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Presentation of Content

In the first article we present, *Technical and economic viability of the cultivation of coriander (Coriandrum sativum L.) in Orinda, Chihuahua* by Ontiveros-Gómez, Guadalupe, Guigón-López, Cesar, Magaña-Magaña, José Eduardo and Olivas-García, Jesús Miguel, with adscription in Universidad Autónoma de Chihuahua, as the next article we present, *Gender gaps in the perception of human labor rights among the staff of a Higher Education dependency* by Andueza-Pech, María Guadalupe, Rodríguez-Angulo, Elsa María, Ojeda-Rodríguez, Ricardo and Cambranes-Puc, Luis Humberto, with adscription in Autonomous University of Yucatán, as the next article we present, *Adaptation of agricultural practices for the sustainability of sugarcane production in the Northern Huasteca Region in Response to Climate Change* by Lorenzo-Márquez, Habacuc, Wong-Arguelles, Cynthia, Acosta-Pintor, Dulce Carolina and Mojica-Mesinas, Cuitláhuac, with adscription in Tecnológico Nacional de México-Instituto Tecnológico de Ciudad Valles, as the next article we present, *Macroeconomic determinants of financial fraud and identity theft* by Rocha-Salazar, José de Jesús, Segovia-Vargas, María Jesús and Camacho-Miñano, María del Mar, with adscription in EGADE Business School, Tecnologico de Monterrey and Complutense University of Madrid, as the next article we present, *Incorporation of QR codes to provide information about academic conferences, register attendance, and generate certificates* by Escorza-Sánchez, Yolanda Marysol & Mendoza-Espinoza, Héctor Eduardo, with adscription in Universidad Tecnológica del Valle del Mezquital and Universidad Politécnica de Tulancingo, as the last article we present, *Comparative analysis of natural disasters in the Mexican Pacific: The case of hurricane Otis and its socioeconomic impact on Acapulco* by Niño-Gutiérrez, Naú Silverio, with adscription in Universidad Autónoma de Guerrero.

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Content

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Article

Technical and economic viability of the cultivation of coriander (Coriandrum sativum L.) in Orinda, Chihuahua

Viabilidad técnica y económica del cultivo de cilantro (Coriandrum sativum L.) En Orinda, Chihuahua

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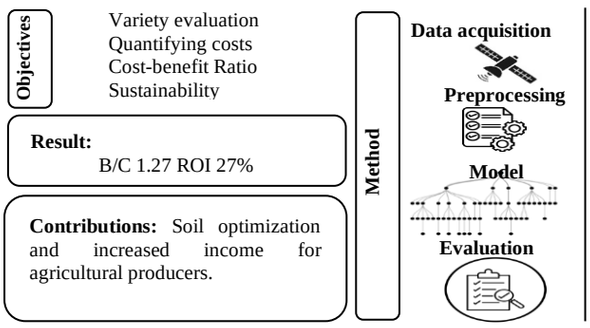
Abstract

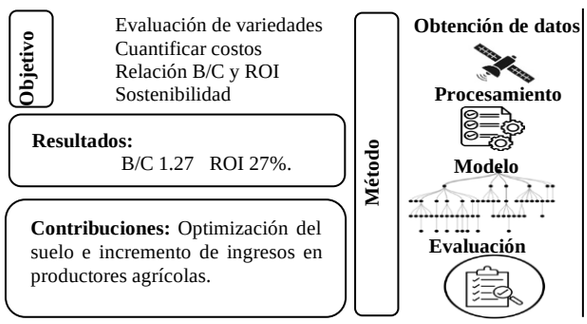
Cilantro is marketed worldwide for its aromatic and gastronomic properties. The aim of this study was to evaluate five cilantro varieties grown under pecan walnut coverage. The variables analyzed included yield, height, stem thickness, number of petioles, and economic performance, aiming to identify the best variety. It consisted of a completely randomized experimental design with five treatments (varieties), and an agro-cost scheme and financial indicators were used to analyze the economic viability of cultivation. The main results revealed that the American Long Standing variety stood out with a yield of 13.1 tons per hectare and a cost-benefit ratio of 1.27. This variety allows for environmental contribution by optimizing soil use through crop association and economically by improving producers' incomes.



Crop association, Agro-costs, Carya Illinoinensis, Economic indicators, Varieties

Resumen

El cilantro, es comercializado a nivel mundial por sus propiedades aromáticas y gastronómicas. El objetivo de este estudio consistió en evaluar cinco variedades de cilantro cultivadas bajo cobertura de nogal pecanero (*Carya illinoinensis*), las variables analizadas incluyeron rendimiento, altura, grosor de tallo, numero de peciolos y rendimiento económico, con el propósito de identificar la mejor variedad. Consto de un diseño experimental completamente al azar con cinco tratamientos (variedades), además se empleó un esquema de agrocostos e indicadores financieros para el análisis de la viabilidad económica del cultivo. Los principales resultados revelaron que la variedad American Long Standing destacó con un rendimiento de 13.1 toneladas por hectárea y una relación beneficio-costo de 1.27. Esta variedad permite una contribución ambiental al optimizar el uso del suelo mediante la asociación de cultivos y económicamente al mejorar los ingresos de los productores.



Asociación de cultivos, Agrocostos, Carya illinoinensis, Indicadores económico, Variedades

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Introduction

The species Coriandrum sativum L., more commonly known as coriander, has its roots in ancient Egypt and various regions of the Mediterranean, being widely recognised for its medicinal and aromatic properties by the pharaohs of the time (Chavez Hernandez, 2018).

