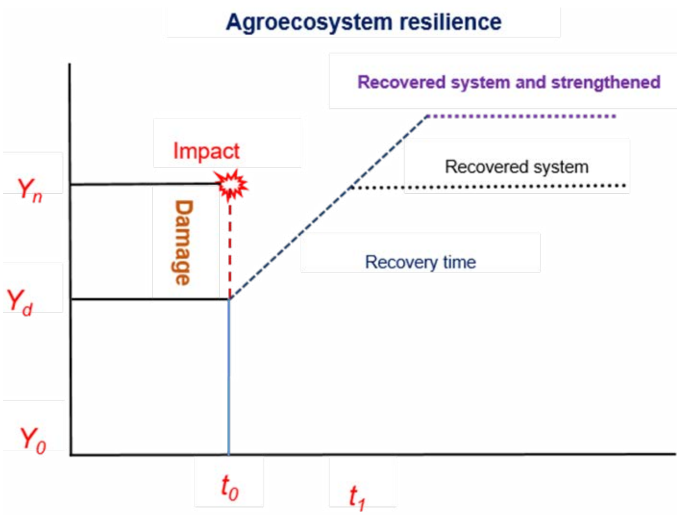

Figure 3. Dimensions of a resilient agroecosystem. t_1 = system recovered at a before-impact level; t_2 = recovery level greater than before-impact; Y_n = normal integrated agroecosystem performance level; Y_d = normal performance reduction level; Y_0 = level with total performance cost; t_0 = the impact occurs and decreases normal performance (Modified from Rose, 2009).

in terms of governance, risk assessment, knowledge and education, risk management and reduction in vulnerability and preparation and response to disasters (CENAPRED, 2015).

Key Elements for the Development of Resilient Agroecosystems

Resilience is related to what may be done by the agroecosystem by itself and how its capacities may be strengthened. Focuses on research-action and social learning turn out to be useful in the analysis of agroecosystem resilience, due to the fact that they allow the conceptualization of the necessary stages for attaining resilience (Table 3). The use of virtual tools, such as modeling based on complex agents and scenarios, allows knowing the behavior of systems under several conditions, in a timescale and with different actors (Masterson et al., 2014; U. S. Climate Resilience, 2016). The multi-factorial nature of the resilience concept predisposes the consideration of a wide diversification of variables to be measured within the agroecosystem. According to Twigg & Bunge (2007), variables may be grouped into five major areas or dimensions in which agroecosystem resilience may be measured: 1) governance, 2) risk assessment, 3) knowledge and education, 4) risk management and vulnerability reduction, and 5) preparation for and response to disasters.

The resilience analysis in the context of agroecosystems allows the conceptualization of the producer as a system of conscience, due to the fact that this intervenes in the access to the external world of communication. It is important that the producer promote learning or adaptation before disasters in order to strengthen prevention and decrease vulnerability, impact and damage of an extreme weather event; this would accelerate the recovery of the system until the attainment of resilience (Cabell and Oelofse, 2012; Casanova et al., 2015).

Another outstanding focus is the social-ecological one (Figure 5), which considers that resilience is a component

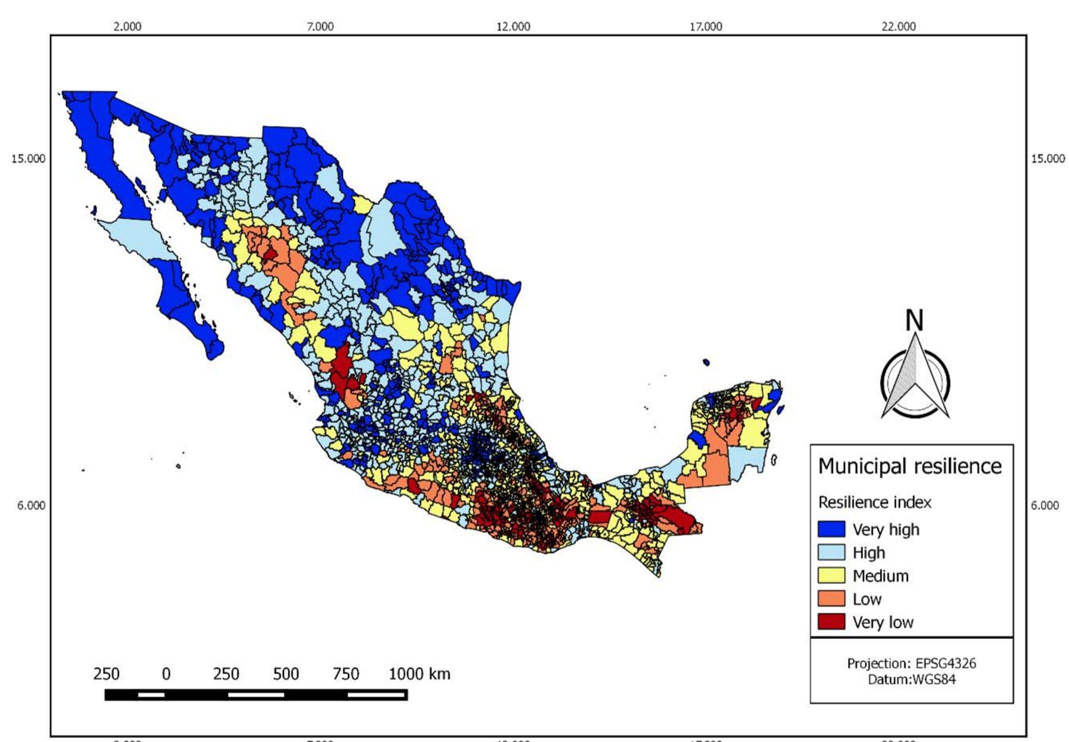

Figure 4. National municipal resilience index classification. Self preparation with information of CENAPRED (2015).

Table 3. Recommendations for attaining resilience in communities and their infrastructure (U. S. Climate Resilience, 2016).

Recommendations	Description
1) Explore climate threats	Organizes a group, explores regional climate threats and considers whether that which is appraised is threatened by weather.
2) Assessment of vulnerabilities and risks	Determines which properties exposed to a likely damage or that may be lost by the impact of climate events.
3) Research options	Performs some brainstorming on potential solutions and does research on what has been done by other groups. Underlines options in a list, where the stakeholders agree.
4) Prioritization of actions	Consolidates actions and determines the better sequence to protect most properties. Organizes resources so as to focus them on greater risks.
5) Action-taking	Implements the plan and monitors results. Modifies the focus as much as necessary.

in the trajectory of agroecosystems based on cyclic adaptability through constant feedback (Walker, 2004). From this focus, there are indicators such as social end ecological self-organization, connectiveness with other systems, rapid response, optimal redundancy, temporary and spatial heterogeneity, self-learning, global autonomy and local interdependence, documentation of past experiences, economic profitability and the constant training of human capital that allow developing an adaptation capacity and the respective redundancy in the expression of agroecosystem resilience (Cabell & Oelofse, 2012; Folke, 2016).

CONCLUSIONS

Both in social-ecological systems and agroecosystems, resilience shows a multi-dimensional and complex nature that allows regenerating in case of suffering damages to their structure. Agroecosystems show environmental, social, economic, technological and communications components that are key in the adaptation stage before changes originated by external disturbances. Making the structure of agroecosystems robust redounds in the decrease of vulnerability and allows developing resilient agroecosystems that remain before and after the impact of climate change to continue with the production of foodstuffs and fibers for the wellbeing of humanity.

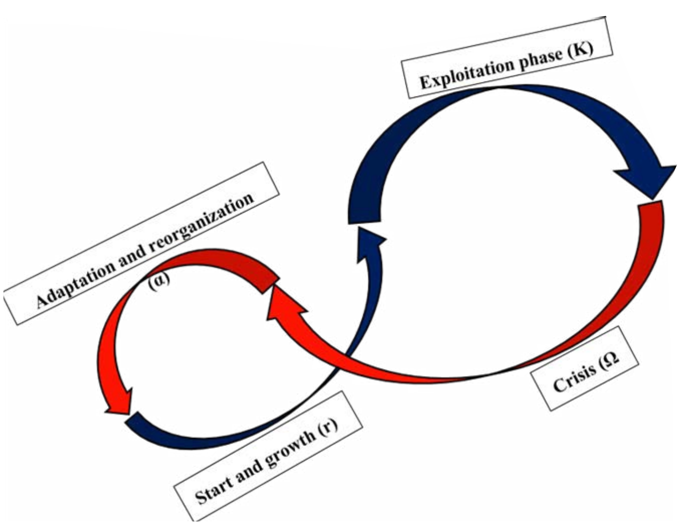

Figure 5. Components integrating the cyclic resilience process from the social-ecological focus (Walker, 2004).

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AGRO PRODUCTIVIDAD

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Waste of Fruits, Vegetables and Aromatic Herbs in the wholesale market of Xalapa, Veracruz, Mexico

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ABSTRACT

Objective: To estimate the waste of fruits, legumes and aromatic herbs in the Wholesale Market of Xalapa, Veracruz (CAX).

Design/Methodology/Scope: CAX local owners and carriers were surveyed and they estimated the information submitted herein.

Results: A daily waste of 1.7 t (0.7 %) of fruits and legumes marketed in CAX was calculated. Sellers do not know the factors that cause this waste.

Study Limitations/Implications: There are few reports on the waste of fruits, legumes, and aromatic herbs in central markets in Mexico. There is little conscience about this issue in the country.

Findings/Conclusions: The amount of waste produced daily in CAX indicates the need to review the applicable public policies to improve their coordination and market problems.

Keywords: food waste, retail, public policy, transportation

INTRODUCTION

In 2015, the General Assembly of the United Nations Organization established the 2030 Agenda for Sustainable Development, which contains 17 objectives endorsed by the member states to "look after the protection of persons, the planet and prosperity" (CEPAL, 2018). Goal 12 on Responsible production and consumption proposes: "Decrease food losses and waste" (12.3.1). A loss is defined as "the decrease in the amount or quality of food as a result of decisions and actions of suppliers in the food chain, excluding retailers, food service suppliers and consumers". Food waste is defined as "the decrease in amount or quality of food as a result of decisions and actions of retailers, food service suppliers and consumers" (FAO, 2020a). Loss and waste differ between the assessed goods and countries. In Mexico, like in other countries, food loss proportion is greater than that of waste, although waste proportion is not negligible (Benítez, 2018). In 2016, the Inter-American Institute for Cooperation on Agriculture (IICA) published an agri-food chain assessment methodology to identify problems and projects, in

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order to reduce food losses. In agri-food product chains, there is an information and planning analysis period, a pre-production stage, a production, harvest, transportation and assembly phases, one or more storage periods and finally another consumer distribution period (La Gra, 2016). Wholesale markets are an essential part of the agri-food chain in many countries and an important link between producers and consumers (Densley & Sanchez-Monjo, 1999; Dachs *et al*., 2016).

Both economic and food availability benefits provided by wholesale markets are widely known (Tollens, 1997; INAFED, 2010; Dachs *et al*., 2016), although their role in the reduction or generation of food losses and waste has not been widely studied (Tollens, 1997; García-Pérez *et al*., 2020). According to Tollens (1997), the storage and handling of foodstuffs in wholesale markets reduced waste in around 30% in European countries. IICA proposed an agri-food chain model based on food losses and waste, where the factors that generate losses in the larger wholesale markets (centrales de abasto) seems to be linked to the food losses during transportation (La Gra, 2016). In the case of Mexico, there are few studies that determine or estimate food losses in wholesale markets. García-Pérez *et al*. (2020) quantified the food loss of some fruits and legumes in the wholesale market of Mexico City and performed a follow-up to the weight of trucks transporting these fruits and legumes; they found an elevated amount of lost product and little care during the transportation. According to a review of these authors, food loss and waste in wholesale markets varies from 2 to 18%, depending on the type of food and the country. The knowledge of the food loss and waste in wholesale markets in Mexico may constitute an input for the re-definition of public policies aimed to increase the efficiency of agri-food chains in the country. These undesired food loss and waste affect both the availability of food, the economy of producers and marketers and the environment and health of society (Robles-Martínez *et al*., 2010). Therefore, the objective of this work was to estimate the waste of fruits, legumes and aromatic herbs in the Wholesale Market of Xalapa, capital city of the State of Veracruz, Mexico.

MATERIALS AND METHODS

The Wholesale Market of Xalapa (CAX) in Veracruz is located in the city of Xalapa de Enríquez, at 4.73 km to the southwest of the geographical center of the municipality of Xalapa (19° 34′ 54″ N, −96° 51′ 14″ W). It has an estimated area of 283 000 m^2 and comprises a parking lot, warehouses and four sections: A) Groceries; B) Fruits and vegetables; C) Miscellaneous goods, and D) Warehouses and cold storage (Figure 1). The estimation of food waste at CAX was performed through semi-structured interviews which were applied to sellers and carriers. The interview aimed to carriers included questions related to the origin of goods (fruit, legumes and aromatic herbs), the transportation time and the care taken during the transportation. Interviews to sellers included questions for the estimation of wasted goods, the use they gave to the goods that could not be sold, the main causes for the waste of goods, the resupply and the property of the vehicle used for transportation. We visited the market stalls where we could see vehicles for the collection of waste. We interviewed to 20 sellers and 10 carriers; the interviews included 15 questions. Figure 2 shows pictures of some CAX market stalls.

The current amount of marketed goods at CAX was estimated from the marketed goods volume data published by the National Market Information

Figure 1. Air picture of CAX (Source: Google Earth).

Figure 2. Fruit and vegetable area shops of CAX (Source: Authors).

and Integration System (SNIIM) in 2010. We calculated the current volume of marketed goods at CAX from the proportion of the market stalls registered in 2010 in the SNIIM and those we verified in the CAX. It is well known that there is a correlation between the number of shops/stalls and the volume of marketed goods (Dachs *et al.*, 2016).

The information of distances between CAX and the origin of the goods stated by sellers was obtained from Google Maps. In cases in which there was more than one arrival path, the closest was chosen. Descriptive statistics of information was performed with Minitab Statistical Software 16.

RESULTS AND DISCUSSION

Table 1 shows the waste of foods reported by the sellers and carriers from the 20 market stalls visited in CAX (CAX has approximately 147 market stalls dedicated to the trade of fruits and vegetables). The estimated waste ranged from 0.2 to 1 t per day. The last National Inventory of Wholesale Markets, Supply Modules and Wholesale Markets published by the SNIIM (2010) showed that CAX marketed a total of 150 t per day; 92% of the registered occupied warehouses was dedicated to the trade of fruits and vegetables. According to these data and the 2010 Government Report from the Municipality of Xalapa, (which considered an increase of the marketed volume of food at CAX in the subsequent ten years), we calculated that 248 t of fruits and vegetables per day were commercialized at the aforementioned wholesale market. With this information, we estimated that 0.7% of the fruits and vegetables daily marketed at CAX was wasted. This value is equivalent to 1.736 t of food wasted per day or 633.34 t wasted per year.

Table 1 also shows the relevance of CAX as a point of connection for the sale of foods coming from other cities within the state. Only nopal cactus and onion were produced at the recorded city of origin (Teziutlán and Oaxaca, respectively). The remaining products (potato, herbs, orange, tomato, grapefruit, lemon, papaya and mango) are not produced in the city of origin mentioned by the interviewees. This suggests that the mentioned cities are intermediate points for the collection of these foods. At current prices, it is estimated that waste equals to MX$2,135,250.00 per year.

There are few studies where the loss and waste generated at the wholesale markets levels were estimated. According to La Gra (2016), factors such as the conditions during transportation, the sanitization of the transport units, the distance and duration of the transportation, and the costs and benefits of the transportation should be also taken into account in the analysis of the main causes of the food loss and waste. Thusly, the analysis of the main causes that could explain the waste observed in CAX was made taking into consideration these points and will be presented subsequently. When we asked sellers about why food was wasted, 100% stated they did not know why. Likewise, when we asked them if they used the generated waste, 100% stated they did not know what to do with it. These findings are even more relevant upon considering that sellers estimated that these wasted goods had an economic value of more than 2.3 million pesos per year (Table 1). This suggests that a) there is a lack of knowledge of sellers about how food waste can be also generated during the transportation and marketing or b) the value of wasted food is perceived as low so that sellers have not addressed this issue. This panorama poses the need of strategies aimed at training sellers considering that 70% of the national agricultural production is distributed through main and wholesale markets in Mexico (SIAP, 2016). It is also critical that those involved in wholesale markets know about the importance of the reduction of food loss and waste, as well as the added value of these loss and waste due to its transformation or processing.

When we asked sellers about the use of refrigeration in the transportation, no carrier stated neither to use refrigeration nor to take a special care of the transported goods (Table 1). Nevertheless, they stated to use wooden crates for the transportation of onions from Oaxaca and in the case of nopal cactus, papaya and mango. A national field study revealed that carriers in Mexico do not consider that refrigeration is relevant during the transportation of fruits and vegetables, however, this is a common practice in developed countries (World Bank, 2018). This fact has two major implications: carriers do not identify the use of wooden crates as a factor that may reduce waste. Also, the manner the goods are packaged for their transportation depends on their origin. This is evidenced in the transportation of onion, a good which is transported depending on its origin (Table 1). As for the sanitation of the units employed in the transportation, carriers reported to sanitize them. The frequency declared by the carriers was quite variable attributing this variability to the fact that units are used constantly which makes difficult to clean them often.

Regarding the transportation time from the cities stated by the carriers as the origin of the transported foods and CAX, we observed differences with the time calculated by Google Maps depending on the origin of the goods. As for the case of Oaxaca, the difference between the stated and calculated times was negligible, while for Veracruz, Teziutlán and Perote a 1-h difference was observed. These differences may be attributed to the condition of the route and the traffic. In the case of the goods transported from Veracruz, it is due to the use of the federal highway route instead of the toll highway. The federal highway is longer than the toll highway but represents no toll cost. The same trend was observed for the transportation times of the goods carried from Córdoba, Orizaba and Tlaxcala.

Lipinska *et al*. (2019) indicated that the reduction of the transportation times of foodstuffs contributes to the reduction of their waste. Aguilar (2020) obtained data for Mexico and argued that the main cause for the food waste is the enormous distances fruits and vegetables in the country should travel due to its transportation: "…In Mexico, some products need to travel hundreds of kilometers from production areas to reach consumption centers in great cities: tomato produced for marketing purposes travels an average distance of 454 kilometers to reach Wholesale Markets. This distance may reach 2,838 kilometers. Oranges travel 668 kilometers in average from its production area, but it may travel up to 3,191 kilometers to reach consumption centers. As for apples, these distances are of 710 and 1,645 km; while lemons travel between 794 and 1,428 km." In this sense, we also asked to the interviewed sellers whether the vehicle used for the transportation of food was of their own or leased. 95% of the respondents stated to have their own vehicle and only 5% leased one. It should be noted that 94.7% (18) of owned vehicles were pickup trucks and the rest were trucks. According to the resupply frequency declared by the transporters, they need to make several trips in a week. This also explains their preference to travel through federal highway roads. These routes are longer and have more traffic which contributes to the waste of foods (Lipinska *et al*., 2019).

The public policy that governs hygienic conditions of CAX is subject to the Regulations of Economic and Tourism Development of the Municipality of Xalapa (RDETX), (Chapter XII, section 2); the Internal Regulations of the Government of the Town Hall of Xalapa (Section 90, subsection III); and the Organic Law of the Free Municipality (Section 55, subsection III) (Town Hall of Xalapa, 2020). The last two mention that the municipality shall "seek that the handling of foodstuffs and beverages be made at adequate places and manners and that wholesale markets meet the necessary hygiene conditions." RDETX provides that CAX shall be located at a place of easy access have good roads. It also states that it should have basic utilities (Section 112, I), and shall have specific areas for refrigerators, among other needs (Section 112, II). The Section 115, subsection XIII, mentions the indications about the sanitation of the market which comprises not throwing away trash (including waste) outside the containers destined to such purpose and to have equipment installed for the transformation of goods or commodities at the wholesale market warehouses (Section 115, XIX).

According to Morales (2011), there are mechanisms for the use of the waste generated in some of the wholesale markets of Mexico (particularly the Mexico City Wholesale Market) such as the food banks and other social institutions. Food banks are civil associations devoted to gathering food in good conditions to bring them to marginalized families in different states

Table 1. Waste stated by the sellers interviewed in the Xalapa Wholesale Market (CAX) and other parameters related to the care given to the transported products.

Carrier	Product	Origin	Distance (km)	Transportation time (h)	Transportation care	Resupply (days)	Waste (t)	Money losses (MX$)	
								per day	per year
1	Onion	Oaxaca	463.0	6	Wooden crates	6	0.7	300	109,500
	Onion	Oaxaca	463.0	6	Wooden crates	6	0.6	250	91,250
	Onion	Veracruz	103.8	2	NC[1]	5	0.6	300	109,500
2	Potato	Veracruz	103.8	3	NC	4	0.4	180	65,700
	Potato	Veracruz	103.8	3	NC	4	0.4	280	102,200
3	Tomato	Córdoba	205.6	3	NC	3	1.0	120	43,800
4	Onion	Veracruz	103.8	3	NC	4	0.5	250	91,250
5	Prickly pear	Teziutlán	100.5	3	Wooden crates	4	0.2	600	219,000
6	Grapefruit	Orizaba[3]	210.5	4	NC	5	0.4	300	109,500
6	Lemon	Orizaba	210.5	4	NC	5	0.7	230	83,950
7	Orange	Orizaba	210.5	4	NC	4	0.6	290	105,850
	Orange	Córdoba	205.6	4	NC	4	0.8	270	98,550
	Orange	Córdoba	205.6	3	NC	4	0.6	250	91,250
8	Papaya	Perote	60.1	2	Wooden crates	5	0.3	600	219,000
	Papaya	Perote	60.1	2	Wooden crates	5	0.4	260	94,900
9	Mango	Tlaxcala[3]	228.7	4	Wooden crates	5	0.8	300	109,500
	Mango	Tlaxcala	228.7	4	Wooden crates	5	0.4	320	116,800
	Mango	Tlaxcala	228.7	4	Wooden crates	5	0.9	320	116,800
10	Herbs[2]	Veracruz	103.8	3	NC	4	0.7	250	91,250
	Herbs	Veracruz	103.8	3	NC	4	0.7	180	65,700

[1]No specific care is taken for the transportation. [2]Includes epazote, parsley, cilantro, chamomile. [3]All distances were calculated using Google Maps. In these cases, there was more than one route to arrive from the declared origin to CAX. MX$ = Mexican Pesos.

of the country (World Bank, 2018; Cáritas Food Bank of the State of Mexico, 2017). The donation of the food waste generated in the wholesale markets does not generate costs for the shop owners or managers. When they donate food waste, they can deduct up to 5% of their sales costs (SAT, 2012). Besides these social initiatives, there are other programs aimed to Wholesale Markets. Recently, FAO (2020b) and the World Union of Wholesale Markets (WUVM) renewed an agreement aimed at reducing food losses and waste globally. WUVM, of which the Mexico City Wholesale Market is part of alongside with other wholesale markets in the country, comprises wholesale markets from 160 different countries. Planned collaboration areas between FAO and WUVM include the knowledge, exchange, promotion and development of capacities to reduce the loss and waste of food in food markets and distribution systems. Until 2018, the National Entrepreneur Institute (INADEM, 2018) of Mexico had the campaign "Innovate your Wholesale and Retail Market" whose objective was to contribute to the increase in productivity through innovation, logistic and commercial practices in wholesale and retail markets through the investment in infrastructure, equipment, and human capital development. Thusly, awareness about the consequences of food waste at wholesale markets may contribute to have funds to train personnel in this subject as well as to equip the markets in order to reduce and utilize such waste.

CONCLUSIONS

In the wholesale market of Xalapa City in Veracruz, where a great amount of fruit and vegetable goods that arrive from different points of origin are marketed, both carriers and sellers stated that the transported and marketed good were wasted. There is little care with goods during their transportation and marketing. Sellers and transporters neither know the origin of generated waste nor how to reduce it. The review of municipal, state and federal policies, social initiatives and national and international programs showed there are proposals that should help to reduce food waste at the wholesale market level. The findings of the present work reflect problems in the coordination and marketing in wholesale markets which generate the waste of fruits, legumes and aromatic herbs. This waste may be reduced through the application of the existing initiatives.

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Coffee Agroecosystem in Mexico: Productive Culture between Tradition and Change

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ABSTRACT

Objective: To know the productive cultural dynamic that underlies to coffee agroecosystems in Sustainable Rural Development District 005 of Fortín, Veracruz, Mexico.

Methodology: A survey with open and closed questions was applied. Information submitted to variance analysis, Tukey tests and frequency tables.

Results: Coffee agroecosystems in Mexico are complex systems with an underlying particular cultural dynamic that expresses a worldview and that not only influences life, but also the reproduction of certain handling practices the logic of which goes beyond economy. Coffee activity is performed mostly by tradition (39%), characterized by *Coffea arabica* agroecosystems under the shadow (100%), with a performance lower than 5.87 t ha^{-1}.

Limitations: It is a case study for a specific zone of the state of Veracruz and the results reflect a local reality.

Findings: Producers perform up to four economic activities external to their trade to complement their family income; the paradox is that this has served as a foundation for continuing the coffee-growing activity, reduces its economic vulnerability and eases the continuity of their production mode and lifestyle.

Keywords: coffee-growing industry, social system, handling practices.

INTRODUCTION

Coffee-growing in Mexico began in the last decade of the 18th century; more than 200 years after its introduction, this aromatic crop is still considered to have great economic, sociocultural and environmental importance (Pérez & Díaz, 2000). Coffee-growing agroecosystems are distributed in 14 states of Mexico on a harvested area of 629 mil ha (SIAP, 2020). Nevertheless, Chiapas, Veracruz, Puebla and Oaxaca concentrate 93% of the production of coffee, an activity performed mainly by small producers (FIRA, 2016). The coffee-growing industry in Mexico involves directly 404 municipalities, which comprise

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4,571 towns (Contreras, 2010) and 510,544 producers, of which 180,000 are indigenous population (Flores, 2015). This way, the coffee-growing industry is deemed to be a fundamental strategic activity in the country, as it allows integrating productive chains, generating currency and jobs, and it also allows the subsistence mode of small producers, many of whom belong to indigenous groups, to persist. Coffee plantations are appraised nowadays as ecological reserves, as more than 90% of this surface is grown under a diversified shade. This production form contributes to preserve biodiversity and provide environmental services that are crucial for society (Giovannucci and Juárez, 2006), utilized through the consumption of food, timber, wood, medicine herbs, soil conservation, carbon capture and water (Méndez *et al*., 2013).

Notwithstanding, the coffee-growing industry in Mexico has been subject to a recurrent crisis since the 1990s, when the international value of coffee went down. This situation became worse with the gradual abandonment of the activity by the Mexican State as part of neoliberal policies implemented as of 1988. The participation of the Mexican State in boosting the coffee-growing industry was reduced with the disappearance of the Mexican Institute of Coffee, the main function of which was to support producers in the production and marketing of this bean. This crisis has deepened in recent years, derived from the overproduction of coffee in other producer countries such as Brazil and Vietnam, which saturates world markets and brings instability to the international price of coffee (Ramírez & González, 2006; Rivadeneira & Ramírez, 2006; Vandermeer, 2011).

The effects derived from climate change (Gay *et al*., 2006), which has modified the weather regime and hence the behavior of main agroclimatic variables such as rain and temperature, should be added to this situation. These conditions have allowed an increase in plague populations and diseases; this is the case of stem rust. In the 2014-2015 and 2015-2016 periods, stem rust reduced the income of producers drastically just as it has happened in other coffee-growing areas in the country (De Adelhart *et al*., 2017). In this context, this research the objective of which was to understand the productive cultural dynamic that underlies to coffee agroecosystems in in the region associated to Sustainable Rural Development District 005 of Fortín, Veracruz, Mexico, was performed.

