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SUSTAINABILITY OF THE AGRICULTURAL SECTOR IN MEXICO – COMPLIANCE OR NOT- WITH KEY UNITED NATIONS' 17 SUSTAINABLE DEVELOPMENT GOALS: AGUASCALIENTES AS A CASE STUDY

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ABSTRACT

Mexico is considered one of the most critical countries contributing to food production worldwide. However, Mexico needs help in agricultural practices and the pressure to optimize water usage. Considering that food production worldwide, directly and indirectly, relates to Goals 2, 4, 6, 7, 11, 12, and 15 of the United Nations' 17 Sustainable Development Goals (SDGs) adopted in 2015, it is essential to address the challenges and pressure Mexico faces in its agricultural practices to optimize technical irrigation, access to land extension, and crop rotation usage. Some productive zones within central Mexico are called the Bajío Region, where Aguascalientes is located and the main focus of the current case study. This study aims to collect information to understand the main factors and challenges in the primary sector in this region. This study used a survey instrument to assess the actions of 54 farmers during the pandemic, to detect farmers' technical needs, level of preparedness, water conservation knowledge, technology adaptability, and knowledge of the current public policy in Aguascalientes State. The data analyzed included; socioeconomic aspects, water and energy conservation, food processing awareness, and public policy perception. The results showed that participants could adjust public policies and use more technical training to build sustainable agricultural growth to the SDGs, and look for increased productivity within the representative crops in the region. The significant challenges Aguascalientes face are, limited water resources, the incentive production mindset, and a more technology-intensive approach, as is needed in Northern Mexico as a region. The primary goal is to develop a more resilient agricultural system, and to find characteristics for small and medium-sized producers. The first step is to increase knowledge among the main actors in the primary sector regarding the potential technical barriers to increasing productivity. The study concluded that the socioeconomic background of agricultural entrepreneurs and their education level is essential to adopting technology for production to increase and strengthen food security for Aguascalientes.

Key words: Aguascalientes, Agricultural Sector, Agricultural Entrepreneurs, Public Policy, Water

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INTRODUCTION

The agricultural sector in Mexico had a strong impact during COVID-19 and became a top priority for the population [1] because its productivity affected the quantity and quality of food security [2]. Mexico was the 48th country in terms of global competitiveness in 2019; because it was open to domestic and foreign competition. According to FAO 2022, during pre-pandemic times, the national population of Mexico reached 126.2 million habitants; 21% lived in rural areas [4]. National agricultural exports were avocado, tomatoes, fruits, vegetables, and beer from barley, which had a significant economic development.

Quandt [3], found a trend for the agricultural system, where agricultural sector exports declined from Mexico to the US during COVID-19 [3]. The leading cause was that U.S. and Canadian supermarkets were the only ones with the purchasing power for this fresh agricultural produce. Between January and August 2022, the Mexican economy showed a surplus of 5,286 million U.S. dollars [1]. Isiodiorca-Lachica *et al.* [4] described technology as the critical factor in successfully adding value to agroindustry operations that influenced food production. Mexico has a diversity of factors that influence its agriculture, including broader agroecological conditions, water scarcity distribution, and in some regions, modernized commercial agricultural production systems, whereas other parts of the country continue to rely on subsistence farming [5].

Mexican farmers can be categorized according to land ownership, and this categorization of farmers directly affects the performance of technology and agricultural practices. A deeper analysis found that farming systems in Latin America can be associated with three more significant categories, according to their level of integration in a bigger market: 1) corporations and large farmers, 2) medium and small entrepreneurial farmers, and 3) smallholders and subsistence farms [6]Lastly, sociodemographic and economic conditions such as education, gender, income, and age affect farmers' adoption of technology and access to government programs [3].

Ortiz-García *et al.* [7] reported that 64% of Mexican soils have some level of degradation. However, only 28% of the farmers identified problems with fertilizers, which affected a quarter of Mexico's production and close to 6.7 million people. For these reasons, to create a sustainable food system is necessary to balance environmental sustainability, economic growth, and social justice in Mexican Agriculture [8]. The national territory has heterogeneity that can be identified via annual precipitation; for example, the northwest desert achieves only 100 mm of rainfall, whereas southern Mexican territories can receive up to 2000 mm [9]. Mexico is the third-largest agricultural producer in Latin America and the twelve-

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largest food producer globally [10]. Aguascalientes can be considered a model in agribusiness (see Figure 1) because of its ubication in the north-central part of Mexico, in a region known as El Bajío, which includes states like Guanajuato, and parts of Michoacán [10, 11]. It is interesting to consider Aguascalientes because being the smallest state in the Bajío region, with an unemployment rate of 3.5%, also has pressure on the water supply due to several industries and agriculture, and the results or interventions implemented here could be extrapolated to other states of Mexico that present water scarcity problems. In 2022, the west-central region produced 78.7 million tons and excelled in livestock production with 10.1 million tons [11]. The production capacity, strategic position, advanced infrastructure, and appropriate public policies make Bajío one of the central food-producing regions in Mexico and a significant contributor to local agribusiness.