MATERIALS AND METHODS

The study area comprised 13 municipalities (Chocamán, Comapa, Córdoba, Huatusco, Ixhuatlán, Sochiapa, Tenampa, Tepatlaxco, Tlacotepec, Tlaltetela, Tomatlán, Totutla and Zentla) that belong to Sustainable Rural Development District 005 of Fortín (DDR005-Fortín), Veracruz, Mexico. This district has a territory of 617,644 ha and a political division of 56 municipalities.

Table 1. Coffee producers surveyed in DDR 005 (Rural Development District) Fortín, Veracruz, Mexico.

Municipality	Total producers
Totutla	41
Comapa	24
Huatusco	14
Tenampa	14
Ixhuatlán	12
Tlacotepec	11
Tlaltetela	7
Zentla	5
Sochiapa	5
Tepatlaxco	4
Tomatlán	4
Córdoba	3
Chocamán	1

In accordance with the study objective, a questionnaire with open and closed questions that allowed the capture, systematization and analysis of information was designed. In order to calculate the sample size, the formula created by Scheaffer *et al*. (1987) was used with a reliability of 95% and accuracy of 10%, which generated an approximate sample of 145 coffee producers in the region (Table 1), in accordance with a list of producers of the Veracruz coffee-growing registry. The questionnaire was applied through the snowball technique, the only requirement of which was being a coffee producer and with no regard to the size of the land devoted to this activity and having a free desire to participate (Taylor & Bogdan, 1987).

The "satisfaction by income" variable was deemed to be the measure that indicates to what degree the producer is satisfied upon covering his basic subsistence needs. In order to measure this variable, a Likert-type scale with five response alternatives was used: very satisfied=5, satisfied=4, regular=3, unsatisfied=2 and very unsatisfied=1.

The information obtained were analyzed through the Statistica software version 7.0, with the application of a variance analysis on unbalanced data, Tukey tests and frequency tables. Frequency tables were made for variables such as: reason why producers continue producing coffee, cropped variety and activities external to the trade, as well as locating the level of satisfaction for producers with their income from coffee sales between among three producer-owned surface ranges.

A variance analysis was applied to the property size, satisfaction level by income generation. When statistic differences were found, the Tukey test was performed.

RESULTS AND DISCUSSION

As shown in results from the survey performed in DDR005-Fortín, the continuity in the production of coffee bean should be sought as this goes beyond financial reasons. Regarding the question on why coffee producers continue their activity despite the conditions facing the sector, 39% of producers answered that they do it for mere tradition, 19% because they enjoy it, 19% because they have no other choice, 14% because this generates income for them and 9% for other reasons. In other words, there is a strong sociocultural component that encourages them to continue growing coffee, although they face the effects of a recurrent financial crisis for more than three decades. Coffee growers are still bonded to this crop when they practice growing forms and the handling of coffee plantations that their parents and grandparents taught them as part of their historical evolution (Rizzo, 2012). On one hand, this productive culture limits their capacity to adapt before market conditions that give little market benefits to the family's income and the adaptation to climate change; this phenomenon has brought water stress to coffee trees and the presence of stem rust, which has brought the plummeting of historical production volumes, as well as affected the coffee bean quality (De Adelhart *et al*., 2017). On the other hand, producers have been allowed to reproduce the coffee ecosystem with lesser environmental impact and even favoring biodiversity.

As for the production system, from the total surveyed producers, 100% grows their coffee trees under the shade. Producers grow the Arabiga (99.9%) variety almost exclusively and Robusta with imitations (0.1%). This contributes to diversifying both flora and fauna in their agroecosystems, as coffee trees and tree species used as shade work as habitat providers for other species (De Adelhart *et al*., 2017). This handling of shade allows the producer to have certain degree of diversification with wood and fruit species, as well as other species important for their food, medicinal, ornamental or religious habits. On the other hand, big corporations give preference to varieties such as Costa Rica, with beans of rapid ripening and produced in the open, such as plantations in Brazil and Vietnam (Bolaños & González, 2008; Vandermeer, 2011).

This way, the local coffee-growing industry is more than a production system, the function of which is to provide income to producers as part of an economic system (Londoño, 2008). Ironically, this has started to change in the last decades, as coffee producers began seeking productive alternatives (Vázquez, 2010; Rosales-Martínez *et al*., 2018). The above is closely related to the productivity of coffee, as the average yield in Mexico accounts for 1.92 t ha^{-1} (Benítez-García *et al*., 2015); this yield has been considered to be low when compared to other regions of the country, especially when compared with the productivity of countries like Brazil and Colombia (Martínez, 2012). The survey observed that producers in the municipality of Tomatlán have a greater coffee yield (5.87 t ha^{-1}), when compared to that of the municipalities of Córdoba (5.24 t ha^{-1}), Huatusco (5.19 t ha^{-1}) and Tlaltetela (2.61 t ha^{-1}). Benítez-García *et al*. (2015) mention that, as well as weather, the production and yield of coffee plantations is due to technology level, agricultural practice application form and production scale.

In order to search for an explanation for these data, a variance analysis was made on the size of the property and the level of satisfaction from the generation of financial income from the coffee-growing activity as a factor. Significant differences ($P=0.002$, Tukey) were found between the satisfied and unsatisfied levels ($P=0.016$); and between the regular and satisfied levels ($P=0.044$). Also, it was found that 12% of producers with the greater property size range were among the those very satisfied by coffee sales income and no producers with the smallest properties were within this group (Figure 1). It is foreseen that this satisfaction level of producers associated to the grown surface size will decrease eventually as the surface per producer is growing smaller mainly as a result of inheritance procedures, as it is the case of the coffee region of Chiapas (Tarrío & Concheiro, 2006).

Upon analyzing the level of satisfaction of income of producers from coffee sales per municipality within the study area, there are significant differences ($P=0.0001$) (Figure 2). Producers from Comapa, Huatusco and Tlacotepec de Mejía show a greater degree of satisfaction, which can be explained by their close

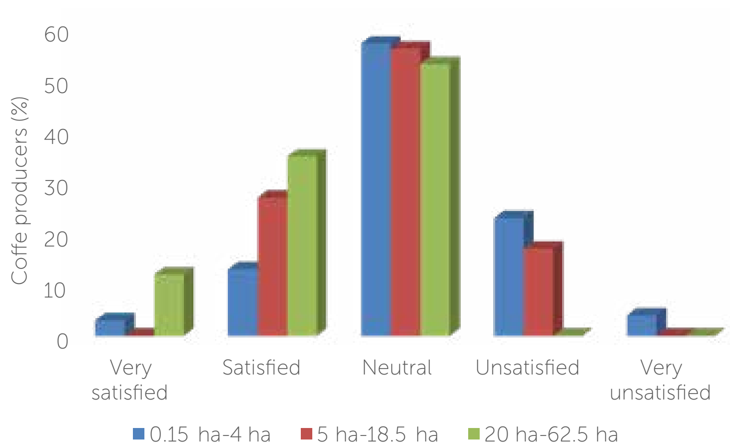

Figure 1. Satisfaction level per coffee income of coffee producers according to their property size.

distance to Huatusco, which is a municipality deemed to be a development pole for the region with greater bean production (Piętak, 2011). As for dissatisfaction among coffee producers, 80.4 % of coffee producers in these municipalities state that the decrease in coffee prices does not allow them to cover production costs nor expenses for their entire family; these results meet the research made in Costa Rica by Guido & Castro (2007). Above all, when the income derived from the sale of coffee harvest is insufficient to pay meals and disbursements on health, domestic electricity, clothing, etc. (Martínez, 2012).

Before this ongoing issue, producers are seeking for alternatives that allow them to continue their trade, and this situation brings them away from their activity as gradual changes in the handling of their agroecosystem are generated. From their viewpoint, however, this is worth the try in order to adapt to the demands of the financial system, in particular within the context of economic liberalization and globalized agriculture (Eakin *et al*., 2006; Luhmann, 2006; Casanova-Pérez *et al*., 2015). In this sense, the results from this research show that 31% of respondents grow coffee as their only activity, 52% perform an economic activity different than the production of coffee, 14% perform two extra activities, barely 1.5% perform three extra activities and another 1.5% perform up to four extra activities apart from their coffee-growing activity in order to get economic gains. Benítez-García *et al*. (2015) also report that producers of Cuetzalan, Puebla turn to non-agricultural activities in order to improve their income among which are masonry, trading and employees. This way, as no sufficient financial resources are gained in order to guarantee the subsequent productive cycle, coffee growers place their workforce for hire either temporarily or permanently (Contreras, 2010). Boltvinik (2007) mentions that, in some cases, this off-farm income more than 50% of their entire income. Nevertheless, in DDR005-Fortín, only 20.68% of coffee growers are devoted to working as laborers, 15.85% have their own business, 10.34% work as coffee cutters and 10.34% work in a trade, and the remaining 8.9% perform a combination of the above mentioned activities (Figure 3).

That is, 45.5% of surveyed coffee producers may be considered as a multi-occupational workforce as a response to the crisis in the coffee-growing industry and a means for surviving it. This is a consequence of what was posed by Cruz & Torres (2015), who considered culture to be a decisive element that allows society to act before certain circumstances and manifestations of environmental components in order to adapt to the latter. Ironically, this deep-rooted culture may also be an obstacle to change processes among coffee producers,

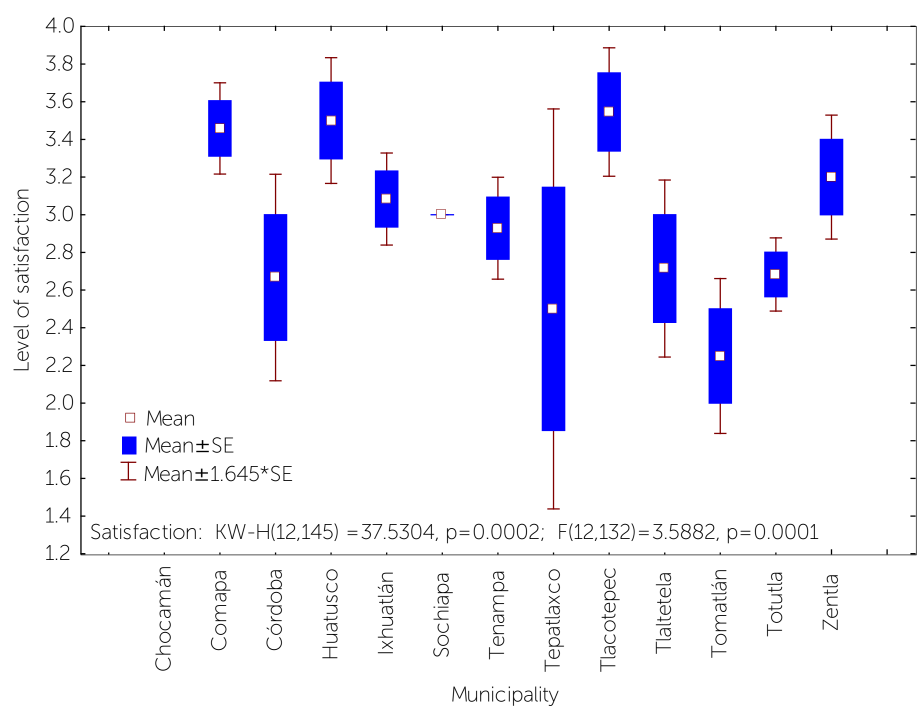

Figure 2. Satisfaction level from coffee among producers per municipality.

as there are difficulties to convince persons to do perform these when they are already used to certain coffee-handling practices (Perea & Rivas, 2008).

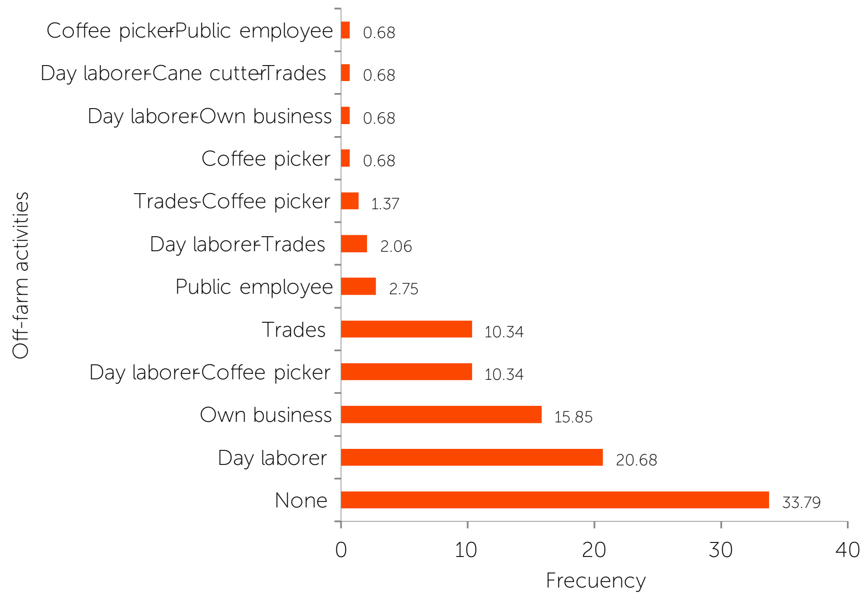

Figure 3. Off-farm activities of coffee producers in District 005 of Fortín, Veracruz, Mexico.

CONCLUSIONS

Coffee agroecosystems, even with their contradictions and drowned in a deep financial and environmental crisis without precedent, will continue their reproduction at least in the short and medium term. This is due to the fact that producers have a deep coffee culture that makes then think that coffee is still feasible as a means of subsistence for their families. Nevertheless, they do acknowledge that coffee is grown at certain degree of uncertainty which is evaded through the performance of other off-farm activities. This increases the complexity of the agroecosystem, and the irony is that this situation fosters its reproduction in an unstable balance.

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Evolution of the Agri-Food Chain Concept in the 21st Century: The Taro Case

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ABSTRACT

Objective: To conceptualize the agri-food chain and analyze its evolution during the 21st century: The taro case.

Design/Methodology/Scope: A systematic literature review of magazines specialized in agri-food chains, value chains, logistics and supply chains for qualitative support and a case study of the taro agri-food chain were performed.

Results: Currently, agri-food chains include supply processes of inputs and necessary equipment, production, transportation, distribution and marketing, among other services. The study of agri-food chains has an effect on globalization within a stricter macroeconomic environment. The increasing industrialization of goods generates an aggregate value and provides a competitive advantage to companies and agents that take part in the chain. The taro agri-food chains, however, shows inconveniences in production, distribution, and storage processes due to the disintegration of links.

Study Limitations/Implications: There is information about the taro agri-food chains.

Findings/Conclusions: The agri-food chain concept has had a continuous evolution. Its structure has the objective to benefit each chain link; this generates commitments to produce based on needs. Both integration and experience allow strengthening and appraising the importance of each link, thus contributing to the generation of better income. Also, their consolidation has made them more sensitive to climate change, nutrition, and sustainability.

Keywords: supply chain, consumer, processes, aggregate value

INTRODUCTION

Agri-food chains will comprise links that go from the obtainment of raw materials to the consumption of the product. Currently, products suffer a great degree of transformation; commercial activities are diverse and there is a greater number of middlepersons that add value to the final product, going from short to long chains (Albusi, 2011).

Agri-food chain are a value chain or chaining of processes that foster a series of relationships and actions to perform specific primary, secondary and tertiary activities within a given territorial space, although with an incidence beyond the territory. Porter (1985) defined the value chain as an instrument for creating value for the buyer or consumer and its configuration or organization is crucial for the attainment of competitive advantages for chain links. In the 1990s, the

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value chain would be defined as the "set of activities developed within a company for designing, producing, marketing, delivering and supporting their products" (Porter, 1999).

Taro (*Colocasia esculenta* L. Schott) is perennial plant with an edible corm that belongs to the Araceae family. The genus is *Colocasia* and it is originary from the Indian-Malayan region (Quero-García *et al*., 2010). As a crop, taro requires warm and humid climate, with temperatures oscillating between 25 and 30 °C (Vázquez, 2013). Also, it demands continuous or intensive rain or irrigation between 1800 a 2500 mm per year (Berlin & Berna, 2009). According to FOASTAT (2017), the five main countries of taro production are Nigeria, China, Cameroon, Ghana and Papua New Guinea. Mexico produces and trades taro at a national and international level, in particular with the United States of America and Canada. In 2016, the part of Mexican taro in the Canadian market was of 1112 t, and occupied the second place with 44.6% of the total imported amount. As for the US market, the part was lesser, in the sixth position, accounting for 3.3% of world exports. Its international sale corresponds to the demand by African-Caribbean and Asian communities in these countries (FAOSTATA, 2017). The objective of this study was to review the concepts of agri-food chain in order to know the dimensions of their evolution and trends applied to the taro agri-food chain.

Conceptualization of Agri-Food Chain

Several authors conceptualize the agri-food chain (CA) by referring to the term value chain (CV). Nevertheless, their meanings and scopes vary depending on the authors. For Guido & Mamani (2000), value chain (CV) is the existing relation between the purchase and sale of agricultural products between different actors or agents, which may include producers, distributors, consumers, industry, and input suppliers. Kaplinsky & Morris (2000) defined CV as a wide set of activities required to bring a product since its conception through the different phases of production, dispatch to end consumers and disposal of equipment and containers after the consumption in each phase. Iglesias (2002) defines CV as the vertical alliance or strategic network between an independent number of business organizations within the supply chain. In the first decade of 2000, CA was an articulation of different actors taking part in flows or movements of goods and services from the supply of inputs, production to the consumption; it takes into consideration the transformation and distribution of the product and provides a series of support services in each process step (Reinoso *et al*., 2007). By the end of that first decade of the 21st century, the agri-food chain was conceived from the socioeconomic reality viewpoint as a system that groups interrelated economic and social actors that have an articulated part in activities that add value to a good or service from their production to their arrival to consumers, including input and transformation, industrialization, transportation, logistics and other supporting services, such as financing (García *et al*., 2009). For Kaplinsky & Morris (2009), CV describes the total variety of activities required for conducting a good or service from its conception to the delivery to the consumer, disposition and final disposal through several intermediate production phases that need to be linked (and involve combinations of physical transformation and inputs of different producer services). Table 1 shows complementary definitions of agri-food chain and their historical evolution.

Includes interactions between agents to produce a good or service, from the raw material, industrial processes by production stages, processing, intermediation and marketing to satisfy a need.

Chain evolution analysis

In the 21st century, the agri-food chain has had several modifications due to new trends in the globalized world that induces companies to adopt changes in organization and integration forms in different environments. At the beginning of this century, chain processes were viewed vertically, and companies began to feel concern about having the correct placement in the global market. One of the main reasons for the implementation of the value chain in companies was the optimization of costs, reason why activities deemed to be essential were set up: production, distribution and marketing. Nevertheless, the objectives posed by companies were not attained, as the consumer became more demanding and with frequency, paying attention to health, environment and safety matters (Hernández & Villaseñor, 2014). In 2004, the focus of agri-food chains experienced a turn in agri-food chains in a wider sense; it considered all stages (production, industrialization, distribution and consumption): This refers both to products consumed fresh and those that include an industrial transformation process (Ballesteros & Ballesteros, 2004). It considered both the transformation and distribution of the product and the socioeconomic situation. In other words, the chain was

Table 1. Evolution of the Agri-Food Chain Concept in the 21st Century.

Reference	Concept / Definition
Kaplinsky and Morris (2000)	Wide variety of activities for transferring a product or service from its conception, through different production phases, to end consumers and final disposal after use.
Guido & Madani (2000)	Relation between the purchase and sale of (agricultural) goods between different actors or agents, which may include producers, distributors, consumers, industry and input suppliers.
Iglesias (2002)	Vertical alliance or strategic network between an independent number of business organizations within the supply chain.
Ballesteros & Ballesteros (2004)	All production, distribution and consumption stages that refer both to products consumed fresh and those that undergo an industrial transformation.
Reinoso *et al*., (2007)	Articulation of different actors taking part in flows or movements of goods and services from the supply of inputs, going through the production, transformation and distribution of the product and provides a series of support services in each process step.
Kaplinsky and Morris (2009)	Variety of activities required to conduct a product or service from its conception to the delivery to the consumer, disposition and final disposal through several intermediate production phases.
García *et al*., (2009)	System that groups interrelated economic and social actors that have an articulated participation in activities that add value to a good or service, from its production to its arrival to the consumer.
Bacigalupo, (2014)	Set of components (links) interrelated between themselves, with specific objectives and a context that conditions it.

Source: Self-modification.

already conceived as a system that grouped economic and social actors which integrates the logistic chain to attain a long-term yield. In this sense, actors that integrate the logistic chain are producers, agroindustry, and trade (Causado & Reatiga, 2013).

Logistics is a competitive force that has moved from the production to the distribution zone. Agricultural product sales include both the digital and physical parts of transactions, among which the relation with logistics in order to perform shipments and the distribution of products stands out. This is why those in charge of logistics should be prepared to lay down chains that respond to existing situations, but that may also change and adapt (Britta & Paul, 2001). Figure 1 shows the evolution of the agri-food chain in the 21st century.

In Phase 1, vertical chain, production and distribution were made for the regional and national marketing only In Phase 2, global market, the international marketing of products such as raw materials began. In Phase 3, industrial chain, the transformation of raw material into processed products was introduced. In Phase 4, the system, interrelated economic and social actors that participate in the addition of value were grouped together. In Phase 5, logistics, the product's time and life regulates the distribution thereof.

The concept of agri-food chain has had major changes within a short timeframe; it seeks to cover needs of consumers and shows a new focus. Thus "agri-food supply chains" (CSA) integrated by organization networks that work together to attain quality and opportunity come into existence. Nevertheless, the CSA concept has not been consolidated in practice to the point of reaching sustainable supply chains (FAO, 2015). In the food industry, supply chains are complex systems undergoing a constant change that involve several participants, both internal and external (Figure 2).

Agri-food chain planning requires designing management models that attain the wide identification of territory dynamics; it considers aspects such as production unit size, primary production conditions, technology, market demand, financial capacity and management practices that allow handling a wider group of variables (Vianchá, 2014).

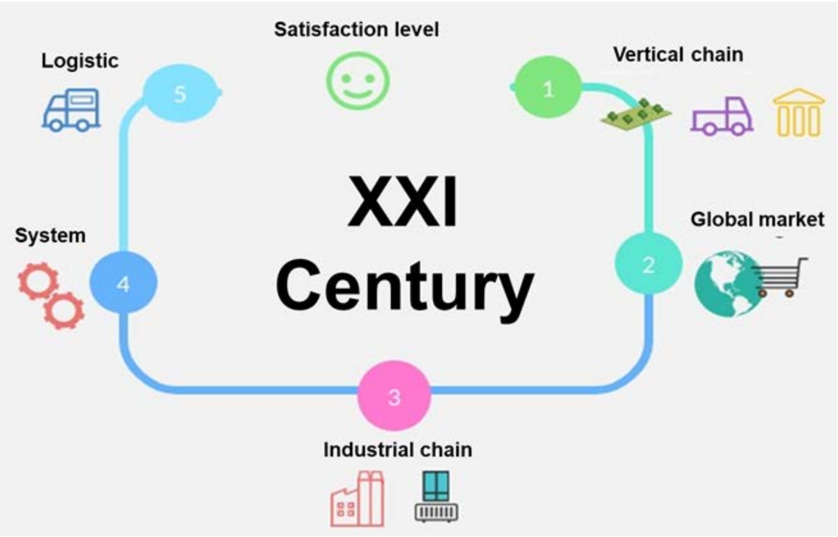

Figure 1. Agri-Food Chain Evolution Mind Map. Source: Self-modification.

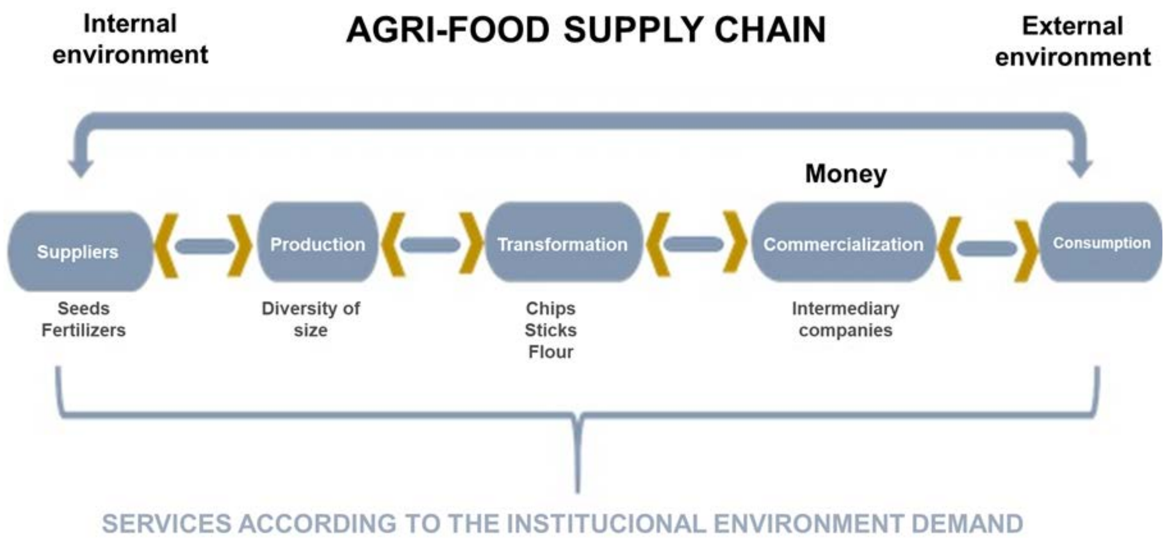

Figure 2. General scheme for an Agri-food Supply Chain. Source: Self-modification.

Agri-food chain of taro

Taro (*Colocasia esculenta* L. Schott, Araceae) is a perennial plant, if not harvested, that is native from Southeast Asia. It is a herbaceous, succulent plant, with no light stem. Leaves come directly from a primary underground corm which is more or less vertical. From here, secondary lateral and horizontal edible corms are formed (Moltaldo, 1991).

Mexico is a major taro exporter. However, there is no record of supply chains for this product (Vianchá, 2014). Currently, there are inconveniences in production, distribution and storage processes in the taro supply chain. Until 2016, there were no records of integration of any supply chain.