This diagnostics case study aimed to explore conditions of the agricultural sector and detect technical needs, water and energy conservation knowledge, and public awareness of policy programs in Mexico. This study surveyed medium and small entrepreneurial farmers and attempted to understand their access to natural resources, and awareness to incentive local programs in the Bajío Region, particularly Aguascalientes. The authors examined the following topics:

1. Effects of technology and natural resources, on agriculture.
2. Farmers' actions during the COVID-19 pandemic.
3. Preparedness levels of agricultural entrepreneurs in the Bajío Region.

This case study highlights how food production in Mexico relates to the United Nations' sustainable development goals (SDGs). Out of the 17 SDGs adopted, the following 6 directly affect food security, and are of main interest for the current case study [12]:
Goal 2: Zero Hunger
Goal 4: Quality Education
Goal 6: Clean Water and Sanitation
Goal 7: Affordable and Clean Energy
Goal 11: Sustainable Cities and Communities
Goal 12: Responsible Consumption and Production
Goal 15: Life on Land

The importance of the SDGs effort relates to countries adopting the UN 2030 Agenda for Sustainable Development in 2015 [13]. The current situation (2024) is more than halfway to the 2030 SDGs. The global agenda is progressing towards some goals, but not with others, and Aguascalientes is growing in production and becoming more challenging to achieve SDG 12 [14].

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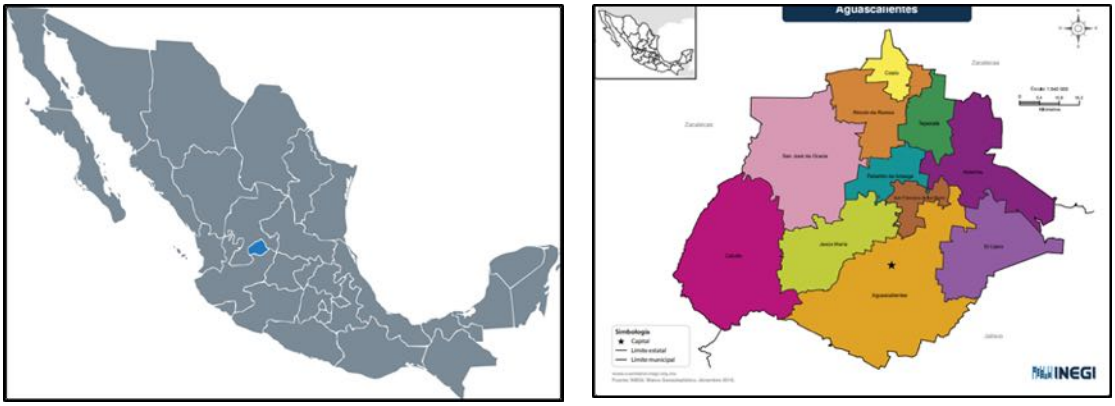

(a) (b)

Figure 1: Machine Maps from Mexico where a) Aguascalientes is marked and (b) the municipalities are shown

Taken from: De Estadística y Geografía Inegi (n.d.) and Mapas para imprimir (n.d.)

MATERIALS AND METHODS

A survey instrument gathered information from 54 agricultural entrepreneurs in the Aguascalientes and Bajío regions. The goal was to gather information on food production through 54 electronic surveys applied to members of the Agribusiness Master's program at the Universidad Panamericana, and other local agricultural experts from September 2021 to December 2022. The selection criteria for the experts were to include professionals with at least five years of experience in the Agricultural sector who knew the Bajio Region. The survey instrument has several sections, and each section was selected to include sustainability and agriculture topics and to gather the participants' experiences in the primary sector (Figure 2). The research team considered studies by Brinkmann [15] to create specific questions to understand a technical or economic activity. Researchers also relied on survey analysis from Abdulai *et al*. [16], to assess rural producers' level of information and preparedness with technology. Figure 2, shows the questionnaire used to detect opportunities and challenges for local agriculture.

The survey instrument was transcribed into a Google Forms questionnaire for data collection and sent via email and WA Business numbers to agricultural entrepreneurs. The form generated a spreadsheet that was stored in an institutional electronic account. Visualization graphs and Pareto Analysis were used as statistical analysis for the results, using a combination of Excel spreadsheets and Minitab software analysis.