The main taro production areas in Mexico have no evidence whatsoever of any supply chain mapping, which causes deficiencies in production, preservation, transformation, marketing and consumption activities, requirements on raw material, labor and inputs, distribution paths, product marketing and customer satisfaction (Parra *et al*., 2017). Berlin & Berna (2009) performed a taro value chain analysis in Rio Grande, Matagalpa, Nicaragua, in order to identify the main problems of the taro value chain. They identified four main problems. 1) deficient taro handling; 2) deficient post-harvest handling; 3) weak organization of producers in the cooperative business 4) scarce marketing channels. Parra *et al*., (2017) performed a taro supply chain analysis in the main producer states of Mexico (Oaxaca, Veracruz and Tabasco); they reported a diagram of agents that intervene in a taro value chain (Figure 3). Currently, there are inconveniences in production, distribution and storage

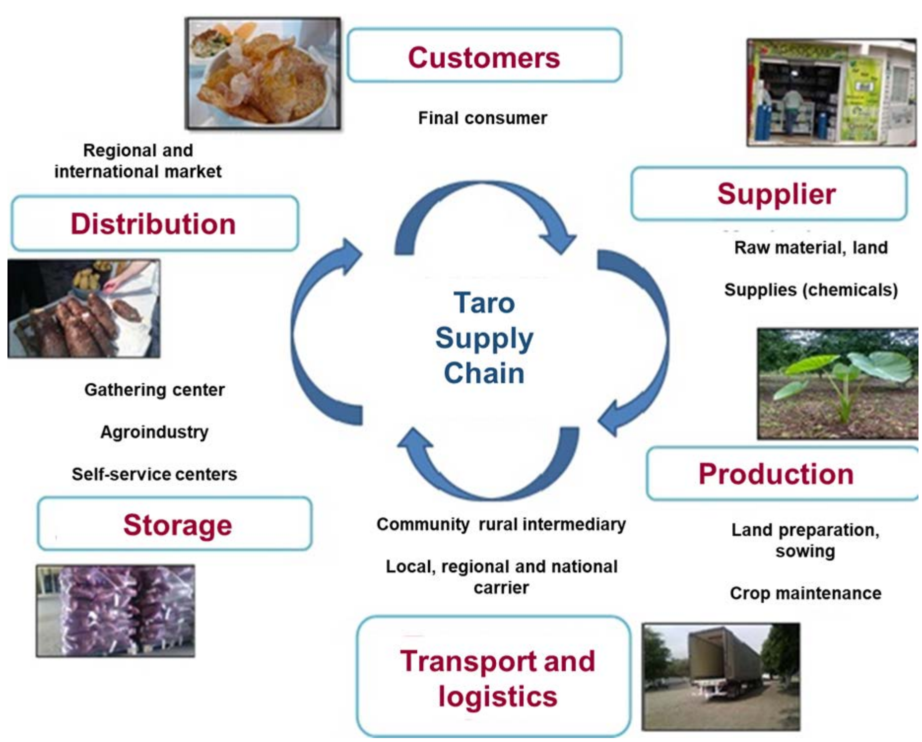

Figure 3. Agents that intervene in the Taro Supply Chain in Veracruz. Source: Self preparation.

processes in the taro supply chain (CS) in Mexico. Agents intervening in the taro CS are not integrated; *i.e.* they work individually, with little efficiency and do not attain the desired capacity (Parra, 2019).

More than 80% of taro production in Mexico is destined to export. Therefore, a logistic control that allows meeting the customer's needs with respect to product volume, quality and characteristics is necessary. Ballou (2004) mentioned the importance in the logistics of the supply chain; this set of functional activities (inventory control transportation, among others) are replicated along the flow channel; with this, the raw material becomes finished products and value is added for the consumer.

The taro agri-food chain is integrated by five links: 1) suppliers, 2) producers, 3) distribution, 4) transformation and 5) marketing. It shows competitive advantages upon being integrated. It streamlines production processes, reduces raw material and product loss, generates aggregate value to attain economic and social development. In recent years, the consolidation of the agri-food chain has been sensitized by three significant foci: climate change, nutrition and sustainability (Figure 4). Value chains strengthen the growth of small and medium companies like in the case of taro. Big companies gain two benefits: 1) a greater organization level that allows obtaining inputs at lower prices 2) a greater aggregate value generated in each productive stage the product goes through is gained. An agri-food chain, seen as a study and political formulation unit, is transcendental to understand and appraise agriculture's contribution to the country's economy. Also, wherever there is good performance and adequate articulation among different agri-food chain links, the competitiveness of the agricultural sector and the country's economy increase.

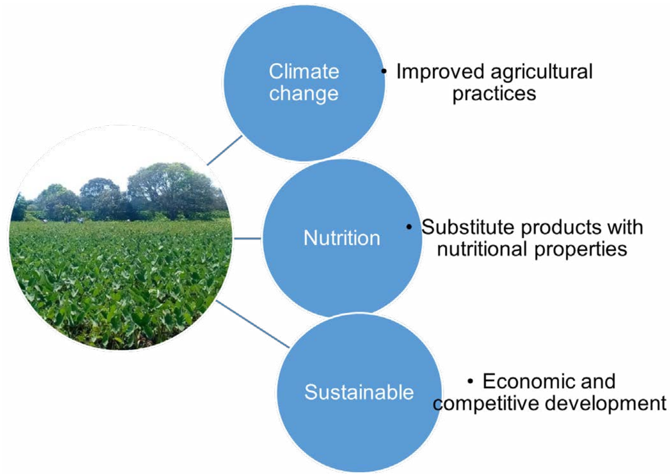

Figure 4. Current Taro Agri-Food Chain Foci in Veracruz, Mexico. Source: Self-modification.

CONCLUSIONS

The agri-food chain concept has had a continuous evolution. The addition of products and services has increased in order to meet the customers' needs and demands. This grants a competitive advantage to companies and agents that integrate the value chain. Agri-food chains have become a relevant subject for companies, organizations and food-processing institutions. Also, they are an instrument that fosters rural development and contributes to the revitalization of competitive and sustainable economic activities that allow increasing their wellbeing level. Finally, the agri-food chain seeks to meet the consumer's needs, generate competitive advantage in companies and agents integrating the value chain.

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Biodiversity, management, and commercialization of ornamental plants at nurseries in Fortin de las Flores, Veracruz

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ABSTRACT

Objective: The aim of this study was to create an inventory of the biodiversity, management, and commercialization of ornamental plants at nurseries in the municipality of Fortín de las Flores in the State of Veracruz, Mexico.

Design/methodology/approach: Semi-structured interviews were carried out with 150 nursery owners.

Results: The respondents reported a total of 230 different plants. With regard to commercialization, 20 species were reported as the most sold. The most notable species were: *Syagrus romanzoffiana* (Cham.) Glassman, *Caesalpinia echinata* Lam., *Anthurium andreanum* Linden, and *Phoenix roebelenii* O'Brien. The biggest problem was the sale price; 65% of the nursery owners reported that they sold their plants to strangers, and that they did not belong to any organization or cooperative.

Limitations on study/implications: The poor local technological development characterized by unspecialized small and medium-sized businesses that compete with each other with little trade organization is a result of the sociocultural context of the region. This context limits regional development. Therefore, more research regarding sociocultural aspects should be promoted.

Findings/conclusions: We have concluded that there is an underutilization of the native agrobiodiversity, since species originating in other parts of the world are what is most often sold. This is evidenced in the main species sold as well as those that generate the highest profits for the nursery owners.

Keywords: Agrobiodiversity, economic botany, flowers, native plants, market

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INTRODUCTION

The ornamental horticulture industry is made up of producers of plants in nurseries and greenhouses, landscaping companies, suppliers of raw materials, and sellers of a variety of products that include: potted flowers, cut flowers, landscaping trees, foliage plants, shrubs and woody ornamentals (Di Vita *et al*., 2015). This is a global industry which, in addition to providing jobs, generates income that has an impact at the local level. In the United States, 2014 sales of horticultural specialties totaled over 13 billion dollars, of which over five billion dollars were from floriculture, which mainly comprises garden plants, potted flowers, and foliage plants (USDA, 2015). In Mexico, the farm-gate value of ornamental horticulture production was $468,000 USD in 2019 (SEDARPA, 2020), including cut flowers (81% of the value and 84% of the surface area), grass (2% of the value and 4% of the surface area), as well as potted flowers, Christmas trees, foliage plants, and other garden plants (16% of the production value and 12% of the surface area). In that year, the two cut flowers with the highest production value were: *Rosa* L. (23% of the value) and *Chrysanthemum* L. (20% of the value); and those with the largest surface area were *Gladiolus* L. (23%) and *Chrysanthemum* L. (13%). The two plants with the highest production value were: *Euphorbia pulcherrima* Willd. ex Klotzsch (46%) and Christmas trees (15%), while those with the largest surface area were: *Euphorbia pulcherrima* Willd. ex Klotzsch (39%) and *Geranium* L. (14%).

Some of the problems faced by the ornamental horticulture industry at a global level are increased international competition due to the entry of plants from countries with lowcost production (Galati *et al*., 2015), the impact on producers of the international financial and economic crises (Rihn *et al*., 2016), the negative effect on ecosystems of the growth of invasive species (van Kleunen *et al*., 2018), the lack of practices ensuring the sustainability of the sector (Castillo Nonato *et al*., 2018), and the lack of adoption of traceability systems by producers and nursery owners in developing regions (García-Mejía *et al*., 2018), among others.

Mexico is considered a megadiverse country, as it has a variety of genetic resources including higher plants, some of which have ornamental, social, and commercial value. This value is derived from the type of flower or inflorescence, the fruits or infructescence, the leaves, and the architecture of the plant (Guadarrama-Martínez *et al*., 2012). Such are the cases of some fruit trees that are used in gardens and backyards as well as plants that are used for their flowers in activities such as offerings on the Day of the Dead, religious events, or special days such as Valentine's Day (February 14) or Mother's Day (May 10) (Rubí-Arriaga *et al*., 2014).

Cut flower production has been recorded in 18 states of Mexico, however, the State of Mexico has 39% of the national surface area and 75% of the farm-gate production value. It is followed by Puebla in surface area (32%) and 13% of the value; Veracruz has 5% of the national surface area but only 1% of the value (SEDARPA, 2020) because, unlike the State of Mexico, it is not oriented towards exportation. As for potted plants and Christmas trees, production is recorded in 12 states, where Puebla represents 48% of the surface area and 22% of the production value; Puebla is followed by the State of Mexico (31% of the surface area and 24% of the value) and Mexico City (9% of the surface area and 26% of the value) (SEDARPA, 2020). Puebla and the State of Mexico achieve better prices due to their proximity to Mexico City, the most populated city in the country.

The municipality of Fortín de las Flores is located in the State of Veracruz in eastern Mexico. It is characterized by a microclimate conducive to the production of ornamental plants; these meteorological conditions have caused the inhabitants' preference for nurseries that grow commercial crops (Major *et al*., 2005), *e.g.* sugar cane. This has made the state a popular place to purchase such products among the regional population. Despite this recognition, the number of scientific publications that account for the diversity of plants that are commercialized by the nursery owners is small and limited to studies by family, e.g. orchids (Murguía-González *et al*., 2016) or species, *e.g.* anthurium (Murguía-González *et al*., 2003). The aim of this study was to create an inventory of the biodiversity, management, and commercialization of ornamental plants at nurseries in the municipality of Fortín de las Flores in the State of Veracruz, Mexico, in order to identify the plants that are used for commercial purposes.

MATERIALS AND METHODS

The study was conducted during the months of May to August in 2017 in the municipality of Fortín de las Flores, Veracruz (18° 48' and 18° 59' north latitude; meridians 96° 56' and 97° 02' west longitude) at an altitude between 585 and 1400 m (Figure 1). The climate is semi-warm humid

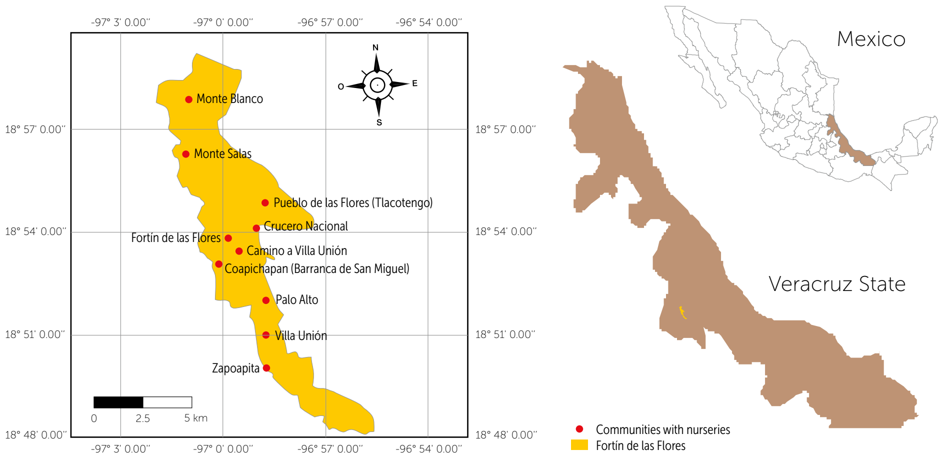

Figure 1. Towns included in the study.
Source: Own elaboration with QGIS® 3.8 Zanzibar with vector data from CONABIO.

with abundant rain in the summer (81%), warm humid with abundant rain in summer (10%), and semi-warm humid with rain all year round (9%). The municipality has an average precipitation of 1900 to 2100 mm and a temperature range of 18-24 °C. The region's ecosystem type is tropical evergreen forest (INEGI, 2009).

Before the study was commenced, the Agricultural Development Office of the Municipality of Fortín de las Flores was contacted, and the objective of the study was discussed. The Agricultural Development Office showed interest and later supported the investigation by indicating the towns that had nurseries registered with the municipality. These nurseries were visited by town following the census registration technique, and their owners or managers were invited to participate. Once permission was granted for the interview, a semi-structured questionnaire with 5 closed questions and 16 open questions was administered, containing the following sections: general information, surface area, plants produced, growing season, general and post-harvest management, infrastructure, plants sold, main client, presentation for sale, problems, associations, and government support. In total, 150 nursery owners in the region were interviewed, and a regional census was taken. The analysis of the qualitative information was done with NVivo® v. 10 and the analysis of the quantitative information was performed with IBM-SPSS® v. 20.

RESULTS AND DISCUSSION

Of the total number of nursery owners, 65.3% were men and the rest were women, in the following communities: Monte Blanco (1.3%), Monte Salas (4.0%), Pueblo de las Flores-Tlacotengo (22.0%), Crucero Nacional (3.4%), Fortín de las Flores (16.7%), Camino a Villa Unión (16.7 %), Coapichapa-Barranca de San Miguel (15.3%), Palo Alto (7.3%), Villa Unión (11.3%), and Zapoapita (2.0%) [Figure 1].

Biodiversity inventory

In total, the respondents reported 230 different plants at their nurseries. 37% of these originate from America, 30% from Asia, 19% from Africa, 11% from Europe, and the rest from Oceania. Of those originating in America, there are plants in Brazil, Peru, Argentina, Paraguay, Chile, Colombia, Venezuela, Uruguay, Ecuador, and the United States. Of the total, 87% were non-native and the rest were Mexican. The following Mexican plants were reported: *Arecaceae* Bercht. & J. Presl, *Agave tequilana* F.A.C. Weber, *Taxodium mucronatum* Ten., *Beaucarnea recurvata* Lem., *Cedrus* Duhamel, *Capsicum annuum* L., *Spathiphyllum cochlearispathum* (Liebm.) Engl., *Dioon edule* Lindl., *Plumeria rubra* L., *Galeana hastata* La Llave, *Yucca elephantipes* Regel ex Trel., *Xanthosoma* Schott, *Agave* Dumort., *Euphorbia pulcherrima* Willd. ex Klotzsch, *Pinus montezumae* Lamb, *Orchidaceae* Juss., *Orchidaceae* spp., *Cattleya* Lindl., *Oncidium maculatum* (Aubl.) Urb., *Oncidium sphacelatum* Lindl., *Brahea armata* S. Watson, *Chamaedorea elegans* Mart., *Acrocomia aculeata* (Jacq.) Lodd. ex Mart., *Chameredorea metallica* O.F. Cook ex H.E. Moore, *Ceiba aesculifolia* (Kunth) Britten & Baker f., *Chamaedorea tepejilote* Liebm., *Sedum morganianum* E. Walther, *Begonia tuberosa* Lam, *Juniperus communis* L., and *Polianthes tuberosa* L.

Of the plants listed by the respondents, only 28 were frequently mentioned as being grown; of these, 3 plants were reported by more than 20 nursery owners, making them the most-frequently-produced plants (Table 1): *Caesalpinia echinata* Lam., *Syagrus romanzoffiana* (Cham.) Glassman, and *Anthurium andreanum* Linden; 2 were reported by 5 nursery owners: *Arecaceae* and *Phoenix roebelenii* O'Brien, and 22 plants had fewer than 5 mentions.

Infrastructure and management

On average, the surface area (cultivation area and point of sale) reported by the nursery owners, was

Table 1. Principal plants reported by nursery owners as produced, sold, and that generate profits in nurseries of the municipality of Fortín de las Flores, Veracruz, number of times a specie is mentioned, only the first mention is considered.

Scientific name	Local common name	Production	Sale	Gen. profits	Total
Anthurium andreanum Linden [NN]	Anturio	21	18	17	56
Arecaceae Bercht. & J. Pres.[M,NN]	Palmas en general	9	7	8	24
Asparagus virgatus Baker[NN]	Trifer	3	4	7	14
Balsaminaceae A. Rich.[NN]	Belén (chino)	1	2	2	5
Beaucarnea recurvata Lem.[M]	Pata de elefante	1	1	3	5
Bougainvillea Comm. ex Juss.[NN]	Buganvilia	1	1	1	3
Cactaceae Juss.[M,NN]	Cactus	1	1	1	3
Caesalpinia echinata Lam.[NN]	Maicera (Palo de Brasil)	34	31	27	92
Chamaedorea elegans Mart.[M]	Palma camedor	1	1	1	3
Chamaedorea tepejilote Liebm.[M]	Tepejilote	1	1	1	3
Chlorophytum comosum (Thunb.) Jacques[NN]	Listón (Listoncillo)	2	1		3
Chrysalidocarpus lutescens H. Wendl.[NN]	Areca		1		1
Chrysanthemum L.[NN]	Crisantemo			1	1
Citrus × *limon* (L.) Osbeck[NN]	Limón			1	1
Cycas L.[NN]	Cica			3	3
Cymbidium Sw.[NN]	Orquídea barco (Cymbidium)	1		1	2
Cynodon dactylon (L.) Pers.[NN]	Pasto	3	4	4	11
Dracaena deremensis var. *Warneckei* Engl.[NN]	Guarneque (Warneckii)	2	2	1	5
Dracaena marginata Lam.[NN]	Dracena (Marginata, Tricolor, Marquinata)	4	1	3	8
Heliconia caribaea Lam.[NN]	Heliconia	2	1	1	4
Heliconia rostrata Ruiz & Pav.[NN]	Trenza de indio	1			1
Hydrangea macrophylla (Thunb.) Ser.[NN]	Hortensia	1			1
Hyobanche sanguinea L.[NN]	Parásito			1	1
Hyophorbe Gaertn.[NN]	Palma Mascareña (de botella, Cuello de botella)	2	2	3	7
Gardenia jasminoides J. Ellis[NN]	Gardenia	1	2	2	5
Juniperus communis L.[M,NN]	Junípero		1		1
Ligustrum lucidum W.T. Aiton[NN]	Trueno	1		1	2
Lilium candidum L.[NN]	Azucena (Lirio, Liris)	2	1	1	4
Oncidium sphacelatum Lindl. [M]	Orquídea flor de mayo		1		1
Orchidaceae Juss.[M,NN]	Orquídeas en general		2	2	4
Phoenix roebelenii O'Brien[NN]	Palma robelina	7	5	13	25
Rosa L.[NN]	Rosa		3	2	5
Rumohra adiantiformis (G. Forst.) Ching[NN]	Helecho cuero (Leder)	1	1	2	4
Strelitzia reginae Aiton[NN]	Ave de paraíso	3	3	5	11
Syagrus romanzoffiana (Cham.) Glassman[NN]	Palma coco plumoso	29	35	23	87
Zingiber spectabile Griff.[NN]	Maraca	2	2	2	6

M = Mexican; NN = Non-native. Source: Own elaboration with field data.

7,332.71 ± 11,870.37 m^2, with a maximum of 90,000 m^2 and a minimum of 2 m^2. 29.9% of the respondents had between 2 and 500 m^2, while 70% had less than 7,500 m^2. Regarding infrastructure, 7 nursery owners did not respond to the question on the subject, and of the rest, 99 mentioned that they do not use any infrastructure and grow their plants in the open field, while 20 reported using shade mesh and only 2 have nurseries. The rest of the respondents (22) reported having combinations of the above; the mixture of open field and shade mesh was the most common combination while only 2 reported having open field with greenhouse production.

46.6% indicated that they use fertilizers and 4.4% did not answer the question. Among the products mentioned are: urea, 17-17-17, potassium nitrate, ammonium sulfate, phosphonitrate, chicken manure, filter cake, compost, foliar Nitrofoska®, blue Nitrofoska®, Gro-green®, Nutrigen®, Solucat®, Osmocote®, and Poly-feed®. Other products mentioned were rooting agents such as Raizal®, and agrochemicals such as fungicides (Promyl®, Ridomil Gold®, Aliette® WG, Cupravit®, Daconil®); insecticides (Foley Rey®, Pirecris®, Arrivo® 200CE, Dimetri® 400, Raid Casa y Jardín®, Malathion®, Ambush®, Furadan®); rodenticides (compound 1080, poison bait, generic poison pills); and other products such as water pH regulators (Agrex®abc, Adherex Acid®); hormones (Foltron® Plus) and substrates (Mapito RFX-1 from Agra-Wool).

When asked about diseases, 15 out of 150 nursery owners reported that they have problems with fungi and 1 had problems with bacteria. With regard to pests, the cricket is the most common (52 out of 150 mentioned this pest); then there is the gopher (13), the Mayate beetle (11) and rabbits (7); spiders, ladybugs, ants, and red mites (4 of 150); worms, the butterflies, and slugs (3 out of 150); while birds, moths, mealybugs, aphids, and moths were mentioned infrequently.

Of the total number of respondents, 18 indicated that they had problems such as lack of water or lack of irrigation systems and 1 reported having problems due to excess moisture. Most of the nursery owners reported that they did not have problems attributable to weather. For those who do have problems in this area, the main issues were meteorological in nature: southerly winds (20 of 150), heat (15), hail (11), and low temperatures (7).

Commercialization

The nursery owners mentioned 20 plants as the most frequently sold, of which only 8 are Mexican, and these are the same as those that were most frequently produced (Table 1); however, the order of the three main plants varies slightly, since *Syagrus romanzoffiana* (Cham.) Glassman ranks first in sales and second in production, *Caesalpinia echinata* Lam. The respondents mentioned 31 plants as those that generate the highest amount of profits, the first three of which correspond to the same three that were most frequently produced. *Phoenix roebelenii* O'Brien was notable as the fourth plant mentioned for generation of profit.

26% said that they have regular customers, while 65%, reported that they sell their products to strangers, and the rest did not answer the question. A third of the nursery owners reported that they sell their plants in a plastic bag and/or with root balls, 32 of the 150 respondents indicated that they sell cut flowers, 4 nursery owners reported that they sell in pots, and the rest of the nursery owners sell combinations of the above. Three of them indicated that they sell plants in bulk with bare roots, and only 1 reported selling bouquets and 1 reported selling arrangements. Those who deliver cut anthuriums (5) mentioned that they sell the product in a box, and grass is sold in rolls.

90 of the 150 interviewees do not carry out any post-harvest handling; in some cases it was reported that the client is the person responsible for this activity. Those who did report post-harvest activities indicated that these activities vary according to the product that they grow and sell the most. Those who grow anthuriums generally cut them and leave them resting in buckets of water. In this case, there are two options: Either the client comes and takes them as they are (7 nursery owners), or, the owners classify the flowers by size and color, and then pack and deliver them to vendors in markets or to wholesalers who take them to Mexico City markets (4 nursery owners). Those whose main product are ferns and palms reported that they clean, roll, interweave, ball or tie them, and bag them (7 nursery owners). Those who mainly sell plants clean them, some bag them or pot them, while others sell them with bare roots, and those who sell grass roll it up and put it in sacks. The rest of the nursery owners indicated that they sell a variety of products, so they reported combinations of the above.

The most frequent period reported as the one with the highest sales was March-May, followed by June-October, November-December, and to a lesser extent January-February and various combinations of periods. The holidays were February 14, May 10, November 2, and December 12.

Commercialization problems

Successful commercialization is a fundamental aspect of any agricultural activity and 25% of the nursery owners reported that they did not have any problems in this regard. The rest gave different answers, which are shown in Figure 2. The first problem is the price. In general, the complaint is that whoever the buyer is always buying at low prices. It was reported that the buyers haggle with them for the amount. This occurred with both the final consumers and the intermediaries, while the producers do not receive any discounts whatsoever on the cost of the materials that they need in order to grow their products. Thus, they are price-takers who sell commodities in a mature market. The second problem is related to aspects such as size, leaves and demand by customers for quality plants. For example, they ask for plants with: leaves/flowers without chopping, scraping, shaving, or breakage, as well as specifications about the size of the leaves or the thickness of the stems and flowers with good vase life. Problems with nonpaying clients and unfair competition among nursery owners were reported to a lesser extent. The remoteness of the nurseries, the lack of organization among them, the lack of advertising, the seasonality of production and demand, the lack of plant diversity or of whatever the customer was looking for, and the lack of an attractive presentation for their customers were other problems mentioned by the respondents.

Associations and government support

Belonging to associations is a relevant factor to achieve common benefits such as the management of government support and consolidated purchasing. Despite the benefits that could be obtained, only 35 of the respondents (24%) indicated that they belonged to

Figure 2. Word cloud with the most occurrence mentioned by the respondents when describing commercialization problems.
Source: Own elaboration.

an association, such as "los Amigos de las Orquídeas de Paso Coyol," "Anturios Selectos de Fortín," and the "Parque Florístico de Fortín" Associations. 19% reported that they had no interest in belonging to any association, due to the problems that would arise among the members, and they did not see any usefulness in it, preferring independence. The rest of the respondents reported that they would be interested in belonging to an association in order to obtain training, government support, increase sales, and management support.

With regard to government support, 9.5% of the respondents (14) reported that they had received some sort of it. Most were from the government of the State of Veracruz. Only one mentioned the Federal Ministry of Agriculture. The support they received was in the form of infrastructure for greenhouses, shade netting, pumps, and in one case financial support.

The production of ornamental plants is an activity for which the municipality of Fortín de las Flores is recognized at the regional level (Murguía-González *et al*., 2003). The present study aimed to construct an inventory of biodiversity, management, and commercialization of ornamental plants in the nurseries of the municipality. Regarding the variety of biodiversity, 230 common names of plants were mentioned. Of all those listed, 28 were the most frequently sold. A study in Brazil found that in the market, 45 species were preferred (Muraro *et al*., 2016). Therefore, markets tend to focus on certain species despite the abundance of them that could be offered.

Unlike other regions of the world that have been characterized by the production of native and exotic species (Junqueira y Peetz, 2018), Fortín de las Flores has specialized in the reproduction and commercialization of non-native commercial plants such as anthuriums, palms, and foliage plants. In fact, the vast majority of plants that are sold are introduced species. Underutilization of native species in Mexico and other parts of the world has been previously documented (Pietersen *et al*., 2018), where a market orientation is predominant (Major *et al*., 2005), and determined by the sociocultural context and the networks of the producers (Cleveland *et al*., 2000). This is exacerbated by consumers who are ignorant and have no interest in knowing the origin of the plants they are buying (Mayett-Moreno *et al*., 2018), so there is not a specific demand for native plants; to the contrary, the consumers of ornamental plants are characterized by the acquisition of imported exotic plants (Poot–Pool *et al.*, 2015).

One should also consider the changes in the legislation for the protection of native species prohibiting the extraction and sale thereof. This limits their propagation (Dénes, 2017). Also worthy of concern is the loss of native species due to overexploitation (Wong y Liu, 2019).

Despite the fact that Veracruz is one of the states with the largest amount of native species with flowers (angiosperms) endemic to Mexico and in particular to the State (Villaseñor y Ortiz, 2014), and as has been identified in previous studies, small producers tend to collect and breed plants that may be of some use, be that medicinal, edible, or as wood material that can be easily consumed or commercialized (Díaz-Forestier *et al.*, 2019). This explains why native plants are not the species that are the most often sold in the studied nurseries.

In a study on nurseries done in Florida, United States, the authors found that 21.5% of the nurseries' sales was palm trees and tropical foliage plants (Hodges *et al.*, 2016), which were the main products sold, a finding similar to what was observed in this study. It is likely that the tropical climate contributes to the decision to mainly produce these types of plants instead of cut flowers, which are produced in colder areas (Castillo Nonato *et al.*, 2018). This represents a business opportunity.

The nurseries, in general, have little technology, and there have been no significant changes in the last two decades (Murguía-González *et al.*, 2003). Low technological levels are related to a lack of training of the nursery owners, which has resulted in a type of production in which there no quality standards oriented to the local market (Fernández-Zamudio *et al.*, 2012). These low standards are in contrast with what is happening in other regions of the world, where high-quality flowers are produced at high technological levels. One such region is the Netherlands (Verdouw *et al.*, 2013). As for innovations such as robotization, water recycling, energy cogeneration, the use of solar panels, alternative methods for pest control, novel packaging, labels, web pages, marketing organizations, or other innovations (Lambrecht *et al.*, 2015), these have not been utilized in the region.

With regard to commercialization, due to the fact that they breed commercial plants, the price of their products is subject to the market prices, which is a weakness for producers (Fernández-Zamudio *et al.*, 2012). Previous results show that producers sell their plants to housewives, as well as to some shops and trade fairs (Murguía-González *et al.*, 2003), which is consistent with our findings. This is also evidence that the marketing systems have not changed. The focus continues to be on the local market or casual clients, with no formation of cooperatives or trading companies in order to export the plants and flowers that they grow. Disorganization among plant traders has also been observed in Brazilian markets (Muraro *et al.*, 2016), especially among small and medium-sized enterprises.

The limited growth of small nurseries is a phenomenon that has already been documented and explained as a lack of specialization, where the owner has the dual role of grower and merchant (Di Vita *et al.*, 2015). This is in contrast with producers from other states in Mexico, where some have attained success as exporters of cut flowers, probably as a consequence of the presence of foreign producers who brought investment and introduced technology (Castillo Nonato *et al.*, 2018). This shows how important the region's sociocultural context is for local development.

CONCLUSION

There is an interdependence between the commercialization of ornamental plants and their propagation, in which the laws of the market are decisive for the floristic landscape of the nurseries in regions that could make better use of their local biodiversity. The case analyzed in the region of Fortín de las Flores, Veracruz is a clear example of the above. We conclude that when imported exotic plants have been sold locally, there has been a resulting underutilization of native agrobiodiversity. This is evident from the main species that are sold as well as those that generate the highest profits for the nursery owners. This goes hand in hand with poor local technological development characterized by small and medium-sized enterprises with no specialization or trade organization, that compete with each other, which occurs, to a certain degree, as a result of the sociocultural context of the region.

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In vitro gas and methane production and dry matter degradation of pumpkin (*Cucurbita argyrosperma*) silages with pangola grass (*Digitaria decumbens*) hay

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ABSTRACT

Objective: Determine the *in vitro* production of gas and methane and dry matter degradation of pumpkin shell and pulp silages (PSP; *Cucurbita argyrosperma*) with pangola grass hay (*Digitaria decumbens*) and, as additives, urea and two inclusion percentages of molasses fermented for 14 and 21 days.

Methodology: Silages (2 kg) were: S1 = 72.5% of PSP, 22.5% of pangola grass, 3% of molasses, and 2% of urea; S2 = 72.5% of PSP, 19.5% of pangola grass, 6% of molasses, and 2% of urea. Both silages were fermented for 14 and 21 days. We evaluated gas and methane (CH_4) production, total bacteria count, and dry matter degradation (DMD). The experiment followed a completely randomized design with a 2 × 2 factorial arrangement, with types of silage and fermentation time as factors.

Results: The S1 treatment, at 21 d, showed the lowest production of gas at 72 h (46.96 mL g^{-1} DM) and the lowest DMD (35.78%; $p \leq 0.05$). Methane production and total bacteria count were not significantly different ($p > 0.05$) between the types of silage or fermentation time.

Study limitations: The inclusion of 3% of molasses with a fermentation time of 21 d showed the lowest gas production and dry matter degradation of silages with pumpkin shells and pulp with pangola grass hay.

Conclusions: The silages made of pumpkin shells and pulp are viable alternatives to preserve and produce ruminant feed during drought periods. Moreover, these silages represent an alternative use for potentially polluting materials, such as pumpkin shells and pulp.

Keywords: *Digitaria decumbens*, *Cucurbita argyrosperma*, gas production, silage, *in vitro*.

INTRODUCTION

Pumpkin is a vegetable from the Cucurbitaceae family that originated from the American continent (Martínez-Valdiviezo *et al*., 2015); of the 825 documented species. Mexico cultivates 13 species of nutritional importance for humans and 128 wild species. One of the most cultivated native species is *Cucurbita argyrosperma*; this species has medicinal properties and is also consumed by humans (Lira *et al*., 2002)

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in tropical and subtropical regions (Ireta-Paredes *et al.*, 2018). In Mexico, the states with the greatest diversity of cultivated species are Oaxaca, Chiapas, Jalisco, Michoacán, Veracruz, and Guerrero (Lira *et al.*, 2002). While the main producers of *Cucurbita argyrosperma* are Guerrero (in the Costa, Centro, la Montaña, Tierra Caliente, and Norte regions; Ayvar *et al.*, 2004), Tabasco, Zacatecas, and Campeche, whose main objective is to obtain seeds, with a production of 0.5 t ha^{-1} (Ireta-Paredes *et al.*, 2018). The rest of the vegetable (shell and pulp) is not consumed by humans, and thus, it is discarded in fields or plots, causing an environmental problem. Therefore, the production of silages using the agricultural by-products available in the region represents a viable alternative in the tropics, which favors obtaining food, particularly during the dry season, reducing feed costs, and taking advantage of potentially polluting agricultural residues (Guzmán *et al.*, 2012).

The pumpkin shell and pulp (PSP) contains: 13.71% of dry matter (DM), 15.40% of raw protein (RP), 48.01% of neutral detergent fiber (NDF), 24.21% of acid detergent fiber (ADF), 23.80% of hemicellulose, 13.78% of ashes, and 86.22% of organic matter (OM; Lorenzo-Hernández *et al.*, 2019). Moreover, PSP has an approximate yield of 1 t ha^{-1} of DM (Dorantes-Jiménez *et al.*, 2016). The silage production process allows the fermentation of soluble carbohydrates into lactic acid to preserve the nutrients of the processed material (Yitbarek and Tamir, 2014). Moreover, using additives like urea and sugarcane molasses improves the lactic acid bacteria fermentation and increases the nutritional value of the silage (Araiza-Rosales *et al.*, 2015).

The gas production technique simulates the ruminal environment under laboratory-controlled conditions (temperature, pH, anaerobiosis, and minerals) and evaluates the fermentation of different substrates (Storm *et al.*, 2012); this technique is also used to evaluate the degradation of unconventional ruminant feeds (Sánchez-Santillán *et al.*, 2018). This study aimed to determine the *in vitro* production of gas and methane and the dry matter degradation of silages made of pumpkin shells and pulp, pangola grass hay, urea, and two percentages of sugarcane molasses fermented for 14 and 21 days.

MATERIALS AND METHODS

Study localization

The research was performed in the Animal Nutrition laboratory of the School of Veterinary Medicine and Zootechnics No. 2 of the Universidad Autónoma de Guerrero, located in Cuajinicuilapa, Guerrero, México (16° 28′ 18″ N, 98° 24′ 55″ W, 50 masl).

Silages

Silages were produced using pumpkin shells with pulp without seeds (*Cucurbita argyrosperma*), pangola grass hay (*Digitaria decumbens*), and, as additives, sugarcane molasses and urea. The pumpkin shells with pulp and the pangola grass hay were ground in a multifunction mill (M.A.GRO® TR-3500, Mexico) with a 2.54 cm diameter sieve. Two molasses inclusion percentages (3 and 6%) were evaluated, silages were: S1 = 72.5% of *C. argyrosperma*, 22.5% of *D. decumbens*, 3% of molasses, and 2% of urea. S2 = 72.5% of *C. argyrosperma*, 19.5% of *D. decumbens*, 6% of molasses, and 2% of urea. Silages (2 kg) were produced in polypropylene bags (40 × 40 cm), the air was extracted with a vacuum (Koblenz®, Spain), and bags were closed with raffia to maintain the anaerobic conditions required to start the 14 and 21 day fermentation process.

Culture medium

The culture medium contained: 30 mL of clarified rumen fluid [fresh bovine rumen fluid centrifuged at 12,857 g for 10 min and sterilized 15 min at 121 °C and 15 psi], 5 mL of mineral solution I [6 g of K_2HPO_4 (Sigma-Aldrich®) in 1 L of distilled water], 5 mL of mineral solution II [6 g of KH_2PO_4 (Sigma-Aldrich®) + 6 g of $(NH_4)_2SO_4$ (Merck®) + 12 g of NaCl (Sigma-Aldrich®) + 2.45 g of $MgSO_4$ (Sigma-Aldrich®) + 1.6 g of $CaCl\text{-}2H_2O$ (Sigma-Aldrich®) in 1 L of distilled water], 0.1 mL of resazurin at 0.1% (Sigma-Aldrich®), 0.2 g of peptone from soybean (Merck®), 0.1 g of yeast extract (Sigma-Aldrich®), 2 mL of cysteine-sulfide solution [2.5 g of L-cysteine (Sigma-Aldrich®) in 15 mL of 2N NaOH (Meyer®) + 2.5 g of $Na_2S\text{-}9H_2O$ (Merck®) made up to 100 mL with distilled water], 5 mL of a Na_2CO_3 solution at 8% (Merck®), and 50.6 mL of distilled water, according to Torres-Salado *et al.* (2019). The medium was sterilized in an autoclave at 121 °C and 15 psi for 15 min based on the Cobos and Yokoyama (1995) methodology, modified by Sánchez-Santillán *et al.* (2016).

Solutions

Saturated saline solution: In 1 L of distilled water, we dissolved 370 g of NaCl and added 5 mL of 0.1% methyl orange. The pH was adjusted to 2. This solution was poured into serum vials (120 mL), at full capacity, to obtain saline solution gas traps. NaOH (2 N) solution: In 1 L of distilled water, we dissolved 80 g of NaOH. This solution was poured into serum vials (60 mL), at full capacity, to obtain NaOH (2 N) traps.

Biodigesters

We added 0.5 g of the sample at a constant weight and 45 mL of culture medium to serum vials (120 mL). Vials were kept under a continuous CO_2 flow to maintain anaerobic conditions. Each vial was hermetically sealed with a neoprene septum (Ø 20 mm) and an aluminum crimp seal. Biodigesters were sterilized and subsequently inoculated with 5 mL of the total ruminal bacteria obtained from the rumen fluid of a Suiz-bu cow. Biodigesters were incubated in a water bath at 39 °C for 72 h. The fresh rumen fluid was obtained from a cannulated cow [fed in pangola grass (*Digitaria decumbes*) pastures] and filtrated through a double gauze layer to eliminate organic matter macroparticles. Bovines were handled following the internal bioethics and well-being regulation of the Universidad Autónoma de Guerrero, which is based on the Official Mexican Standard NOM-062-ZOO-1999.

***In vitro* gas production**

The biodigesters' gas production was determined at 24, 48, and 72 h with a Tygon® hose (internal Ø: 2.38 mm, length: 45 cm) with hypodermic needles (20 G × 32 mm) at the ends. Needles were used to couple a biodigester with the gas trap vial (saturated saline solution). The trap vial was placed upside down in a modified graduated cylinder, which collects the saline solution displaced by the gas produced during the incubation through a hypodermic needle positioned as an outlet valve (Torres-Salado *et al*., 2019).

Methane (CH_4) production

To measure methane (CH_4) production, we followed the same procedure described to measure gas production, but tramp vials were filled with a NaOH (2 N) solution, modified from the methodology described by Stolaroff *et al*. (2008). CH_4 production was measured as milliliters displaced from the NaOH (2 N) solution at 24, 48, and 72 h. CO_2 reacts with NaOH and forms Na_2CO_3 (Prada-Matiz and Cortés-Castillo, 2011).

pH and total bacteria count

At the end of the incubation period (72 h), we measured the pH with a pH meter (Hanna® HI2211, Italy; calibration: pH 7 and 4). We used a micropipette (Corning®, USA) to extract 1 mL of the medium contained in each biodigester and placed it in a test tube (Pirex®) with 0.25 mL of 10% formaldehyde (Sigma-Aldrich®). The total bacteria count was calculated by direct counting in a Petroff-Hausser cell-counting chamber (Hausser #39000, Electron Microscopy Sciences, USA), with an area of 0.0025 mm^2 and a depth of 0.02 mm. Cell-counting was performed using a microscope (BX31, Olympus, USA) at a magnification of 1000 (Sánchez-Santillán *et al*., 2016). Total bacteria count was calculated with the equation: Total bacteria count = (average) (dilution factor, 2×10^7) (Sánchez-Santillán and Cobos-Peralta, 2016).

Dry matter degradation

After the incubation period, the residual content in the biodigester was filtered through ANKOM® bags (ANKOM® Technology) to constant weight. Filter bags were then sealed. The bags were dried at 60 °C in a forced-air oven (RIOSSA® HCF-41, Mexico) for 24 h. Dry matter degradation (DMD) was calculated with the equation DMD % = (initial sample - final sample / initial sample) * 100 (Sánchez-Santillán *et al*., 2016).

Statistical analysis

Results (four replicates per interaction) were analyzed in a completely randomized design with a 2 × 2 factorial arrangement (SAS, 2011). Factors were type of silage (S1 or S2) and fermentation time (14 and 21 d). Averages were adjusted by least squares and compared using the Tukey test.

RESULTS AND DISCUSSION

The *in vitro* gas production technique has been used to evaluate the effect of different forages, feeds, diets, and ruminal fermentation additives (Crosby-Galván and Ramírez-Mella, 2018). This technique simulates the digestive processes of the microbial fermentation of carbohydrates to determine the nutrient quality and availability for rumen microorganisms (Antolín *et al*., 2009). The gas production analysis was performed separately for the ingredients used to prepare silages (PSP and pangola grass hay) and the silages. In silages, we observed interactions between factors in all the variables analyzed. The gas production of PSP was higher (32.47, 50.09, and 37.76 mL of gas g^{-1} DM at 24, 48, and 72 h, respectively) than that of pangola grass hay (Table 1); this is associated with the higher content of non-structural carbohydrates in the PSP. At 24 h, the gas production of S1 with 21 d of fermentation was lower ($p\leq0.05$) than the rest of the silages. However, at 48 h, the highest gas production was observed in S1 with 14 d of fermentation ($p\leq0.05$). At 72 h of incubation, S1 with 21 d had a lower gas production ($p\leq0.05$), representing 73.88% of the total gas production averaged by the rest of the evaluated silages (63.56 mL of gas g^{-1} DM; Table 1). The levels of gas production were obtained from the anaerobic fermentation of soluble or structural carbohydrates, but silages originate from anaerobic fermentation (Sánchez-Santillán *et al*., 2015). Antolín *et al*. (2009) reported higher values than those observed in this study, with a production of 217.5 mL of gas g^{-1} DM at 96 h of incubation in hybrid corn silages. Navarro-Villa *et al*. (2012) evaluated the *in vitro* gas production of silages made of *Lollium perenne* grass; their results show that gas production was 2.4 times higher than what is reported in this study. Moreover, compared to this study, Rojas-García *et al*. (2020) reported higher values at 24 h (112 mL of gas g^{-1} DM) and similar values at 48 h (47.6 mL of gas g^{-1} DM); however, at 72 h, the production is lower (33.9 mL of gas g^{-1} DM) in the complements prepared with PSP flour (70%) and parota pod flour (30%).

Methane (CH_4) production differ ($p\leq0.05$) at 24 h, but there were no differences at 48 and 72 h ($p>0.05$) between S1 and S2 (Table 2). The difference at 24 h was observed in the fermentation times of S1. The fermentation time of 21 d produced 3.46 mL of CH_4 g^{-1} DM more than the 14-d fermentation ($p\leq0.05$). Silages averaged 13.43 and 17.21 mL of CH_4 g^{-1} DM at 48 and 72 h of incubation (Table 2).

These data are lower than the 22.9 mL of CH_4 g^{-1} DM

Table 2. CH_4 production (mL g^{-1} of DM) in silages with pumpkin shells and pulp, pangola grass hay, urea, and two levels of molasses fermented for 14 and 21 days.

Silage	Fermentation (d)	Incubation time (h)		
		24	48	72
S1	14	6.37[a]	14.40[a]	17.27[a]
S1	21	9.83[b]	13.94[a]	18.84[a]
S2	14	7.32[a]	12.68[a]	16.19[a]
S2	21	8.03[a]	12.70[a]	16.56[a]
Cucurbita argyrosperma		21.48	31.60	35.25
Digitaria decumbens		10.32	18.42	24.90
SEM		0.67	0.91	0.96

[a,b] Means with different letters in the same column indicate statistical difference ($p\leq0.05$).
CH_4 = Methane gas; S1 = 72.5% of *C. argyrosperma*, 22.5% of *D. decumbens* hay, 3% of molasses, and 2% of urea; S2 = 72.5% of *C. argyrosperma*, 19.5% of *D. decumbens* hay, 6% of molasses, and 2% of urea; SEM = standard error of the mean.

Table 1. *In vitro* gas production (mL g^{-1} of DM) in silages with pumpkin shells and pulp, pangola grass hay, urea, and two levels of molasses fermented for 14 and 21 days.

Silage	Fermentation (d)	Incubation time		
		24	48	72
S1	14	25.43[a]	53.96[a]	69.77[a]
S1	21	21.04[b]	34.36[b]	46.96[b]
S2	14	28.03[a]	40.22[b]	59.52[a]
S2	21	26.92[a]	41.20[b]	61.38[a]
Cucurbita argyrosperma		95.53	140.40	154.12
Digitaria decumbens		63.06	90.31	116.36
SEM		4.404	6.14	6.08

[a,b] Means with different letters in the same column indicate statistical difference ($p\leq0.05$).
S1 = 72.5% of *C. argyrosperma*, 22.5% of *D. decumbens* hay, 3% of molasses, and 2% of urea; S2 = 72.5% of *C. argyrosperma*, 19.5% of *D. decumbens* hay, 6% of molasses, and 2% of urea; SEM = standard error of the mean.

reported by Navarro-Villa *et al*. (2012) in *Lollium perenne* grass silages. However, the CH_4 production reported by Navarro-Villa *et al*. (2012) represented 15.3% of the total gas produced during the gas production assay; this value is lower than what we observed in this study; CH_4 production represented between 24.75 and 46.72% of the total gas produced during rumen microbial fermentation of the silages.

Methane production was higher in PSP than in pangola grass hay at the three evaluated incubation times (Table 2). The CH_4 production of PSP was 2.5, 1.7, and 2.0 times higher than that of the silages at 24, 48, and 72 h of fermentation. The CH_4 production of hay was 1.2, 1.1, and 1.5 times higher than S1 and S2. This is probably due to the lactic acid concentration of silages (Lorenzo-Hernández *et al*., 2019), which favors less methanogenic *in vitro* fermentations (Counotte *et al*., 1981; Navarro-Villa *et al*., 2012) compared to the unprocessed ingredients. The differences in CH_4 production can be associated with the structural and non-structural carbohydrates available during fermentation (Ferro *et al*., 2017). The acetate and hydrogen produced by the fermenting microorganisms (Zhang *et al*., 2015; Sánchez-Santillán and Cobos-Peralta, 2016) favor a syntropic relationship between methanogenic microorganisms, which use hydrogen (H_2) and carbon dioxide (CO_2) as substrates to produce CH_4 as a metabolic pathway for energy production (Torres-Salado *et al*., 2019).

The pH of the biodigester's culture medium was not significantly different ($p>0.05$) between silages or between the unprocessed ingredients (Table 3), with an average pH of 6.78. These values remain between the normal range (6.0 to 7.0) of the ruminal microbiota (Kolver and de Veth, 2002), particularly of cellulolytic bacteria, since their activity is not inhibited (Rojas-García *et al*., 2020). However, pH values lower than 6.0 inhibit their activity (Ley de Coss *et al*., 2016). In this study, the pH values are similar to those reported by Navarro-Villa *et al*. (2012). They reported a pH of 6.69 in the culture media after the *in vitro* ruminal anaerobic fermentation of silages made of *Lollium perenne* grass. Furthermore, the pH in this study is similar to that reported in complements prepared with 70% PSP flour and 30% of parota pod flour (Rojas-García *et al*., 2020). After 72 h of *in vitro* fermentation, the total bacteria count was not significantly different between the ingredients used to prepare the silages. The molasses inclusion percentages and the silage fermentation time did not differ in the total bacteria count at 72 h of incubation ($p>0.05$). The average bacteria count in the silages was 8.2×10^{8} bacteria mL^{-1} (Table 3), which classifies them as fibrous feed since they have 50.76 and 56.99% of NDF (Lorenzo-Hernández *et al*., 2019). The total bacteria count in this study was lower than that reported by Rojas-García *et al*. (2020). They determined the total bacteria count after the fermentation period in the culture media elaborated with pumpkin shell and pulp, reporting 16.7×10^{8} bacteria mL^{-1}.

Dry matter degradation (DMD) was lower ($p\leq0.05$) in S1 with 21 d of fermentation. There were no differences in the remaining silages ($p>0.05$; Table 3). The DMD of silages differed from the degradation observed with PSP. The silages with no observed differences ($p>0.05$) had a DMD average of 49.5%, which represents 69.3% of the DMD of PSP. Higher values (74.6% of DMD) were reported in complements that include 70% of PSP (Rojas-García *et al*., 2020). To find alternative ruminant feeds, different potential products that can cause environmental contamination problems have been evaluated *in vitro*. However, DMD results are variables and depend on the type of products to process. De Haro *et al*. (2001) reported a DMD of 55% in pepper silages; Martínez-Teruel *et al*. (2007) reported a DMD of 63.6% in artichoke silages; Araiza-Rosales *et al*. (2015) reported a DMD ranging from 65 to 70% in silages with increasing apple and molasses concentrations; Gusha *et al*. (2015) reported a DMD ranging from 61 to 75% in cacti silages with tropical legumes; Caicedo *et al*. (2015) reported a DMD between 63.83 and 74.75% in silages with increasing taro concentrations; and Espinoza-Guerra *et al*. (2016) reported DMD between 52.9 and 59.1% in passion fruit silages. This variation and the use of various products impede the comparison with the DMD observed in this study (Table 3). Degradation is affected by the bromatological composition of the products used to prepare the silages (Posada and Noguera, 2005), specifically the amount of soluble sugars available (Araiza-Rosales *et al*., 2015) and the cell wall composition of the products (Ramírez *et al*., 2002).

Table 3. pH, total bacteria count, and dry matter degradation in silages with pumpkin shells and pulp, pangola grass hay, urea, and two levels of molasses fermented for 14 and 21 days.

Silage	Fermentation (d)	pH	[B] (10^{9} cells mL^{-1})	DMD (%)
S1	14	6.77	0.81	50.47[a]
S1	21	6.84	0.80	35.78[b]
S2	14	6.86	0.72	50.35[a]
S2	21	6.78	0.93	47.57[a]
Cucurbita argyrosperma		6.71	1.20	71.47
Digitaria decumbens		6.69	1.14	43.91
SEM		0.018	0.0040	1.700

[a,b] Means with different letters in the same column indicate statistical difference ($p\leq0.05$).
[B] = total bacteria count; DMD = dry matter degradation; S1 = 72.5% of *C. argyrosperma*, 22.5% of *D. decumbens* hay, 3% of molasses, and 2% of urea; S2 = 72.5% of *C. argyrosperma*, 19.5% of *D. decumbens* hay, 6% of molasses, and 2% of urea; SEM = standard error of the mean.

CONCLUSIONS

The silages made of pumpkin shells and pulp are viable alternatives to preserve and produce ruminant feed during drought periods. Moreover, these silages represent an alternative use for potentially polluting materials. The inclusion of 3% of molasses with a fermentation time of 21 d showed at 72 h the lowest gas production and dry matter degradation of silages with pumpkin shells and pulp with pangola grass hay.

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Historical Reconstruction of Subordination in a Local Context: Agroecosystems with Sugarcane in Veracruz, Mexico

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ABSTRACT

Objective: To rebuild the historical transformation of agroecosystems based on sugarcane in the sub-humid tropic, as a consequence of the change in public policies of the Mexican State in the last three decades.

Design/methodology/approach: The transformation of sugar cane agroecosystems was studied in the continuum of reality, as changes in their resource management and management practices. Thus, methodologies used included life stories, field diary, and documentary review. The information collected was transcribed and classified in a database, using keywords for their previous identification by categories. The statements were identified and ordered based on their content, interpretation, and underlying concepts.

Results: During the last century, public policies directed towards the sugar sector encouraged the existence of sugarcane agroecosystems as a monoculture. This implied changes in the management of time, work organization, orientation of the production, dependence on credits driven by the mills, and a process encouraged by the individualization of production, eroding the collective and solidarity work that lay behind other crops.

Study limitations/implications: It is important to compare these findings with other investigations done in sugar cane producing municipalities.

Findings/conclusion: Neoliberal public policies aiming the sugar sector deepened the producers' financial dependence on mills; as a consequence, they lost their autonomy in the management and use of their agroecosystems.

Keywords: Individualization, management practices, oral history, public policies, social trust, subordination.

INTRODUCTION

The presence of sugar cane plantations in the central-south part of the state began in 1519, when it was introduced by the Spanish conquistadors in the region of San Andrés Tuxtla (González, 1994). In colonial times, just like in other producing regions of New Spain, sugar cane growing in Veracruz was based on a system of haciendas, which suffered financial falls during the War of Independence. The result was that, during the first decades of Independent Mexico, the Mexican State acted as a

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protector of cane activity by enacting a law that prohibited the introduction of sugar and honey from abroad in 1824 and established a series of levies to the imports of these products in 1856 (Aguilar-Rivera, 2012). By the end of the 19th and 20th century, sugar cane production was developed under favorable conditions with the increase of exports and the internal demand generated by industrial growth. During this period, Veracruz became one of the main sugar cane producers (Banko, 2005). This changed by the end of the 20th century, when the Mexican State, through public policies framed within a neoliberal development model, limited credit supports, technical assistance and allowed the import of sugar substitute products, which induced the producers to make changes in the management and handling of their agroecosystems (Rubio, 2001; Millán, 2008; Baca de Moral & Cuevas, 2018). Currently, sugar cane producers from the Mexican subhumid tropic continue their activity by enduring the deep crisis derived from the fall in productivity (field and factory), the decrease in international sugar prices, decrease in domestic consumption with the substitution of sucrose for high-fructose corn syrups and non-caloric artificial sweeteners, as well as the instability of petroleum prices, among others (Aguilar-Rivera, 2012; Jiménez, 2017). In areas of greater understanding about the perspective of those that are main actors, this study sought to rebuild the manner in which producers, ejido owners and small owners, from their local domain, construct the impact of public policies boosted by the Mexican State in their agroecosystems.