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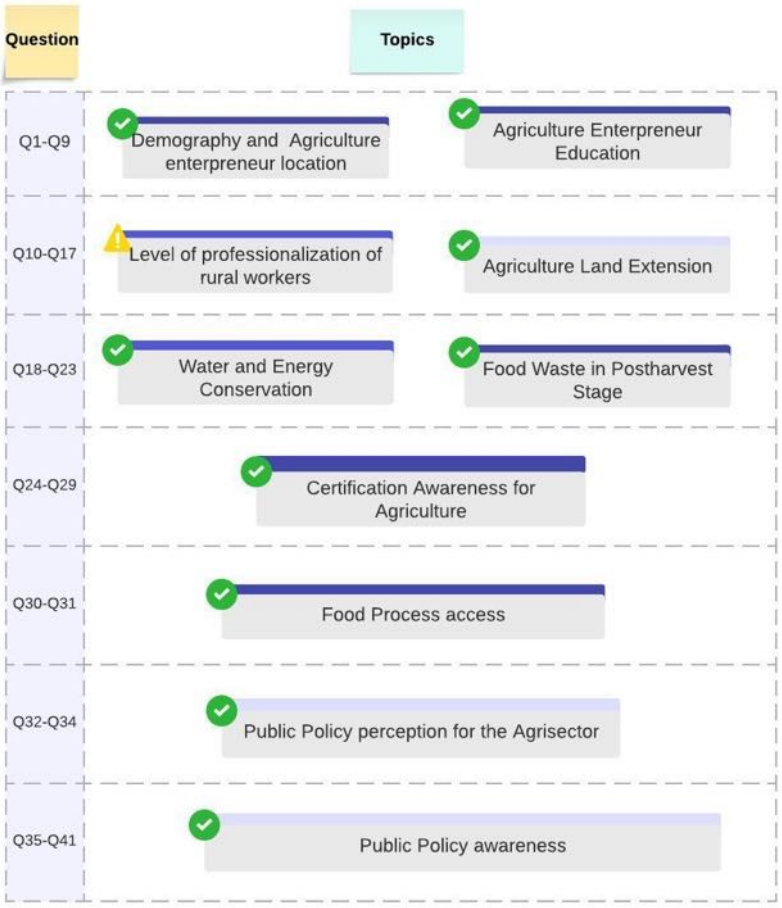

Figure 2: Sections for the current research survey instrument

This preliminary study allowed us to learn about the perspectives of 54 experts related to critical topics in the Agriculture Sector

RESULTS AND DISCUSSION

Socioeconomic aspects of Bajio farmers

A survey was conducted with 54 agriculture experts, including several young professionals and farmers in Aguascalientes and the Bajío Region. The results found that 70.59% of the participants were male. The studies of Abdulai *et al.* [16] and Doss [17], have shown a similar trend and found that gender affects agricultural technology participation. The predominant age of 51% of respondents was in the range of 20 and 35 years, whereas the nationwide farmers' age average is 52 years (Figure 3). Respondents aged 35 to 50 and 50 to 60 years represented 41.2% and only 5.9%, respectively (Figure 3).

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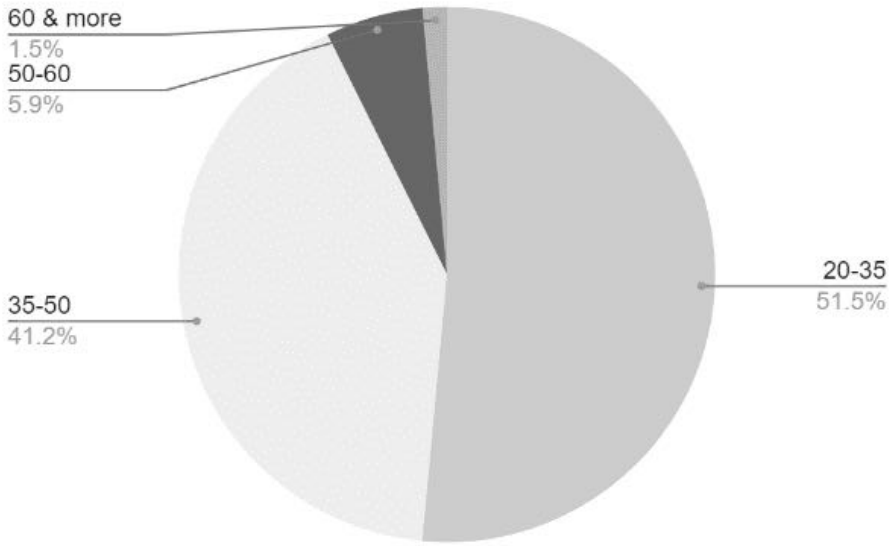

Figure 3: Age distribution for the participants of the survey

Producers were located across several counties in Aguascalientes State with 9.3% in Jesus Maria County and 11.1% in Rincon de Romos. The Mexican workforce, which constitutes 56 million people, is divided into 11.6% in the primary sector, 25.3% in the secondary sector, and 62.5% in the tertiary sector in 2022 [11].

The distribution of professionals interviewed included nationwide experts, with 40.7% participation from other regions in México, including Jalisco and Guanajuato. Education was one of the survey questions for the primary sector, 50% of respondents had an undergraduate degree, and 48.1% had further studies (see Figure 4).

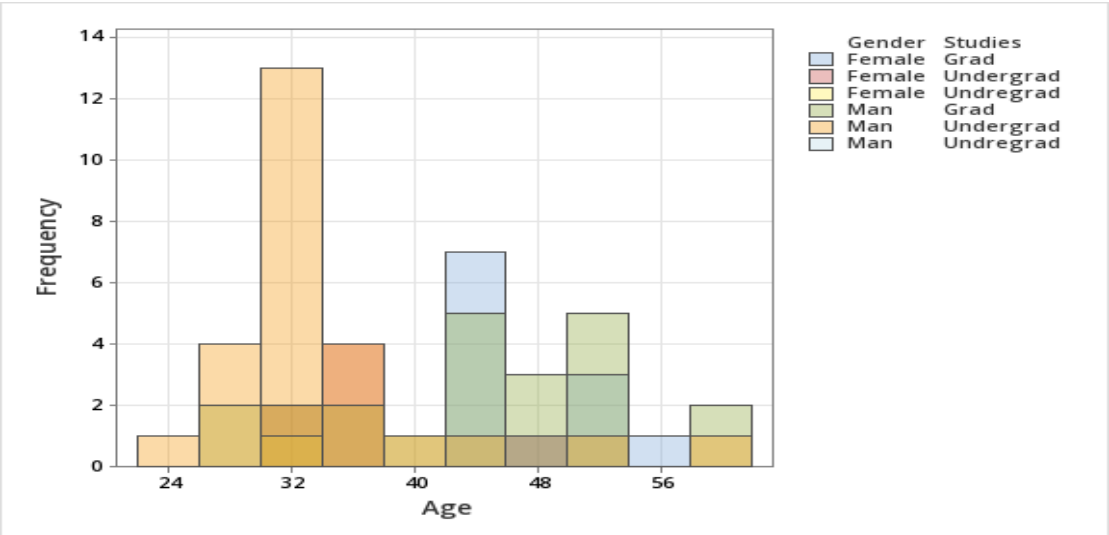

Figure 4: Histogram of studies and gender among the survey participants divided by gender using Minitab

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Vargas *et al.* [18] report a strong trend in farmers' demographic characteristics in Mexico. For example, on average, citrus growers are 52 years old, with five years of schooling and 20 years of experience in crop production. Depending on the community, farmers form an association and network to access government subsidies to improve agronomic productivity after extensive agriculture programs.

Farmers' education helps them to implement technical agricultural strategies or to increase awareness of government incentives that benefit economic development [19, 20]. In the survey, 50% of agricultural entrepreneurs had access to higher education and collaborated directly with employees. Among those, 25.9% of employees for different farms and agroindustry only had elementary education and only 14.8% had higher education. From the sustainability viewpoint, access to education for an employee's children is an important issue, which was considered a key indicator because of agriculture's economic and social impact. 67.9% of the participants had an awareness that their children were attending school, while 18.9% lacked that awareness, and 11.3% knew that farmers' children were not attending school. This finding is valuable information for the Bajío Region skill set in the rural workforce, and vital to government training programs. The survey estimates that 25.9% of rural workers have some elementary school education. Indeed, SDG 4 proposes "Quality Education" for all [13].

The current analysis represents profiles for small and medium-sized producers. Different specialities within the primary sector were represented as fresh produce (40.7%), cattle industry (27.8%), and apiculture (11.1%). Within fresh produce, the representative crops were corn (37%), broccoli (11.1%), strawberry (11.1%), beans (9.3%), and green pepper (9.3%).

Figure 5 shows the distribution of the survey producers (31%) with land extensions above 15 ha, compared with smallholder producers (29.4%) with land access between 0 and 5 ha. This trend is consistent with previous studies comparing small- and medium-sized producers. Experts realized that agricultural incentives in Mexico could be perceived in two categories either from the viewpoint of productivity or social. The first is focused on increasing productivity in the agricultural sector; the second is oriented toward poverty alleviation [19]. Bajío producers with considerable land tend to focus their production model on productivity. Smallholder producers with access to government incentives are trying to migrate from the social aid category.