MATERIALS AND METHODS

This research was performed in the towns of El Mango and El Faisán, municipality of Paso de Ovejas, Veracruz, Mexico, located between the coordinates 19° 17' - 19° 22' north latitude and 96° 20'- 96° 38' west longitude, with a height of 10 to 400 m (INEGI, 2010). The initial recognition of the area of study and their main characteristics was through secondary sources; both conventional maps and Google Earth and Google Maps were used. A script for deep interviews with key informants was prepared in order to know their life stories with the reconstruction of the social-historical process told though their protagonists; this sought a better understanding of the phenomenon from its social, cultural, economic and political character of what happens in what Lara (2014) has named micro-societies and their environment. The intended sample of participants (n = 27) was obtained with the snowball technique (Taylor & Bogdan, 1987), when the information began to be redundant (Baker & Edwards, 2013). Information was transcribed and classified in a database based on keywords (Mayring, 2002), which implied the previous identification of categories. Finally, the statements were identified and ordered based on their contents, construction and underlying concepts.

RESULTS AND DISCUSSION

The part of the agroindustry in the conversion of sugar cane as single component in an agroecosystem

In 1931, sugar entrepreneurs incorporated the Sugar and Alcohol Stabilizing Company, the function of which was to regulate markets to balance sugar production and consumption; this allowed avoiding national overproduction and, therefore, the plummeting of prices. Azúcar S.A. was incorporated in 1932 as a para-state body that represented the main producing zones and cane mills of the country, which were bound to sell their entire sugar stock to the company (Banko, 2005).

From 1946 to 1952, agricultural and industrial development encouragement practices continued within the framework of an increasing economic action by the Mexican State and the application of protectionist mechanisms. The national sugar industry experienced an unprecedented growth, which allowed covering the internal demand and obtaining surplus that was placed in the international market (Banko, 2008). In 1950 the First Sugar Plan was approved in Mexico. It integrated offers of credit resources, social security and retirement for producers. Producers began growing cane in their agroecosystems with the initial use of areas with the poorest irrigation lands and salinity or sewage issues (Thiébaut *et al*., 2013).

> *"In 1950 I began growing cane, and I only grew 1 ha because most of the land was devoted to tomato, papaya, pepper."* (I38, 72 years, Ejido Owner, El Mango).

In 1970, the National Sugar Industry Commission (CNIA) was created. It was responsible for planning and increasing sugar productivity and assuring both internal and external distribution of the product. The industry's financing and the establishment of an administration body for the cane mills that belonged to the public sector were fostered (Banko, 2005), which boosted the growing of cane and its gradual predominance in agroecosystems of the subhumid tropic of Veracruz in decades to come.

This situation changed radically as of 1980, when the Mexican State began reducing the public expense and implementing policies to deregulate the economy and release market forces (Millán, 2008). Under this context, Azúcar, S.A. disappeared and cane grower subsidies and credits were reduced. The Law of Sustainable Development of Sugar Cane was enacted in 1992. The Sugar Industry Reconversion Program was implemented to assure both the national and international demand of sugar. Also, for the first time, the quality of delivered cane was considered to establish its price (sucrose content, purity, juices and fiber). In other words, the standard base recoverable sugar kilograms (KARBE) parameter was abandoned and substituted for standard base sugar (KABE). In the KABE formula, the price of sugar was assigned per the actually recovered sugar. Also, the cane price was closely related to fluctuations in national and international sugar markets and the industry's capacity to adapt to said markets. This impacted producer income from cane growing and they began depending on efficient coordination for the delivery of cane with maximum sucrose and purity in every day of harvest, which should be processed according to the capacity of the sugar mill (this capacity decreased always due to reasons outside the producer).

This way, since the issuance of the sugar cane decree, the conditions for avoiding the rapid loss in sucrose in cane recently cut by the producer would be linked to the cane mill's operating conditions. The continuous operation of industrial machinery during the harvest in the reality of the subhumid tropic of Veracruz has been an exception more than a rule. The certainty of income to be gained by producers increased when the government induced sugar-processing and growing groups to create trusts to assure the growing and payment of cane by taking the future sugar of the harvest as a guarantee (Singelmann, 2003).

The operation and signature of the North America Free Trade Agreement (NAFTA) in 1996, customs barriers that historically protected the national sugar production were demolished. The national production of sugar was threatened by the import of powerful and cheap artificial sweeteners such as corn fructose. Two corn syrup producing plants were installed in Mexico. These were affiliates of other companies in the United States, which would seek to satisfy 25% of the national artificial sweetener demand. In 1998, in order to protect sucrose production, compensation quotas for fructose were established, although its internal production continued based on yellow corn imported at subsidized prices and with no tariff as part of the NAFTA agreements (Loyola, 2003). The Mexican government introduced a commercial dispute that was solved by the NAFTA Binational Panel in 2001 by favoring the production and import of fructose as it did not consider it to be dangerous for the Mexican sugar industry. The World Trade Organization issued a ruling against Mexico and made it cancel the antidoping quota imposed to the import of fructose (levulose), which was 1.5 times sweeter than sucrose, with high fermentation, great humectation power, transparency and adequate viscosity, which turned it into the great substitute of sucrose (Loyola, 2003). This reduced the demand of sugar, which affected both the production and transformation of sugar cane (Thiébaut *et al*., 2013).

How did these changes affect producers and how were their ecosystems affected? The main changes observed during this research in the last three decades in the Veracruz subhumid tropic region are argued. This state is the third sugar producer of the country, with 20 out of 60 cane mills (Mestries, 2000).

Sugar Cane Agroecosystem Transformation in the Veracruz Subhumid Tropic in the Last Three Decades

Historically, cane-growing pioneers in the area of study were the self-named "original" ejido owners and small owners. The grown surface increased progressively, which lead the marginalized corn and bean crops and the abandonment of livestock breeding.

> *"When people began growing more cane, livestock was sold as it occupied space. People have little land and may not have both cane and livestock"* (I99, Borrowed land, successor of land rights, 43 years old, El Mango).

Cane took a progressive occupation of spaces devoted to basic crops and livestock. Nevertheless, sugar cane growing was always linked to supports granted by the Mexican State. This is why, when their policies aimed at fostering cane production changed, cane producers were left defenseless against financing obtained through the resources of cane mills. Producers began losing their autonomy in the handling of their agroecosystems and were subject to decisions made from the cane mill bureaucratic management.

This led producers who turned into caretakers of cane mill interests. In exchange, they gained a weak income and healthcare as beneficiaries of the Mexican Social Security Institute (Vázquez-Palacios, 2003). Cane producers from the study area turned gradually into subordinates of adverse economic interests (Paré, 1987). This subordination was due to the fact that there was a nearby mill that purchased cane. The mill was installed there as it was an ideal place for growing cane and hence find the raw materials needed (Singelmann, 2003). Cane mills have had a direct influence in the pattern of cane varieties, from the substitution of sugar cane, a high producer of sucrose although sensitive to extreme temperatures and flattening (SIAP, 2013) to the introduction of existing varieties.

> "[...] *we have grown several varieties, 290, pineapple, RD, 208; said the sugar mill*." (199, 43 years old, Borrowed land, successor of land rights, El Mango).

In the study area, grown varieties were introduced at least 30 years ago (RD 75-11 & MEX 91-662). Renewing cane plantations implies a big expense in a moment of low cane prices. In order to maintain their plantations, producers restore plants to the land, when the plantation gets into the recovery phase.

> *"Growing a new plantation is expensive. I've got these plants instead. When the time comes, we'll transplant them. That's cheaper."* (I42, Ejido owner, 76 years old, El Faisán).

A change in the harvesting manner has been implemented. This happened as of the first privatization of mills in the 1980s (Skerrit, 2008). New administrations reduced production costs, reason why the employment of machinery was increased both for truck loading at plantations and for increasing the use of harvesting machines in supply areas of the La Gloria and El Modelo cane mills.

Fertilization is fundamental, as it determines the yield of cane; upon decreasing the vigor of plantations, nitrogenated fertilization should increase with the number of cuts (second and third cuts). Upon obviating the foregoing, issues such as the decrease in nutritional level the compaction of soil and presence of plagues and diseases were generated (Aguilar *et al*., 2013). The fertilization made by producers depends on the working capital loans granted by the cane mill and its financial capacity; although this is not an option for all producers in the study area.

The logistics for the cutting of cane involves a Brix content study (total soluble solids present un the juice expressed in percentage), the contents of sucrose in juice or Pol (actual amount of sugar cane present in the juice) and the purity coefficient (percentage of sucrose with regards to total contents of juice soluble solids). Results area communicated to the zone inspector who in turn informs the cane representative and the latter to the land owner. Planning shall include the total surface to be grown, labor, expenses, machinery and potential units in relation to previous years or similar lands, without forgetting the receipt capacity held by the mill at that moment. This is made by mill personnel, which differs with what happened decades ago, when producers were in charge of hiring and managing labor.

> *"One used to hire laborers and work on everything that was needed. Now, you have to pay for files, meals and who knows what else. The mill collects. If you don't agree, you cope with it."* (127, 52 years old, Ejido owner, El Faisán).

The result is that the growing of cane has become a single component in agroecosystems of producers in the study area, although the reproduction of the subsequent cycle is not assured anymore, and the economy of both the producer and his family is at risk. One option is to continue off-farm works of local and extra-local character, hoping that this critical situation will pass. This possibility depends on the behavior of the international market (Thiébaut *et al*., 2013).

Some producers see possibilities in urban expansion above agricultural lands. *El Faisán* and *El Mango* have become areas with high land demand for urban settlements for the children or grandchildren of ejido owners and small owners, who work in neighboring cities and get back to the community every day. The Ejido Rights and Solar Title Certification Program allowed full dominion by the ejido, as its land title was changed for a private property title, which allows them to sell without asking the ejido (Thiébaut *et al*., 2013).

Also, cane producers are being left alone, either because their sons migrated or they are no longer interested in continuing their activity. Terms such as "old-man", "widow" or "poor-man" plantation are common. "Widow plantations" belong to women who inherited land rights from their husbands and work with some relative (sons-in-law, nephews, grandsons) in an improvised agreement. They are in charge of obtaining financing before the cane mill, enforce their rights as users of the irrigation system and have the surface to grow available. Their relatives are in charge of providing follow-up to plantation handling practices.

The price of cane has decreased substantially; government support received per hectare is laughable. Therefore, there is the possibility that producers abandon their agricultural activity as they can no longer have resources for the performance of the subsequent cycle or losses that prevent paying debts to the government. Arbitrary abuse or thefts by the mill management may be added to this uncertainty. Examples are disagreements in the establishment of KARBE, financial cost of credit, inefficient and unnecessary plague control through plane fumigation, change of parameters for defining the payment of the harvest and their progressive decapitalization. The consequence is that decisions that the producer may make with respect to this crisis are minimal, as fundamental management practices in the plantation respond to the mill's decisions. Therefore, adjustments made by the producer in his agroecosystems are minimal and limited to the reduction of the number of fertilizations, application of herbicides and pesticides.

CONCLUSIONS

Changes in public policies aimed at the sugar sector in the 1980s brought modifications in the management of time, work and production orientation. Conditions of greater economic uncertainty promoted the individualization of production, as collective and solidary work was eroded based on social trust. Nevertheless, the fundamental change was the loss of autonomy of producers in handling decisions for their agroecosystems before a decision subordination scheme made from the bureaucratic management of mills. This makes producers make the most radical decision with respect to the handling of their agroecosystems: to keep growing or abandon sugar cane production for good.

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The Mango Value Network (*Mangifera indica* L.) in Campeche, Mexico

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ABSTRACT

Objective: To characterize the mango value network in the state of Campeche and identify its challenges.

Design/Methodology/Scope: Based on secondary information and 40 semi-structured interviews, the structure of the value network structure, its key actors and technology was identified.

Results: Researches recommend a high-density plantation of 3,333 plants ha^{-1}, although producers seek to increase from 69 to 278 plants ha^{-1} only. Generating new production technologies for major cultivars such as Tommy Atkins, Manila and Criollo are required; their vegetative vigor responds differently to local humidity, rain and soil conditions due to their monoembryonic or polyembryonic origin.

Study Limitations/Implications: Producers in the social sector do not keep accounting and production records. An estimate of mango yields, investment, income and profits was obtained based on the opinion of producers from the social and business sector of Campeche.

Findings/Conclusions: Mango producers in the social sector are willing to grow their orchards with 278 plants ha^{-1}; the production technologies of the Tommy Atkins, Manila and Criollo mango cultivars are required and production costs should be estimated. Private sector producers choose to convert mango crops to Persian lime in high plantation density; they deem it to be a priority to address the handling of the fruit fly and its marketing.

Keywords: crop handling, high-density plantations, vegetative vigor.

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INTRODUCTION

Mexico is the main exporter of mango (*Mangifera indica* L.) in the international market (FAOSTAT, 2020). From 2006 to 2015, the state of Campeche held the 10th position nationwide in average production of mango with 35 994 t, with an average performance of 14.1 t ha^{-1}, above the average national yield (9.2 t ha^{-1}) (SIAP, 2016), and similar to 14.3 t ha^{-1} of the leading state, Guerrero. The production has been stable despite having an average annual growth rate (AAGR) of −0.8%. The main grown variety is Tommy Atkins (87.4%), followed by Manila (7.1%) and Criollo (6.1%) mango. From 2006 to 2015, the average harvest of Tommy Atkins mango was 33,734 t and accounted for 93.7% of the state production (SIAP, 2016). According to INIFAP (2012), Campeche has 180 564 ha with productive potential for mango, 62% of which had a high potential. In 2013, Colegio de Postgraduados (COLPOS) Campeche Campus promoted the laying down of mango demonstration lands in its "Champotón" Priority Attention Microregion, located on Carretera Haltunchén-Edzná Champotón, Campeche, where producer visits were received and high-density mango handling courses were given. Also, together with the Department of Rural Development (SDR) of Campeche and the PRODUCE Campeche Foundation (FUFROCAM), the mango production in the demonstration module located in Cayal, Campeche was boosted. Nevertheless, mango production and marketing systems that prevail in the state of Campeche, and the bond that there is among different participant actors were not known. For this, the research objective was to characterize the mango value network in the state of Campeche and identify its issue.

MATERIALS AND METHODS

The research was performed in two stages. The Value Network methodology that was used allowed analyzing the organization of a specialized productive system in a common activity, with the territorial concentration of its economic actors and other institutions, with the development of economic and non-economic nature bonds for the creation of richness, both for their members and territory (Nalebuff & Brandenburger, 2005; Muñoz, 2010). The value network is integrated, at its core, by the actor recognized as the spot of economic activity. On the vertical axis, customers appear on the upper part. They will purchase the produce produced at the center of the network. Also, suppliers appear on the lower part. They will provide all inputs necessary for production. On the horizontal axis, on the left part, complementors that contribute to improve the product for the client appear. On the right side, competitors contribute to make the product less attractive for our clients.

The first research phase was performed from March to August 2016; 20 key actors were interviewed as they were known inside the network as knowledge-bearers and leaders in their activity. Also, information on the plantation environment, agronomic handling and mango marketing was obtained. In the second phase executed from May to June 2018, 20 additional key actors were interviewed and they were asked about the marketing and issues of the mango value network. In both stages, SADER (Ministry of Agriculture and Rural Development), Department of Rural Development (SDR) of Campeche, the PRODUCE Campeche Foundation (FUPROCAM) collaborators and researchers of the National Forestry, Agricultural and Livestock Research Institute (INIFAP) and COLPOS in the state were interviewed. As for the productive part, the non-governmental representative of the Mango Product System in the state, together with the private and social sector producers of the municipality of Campeche, Tenabo, Champotón and Escárcega were interviewed. The social sector is defined by the set of organizations that do not depend on the public sector and which are outside the private sector and includes ejido owners, agricultural communities and some small agricultural owners (Alfaro *et al*., 2009).

RESULTS AND DISCUSSION

With the information obtained in the interviews, the identification and structuring of two mango value networks in Campeche was possible. The first one is located in the social sector and the second one in the private sector, which has a more entrepreneurial-oriented vision.

Mango Value Network in the Social Sector

Producers are at the center of this value network (Figure 1). Orchards are handled traditionally; limited innovations have been adopted in some of these and this allows observing different production levels. Also, it is common to find mango trees in community yards.

Mango orchards are characterized as they have a low growing density, minimum agronomic handling and limited application of fertilizers and fungicides. The quality of the fruit handled this way is better than the one obtained in orchards with no agronomic handling and

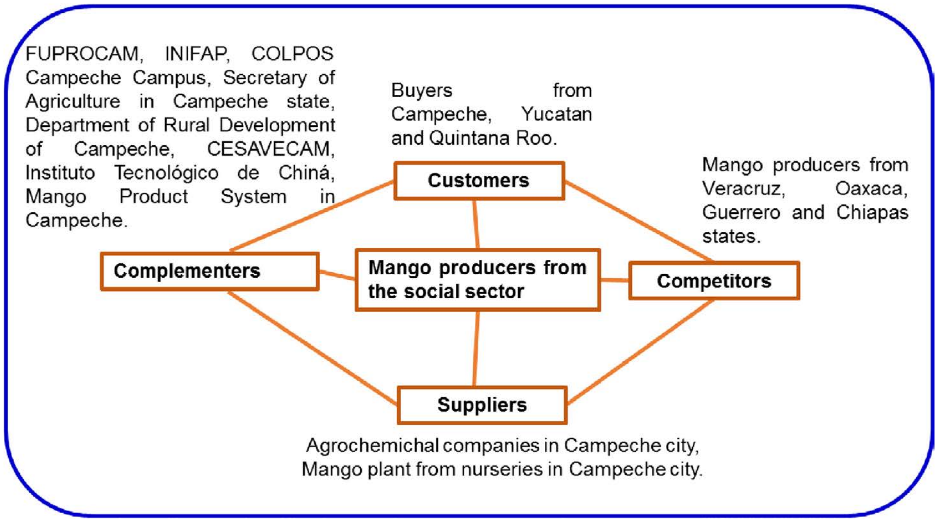

Figure 1. Mango Value Network in the Social Sector in Campeche, Mexico. Source: Self preparation, with field information gathered from 2016-2018.

increased their mean plantation density in their parcels upon increasing from 69 to 278 plants ha^{-1}. Nevertheless, producers do not accept high-density planting; they are concerned about the trunk not being at the posed distance after some years. In comparison with the traditional culture handling, each agronomic practice is performed on specific dates to favor or inhibit the physiologic process of the tree (Vázquez-Valdivia *et al*., 2009). Also, the social sector producer does not implement quality processes and is unware of Best Practices for Agriculture (BPA), which would allow them to obtain fruit for the export market (EMEX, 2016).

the income derived from the sale of fruit is not regular. Orchards are established in soils classified traditionally as type K'ANCAB (honey red land) or "Chromic Luvisol" in the FAO-UNESCO Classification. Other orchards are on YA´AX HOM-type soils (fertile land with vegetation, i.e. "Eutric and dystric Vertisol"), and in AK´AL CHE (lowland flooded land, *i.e*. "Molic and Eutric Gleysol"). Trees grown in AK´AL CHE soils have a limited growth and they do not require maintenance trimming. Producers have incorporated both the trimming and removal of brushes after the harvest, followed by the application of KNO_3 for the floral-fructification advance induction and a fertilization with 3 kg of triple-17 plants^{-1}. In 2018, the municipalities of Campeche, Tenabo, Champotón and Escárcega recorded an average yield of 13.2 t ha^{-1} for the Tommy Atkins cultivar, with an average investment of MX$18,400.00 ha^{-1}, an estimated income of MX$37,000.00 ha^{-1}, and an income of MX$14,800.00 ha^{-1}; nevertheless, improving this income is possible. Since 10 years ago, a producer advances blossoming and produces mango in February, when the price is high (MX$300.00 per 30-kg box). After the courses given by FUPROCAM-COLPOS to grow mango in high density (3,333 plants ha^{-1}) and guided visits to the high-density plantation of COLPOS, Campeche Campus, located at carretera Haltuchen-Edzná, km 17.5, mango producers have implemented some practices in their lands. To induce an advance blossoming, it is common that producers select mango branches based on the amount of present mature shoots, from 5 to 7 months of age in order to spray them with 4 to 6% potassium nitrate (KNO_3) via foliage. Also, formation trimming after the harvest in May have been adopted and they have

Mango value network customers are intermediaries and purchasers from the states of Yucatán and Quintana Roo, who purchase its fresh form, addressed preferably to tourist consumption; also, there are local purchasers from Ciudad del Carmen, Campeche, who bring this to oil rigs. The producer contacts the middleperson through a cell phone, who in turn handles the mango cutting at the orchard. Should the producer harvest, he is responsible for the quality characteristics demanded by the purchaser; should size and color not match the purchaser's request, the price decreases. The fruit offered in town also affects the price because of the competition that exists to sell the product, which is utilized by middlepersons, who speculate with a lower price.

Mango value network competitors in Campeche are producers and sellers in states where mango matching the harvest time is grown, such as Veracruz, Oaxaca, Guerrero and Chiapas. Another actor that takes part in this value network is constituted by input suppliers in agrochemical stores. These companies do not provide credit for producers and only get a payment for the immediate sale of their goods; on occasion, some mango producer families organize to perform consolidated purchases. As for the plant for the establishment of orchards, it comes from local nurseries. Producers take part in training courses and the horizontal transmission of experiences among them for the technical handling of crops.

As a result of the activity of mango value network complementors, a bond between producers with COLPOS has been achieved through demonstrative activities organized by FUPROCAM, SDR and COLPOS itself. Research institutions such as INIFAP, CESAVECAM and Instituto Tecnológico de Chiná do not take part in the resolution of state issues of mango value network and the timely disclosure of results. INIFAP (2013), however, may offer growing production technologies, such as high-density plantation orchards with varieties adapted to the Campeche agroclimatic conditions. In Nayarit, INIFAP showed that, with trimming, the application of paclobutrazol (PBZ) and blossoming inducers, it is possible to control the size of trees and obtain advance harvests with Ataulfo mango (Vázquez-Valdivia *et al.*, 2009). In Sinaloa, INIFAP's results indicate that the Fabián and Palmer cultivars have a post-harvest competitive quality (Siller-Cepeda *et al.*, 2009). In Campeche, FUPROCAM has promoted the plantation of mango in high density; nevertheless, SDR personnel indicate that it is more crucial to find the more adequate date for produce sales. For the Mango Product System Committee in Campeche, the main problem lies in the withdrawal of financial supports for the growing of mango aimed at the social sector.

Mango Value Network in the Private Sector

Mango producers in the private sector are the core of the network (Figure 2), they handle their orchards with production technology provided by technicians from the United States, Brazil or Colombia; or they have applied technology that works in other states of Mexico with weather similar to Campeche.

Orchards are established in K´ANCAB soils (chromic Luvisol). Pruning and thinning out after the harvest, the application or KNO_3 so as to advance blossoming, the application of paclobutrazol (PBZ) to regulate growth and production of ethylene so as to homogenize the yellow color of fruit demanded in the market stand out in the handling of the orchard. These producers mention that the Campeche climate allows the plant to have a rapid and exuberant vegetation growth; nevertheless, these characteristics do not always correspond to a high production level. Producers do not perform the handling of mango orchards in high-density growth, as they consider that the vegetative vigor attained by the mango plant under the Campeche climate conditions does not favor the high-density growth handling technique, reason why they choose to reconvert mango plantations to Persian lime in high-density growth. To this respect, Avilán *et al.* (2007) mention that the trimming type and its periodicity is to be adjusted to the vegetative vigor of the cultivar. Therefore, it is important to consider the excessive vegetative development that characterizes monoembryonic cultivars in the tropic, as it negatively affects the blossoming process and, consequently, the plant's productivity (Avilán *et al.*, 2005).

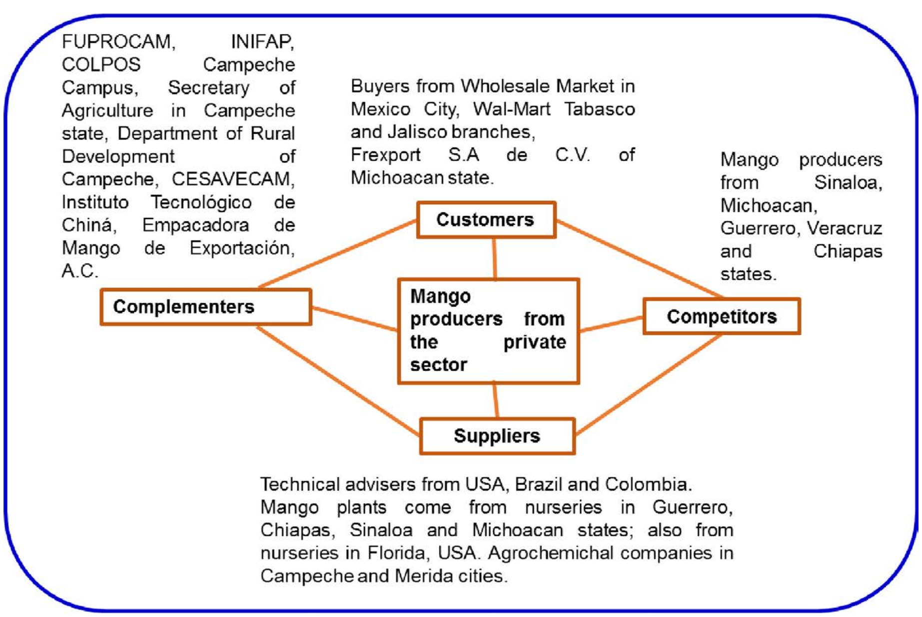

Figure 2. Mango Value Network in the Private Sector in Campeche, Mexico. Source: Self preparation, with field information gathered from 2016-2018.

Entrepreneurial producers sustain that the business key is to advance blossoming to harvest before the Pacific states (Sinaloa, Michoacán, Guerrero), and market the fruit at the Wholesale Market of Mexico City (CA-CDMX). Also, obtaining a fruit fly-free zone certification to access the United States or Europe markets via air freight is vital. Fruit flies (*Anastrepha* spp.) (Dipera: Tephritidae) are the main plague that affects fruit-growing activity in Campeche and that restrict their marketing (Tucuch-Cauich *et al.*, 2008). The annual average production of producers interviewed in the municipalities of Campeche, Tenabo, Champotón and Escárcega was of 22.5 t ha^{-1}, with an investment of MX$19,422.00, an income of MX$72,000.00 and profit of MX$52,578.00. These values are above those obtained by producers from the social sector. Private sector producers have noticed a decrease in blossoming accounting to 20% and they attribute this factor to climate change; also, they consider that the Keith and Haden late varieties are those that better adapt to the Yucatán Peninsula.

The private sector network customers in Campeche are purchasers coming from Mexico City, Wholesale Markets and Wal-Mart Tabasco and Jalisco branches, as well as Frexport S. A. de C. V., a Michoacán-based company. The export quality standards demanded by Wal-Mart stand out. Some producers in this sector have exported mango to the United Kingdom and France via air freight. Nevertheless, producers underline the importance of a strict phytosanitary control of flies in the state that allows them to efficiently market mango in both domestic and foreign markets.

Private sector mango plant suppliers are diverse; the plant may come from plant nurseries in the states of Michoacán, Sinaloa, Guerrero and Chiapas and even Florida, USA. Buds used for grafting come from nurseries in Campeche, Chiapas or Michoacán. Agrochemicals are purchased from companies based in Campeche. However, some producers purchase in Mérida, Yucatán, where they find greater diversity of products, including inputs for organic crops.

Complementors actors are experts in tropical fruit-growing from research institutions such as INIFAP and Tecnológico de Chiná in the state of Campeche. As competitors, mango producers from Sinaloa, Michoacán, Guerrero, Veracruz and Chiapas are recognized; in Sinaloa, fruit with export quality is produced, as they have favorable weather conditions and good soil quality (Siller-Cepeda *et al*., 2009). Also, the mango price for the national market is set there.