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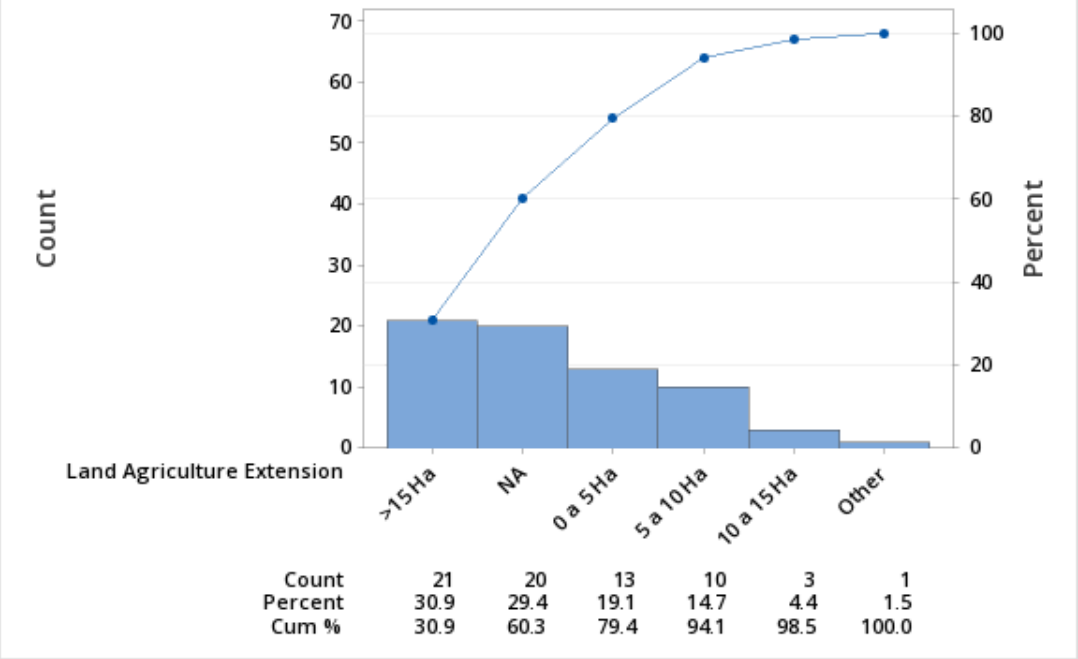

Figure 5: Pareto Chart related to the land extension and the nature of the producers

Farming systems that can be found not only in Mexico but in Latin America can be associated with three more significant categories according to their level of integration in a bigger market corporation, large farmers, medium and small entrepreneurial farmers, and smallholders and subsistence farms. In this study, only 30% of the participants had access to land above 15 ha. Whereas 63.2% have land access between 0 and 15 Ha. According to experts, there are about 2.1 million subsistence farmers in Mexico, which explains the trend of 20% of the survey participants having access to land with less than 5 ha among the Bajío Region and national territory. Researchers call this process "deagrarianization," which is influenced by factors including productivity pressures on small-scale farmers and the vulnerability of rural households [19, 20].

Organic supplementals and crop rotation with leguminous plants have been options to improve crop management [4]. In some proportions, asparagus and strawberries have been considered reconversion crops. However, 59.3% of the participants have not explored or implemented crop management programs (reconversion) even though in 2018, Aguascalientes invested 25 million pesos to promote avocado, asparagus, guava, grapes, cranberries, strawberries, and lime production [21]. This investment was aligned with SDG 12: “Responsible Consumption and Production” [13]. Southern Mexico has developed the expansion of reconversion programs that change maize production land to integrate soybean production with the agrarian productivity structure [22]These actions are significant because they avoid the excessive use of fertilizers, reduce the pollution of water

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bodies within the region, and prevent future soil salinization. They are very aligned with SDG 6: Clean Water and Sanitation.

Water and Energy conservation knowledge

Water access and availability mark the leading regions in Mexican agriculture, and it depends on national geography [22]. The northern region of Mexico has a higher population density, and economic development represents 77% of the gross domestic product (GDP). However, it has only 31% of water available, whereas the southern region has access to 69% of water resources, with 23% of the population, but produces only 13% of the national GDP [23]. The survey asked if farmers tried to optimize water consumption; 61.1% of the producers tried to implement some strategy to optimize usage in contrast with 11.1% that did not implement any strategy, and 27.8% that did not have the knowledge nor resources for water management. Figure 6 shows strategies implemented by producers: drip irrigation (30.8%), water catchment (10.3%), and technical irrigation systems (17.9%), among others. Mexican water laws have provoked significant changes; for example, Sonora pioneered water irrigation with cutting-edge technology for planting and harvesting. Aguascalientes has limited water resources but is less technologically intensive than northern Mexico. SDG 6 calls for "Clean Water and Sanitation" [13]. To achieve this goal within the current agricultural system in the region, increasing the 20.4% in technical irrigation systems is essential.

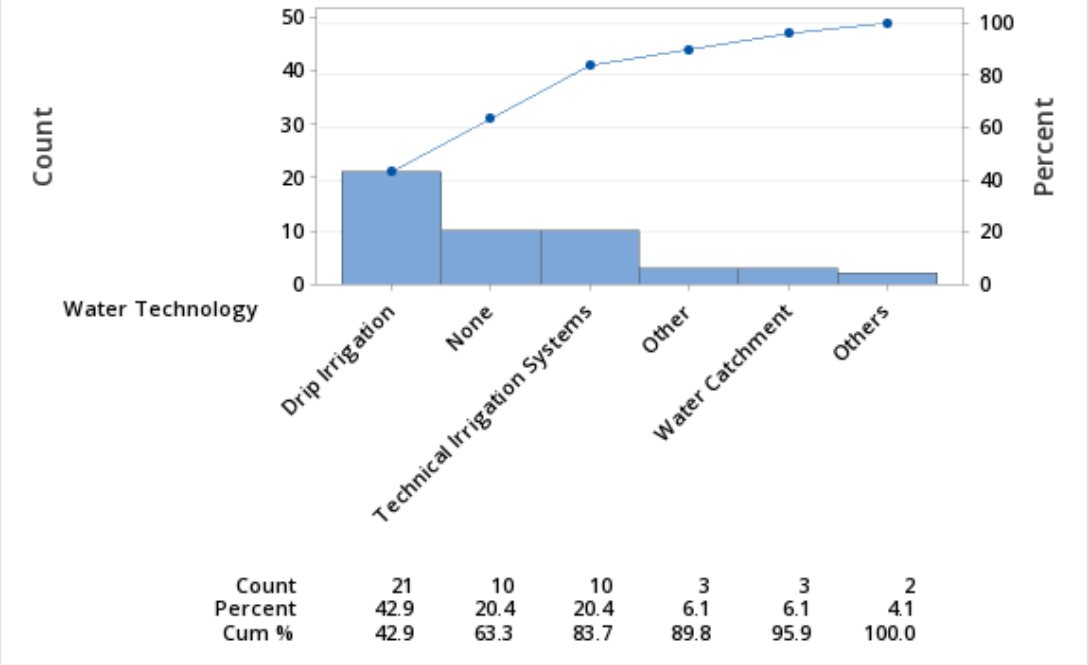

Figure 6: Pareto Chart of strategies implemented for water efficient management in agriculture among the participants

Source: Field survey

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Energy Efficiency in Agriculture

Energy access and distribution is a problem that Mexican agriculture faces to increase productivity, but more importantly, to create a sustainable food production system and link to SDG 7 that addresses "Affordable and Clean Energy." Only 42.6% of the producers had made changes within the last few years to consider energy efficiency strategies. From the technological portfolio, producers considered the following energy strategies: solar panels (46.7%), photovoltaic installations, low energy consumption equipment (20%), and hybrid vehicles (less than 5%). Understanding the distribution of policy incentives and economic subsidies is crucial, and energy input is vital for agricultural production. Soto *et al.* [24] reported the need to know more about the impact of subsidies on rural development. Strategies focused on jatropha cultivation have been studied to enhance rural development [25]. Jatropha is an example of the difference in design and implementation. In 2008, the original idea was to support the highly marginalized rural communities with small producers struggling with existing structures [24].

Energy linked with post-harvest is a critical stage in food production, but it has been implemented in a few cases [26]. Only 35.2% of survey participants invested in implementing activities to reduce food waste at this stage of the supply food chain. Participants described themselves as medium and small producers and efforts need to be made to account for food losses in the post-harvest facilities [27]. Experts studied that maize has been stored for several months before distribution, which implies losses in the quality and quantity of the grain [26]. Smallholder farmers have storage technologies with non-controlled conditions [28].

Certification awareness and food processing for Agriculture

Producers considering a certification in their production cycles have had a big economic impact. A wide range of food safety certifications was considered among participants, including FSSC 22000, Global STD Certification, and Primus; among them, 11.6% had Primus. Of the participants, 72.2% did not count on an organic denomination, food label, or certification, while only 13% adopted this tool [29]. However, 53.7% have considered implementing organic production within their products. Food safety requirements play a significant role in agriculture essential to gaining trust in the supply chain. Challenges to agriculture are not only limited to how much food is produced but also produce quality (nutritious and safe) [30]. In the current instrument, there was a question related to increased product demand using e-commerce. 48.1% of respondents reported demand in e-commerce, whereas 37% did not experience increased sales through e-commerce in product demand during COVID-19. Food safety efforts to strengthen the supply chain and food processing are essential, and increased awareness is gaining traction among agricultural professionals [31]. Nevertheless, work must be done to integrate the

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agricultural production system into a bigger market, as only 29.6% of the participants export their products [16].