CONCLUSIONS

Mango production in Campeche is made in two contrasting production systems carried out by social and private sector producers, with scarce bonds between sectors in agronomic and marketing handling processes; they comprise differentiated value networks with particular challenges and they define how they will face them with their own means. It is required that adequate production technologies for the most important mango cultivars be generated, depending on their monoembryonic or polyembryonic origin that takes advantage of humidity, rain, and type of local soil. No high-density mango commercial orchards have been established in Campeche, as both social and private sector producers have not been convinced about this technology yet. Those in the social sector are willing to work with medium-density orchards (278 plants ha^{-1}), while those of the private sector do not consider this technology to be an alternative for mango growth in the state. It is necessary to assess production technologies available in Tommy Atkins, Manila and Criollo mango cultivars, as well as estimating production costs and profitability margins for this crop at different growth densities in producer orchards.

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Evaluation of the functionality of a constructed wetland system under semidesert and saline conditions

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ABSTRACT

Objective: Evaluate the functionality of a constructed wetland used to treat the wastewater from a school by recording water inflow and outflow, in addition to the local conditions that affect its operation and compliance with environmental regulations.

Design/methodology/approach: Verification of the installation specifications; programmed measurements of the inflow-outflow water balance and ambient temperature; and analysis of the salinity effect and wetland performance.

Results: The high evapotranspiration at the site contributed to the decrease in the resident volume of water within the wetland, causing water stress to the vegetation, not complying with the regulation about the reduction/elimination of water pollutants.

Study limitations/implications: The high daytime temperature significantly decreased the daily inflow volume of wastewater, even after adding the precipitation water, which affects the biological activity of the vegetation; therefore, the study was performed on half of the wetland surface. Thus, the wetland was unable to reduce the pollutants to safe levels.

Findings/conclusions: The amount of recovered treated water is minimal. The inflow is five times lower than the designed flow of the construction. The weekly log was appropriate to observe fluctuations in the water balance and its effect on the vegetation within the wetland.

Keywords: rural constructions, biological processes, water balance, wastewater treatment, climatic conditions.

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INTRODUCTION

The Universidad Autónoma de San Luis Potosí (UASLP), the most prestigious university in San Luis Potosí (SLP), Mexico, is working on a comprehensive project to implement appropriate technologies for the treatment of the wastewater generated in its different campuses. In 2015, an artificial wetland was designed and constructed in the Altiplano Oeste Campus in Salinas, SLP, Mexico. This facility had to comply with the maximum permissible limits of contaminants in treated water for its safe discharge into water bodies (Marín-Muñiz, 2017; NOM-001-SEMARNAT-1996, 2003).

Furthermore, the constructed wetland (CW) had to withstand variations in temperature and biological reactions, which should consider a water flow similar to that produced in a piston, hence the importance of considering climate and water balance.

However, the original design did not consider the climatic conditions at the site. Therefore, it has not been possible to evaluate its performance. Hence, it is convenient to evaluate the facilities and wetland under high-stress situations. It is also impossible to define the reaction of the water balance, salinity, and biochemical effects. The following priorities have been established to comply with the NOM-001-SEMARNAT-1996: 1. Evaluation of the sizing of the CW; 2. Water balance; 3. Salinity; and 4. Wetland performance.

The current hydraulic and biological design of the CW in the Altiplano Salinas Campus of the UASLP is located at 22° 37′ 39″ N and 101° 42′ 52″ W and represents a suitable facility to study its performance, without interference from the available underground water, with an appropriate pretreatment of the sewage influent. The current facility includes a preliminary treatment (P: separation of coarse solids), a sand trap (D), two parallel cells (A and B) that consist of horizontal subsurface flow wetlands (HSF), and a collection pond (E) (Figure 1). The inflow from cells A and B discharges in pond E.

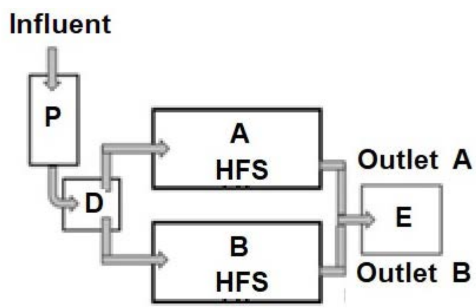

Figure 1. Schematic diagram of the flow of wastewater in the treatment system. Preliminary treatment (P: separation of coarse solids and D: sand trap); horizontal subsurface flow wetland (HSF), and collection pond (E).

The treatment capacity considers flow rate of 14 m3 d^{-1}; a biochemical oxygen demand (BOD) of 290 mg L^{-1}; total suspended solids (TSS) of 226 mg L^{-1}, total nitrogen (TN) of 35 mg L^{-1}, total phosphorus (TP) of 12 mg L^{-1}, and 8E07 MPN (Most probable number of microorganisms in the sample)/100 mL of fecal coliforms (FC). Table 1 documents the technological characteristics of the constructed wetland, and Figure 2 shows an overview of this wetland in 2017.

Table 1. Characteristics of the horizontal subsurface flow wetland.

Parameter	Wetland	Each cell
Area (m^2)	378	189
Length (m)	21	21
Width (m)	-	9
Water depth (h, m)	0.6	0.6
Factor of safety (Fs, m)	0.4	0.4
Wetland total depth (m)	1	1
Ks hydraulic constant (m^3 m^{-2} day^{-1})	5,000	
Effective size of granular medium D10 (mm)	8-16	
Porosity (%)	35	
Wetland slope (%)	1.0	
Vegetation considerations		
Parameter	Cell A	Cell B
Species	*Phragmites australis*	*Typha latifolia*
Planting density (n m^{-2})	3	3

MATERIALS AND METHODS

This study was carried out in the Altiplano Oeste Campus of the UASLP in Salinas de Hidalgo. At the beginning of the study, there was no effluent in both cells, and *T. latifolia* showed little development since its planting. Therefore, we decided to close the inflow entrance of cell B, restricting the evaluation of the wetland efficiency to cell A.

Biological and hydraulic sizing: The current sewage-generating population consists of 364 people. The University Campus consumes 25 L per person per shift, of which 75% are wastewater. Therefore, the generation of wastewater is 18.75 L per person per day, with a mean

Figure 2. View of the wastewater treatment plant. Vegetation within cell A (left) and complete view of the area (right).

flow of 6.825 m^3 d^{-1}. Resulting in a flow of 14 m^3 d^{-1} for the construction of the CW, and the biological sizing consists of applying the equation of Kadlec (1996) (Table 2) and rigorously ensuring the maximum limits of the Official Mexican Standard (NOM-001-SEMARNAT-1996).

Once the area is defined, we proceed with the hydraulic sizing to determine the length and width of the wetland applying Darcy's Law and from there the cross-sectional area is obtained:

$$A_s = \frac{Q}{K_s \times s} \quad (1)$$

Where: A_s = cross section of the wetland with the flow direction, m^2, Q = mean flow rate, m^3 d^{-1}, K_s = hydraulic constant of the medium in a cross-section unit with the flow direction, 5000 m^3 m^{-2} d^{-1} (Table 2), s = hydraulic gradient, 0.01 m m^{-1} (Table 1). Width and length are determined with the following equations:

$$w = \frac{A_s}{h} \quad (2)$$

$$L = \frac{s}{w} \quad (3)$$

Where: w = width, m; L = length, m; h = depth, m (0.6 m of Table 2); S = surface area, m^2.

Contaminant removal efficiency of the constructed wetland for sewage treatment

During March-June 2018, the flow rate and *in situ* physical parameters were measured every week; the chemical parameters were measured monthly. The inflow (influent) and outflow (effluent) rates of cell A were determined by a volumetric method. The ambient and wastewater temperatures, the pH, and electrical conductivity were determined every hour by triplicate in the influent and effluent. For the determination of the chemical parameters in the laboratory, we collected influent and effluent composed samples to measure BOD, QOD, TSS, PO_4, NO_2, NO_3, anions, cations, and four simple samples for total and fecal coliforms. The water analysis was performed following the NMX-AA 028-SCFI-2001 for BOD. The water balance components of the CW are shown in Figure 3.

It is important to mention that the infiltration was not measured, so the result of equation (4) is not completely correct, although it can be used with certain restrictions. The following equation expresses the global water dynamics within the wetland(Kadlec, 2009).

$$\frac{dV}{dt} = Q_a - Q_e + Q_c - Q_b - Q_i + Q_{dh} + (P \times A) - (ER \times A) \quad (4)$$

Table 2. Considerations for calculating the required area for the removal of contaminants.

Equation	Parameter	Q ($m^3 d^{-1}$)	K_A(m^3 d^{-1})	C_0 (mg L^{-1})	Q_1 (mg L^{-1})	C*(mg L^{-1})
$S = \frac{Q}{K_A} \times \ln\left(\frac{C_0 - C^*}{C_1 - C^*}\right)$	BOD	6.825	0.43	800	30	18.87
	TSS		8.22	226	40	22.04
	TP		0.033	15	5	0.02
	FC		0.26	5E+14 MPN/100 mL	1000 MPN/100 mL	10.00

S, superficial area; Q, mean flow; C0, initial concentration of the contaminant; C1, final concentration of the contaminant (NOM-001-SEMARNAT-1996); KA = first-order kinetic constant; C*, concentration at the bottom; BOD, biochemical oxygen demand; TSS, total suspended solids; TP, total phosphorus; FC, fecal coliforms.

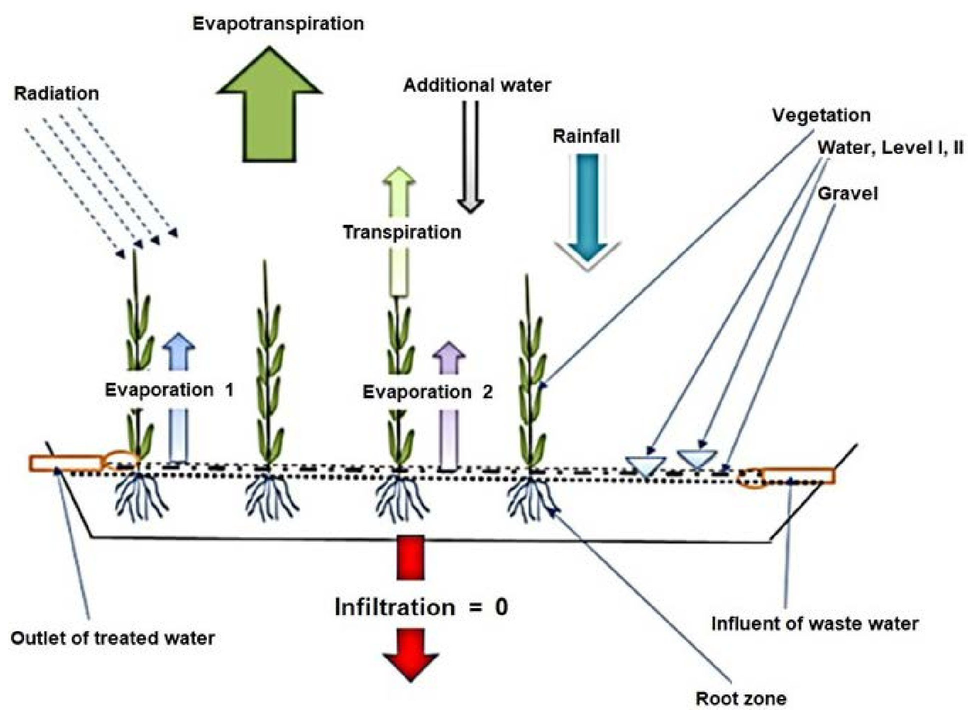

Figure 3. Water balance components and constructed wetland (CW) model.

Where: A = wetland surface area, m^2; ER = evapotranspiration rate, m day^{-1}; P = precipitation rate, m day^{-1}; Q_a = inflow, m^3 day^{-1}; Q_e = outflow, m^3 day^{-1}; Q_c = runoff capture rate, m^3 day^{-1}; Q_b = loss rate due to the strip between the outer edge and the gutter, m^3 day^{-1}; Q_i = infiltration, m^3 day^{-1} = 0 (there is no interaction with groundwater); Q_{dh} = thaw rate, m^3 day^{-1}; dt = time, d; V = volume of water stored in the wetland, m^3.

In the evaluated wetland, the evapotranspiration rate was higher than the precipitation rate. In this case, the important factors are: 1. The dual coefficient (FAO, 2016) of plant growth (plants, based on their age, depend of different evapotranspiration values) with the values of 1.20 ($K_{c\ med}$) from March to June and 0.70 from June to July, 2. The irrigation lamina per day, determined by the influent and possible precipitation at the wetland site.

RESULTS AND DISCUSSION

Evaluation of biological sizing

The biological sizing of the wetland is shown in Table 3 for removing contaminants; biochemical oxygen demand, total suspended solids, total phosphorus, total nitrogen, and fecal coliforms. To comply with the NOM-001-SEMARNAT-1996 a surface area of 296.63 m^2 is required to remove the contaminants, considering an average flow rate of 6.8 m^3 day^{-1}.

The area that ensures the removal of fecal coliforms (707.4 m^2) also guarantees the removal of other contaminants. This area is larger than that used for the design, even though the system was built for a total population of 750 people with a flow rate of 14 m3 day^{-1}. The sizing of the wetland differed from the real size of the constructed wetland. This difference is related to the variation of the hydraulic sizing up to a 4:1 ratio. This variation does not affect the functioning of the wetland.

Temperature, pH, and conductivity

During the sampling period, the average pH values of the influent and effluent in cell A were 7.8 and 5.0, respectively. The mean daily temperature was 22.2 ± 4.2 °C. The average temperature of the influent water was 21.1 ± 2.6 °C, and 4.2 ± 5.9 °C in the effluent. The average electrical conductivity for the influent was 5.5 mS cm^{-1}, and 11.35 mS cm^{-1} for the effluent. The electrical conductivity was higher in the effluent due to the salt accumulation resulting from its concentration-evapotranspiration.

Contaminants removal

Table 4 shows the average values of the removal percentage and the standard deviations of BOD, COD, PT, TSS, and FC for the entire system during the sampling stages.

The concentration of influent contaminants (except FC and TC) was significantly higher than the typically

Table 3. Area required for the removal of each contaminant.

Parameter	Area (m^2)		
	Design	Evaluated	Real
BOD	90.67	67.5	
SST	4.14	2.02	
TN	171.95	---	378
TP	372.4	227.5	
FC	608.45	707.4	

Table 4. Average concentrations of BOD, COD, TP, TSS, and FC during March-May. Standard deviation in parenthesis.

Parameter (mg L^{-1})	Influent	Effluent	Removal %
BOD	658.4 (85.9)	117.7 (48.2)	82.2
COD	1549.5 (116.8)	493.9 (372.4)	68.8
TSS	202 (139.1)	60.7 (35.2)	62.3
TP	13.3 (1.3)	0.65 (0.4)	95.2
TC, (MPN 100 mL^{-1})	8.80E+12 (9.78E+12)	9.86E+08 (1.22E+09)	98.8
FC, (MPN 100 mL^{-1})	8.40E+08 (5.35E+08)	1.61E+08 (2.00E+08)	80.8

reported composition, which results in an evident reduction of TP (95.2%). However, although the removal percentages are above 60% for BOD, COD, and TSS, the final concentration exceeds the limits in Mexico. These results only correspond to cell A.

Biochemical oxygen demand (BOD) removal

The removal percentage of BOD during the sampling period was 82.2% due to its different treatment units and operation conditions (TRH, plants used, etc.). The average value of inflow BOD (658.4 mg L^{-1}) was significantly higher than the system design value (290 mg L^{-1}).

Water balance evaluation

The elements of equation (4) and the measurement values were fundamental to evaluate water balance. Table 5 summarizes the measured and calculated values of water balance in the constructed wetland.

The reserve volume refers to the water that enters the cell and does not come out as a liquid, which increases the water level in the cell (+ indicates an increase in level; − decrease in level). In the effluent, this value reduces the amount of water in the influent; thus, it is not included in the water balance calculation of the cell. Due to the porosity volume (35%), 1 mm of precipitation represents an increase in the water level 3 mm. Therefore, the height of the liquid in the cell is only 600 mm (total reserve), which means that an evapotranspiration of 200 mm results in the total restriction of plant development.

Figures 4 and 5 show the great variation in the distribution of the influent and effluent values, respectively, during successive periods of academic activities.

Figures 6 and 7 clearly show the importance of climate impact on water balance evaluation. Figure 7 represents

Table 5. Sampling schedule to calculate the water balance (mm m^{-2}).

Date	Inflow volume			Outflow volume			Reserve volume
	Q_a	PP	total	ERc	Q_e	Total	
March 12 -18	6.50	0.047	6.54	4.80	0	4.8	1.74
March 19 -25	5.67	0.000	5.67	4.68	0	4.7	0.99
March 26 - April 1	0.00	0.431	0.43	6.53	0	6.5	−6.10
April 3-8	0.00	0.000	0.00	9.78	0	9.8	−9.78
April 9-15	6.17	0.000	6.17	8.74	5.88	14.6	−8.45
April 16-22	7.48	0.000	7.48	6.69	5.08	11.8	−4.30
April 23-29	8.43	0.669	9.10	6.82	5.59	12.4	−3.31
April 30 - May 6	11.10	6.522	17.62	5.90	0.66	6.6	11.07
May 7-13	8.76	0.384	9.14	5.52	5.08	10.6	−1.46
May 14-20	13.79	0.384	14.17	5.90	0.9	6.8	7.37
May 21-27	14.27	0.000	14.27	7.81	4.53	12.3	1.93
May 28 - June 3	2.04	0.384	2.42	8.24	0	8.2	−5.82
June 4-10	1.81	0.000	1.81	7.36	0	7.4	−5.55
June 11-17	1.91	4.358	6.26	4.01	0	4.0	2.25
June 18-24	1.64	17.322	18.97	4.29	0	4.3	14.67
June 25 - July 1	1.82	2.442	4.26	3.33	0	3.3	0.93
July 2-8	1.60	0.297	1.90	3.76	0	3.8	−1.86
July 9-15	1.53	0.397	1.93	3.24	0	3.2	−1.31

the average precipitation from 2000 to 2018 in each of the months of those years. Thus, the average accumulated precipitation of those months during those years is 350.8 mm per year.

The blue-colored lines of Figures 6 and 7 indicate the period in which this study took place and qualitatively explain the behavior of the constructed wetland. The average climate conditions from 2006 to 2018, being adverse, are the main cause for which a balance was not achieved between the evapotranspiration, representing the output, and precipitation values, as an additional contribution added to the entry of sewage.

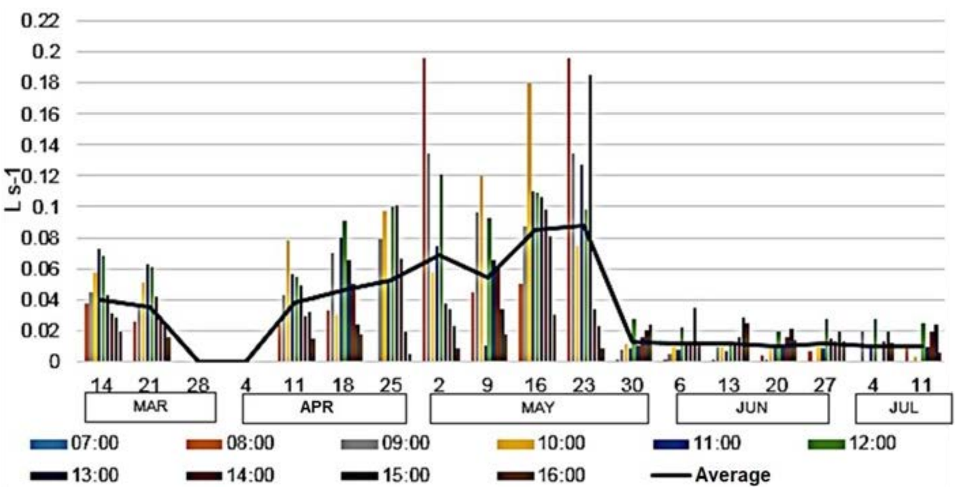

Figure 4. Inflow rate (L s^{-1}) of the HSCW-Salinas during the academic activities on campus.

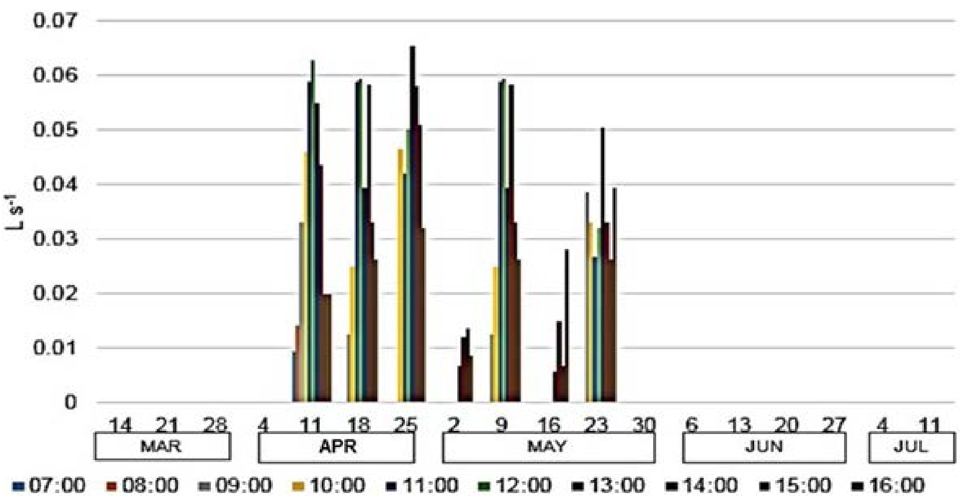

Figure 5. Outflow rate (L s^{-1}) of the HSCW-Salinas during the academic activities on campus.

CONCLUSIONS

The extreme climatic conditions and high to low temperature fluctuations had an adverse effect on the amount of water recuperated from sewage treatment. Additionally, the inflow rate was overestimated. The study demonstrated that the inflow rate was five times lower than the flow rate considered for the wetland design and that, due to the effects associated with climate change, the expected temporary precipitations were not enough to increase the wetland reserve. Evapotranspiration was the main factor responsible for reducing the water reserve in a shorter time, which induces hydric stress in the cell plants. The weekly sampling and data analysis of the water balance allowed us to observe specific changes in the four components of water balance, particularly the change in the water reserve.

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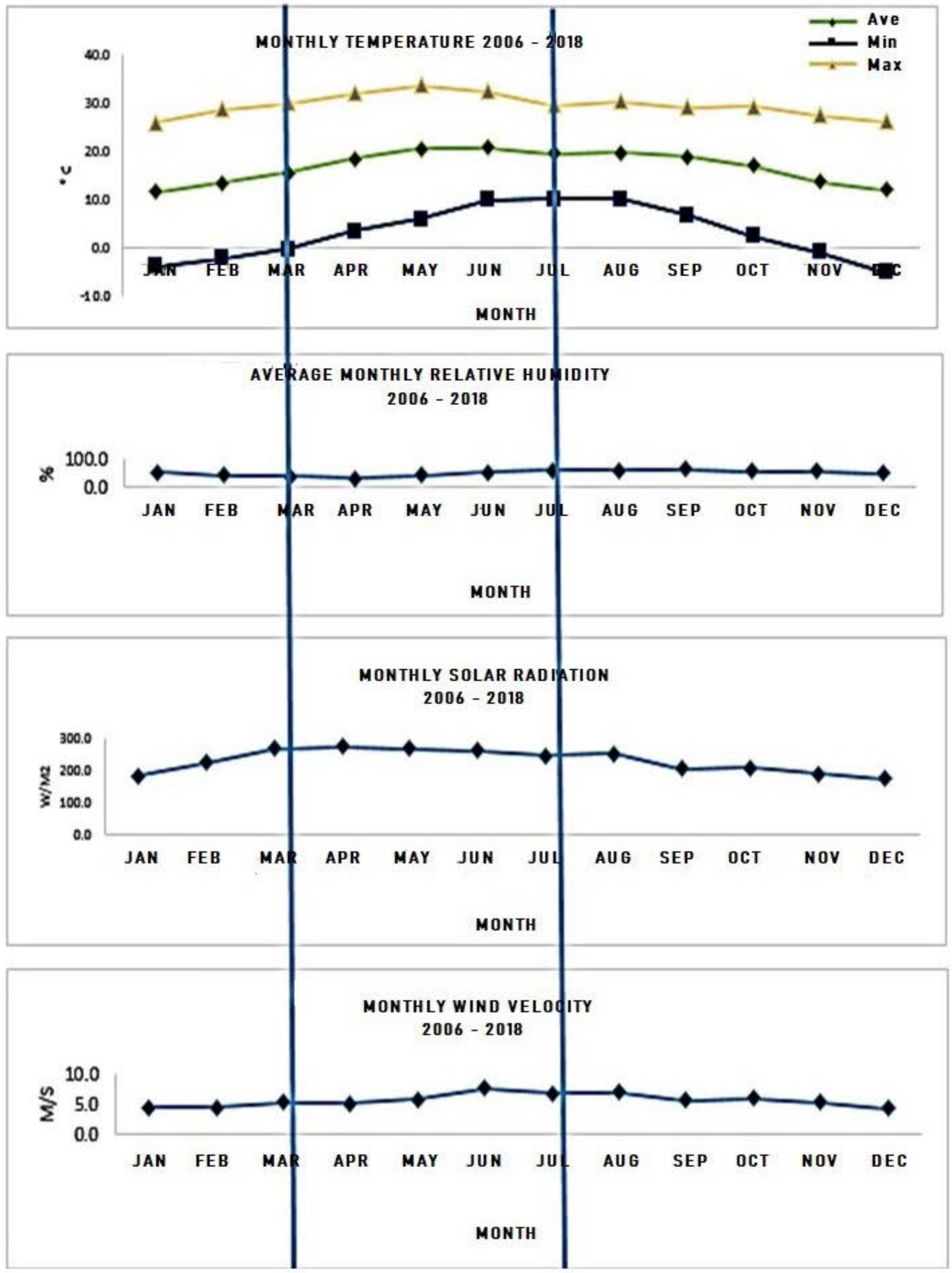

Figure 6. Monthly average climatic values of the study site in Salinas, San Luis Potosí, Mexico.

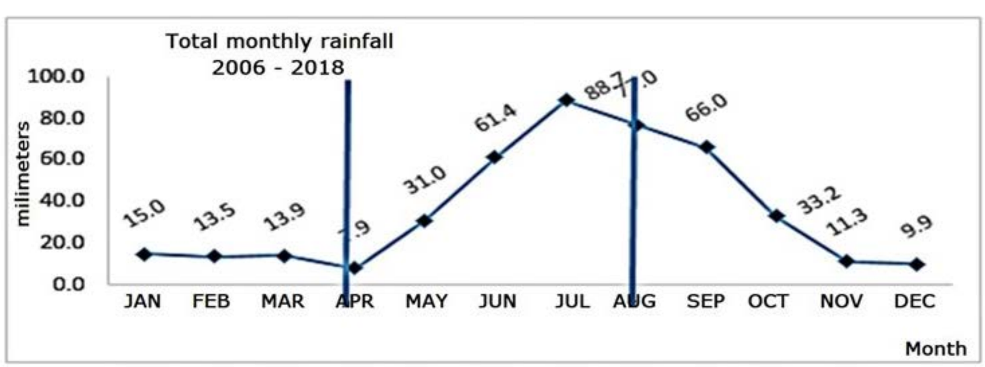

Figure 7. Monthly total precipitation of the study site in Salinas, San Luis Potosí, Mexico.

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Advances in the selection program of sugarcane (*Saccharum* spp.) varieties in the Colegio de Postgraduados

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ABSTRACT

Objective: To evaluate the progress in each of the stages of the selection program of sugarcane varieties that has been carried out at the Colegio de Postgraduados Campus Córdoba (Mexico) since 2009.

Design/methodology/approach: The breeding program employed the methodology developed by the Institute for the Improvement of Sugar Production (Instituto para el Mejoramiento de la Producción de Azúcar, IMPA). For the varietal description, we employed the protocol of the International Union for the Protection of New Varieties of Plants (UPOV).

Results: In 2009, the Colegio de Postgraduados Campus Córdoba started the varietal selection program with more than six thousand hybrids from 40 crosses, from which 4422 materials were selected after they showed resistance to the sugarcane mosaic virus. From the 4422 materials in the Seedling phase, 352 clones were selected and evaluated in the Furrow phase, selecting 57 varieties for the Plot phase. From those 57 varieties, 35 were selected in the Adaptability testing phase and 27 in the following Agroindustrial evaluation phase. Some of these 27 varieties show yields higher than 100 t ha^{-1}, more than 18 °Brix in juices, and good adaptability to different environments.

Study limitations/implications: The current challenges of the breeding program are environmental due to climate change, economical due to the global recession that affects our country with budget cuts, and sociopolitical as a result of the organizational structure of national the sugarcane sector.

Findings/conclusions: This variety breeding and selection program started with 6000 individuals from 40 crosses, of which to date there are 27 in advanced stages of selection, with the possibility of adaptation and good yields for the area of influence of the Campus Córdoba.

Keywords: Poaceae, *Saccharum* spp., plant breeding, COLPOSCTMex, °Brix.

INTRODUCTION

Sugarcane is a crop highly efficient in the use of solar energy, water, and fertilizers. When evaluating its biomass production capacity per unit area, sugarcane is among the most profitable conventional crops in the world (Moore *et al*., 2014).

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In Mexico, The 2019-2020 harvest in 50 sugarcane mills in an area close to 810,803 ha, reached 50.8 million tons of sugarcane milling and a production of 5.2 million tons of sugar (CONADESUCA; 2020; USDA, 2020), with a value close to 40 billion pesos, with the contribution of 8% of the Agricultural Gross Domestic Product (CEDRSSA, 2020; CONADESUCA, 2020).

In this value chain, there are crucial problems related to lags in the production processes, which require the implementation of different innovation schemes (Gómez-Merino *et al.*, 2014a). In terms of genetic resources, in Mexico, the generation of varieties has shown a drop in the last 30 years, and the current production of sugarcane is sustained by only three varieties, which are cultivated in about 70% of the cultivated area of this crop, which endangers the system because with the increase in genotype uniformity, the susceptibility to biotic and abiotic stress factors also increases (Sentíes-Herrera *et al.*, 2016; Sentíes-Herrera *et al.*, 2017a; Sentíes-Herrera *et al.*, 2019). Therefore, since 2009, the Colegio de Postgraduados Campus Córdoba undertook an ambitious variety selection and exchange program. The initial phases have been described by Gómez-Merino *et al*. (2014b).

The variety selection program consists of different logical sequential phases, in which the characteristics to be evaluated increase as the experiment advances. Hybridization is the main part of sugarcane breeding and is the basis for obtaining commercial varieties. This phase is carried out in the Centro de Investigación y Desarrollo de la Caña de Azúcar (CIDCA), in Tuxtla Chico, nearby Tapachula, Chiapas. The experiments should be located in representative sugarcane areas, preferably flat and homogeneous terrains according to the planting season, with sufficient residual humidity or near a water source. Sugarcane breeding aims to develop more productive varieties with greater tolerance to water stress, greater resistance to pests and diseases, and better adaptation to mechanical harvesting. This study recapitulates the breeding and selection program of sugarcane varieties that started in 2009 in the Colegio de Postgraduados Campus Córdoba. We report the most outstanding findings of the 27 most advanced varieties that derived from this program and that are in the Agroindustrial evaluation phase, before the Semicommercial testing phase, based on the methodology described by the IMPA (1983) and by Sentíes-Herrera *et al*. (2017b).

MATERIALS AND METHODS

The selection process began with the progeny from 40 crossings performed in 2009, of which 38 were biparental and two were polycross.

1. Establishment of the Seedling phase

At the initial phase, Fuzz (hybrid seed) was germinated to obtain a population of more than six thousand hybrids, which were mechanically inoculated with the sugarcane mosaic virus. The plants that showed symptoms of this disease were eliminated, which resulted in a total population of 4422 for the establishment of the Seedling phase.

The hybrid material was arranged progressively based on the number of crossing. The transplant was performed following a wide zig-zag pattern from right to left; the planting record and sketch map were performed at the time of planting. Protection furrows and headings were established with the early, medium, and late maturity control varieties. Hybrids were transplanted with 1 m of distance between them and 1.4 m between furrows, with intercalated controls, one at the beginning and another one at the end of each crossing with a 2 m space between them. The agricultural practices were the same as those used in the region, based on those described by Herrera-Solano (2001).

Materials in seedling cycle were evaluated through quarterly phytosanitary inspections (Mosaic, Smuts, and Rusts are discriminatory diseases) and agroindustrial qualifications (°Brix, pith, hollowness, diameter, height, and population 12 months after planting). The hybrid scores were performed following the ranges established in each control maturity type (early, CP 72-2086; medium, Mex 79-431; and late, Mex 69-290).

2. Establishment of the Furrow phase

In 2011, the Furrow phase was established using the 352 sugarcane clones selected in the Seedlings phase. These clones were identified with the following nomenclature: research center in which they were selected, year of crossing, and hybrid number. For example: COLPOSCCMEX 09-1, that is, Colegio de Postgraduados Campus Córdoba, Mexico, generation 2009, and hybrid number one.

Planting was carried out during November. The clones were arranged progressively based on the number of crossing. The transplant was performed following a wide zig-zag pattern; the planting record and sketch map were performed at the time of planting. Protection furrows and headings were established with the control varieties (early, medium, and late maturity). Clones were transplanted into plots with three 3-m-long furrows spaced 1.4 m apart. Clones were spaced 2 m apart, intercalating controls, one at the beginning and another at the end (every 25 clones). The agricultural practices were the same as those used in the region. Clones in plant cane and first ratoon cycles were evaluated. The scores were the same as those in the Seedling phase.

3. Establishment of the Plot phase

In 2013, the Plot phase was established using the 57 sugarcane varieties selected in the Furrow phase. Planting was carried out during November. The clones were arranged progressively based on the variety number. The transplant was performed following a wide zig-zag pattern; the planting record and sketch map were performed at the time of planting. Protection furrows and headings were established with the control varieties (early, medium, and late maturity). Clones were transplanted into plots with three 5-m-long furrows spaced 1.4 m apart. Clones were spaced 2 m apart, intercalating controls every ten clones. According to Herrera-Solano (2001), agricultural practices were the same as those used in the region. Clones in plant cane and first ratoon cycles were evaluated through quarterly phytosanitary inspections and agricultural inspections at 12 months of age. In the seedling cycle, a 20% maximum selection pressure was established based on the considerations indicated in the Seedling phase for the inspection determinations and the stipulated selection criterion. The selection also considers the incorporation of the agricultural characteristics that correspond to uniformity, toughness, juiciness, flowering, and modification of the qualification to smut and rust diseases.

4. Establishment of the Adaptability testing phase

In 2016, the Adaptability testing phase was established using the 36 sugarcane varieties selected in the Plot phase. Planting was carried out at the end of December. The hybrid material was arranged progressively based on the number of crossing. The transplant was performed following a wide zig-zag pattern; the planting record and sketch map were performed at the time of planting. Protection furrows and headings were established with the control varieties (early, medium, and late maturity). Clones were transplanted into plots with four 10-m-long furrows spaced 1.4 m apart. Clones were spaced 2 m apart, intercalating controls. According to Herrera-Solano (2001), agricultural practices were the same as those used in the region. Clones in plant cane and first ratoon cycles were evaluated through quarterly phytosanitary inspections and selection at 12 to 14 months of age. In this phase, the selection criteria are based on the agricultural characteristics, maturity type, and adaptation range of the varieties. The considered characteristics were: stem diameter, bud type, number of small prickles, population of sucker tillers and main stalks, growth habit, stalk height, development uniformity, clearance, toughness, resistance to lodging, flowering, pith, hollowness, internal and external health, maturity, juiciness and sucrose content, purity, and fiber. The adaptability to conditions such as altitude, rainfall regime, soils, drainage, drought, winds, and ground frost was also considered.

5. Establishment of the Agroindustrial evaluation phase

In 2018, the Agroindustrial evaluation phase was established using the 27 sugarcane varieties selected in the Adaptability testing phase. Planting was carried out during December. The material was analyzed following a randomized block design with three repetitions. The planting record and sketch map were performed at the time of planting. A total of 27 promising varieties and three control varieties were transplanted into plots with four 8-m-long furrows spaced 1.4 m apart. Clones were spaced 2 m apart. According to Herrera-Solano (2001), agricultural practices were the same as those used in the region. Clones in plant cane and first ratoon cycles were evaluated; the evaluation of the second ratoon is in progress. In each cycle, the corresponding information was recorded in the different phenological stages of the crop. In this phase, the statistical interpretation of the data related to field and factory yields, along with the information corresponding to the sanitary and agricultural characteristics, are the determinants for the selection of varieties. The characteristics considered in the evaluation of varieties are: germination, tillering, field closure, population of sucker tillers and main stalks, stalk diameter, bud type, number of small prickles, growth habit, stalk height, development uniformity, clearance, resistance to lodging, flowering, pith, hollowness, internal and external health, deterioration (sprouting of buds, emission of adventitious roots, and presence of non-canceled cracks), reaction to herbicides, field yield, qualities related to the mechanical harvest, sucrose percentage, purity and fiber, sugar theoretical yield, juiciness, and rind hardness. The adaptability to conditions such as altitude, precipitation, soils and drainage, winds, drought, and ground frost was also considered. These characteristics were recorded in the two central furrows corresponding to the useful plot and in all repetitions.

Statistical analysis

An analysis of variance was performed for the estimated yield variables and degrees Brix, and the means of each variety were compared with the Tukey test ($P \leq 0.05$) using the statistical software SAS, version 9.4.

RESULTS AND DISCUSSION

Sugarcane breeding can take from 12 to 16 years, which implies that from a germplasm bank it is only possible to select between one and four new varieties (Sentíes-Herrera *et al.*, 2016; Sentíes-Herrera *et al.*, 2017a). In Mexico, where sugar production depends on three varieties that produce 70% of the sugar in the country, it is urgent to generate new materials that broaden the restricted genetic base (Sentíes-Herrera *et al.*, 2017b; 2019).

The variety selection program of Campus Córdoba has established 4422 hybrids in the Seedling phase; these hybrids were selected based on validated scales for the traits considered in said phase and compared to the local controls used. Subsequently, the Furrow phase was established with 352 clones and selected 57 varieties, evaluated in the Plot phase. Of the 57 varieties evaluated in the Plot phase, 36 were selected for the Adaptability testing phase. From those 36 varieties, 27 varieties were selected in the third year of the Agroindustrial evaluation phase. Table 1 describes the details of the progenitors and shows the nomenclature of the 27 varieties selected in the Agroindustrial evaluation phase. Table 2 includes some of the most prominent characteristics of these advanced varieties.

In Table 2 and Figure 1, 11 of the 27 selected varieties in this phase show estimated yields similar or higher than the local commercial controls (between 100 and 120 t ha^{-1}), with juices of good agroindustrial quality (18 to 20 °Brix in the refractometer). The varietal characterization started in this phase based on the protocols described by the UPOV (2004) and Gómez-Merino and Sentíes-Herrera (2015).

Table 1. List of the 27 varieties selected in the Agroindustrial evaluation phase in the Colegio de Postgraduados Campus Córdoba, located in Amatlán de los Reyes, Veracruz, Mexico (18° 86′ N, 96° 85′ W, 650 masl). 2018-2019 period.

Number	Crossing	Progenitors			Variety (COLPOS nomenclature)
		Female		Male	
01	222	LCP 81-10	X	Gloria 57	COLPOSCCMEX 09-29
02	255	CP 52-68	X	CP 70-1527	COLPOSCCMEX 09-50
03	256	CP 92-1401	X	CP 80-1743	COLPOSCCMEX 09-58
04	257	CP 92-1401	X	CP 81-1384	COLPOSCCMEX 09-62
05	257	CP 92-1401	X	CP 81-1384	COLPOSCCMEX 09-66
06	257	CP 92-1401	X	CP 81-1384	COLPOSCCMEX 09-75
07	257	CP 92-1401	X	CP 81-1384	COLPOSCCMEX 09-79
08	258	CP 81-10	X	CP 70-133	COLPOSCCMEX 09-93
09	258	CP 81-10	X	CP 70-133	COLPOSCCMEX 09-95
10	264	Tue 72-9	X	CP 80-1827	COLPOSCCMEX 09-97
11	264	Tue 72-9	X	CP 80-1827	COLPOSCCMEX 09-99
12	264	Tue 72-9	X	CP 80-1827	COLPOSCCMEX 09-125
13	294	CC 93-3826	X	CP 62-378	COLPOSCCMEX 09-132
14	294	CC 93-3826	X	CP 62-378	COLPOSCCMEX 09-136
15	CMI V	LTMex 92-52	X	Multiparental	COLPOSCCMEX 09-208
16	CMI V	LTMex 92-52	X	Multiparental	COLPOSCCMEX 09-212
17	CMI V	LTMex 92-52	X	Multiparental	COLPOSCCMEX 09-217
18	CMI V	LTMex 92-52	X	Multiparental	COLPOSCCMEX 09-220
19	CMI V	LTMex 92-52	X	Multiparental	COLPOSCCMEX 09-222
20	774	PR 62-632	X	CP 80-1743	COLPOSCCMEX 09-273
21	707	Mex 79-431	X	CP 89-2377	COLPOSCCMEX 09-289
22	707	Mex 79-431	X	CP 89-2377	COLPOSCCMEX 09-290
23	529	ITV 92-1424	X	B 45-181	COLPOSCCMEX 09-312
24	529	ITV 92-1424	X	B 45-181	COLPOSCCMEX 09-321
24	527	ITV 92-1424	X	CP 81-1384	COLPOSCCMEX 09-333
26	523	CP 87-1490	X	Mex 79-341	COLPOSCCMEX 09-341
27	523	CP 87-1490	X	Mex 79-341	COLPOSCCMEX 09-348

Cruza multiparental con progenitor masculino no identificado.

Table 2. Prominent traits of the 27 varieties selected in the Agroindustrial evaluation phase in the Colegio de Postgraduados Campus Córdoba, located in Amatlán de los Reyes, Veracruz, Mexico (18° 86′ N, 96° 85′ W, 650 masl). 2018-2019 period.

Variety number	Variety (COLPOS nomenclature)	Flowering	Lodging	Leaf shedding	Estimated yield (t ha^{-1})
1	COLPOSCCMEX 09-29	Present	Present	Excellent	120.80
2	COLPOSCCMEX 09-50	Present	Absent	Excellent	105.80
3	COLPOSCCMEX 09-58	Absent	Absent	Excellent	67.51
4	COLPOSCCMEX 09-62	Absent	Present	Excellent	74.15
5	COLPOSCCMEX 09-66	Present	Present	Excellent	74.03
6	COLPOSCCMEX 09-75	Absent	Absent	Excellent	71.08
7	COLPOSCCMEX 09-79	Absent	Present	Regular	75.64
8	COLPOSCCMEX 09-93	Present	Absent	Regular	76.44
9	COLPOSCCMEX 09-95	Present	Present	Excellent	76.44
10	COLPOSCCMEX 09-97	Present	Absent	Hard	107.91
11	COLPOSCCMEX 09-99	Absent	Absent	Excellent	138.08
12	COLPOSCCMEX 09-125	Present	Absent	Excellent	90.24
13	COLPOSCCMEX 09-132	Absent	Absent	Excellent	90.79
14	COLPOSCCMEX 09-136	Present	Present	Excellent	114.77
15	COLPOSCCMEX 09-208	Absent	Absent	Excellent	70.74
16	COLPOSCCMEX 09-212	Absent	Present	Excellent	70.90
17	COLPOSCCMEX 09-217	Absent	Absent	Excellent	121.18
18	COLPOSCCMEX 09-220	Present	Present	Excellent	100.18
19	COLPOSCCMEX 09-222	Present	Absent	Excellent	93.51
20	COLPOSCCMEX 09-273	Present	Absent	Hard	156.15
21	COLPOSCCMEX 09-289	Absent	Present	Hard	133.39
22	COLPOSCCMEX 09-290	Absent	Present	Excellent	165.56
23	COLPOSCCMEX 09-312	Absent	Present	Excellent	127.48
24	COLPOSCCMEX 09-321	Absent	Absent	Regular	103.48
25	COLPOSCCMEX 09-333	Absent	Absent	Excellent	174.95
26	COLPOSCCMEX 09-341	Present	Absent	Excellent	134.60
27	COLPOSCCMEX 09-348	Absent	Absent	Regular	119.17

According to the mathematical models based on experimental data, sugarcane has been estimated to reach yields close to 400 t ha^{-1} or up to 500 t ha^{-1} in fresh main stalks and between 100 and 200 ha^{-1} of dry matter (Moore, 2009; Waclawovsky *et al*., 2010; Dal-Bianco *et al*., 2012; Hoang *et al*., 2015), which suggests that in Mexico it is possible to expect an increase in yields. Additionally, sugarcane is projected as an essential crop for the establishment of new biofactories for the production of novel compounds such as bioplastics, pharmacological proteins, and alternative sugars (Gómez-Merino *et al*., 2014c; Gómez-Merino *et al*., 2017), which encourage efforts to continue breeding programs aimed to increase field and factory yields. Therefore, the Colegio de Postgraduados has implemented strategies like the one described in this report, and in subsequent phases, there will be molecular tools to analyze phylogenetic relationships and genetic variability and identify productive traits associated with the genome. An important advance of these studies has been reported by González-Jiménez *et al*. (2011). They observed two different groups of *Saccharum* spp. and a variety that differed from both. Group I consisted of the varieties C 87-51, ATM 96-40, B 4362, Mex 69-290, Mex 57-1285, and Mex 91-130, which formed a conglomerate and presented a similarity of 0.77%. Grouped II comprised the varieties RD 75-11, Mex 79-431, SP 70-1284, Mex 59-32, and CP 72-2086, which formed a different conglomerate with 0.70%. The Mex 68-P-23 variety differed from the other varieties. In the breeding program in Campus Córdoba, some

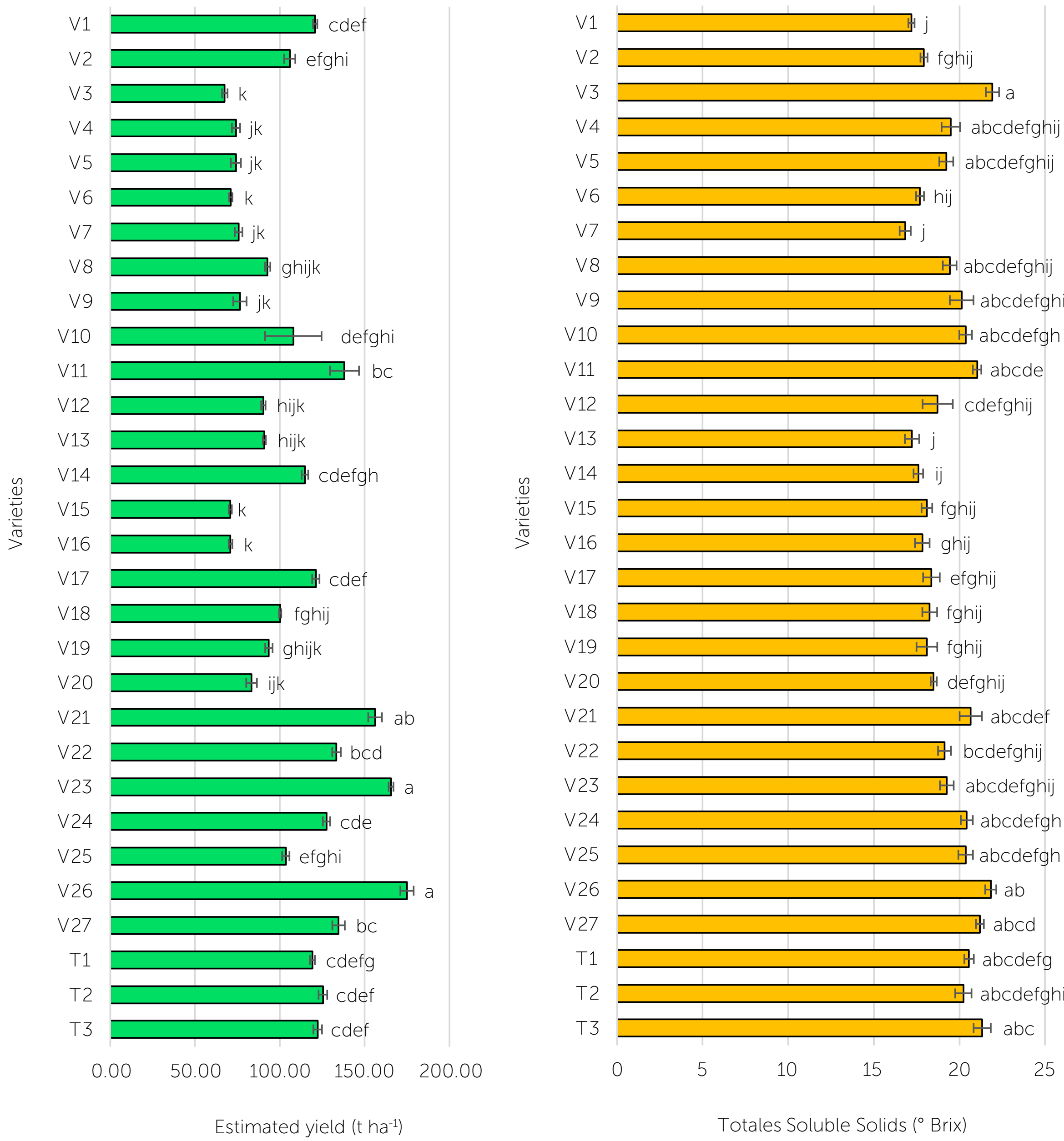

Figure 1. Estimated yields (left) and total soluble solids as °Brix (right) for the 27 sugarcane varieties in the Agroindustrial evaluation phase and three local controls in the Colegio de Postgraduados Campus Córdoba, located in Amatlán de los Reyes, Veracruz, Mexico (18° 86′ N, 96° 85′ W, 650 masl). The nomenclatures assigned to the varieties correspond to numbers 1 to 27 of Tables 1 and 2. The controls are: C1, CP 72-2086; C2, Mex 79-431; and C3, Mex 69-290. 2018 -2019 period. Different letters in the columns of each variety for each variable measured indicate statistical differences between the materials (Tukey, P≤0.05).

progenitors come from this previously analyzed collection, which will facilitate subsequent studies and function as a useful tool for identifying the best crossings (Sentíes-Herrera and Gómez-Merino, 2014).

Additionally, the breeding and variety selection program is carried out along a fertilization and biostimulation program, with promising results in the use of beneficial elements such as iodine, silicon, and vanadium (Sentíes-Herrera *et al.*, 2018).

CONCLUSIONS

In conclusion, the variety selection program started with more than six thousand materials, and to date, there are 27 varieties in the Agroindustrial Evaluation Phase. Of the 27 varieties, 11 show a prominent yield and juice quality. These varieties will have to be evaluated in local and domestic sugarcane mills to continue with the phases in the program.

It is important to mention that of the 40 crossings, only 22 resulted in outstanding individuals under the local conditions of Córdoba. Among these individuals, the most outstanding progenitors are: CP 92-140, Tue 72-9, LTMex 92-52, as PR 61-632, as females; CP 81-1384, CP 80-1827, and CP 80-1743 as males. These progenitors represent important references for future crossings and the continuation of local selection studies for sugarcane varieties.

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Public Policies for the Development of Agroecosystems Resilient to Climate Change

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ABSTRACT

Objective: To analyze public policies in Mexico to cope climate change in agriculture that allow a chieving the development of resilient agroecosystems.

Design/Methodology/Scope: The analysis of research on resilience to climate change in the agricultural and rural sectors, as well as the literature on public policies formulated to face climate change in the agricultural sector (2013-2019 period).

Results: There are multiple resilience sources for agroecosystems. Policies may be oriented toward the identification of such sources and strengthening capacities depending on different scales and contexts. There is a possibility of considering factors associated to the evolution of these systems in order to employ adequate strategies that allow the coordination between political levels.

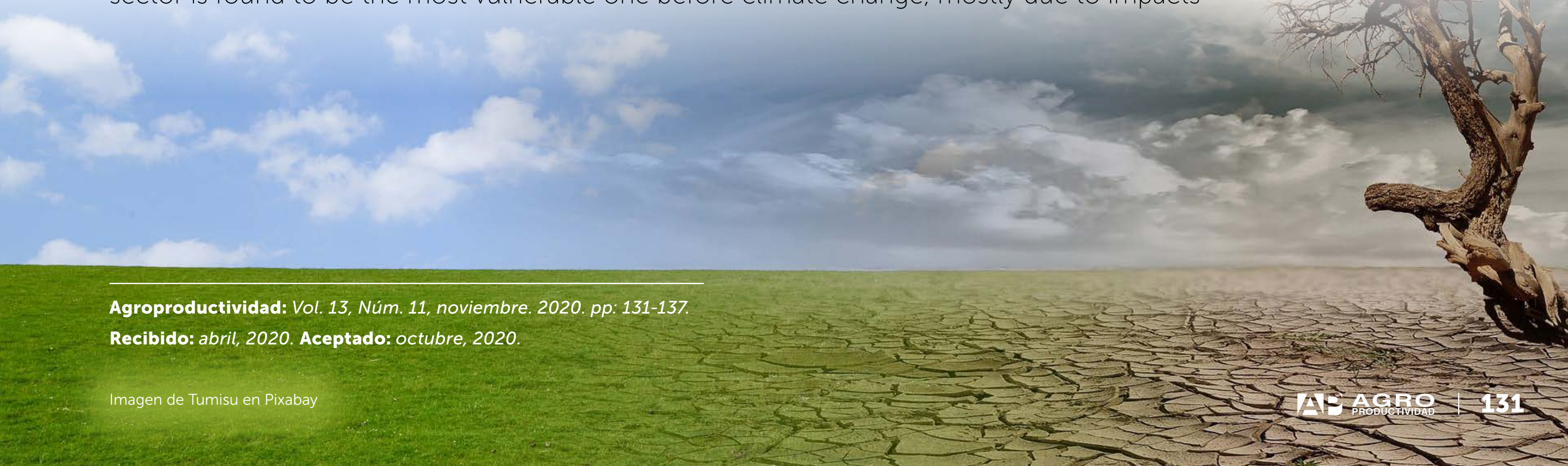
Study Limitations/Implications: This is theoretical essay limited to the analysis of literature published by 2019.

Findings/Conclusions: Public policies demand the integration of the perspective of the complex agricultural system dynamics and multiple resilience sources at different scales and contexts to articulate the development of agroecosystems resilient to climate change.

Keywords: political dynamics, rural development, agricultural system.