Public Policy Perception for the Agricultural Sector

Public policy awareness among producers is key to the type of incentive programs and alliances that would allow them to enhance economic development. 75.9% of participants did not know about Aguascalientes' food and agricultural policy programs. Specific details about the answers of the 54 participants appear in Figure 6, which is related to the public policies or types of programs that boost productivity. Determining the adequacy of public policy, 70.4% of the participants needed to be made aware of a given policy, while only 20.4% considered the public policy adequate. Overall, more studies are needed to gauge public policy efficacy and implementation.

Figure 7 gives preliminary information for all the post-COVID food public policies that could be established in Aguascalientes. San Pedro River has some work in progress for water treatment and a roadmap to improve water infrastructure. The primary motivation for the water treatment is the agricultural economic impact at the state level. In 1980, only 33% of the state land was for agriculture. In 2016 the overall state land for agriculture was 43% [29]. The current study has identified the following key agricultural concerns including small producers' participation, limited access to market and food pricing, and a lack of cooperatives for farmers (Figure 7), and these factors have an important impact on SDG 11: Sustainable Cities and Communities. Experts recommend that agriculture abandon the conventional food production scheme because of the uncertainty that small producers face after COVID-19 [9, 30, 32].

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Figure 7: Which public policies will be necessary to increase your productivity?
Source: Field Survey

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Public Policy Awareness

The results showed only 53.7% of producers knew about the public policy to increase productivity in the field or an incentive program at the state level that sought to enhance Aguascalientes' potential in agriculture. 46.3% of survey participants explained their perceptions of why Aguascalientes cannot be an agriculture referent in Figure 8. The identified causes were categorized as a focus on the manufacturing sector, water scarcity, and the need to exploit resources to improve the growing curve among the perception of the participants.

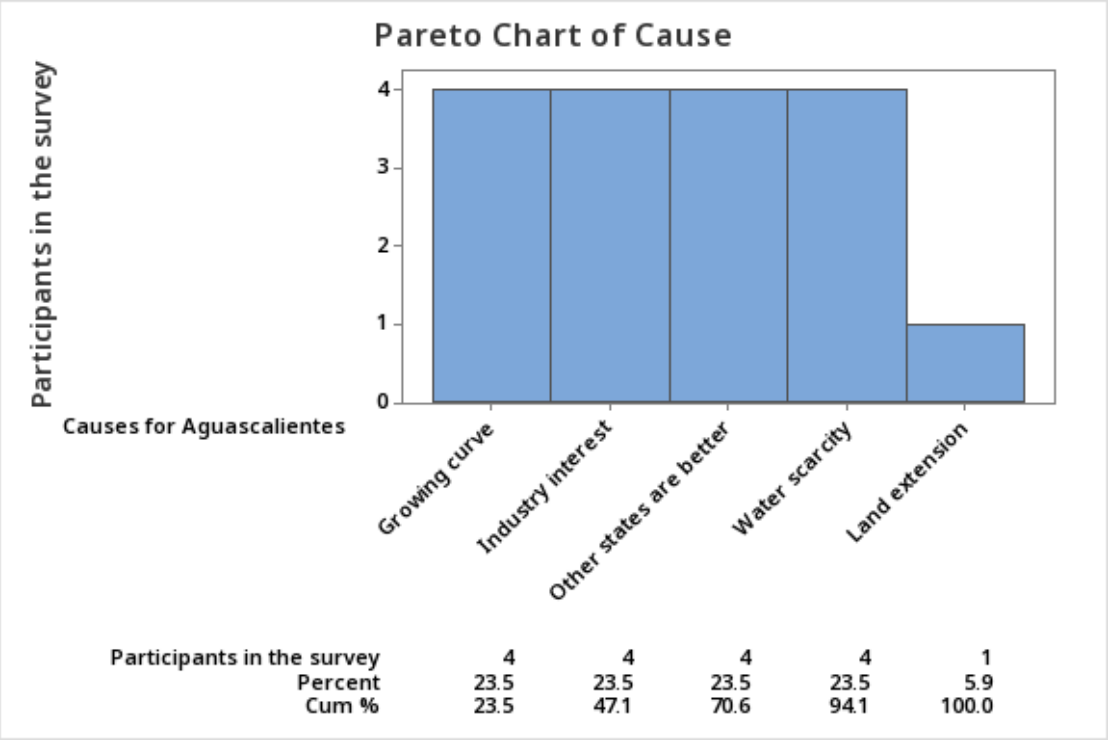

Figure 8: Producer´s perceptions explain why Aguascalientes cannot be a national agricultural reference
Source: Field survey

Aguascalientes is perceived by 71.2% of the experts interviewed as an agriculture reference. However, 28.8% did not agree with the statement that this Mexican state has the potential to grow into a bigger producer. Several experts in Mexico have reported concerns about land access among Aguascalientes' farmers and the need to increase productivity (Figure 8). Ortiz-Garcia *et al.* [7] found the following challenges related to Mexican governance must be addressed: 1) Lack of boundaries between agricultural and forestry land, 2) existence of communal property, and 3) significant incidence of rented land for agricultural and livestock use [7, 33].