INTRODUCTION

Climate change is one of the most challenging issues facing humanity (Urry, 2015). Both scientists and policy-makers have debated at the IPCC (*Intergovernmental Panel on Climate Change*) about potential effects of climate change and what would be the mitigation and adaptation strategies before a complex scenario of impacts differentiated by vulnerability levels with regard to this phenomenon. The agri-food sector is found to be the most vulnerable one before climate change, mostly due to impacts



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in performance, prices of basic commodities and imports and exports (Lobell *et al*., 2008). Therefore, a minimization in vulnerability of agroecosystems is sought upon increasing the capacity of adaptation in order to be resilient to the changing circumstances of contemporary life and, in particular, climate change (Altieri *et al*., 2015). The study and development of resilience of agroecosystems has been proposed worldwide to face the effects of climate change in agriculture. This way, the resilience concept acquires relevance as an analysis focus of proposals that will face potential climate events (Folke, 2006; Anderies *et al*., 2013); this may also be used as a tool for designing and managing agroecosystems (Altieri *et al*., 2015). This would allow elucidating paths that would improve the response before stressing or unexpected events before the increasing complexity and interdependence of several critical networks of society. This way, resilience management goes beyond risk-management in order to address the complexities of big integrated systems and the uncertainty of future threats, especially those related to climate change (Linkov *et al*., 2014). Therefore, the objective of this work was to analyze public policies in Mexico to cope climate change in agriculture that allow attaining the development of resilient agroecosystems.

MATERIALS AND METHODS

The literature published during the 2013-2019 period on research on resilience to climate change or natural disasters in the agricultural and rural sectors was reviewed together with that which referred to public policies formulated to face climate change in the agricultural sector, from the international and national context. The information gathered was systematized through the identification, classification and grouping of research that has proposed strategies for the development of resilience at a level of agri-food systems, agricultural systems, agroecosystems and rural communities. This was compared to national policies that may contribute on the attainment of such strategies in agroecosystems.

RESULTS AND DISCUSSION

Research on Climate Change Resilience of the Agricultural Sector

Several definitions were found for the concept of resilience, even for the same agricultural-rural study field. This indicates that there is no single resilience research framework, which shows the influence of dominant paradigms in accordance with the scientific communities that employ such concept. To this respect, two main theories were distinguished: ecology and social-ecological systems (SES) from which the definitions of resiliency most employed in the agricultural-rural sector emerge. From the ecology perspective, Holling (1973) defines resilience as "the persistence of relations within a system and it is a measure of capacity of these systems to absorb changes of variables of state, conduct, parameters and yet prevail." As for the agroecosystem domain, Cabell and Oelofse (2012) define it as "the capacity that a system has to self-organize and its ability to adapt to stress and change after a disturbance."

From the SES perspective, it is considered that ecosystems are attached to a society. This is why the proposed definition of social-ecological resilience is "the capacity that social-ecological systems have to absorb recurrent disturbances, in order to withhold structures, processes and essential feedback" (Adger, 2006). In this focus, a system analysis tends to incorporate specific values such as cultural diversity. From this theory, SES are defined as a framework of relations around resources necessary for human life, where social and environmental variables interact. Therefore, from this viewpoint, agriculture is understood to be a complex and adaptive system in which different cultural, political, social, economic, ecological and technological components interact (Resilience Alliance, 2007). This focus is not centered on system components, but rather on its relations, interactions and feedback. This is congruent with the complex adaptive system (CAS) theory it is supported on together with the more current focus to understand the contemporary agricultural dynamic from its complexity (Preiser *et al*., 2018; Jagustović *et al*., 2019). CAS characterizes systems composed by agents in interactions, described in terms of rules that are changed or adapted in the measure in which the system accumulates experience. Therefore, in agroecosystem resilience, the coherence and persistence thereof depends on multiple interactions between the parts, the addition of several elements, as well the capacity to adapt or learning (Holland, 2006). Due to the foregoing, from the CAS focus, agroecosystem resilience is defined as the capacity to recover the function after an event that generates stress, disturbance or collapse in the system. In this case, recovering a function refers to the system being capable of producing some type of food. The change that all living systems experience through time is assumed, reason why no returns to previous characteristics or structures are not modeled. The maintenance of the function, which may persist without the need of keeping past structures is modeled instead. And even under the assumption of behavior with high degree of complexity, non-linearity and non-predictability, these systems are not as predictable due to adaptive cycles that exist in their dynamics. The "adaptive cycle" metaphor has its origin in the ecological perspective posed by Holling (1996). This has been applied to SES and the study of the evolutionary nature of CAS through the panarchy concept. It explains the hierarchical structure in which SES follow never-ending adaptive cycles of growth, accumulation, re-structuring and renewal. The identification of these cycles and the scales thereof is useful for the strengthening of system resilience and its path toward sustainability (Holling, 2001). For Folke (2006), the SES study challenge resides in the understanding of their feedback related to the vulnerability in the system and those that strengthen resilience. The adaptive cycle model conceived by Holling (1986) is a powerful and useful metaphor of the system dynamics, which includes four stages: 1) Phase "r" of rapid exploitation and growth, 2) Phase "K" of preservation and steady state or balance, 3) Phase "Ω" of collapse and liberation, and 4) Phase "α" of system re-organization or re-structuring. This widens the traditional succession logistic curve (r→K), to explicitly include collapse and re-organization phases (Figure 1). Also, as the systems are in constant motion through adaptive cycles in numerous temporary and spatial scales, each conservation phase will also reach its end (Walker and Salt, 2006).

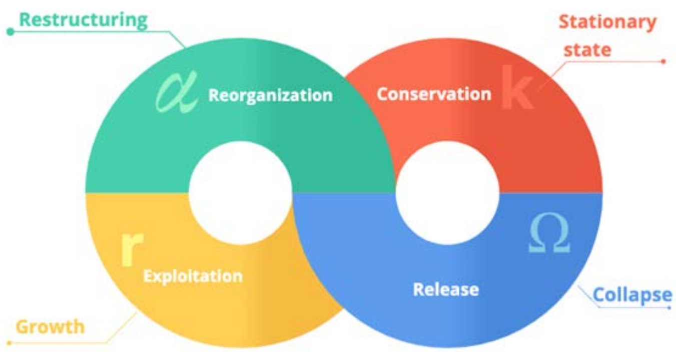

Figure 1. Illustrative scheme of adaptive cycle dynamic stages. Source: Self preparation of the version proposed by Holling (1986).

Strategies for the Development of Agroecosystems Resilient to Climate Change

Some coincidences were found in the recommendations or strategies for increasing resilience proposed in the analyzed research. Table 1 retakes the adaptive cycle model proposed by Holling (1996) and the possible strategies to be employed are distributed according to the state the agroecosystem passes by (Darnhofer *et al*., 2010). It is important to consider the variability of vulnerability in strategies, both at a spatial level and through social groups. Vulnerability may be understood as the level of damage susceptibility by the exposure to stresses related to environmental and social changes and the lack of adaptation capacity (Adger, 2006). Each agroecosystem will have a unique level of resilience to climate change, which will depend on a series of factors; the most vulnerable will be those that are more exposed or sensitive to disturbances, with limited response capacity and a lesser recovery capacity (Bohle *et al*., 1994).

At a spatial level, the biophysical vulnerability refers to physical conditions of landscape and how humans or biological diversity are affected which social vulnerability is defined according to the political, social, and economic conditions of society (Appendini and Liverman, 1994). Kelly & Adger (2000) break down social vulnerability into vulnerability of individuals or households, and collective vulnerability (national, regional or community), while Reilly and Schimmelpfennig (2000) differentiated

Table 1. Main strategies for increasing resilience of agroecosystems or rural communities for each stage the SES is in.

Stage	Strategy
Growth (r)	Utilize the advantages of successful activities that are well adapted to the current environment, compensate the stress through the transfer of more resources to successful activities (specialization) and utilize scale economies.
Balance-Development (k)	The stress or disturbance is absorbed without need for changes. The agroecosystem develops sufficient buffering capacity to cope the crisis.
Collapse-Adjustment (Ω)	The disturbance requires some adjustment at the level of production unit, such as new production methods or crops, introduction or suppression of activities, among others.
Reorganization-Transformation (α)	The disturbance requires the re-alignment of resources that diversify the traditional agricultural domain: agritourism, therapeutic agricultural practices, power production, among others.

between the vulnerability of the sector, regional economy and famine vulnerability. This shows the importance of considering analysis or impact scales and the context of public policy design. Generalizing strategies to reduce vulnerability or increase resilience in the agricultural sector is not possible, as this is characterized by a set of manifestations dictated by the rationality of the produce and social group he/she belongs to, in a given context, influenced by public policies and macroeconomic conditions. Nevertheless, it is possible to distinguish general lines for developing resilience at a social level, associated to a resilient human development, which will influence on better decision-making by the producer before unexpected o stressing events. This evidences the need to link adaptation principles to current and future challenges, at the level of policy and territorial governance (Folke *et al*., 2016). Economic re-structuring may also intensify the effects of climate change upon marginalizing production conditions. Also, in order to improve the understanding of the future of agriculture and associated sectors, the joint impacts of globalization and climate change, *i.e*. how the impacts of each process may exacerbate or compensate between themselves, as proposed with the double exposure concept (O'Brien & Leichenko, 2000).

Public Policies for the Resilience of Agroecosystems to Climate Change

The term resilience is present in the statements of organizations at a world level, associated to the economic development of societies, both in rural and urban regions (Simmie & Martin, 2010). Relevant coincidences were found among the policies dictated by the United Nations Organization (UN), the World Bank (WB) and the Food and Agriculture Organization (FAO) with those of the National Development Plan (PND) 2013-2018 (Presidency of the Republic, 2013), the 2019-2024 National Development Plan (Presidency of the Republic, 2019) and the General Law of Climate Change (DOF, 2012), associated to agreements and treaties subscribed for the mitigation of and adaptation to climate change. They refer to the need of climate change-resilient agriculture and populations. The UN, by means of the United Nations Development Program (UNDP, 2018) and FAO (2018), derive policies aimed at "generating and increasing resilience of rural communities and primary activities performed therein."

Sustainable development is another element related to resilience, present in policies at all levels; it gets relevance according to the construction assumed for resilience. In the rural domain, a more resilient agroecosystem will be that which has greater capacity to remain through time and contributes to its sustainability (Cabell and Oelofse, 2012). The 2013-2018 National Development Plan that allows generating greater certainty in the primary sector through risks management and climate prevention upon fostering the sustainable utilization of the nation's natural resources. This policy is more oriented to the acquisition of insurance for agricultural production than to the development of social-human and biophysical capacities to face the effects of climate change, as suggested by the research in resilience as key and basic elements for the improvement of decision-making, biophysical potential management and vulnerability before phenomena such as climate change. The enactment of the General Law of Climate Change in 2012, and 2018 review thereof, which sets forth the importance of generating climate change adaptation and vulnerability reduction measures, aspects associated to resilience both in populations and ecosystems, stands out in climate change matters. Nevertheless, the exclusion of most policies associated to resilience in the agricultural and rural sectors is observed in state plans. As an example, in the 2016-2018 Veracruz Development Plan (PVD), the policies that relate more to resilience are associated to the rural environment and the attention for indigenous peoples to improve their income and eradicate food poverty, which are only part of the series of factors that integrate agroecosystem resilience. Also, policies for improving income and eradicate food poverty for such plan are of assistentialist type, with the handing of groceries and financial support for vulnerable populations. This action is far from what Cabell & Oelofse (2012) have acknowledged with regards to resilience, climate change and territorial development. The former underline the importance of the development of response and self-management capacities by society, and the part of territorial governance as a key indicator for the increase in socio-ecological resilience (Folke *et al*., 2006). On the other hand, the 2019-2024 Veracruz Development Program refers to the Sustainable Development Goals (SDGs) proposed by the UN (2015), although it does not develop a systemic perspective to address problems and strategies for the agricultural sector or the environmental domain, as proposed by the UN. It omits the resilience subject, when the SDG sustainable city and community objective demands planning and management to attain inclusiveness, security, resilience and sustainability. Also, goal 1 of Objective 13 of SDG "Strengthening resilience and the capacity of adaptation to risks related to climate and natural disasters" was ignored. Nevertheless, the 2014-2018 Special Climate Change Program (PECC) does specify the objective of increasing the resilience of population and productive sectors, as well as increasing resilience to the effects of climate change (INECC, 2014). In this context, even though national policies address the resilience subject for the population and productive sector before the effects of climate change, this is not addressed in the Veracruz state. Also, there is an evident lack of institutional coordination at different political levels to develop public policy instruments that allow addressing resilience, not only as a need, but from a complex system thinking where processes such as resilience and sustainability are inter-related with human, social, cultural, environmental, climate, economic, technology and political domains. Relations between elements of these domains or subsystems are those that will determine the maintenance of agroecosystems. The development of this focus allows understanding agricultural practices and addressing them in terms of co-production; *i.e.*, the finding, interaction and co-evolution in course of social and natural processes, the spatial heterogeneity and temporary non-linear fluctuations; this is why the continuous contextualization of processes and their characteristics is required (Wilson, 2008).

IPCC (2012) and Cutter (2016) suggest not to generalize strategies for improving resilience, in view of the variability of the main resilience factors before disasters at different scales, sectors and contexts. For Cutter (2016), in urban areas resilience is boosted mostly by the economic capital, while the community capital is the main booster of resilience before disasters in rural areas. Also, physical and social impacts of climate change are not to be deemed to be homogeneous due to the spatial variability in components of resilience before disasters in rural areas (IPCC, 2012). Global circulation models project spatial differences in the magnitude and direction of climate change, and even within a region that experiences the same characteristics of climate change (INECC, 2016); it is more likely that impacts vary more in ecosystems, sectors or social groups more vulnerable to climate change (Ge *et al*., 2016). The mechanisms that underlie to resilience to climate change work and interact at different scale levels (Dhar & Khirfan, 2017) and impacts from one scale level to another (activity, agroecosystem, community, region, landscape, State), are to be considered and therefore the interactions and synergies between these levels will have a strategic importance (Renting *et al*. 2009).

Also, it is acknowledged that the type of policy will affect the options of farmers and it needs to understand the evolution of motivations of the involved actors and their ever changing social and political environment (Herzfeld & Jongeneel, 2012). Human beings are "stakeholders" or decision-makers in the change of land use. Janssen & Van Ittersum (2007) discuss several models of bioeconomic farms, the objective of which is to incorporate key factors in decision-making processes by farmers and increase the efficacy in the perception of risk. The differences in results or motivations of decision-making processes may be incorporated in public policies stratified by producer typology, scenarios or others, in accordance with differentiated levels of agronomic, economic, environmental efficiency, the relations between agroecosystem strategies and biodiversity or landscape patterns (Schmitzberger *et al*., 2005). Also, attention must be paid to the option of generating parallel markets for non-basic agricultural products (OECD, 2001; Huylenbroeck *et al*., 2007). Finally, performing a more integrated policy-territory-development analyses that allow the interaction of sciences that complement each other in order to improve our understanding and action on complex phenomena such as climate change resilience that allow overcoming the current political-administrative obstacles is suggested.

CONCLUSIONS

Several research works suggest the existence of multiple resilience sources for agroecosystems. Accordingly, public policies should be focused on identifying such sources and strengthening capacities at different scales and contexts, depending on such sources. Greater coordination between government agencies that allow articulating resilience policies between ministries and programs, as well as at the level of states and municipalities, is required. The variety of responses to climate change may be self-induced or the result of deliberate political processes, therefore, managed policies may be crucial in the resilience capacity. The design of resilience policies should be based on the understanding of the dynamics of complex adaptive systems for the nature of social-ecological dynamic processes.

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Groundwater Contamination due to the Use of Agrochemicals in Sugar Cane Agroecosystems

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ABSTRACT

Objective: To assess the risk of groundwater contamination due to the application of pesticides and the amount of nitrogen lost by leaching, in agroecosystems with sugar cane, in the area of influence of sugar mills, La Gloria y El Modelo, Veracruz, Mexico.

Methodology: The presence of pesticides in 30 groundwater sampling points was determined based on the NOM-041-SSA1-1993 standard and the methods of EPA 608 and EPA 608.1 described by the Environmental Protection Agency (EPA). Nitrogen (N) loss by leaching was assessed evaluating nine treatments by combining two factors: dose (250, 200 and 150 kg ha^{-1} of N) and application of fractionated doses (2, 3 y 4).

Results: Pesticides such as β-HCH, heptachlor, heptachlor epoxide, α-endosulphan, β endosulphan, endosulphan sulfate, aldrin, dieldrin and 4.4'DDE were found in deep-well water. Application of low doses of N resulted in lower losses of N due to leaching. A dose of 150 kg ha^{-1} N, applied in two, three and four fractions, resulted in losses of N between 15.40 and 18.18 kg ha^{-1}.

Conclusions: Groundwater contamination by pesticides is evident. Therefore, its reduction must be a priority for crop production, and soil and water conservation practices. This will result in a less negative impact to the environment and public health. Water and nitrogen fertilizers management, at plot level, must be improved, in order to increase water irrigation and nitrogen efficiency in agricultural areas.

Keywords: Agrochemicals, isomers, metabolites, environmental contamination.

INTRODUCTION

Mexico has a surface of 6.5 million of hectares under irrigation and 14.96 million under rainfed agriculture. From the irrigation surface, 3.3 million hectares belong to 86 irrigation districts (DR), from which 82 have already been transferred to users; the remaining 3.2 million were relocated to more than 40 000 irrigation units (UR) (CONAGUA, 2018).

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In order to obtain higher productivity per surface unit, there has been a gradual increase in the usage intensity of agroecosystem soils. This situation has risen the use of agrochemicals, mainly pesticides and nitrogen fertilizers (Castañeda, 2006; García-Gutiérrez and Rodríguez-Meza, 2012), which has had a negative impact on public health and the environment (Popp *et al.*, 2013; FAO-GTIS, 2017).

At the same time, the inefficient management of irrigation water and nitrogen fertilizer at plot level contributes to increase nitrogen leaching to the surface current and aquifers. Castro-Luna *et al*. (2006) have stated the need to develop and establish cheaper and more efficient alternative sustainable fertilization practices, as there is evidence that the growing of sugar cane (*Saccharum officinarum*) utilizes only 57% of N applied under a conventional management (Landeros-Sánchez *et al*., 2007). Even though agrochemicals provide immediate benefits, their use implicates a high environmental and public health cost, mainly because of the fact that these products are transported, in high concentrations, to riverbeds, lakes, and other water bodies. Therefore, the objective was to assess the risk of groundwater contamination due to the application of pesticides and the amount of nitrogen lost by leaching, in agroecosystems with sugar cane, in the area of influence of sugar mills, La Gloria y El Modelo, Veracruz, Mexico.

MATERIALS AND METHODS

Pesticide determination in the aquifer

Well location

Thirty groundwater-sampling points were randomly selected, 23 were from public supply deep wells for human consumption, six from agricultural irrigation and one from a shallow well (Table 1).

Table 1. Sampled well locations and types.

Potable water	Agricultural irrigation	Shallow
El Bobo	Despoblado I	Chachalacas
La Gloria I	Despoblado II	
La Gloria II	La Florida	
Real Del Oro	El Canal	
El Despoblado	El Aguaje	
Cempoala	El Zapote	
Tolome		
El Hatito		
Carretas		
La Víbora		
La Ceiba		
El Faizan		
La Charca (El Paraíso)		
Cempoala		
El Zapotito		
El Mango		
El Salmoral		
San Pancho		
El Modelo		
ÚrsuloGalván I		
Úrsulo Galván II		
Mata Verde		
Chalahuite		

Field sample collection

A one-liter water sample was taken on each sampling site at a point close to the well discharge and before the chlorine application. For this, amber plastic flasks, washed with neutral soap and sterilized water, were used. Immediately after taking samples, the flasks were closed, labeled and refrigerated at approximately 4 °C until analyte extraction was done at the laboratory. When wells did not have water taps, samples were taken from the closest water tap to the well. Samples were collected according to the Official Mexican Standard NOM-014-SSA1-1993, which states the "Health procedures for water sampling for human use and consumption, in public and private water supply systems."

Official methods for pesticide analysis

The method used for determining pesticides is described in the N0M-041-SSA1-1993, which determines a group of ten organochlorine pesticides by using the Liquid-Liquid Extraction (ELL) as an extraction technique and the Gas Chromatography with Electron Capture Detector (GC-ECD) for the later analysis of extracts. The EPA 608 and EPA 608.1 methods described by the Environmental Protection Agency (EPA) were also used (1995a). Regarding organochlorine pesticides, the methods consider the analysis of up to 45 analytes. Both methods describe the use of GC-ECD for the analysis of these compounds (EPA, 1995b).

To assess the loss of nitrogen by leaching, an experimental plot with sugar cane, CP 72-2086 variety, in the first ratoon production cycle was established. Soils in this plot are alluvial type with clayey crumb texture and water table is from 75 to 95 m in depth. The nine treatments (Table 2) used were the result of combining the following factors: dose (200, 250, and 150 kg ha^{-1} of N) and the fragmentation of doses (2, 3 and 4). The first application of fertilizer was done five days after the ratoon cane regrowth and the following ones were 30, 60 and 90 days after the first application. The nutrition of plants from all treatments was balanced by adding phosphorus (P_2O_5) and potassium (K_2O) at doses of 20 and 60 kg ha^{-1}, respectively. During the growing season, six irrigations were applied at all experimental units and the nine installed lysimeters, with a 15-cm water depth. A randomized experimental block design was used. Nitrogen leaching was measured by installing nine water balance lysimeters in which the field treatment conditions were replicated.

Table 2. Treatments assessed to study the effect of nitrogen dose and fragmentation.

N°	Code	Dose (kg N ha^{-1})	Applied fragmentation (kg N ha^{-1})
1	D1F1*	250	Two applications (125 and 125).
2	D1F2	250	Three applications (80, 90 and 80).
3	D1F3	250	Four applications (60, 70, 60 and 60).
4	D2F1	200	Two applications (100 and 100).
5	D2F2	200	Three applications (70, 70 and 60).
6	D2F3	200	Four applications (50, 50, 50 and 50).
7	D3F1	150	Two applications (75 and 75).
8	D3F2	150	Three applications (50, 50 and 50).
9	D3F3	150	Four applications (40, 40, 40 and 30).

*Control: equals to the fertilizer dosage and application recommended by the sugar cane mills.

RESULTS AND DISCUSSION

Pesticide presence and concentration

All wells registered the presence of some pesticides, their isomers or metabolites. Table 3 shows the mean concentrations of these compounds.

As for HCH, the isomer β-HCH was the only one detected. This may be related to the fact that the diverse isomers have different physicochemical properties. Although HCH isomers have low solubility in water, the beta isomer is the one with the lowest solubility (Rodríguez, 2009). α-endosulphan, β-endosulphan, and β-HCH isomers exceeded the limits provided by the standards. Endosulphan and its by-products have been found more frequently in drinking water wells (Martínez *et al.*, 2004). Even if the other pesticides found (isomers or metabolites) did not exceed the permissible limits in the standards, their presence itself indicates contamination of groundwater.

Nitrogen leaching

It was found that applying lower nitrogen doses, losses of this element by leaching are lower. When a dose of 250 kg ha^{-1} of N was applied and fragmented in two, three and four applications, there were cumulative losses of N from 30.62 to 40.86 kg ha^{-1}. When applying 200 kg ha^{-1} of N, fragmented in two, three and four applications, a cumulative loss varied between 21.82 and 30.16 kg ha^{-1}; this represented a loss of up to 15%. These results coincide with those of Bergström & Johansson (1991), who reported similar percentage of N lixiviation losses applying the same dose. Upon applying a dose of 150 kg ha^{-1} N, fragmented in two, three and four applications, it was observed that N losses oscillated between 15.40 and 18.18 kg ha^{-1}, which represents a loss of up to 12.1% (Figure 1). The lowest N loss occurred in treatment nine (D3F3). This is similar to that reported by Chávez (1999), who stated that the

Table 3. Pesticide level comparison according to official standards (mean±DE).

Pesticide	Permissible limit (mg L^{-1})	Mean±DE in samples (mg L^{-1})	Minimum detectable (mg L^{-1})
β-HCH	0.01	0.032456 ± 0.014937	0.0001
Heptachlor	0.03	0.026467 ± 0.025572	0.0001
Heptachlor epoxide	0.03	0.014995 ± 0.018524	0.0001
α-endosulphan	0.0003	0.024500 ± 0.013373	0.0001
β-endosulphan	0.0003	0.016594 ± 0.021799	0.0001
Sulphate-endosulphan	0.0003	0.001071 ± 0.001714	0.0001
Aldrin	0.03 (Combined with dieldrin)	0.005287 ± 0.008432	0.0001
Dieldrin	0.03 (Combined with aldrin)	0.002156 ± 0.014252	0.0001
4.4´DDE	1 (Total isomers DDT)	0.016444 ± 0.021863	0.0001

β-HCH=β-hexachlorocyclohexane, DDE=dichlorodiphenyldichloroethylene, DDT=dichlorodiphenyltrichloroethane.

nitrogen fertilizer fragmentation is a practice that reduces nitrogen losses due to lixiviation.

Fertilizer management to reduce aquifer and natural stream water contamination

One practical and realistic alternative to reduce water contamination depends on training technicians and producers about nitrogen fertilizers management required by the plant for its development. This means reducing excessive amounts of such fertilizer. On the other hand, raising awareness among producers on the fact that water contaminated with nitrogen affects public health, wild flora and fauna, water ecosystems and the environment is a priority. Also, it is important to train them on the use of organic fertilizer instead of mineral ones. Besides, the application of nitrogen fertilizers of slow release must be introduced in order to extend their availability at the plant´s root zone, which occurs similarly when organic compost is applied. Not burning sugar cane before and after the harvest means utilizing the nitrogen contained in leaves and top of sugar cane stems. Training is also necessary on subjects related to environmental protection and the effect that sugar cane burning has on the climate change phenomenon (Landeros-Sánchez *et al*., 2016).

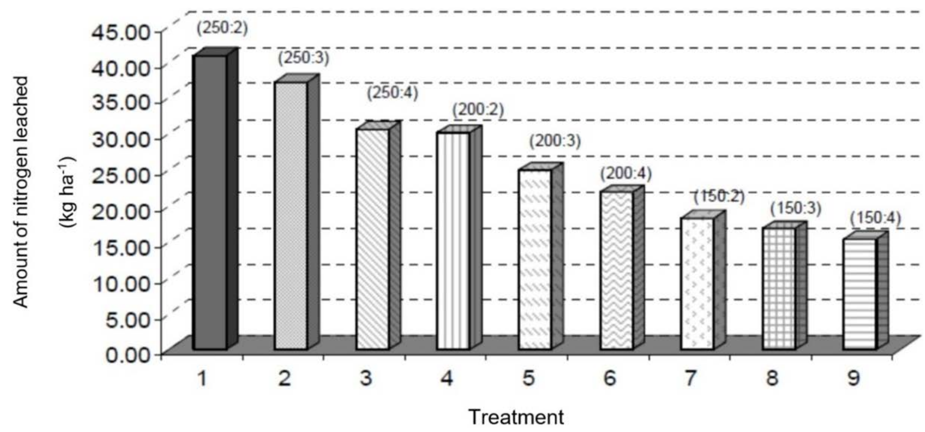

Figure 1. Total N cumulative leaching recorded in lysimeters. In parentheses: doses of N (kg ha^{-1}) and applied fragmentation (Source: Landeros-Sánchez *et al*., 2016).

CONCLUSIONS

Groundwater contamination by pesticides in agricultural areas is evident; therefore, reducing such contamination shall be a priority task for those involved in the production of sugar cane and other crops, along with the application of soil and water conservation practices. This will result in a lower negative impact to the environment and public health. The water and nitrogen management modernization at plot level may aid to increase the efficiency of water and nitrogen usage in tropical and the country's agroecosystems. The formulation of strategies for the integrated utilization of natural resources through an agroecological and agrosystemic approach that result in an environmentally friendly agricultural development is urgent.

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