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Mexico is a net importer nation. The current findings about Aguascalientes and the Bajio Region, and their need to increase productivity (see Figure 6), and improve knowledge about land resources, are needed to provide enough crops to strengthen food security, which follows the UN 2030 agenda of Sustainable Development Goals [32]. This section of the paper focused on SDG 15: "Life on Land," which is critical, as "Forests cover 30 percent of the Earth's surface, and, in addition, to providing food security and shelter, forests are key to combating climate change, and protecting biodiversity and the homes of the Indigenous population" [12]. Aguascalientes' challenge is mediating agricultural productivity to bring economic development and respecting the water restraints in the region coexisting with other industry sectors (Figure 8).

Mexico towards sustainability

The 1980s provided context for discussing the activities pursued in the Aguascalientes and Bajio Region. The issue of achieving sustainable development addresses the unsustainable trajectory of "waste for waste's sake." This concept appeared in the 1987 book, *Our Common Future*, by the United Nations World Commission on Environment and Development (WCED) within achieving sustainable development, which is daunting, and we must ask the question:" How?*"* The concept of "sustainable development" has come to mean, *"*Meeting the needs of the present without compromising the ability of future generations to meet their own needs*"* according to the United Nations. The result of the 1992 Earth Summit, including 172 countries, was the document Agenda 21, which set forth general instructions to reverse the unsustainable path we were on as a global society in our developmental practices [12]. But how do we achieve this in Aguascalientes and the Bajío Region as small extensions of a broader, worldwide effort? It started with the questionnaire.

Mexico's Government should invest in adequate public policies to address problems the primary sector faces to ensure growth in the foreseeable future [34]. Challenges are complex, and several factors should be taken into consideration such as socio-demographic, educational, and farmers' preparedness. Results show that Bajio producers have increased their agricultural professionalization, following a similar national trend [35].

Mayett-Moreno & López-Oblesby have found a critical decline in farm workers migrating to the U.S. due to decreasing rural family size, growth in non-farm employment, expansion of rural education, and aging of the workforce in rural Mexico [31]. Also, off-farm activities helped generate more than half of the income in Mexico's communal farming (Ejido) system. Education plays a significant role in access to better-paying non-agricultural jobs and sectors with educational lag have less access to other labor opportunities [19, 20]. These factors are crucial to

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developing new technology and strategies to maintain the Mexican food production system. Youth initiatives/activities, e.g., education (academic and vocational) and farmer training programs, are required to achieve sustainable development, especially with the decreasing family size and the aging workforce [12, 14].

Ibarrola-Rivas *et al.* [27] found that the Mexican agriculture system has different components and employs 8.9 million Mexicans. The perception of the Bajío Region views is that it needs to increase domestic supply. Farmers' beliefs on the matter need to be addressed with more studies to better understand the Mexican domestic supply system and its aggregates, including food losses, non-food items, and food supply availability [27, 36, 37].

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Differences between small, medium, and large-holder farmers are essential factors in the perception of productivity in the agricultural sector in Aguascalientes. 63.2% of the participants have access to less than 15 ha for their crops.

Agricultural entrepreneurs' and farmers' socioeconomic information is essential in determining the feasibility of technological implementation. The producers' perception of Aguascalientes about agricultural productivity is limited water resources. It might be worth considering a more technology-intensive approach, with technical irrigation systems for agriculture like northern Mexico. Further studies are necessary to assess the Bajío Region's climate, awareness of water irrigation, access to water, and its economic development importance as a food production center for Mexico. The primary goal is to develop a more resilient agricultural system and to increase the knowledge of the main actors in the primary sector about the potential technical barriers to improving their productivity. Public policy programs oriented to guarantee prices have been one of the more successful national initiatives. However, more programs must be oriented towards competitive tools with water usage, technological enhancements for production, professional training, and strategies to introduce intensive agriculture needed in Aguascalientes. Analysis of this state and the Bajío region as a case study is essential for Mexico to achieve its UN's SDGs. Suppose Aguascalientes and the Bajio region can achieve small steps toward the SDGs. In that case, Mexico will gradually grow its agricultural production towards the SDGs, impacting North America's sustainable development goals and UN 2030 goals. A more integrated system between the food production system, the producers' extension land, and programs focused on supporting sustainable farming are essential to the Bajio Region's food security and sustainability.

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