The term "coriander" derives from the Greek koriannon, a combination of koris (insect with an unpleasant aroma) and annon (an aromatic aniseed), alluding to the unpleasant smell emanating from its still-green fruits, which transforms into a more pleasant aroma as they mature (Apolo Romero and Basurto Jimbo, 2017). Globally, coriander is widely traded and used in the preparation of a variety of foods (FAO, 2015), including liqueurs, pickles, sausages, sauces, sweets and soups, among other gastronomic dishes (Holmes Naranjo and Bermeo Salvatierra, 2017).

Likewise, it is estimated that world production is between 300,000 and 335,000 MT annually (FAO, 2015). According to data from the Servicio de Información Agroalimentaria y Pesquera (SIAP) in 2022, agricultural producers in Mexico generated around 114,245.24 tonnes of coriander, cultivated on an area of 7,809.86 hectares.

The state of Puebla leads production at national level, contributing 46,747.18 tonnes on an area of 3,311.05 hectares. It should be noted that most of this production is destined for the international market, mainly the United States (SIAP, 2018).

In the state of Chihuahua, only 8.5 hectares of coriander area was recorded in 2022, with a production of 67.68 tonnes. In comparison, the area dedicated to walnut cultivation reached 101,272.04 hectares for the same year (SIAP, 2023).

It is worth noting that numerous producers, especially those dedicated to walnut production, have implemented the incorporation of crops such as alfalfa, clover, oats and pasture among their walnut orchards, to provide soil cover and other benefits (Osman, 2022), which can be agronomic and economic (Tamayo Ortiz and Alegre Orihuela, 2022).

According to SIAP (2022), from 2000 to 2021, 16.66% of arable hectares in Mexico were no longer sown, with only 18,151,034.91 ha currently being sown, due to population growth (Badii et al., 2015), drought and the desertification process (Bolaños González et al., 2016), FAO 2024 warns that, in addition to the growing demand for food and the exploitation of natural resources, it will be difficult to achieve food security, and stresses the importance of sustainable agriculture to counteract the current challenges of agricultural and food production.

According to Tamayo Ortiz and Alegre Orihuela (2022), the combination of crops makes it possible to increase yields per arable area, which helps to conserve soil, use water more efficiently and generate greater economic gains.

This approach, supported by the agro-costing scheme (FIRA, 2023) and the use of financial indicators, makes it possible to assess the economic viability of the crop (Molina De Paredes, 2017), by structuring production costs and thus making informed decisions in the agricultural sector. In the municipality of Rosales, Chihuahua, there is a lack of information about which variety of coriander adapts and performs best under the cover of pecan walnut and an analysis of production costs for the same.

However, as it is an autumn-winter cycle crop, it presents two difficulties for its production in the municipality: first, the low availability of irrigation water in the crop cycle; second, in the spring-summer cycle, the crop presents "premature sprouting", which means that it does not meet the quality characteristics demanded by the market. These difficulties motivate the development of studies on its association with the pecan nut crop and to determine its yields in the spring-summer cycle.

This approach will not only serve as an integral production system, but will also offer small producers an alternative crop that they can implement in their walnut orchards. In this sense, the objectives of this research are: 1) To compare the productivity of five coriander varieties established under pecan nut cover 2) To quantify the establishment costs of the coriander variety with the highest productivity 3) To calculate the return on investment of the coriander variety with the highest productivity.

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Materials and methods

Location of the study area

A field experiment was established in 2023, in an orchard with 15-year-old walnut trees. The orchard is located in the community of Orinda, municipality of Rosales, in the state of Chihuahua, Mexico, at coordinates 28°25'86.49" North Latitude and 105°55'42.54" West Longitude. The study area has a mostly semi-warm climate, with an average annual temperature range of 14-20º C. However, there are extreme values in the winter months (December-February) with minimum temperatures that can reach -10°C and maximum values in the summer months (June-August) with temperatures that can exceed 40°C.

The average annual rainfall is 200 to 500 mm from June to September. Occasionally, light snowfall may occur in December or January. The prevailing winds come from the southwest (INEGI, 2010) and the soil type according to the taxonomy of the United States of America is of the order of aridisols.

Agronomic management

The experiment used the following five coriander varieties: Long national (T1), Morocco (T2), Turko (T3), Líder (T4) and American long standing (T5). Six replications were used and set up in a randomised complete block design. Cultural practices were as follows. Sowing was carried out on 29 March, by hand, three rows per furrow and a useful plot of 300 plants was considered. For the variables fresh foliage weight (kg) and number of bunches, 50 cm were considered for each replicate. Once the treatments were sown, a fertiliser dose of 80-100-120 and a rooting agent (ROOTEX-1 kg $^{ha-1}$) were applied.

For weed control, Trifluralin was applied pre-emergence and Diler 120 EC post-emergence, both at a dose of 1 L $^{ha-1}$. Pest control was carried out with the application of the insecticide Toreto applying 0.15 L $^{ha-1}$ and disease control with the application of Prontius® (Methyl Thiophanate) and Agrimycin 100® (Oxcitetracycline + Steptromycin) both at a dose of 1 L $^{ha-1}$.

Variables evaluated

The agronomic variables evaluated were plant height (cm) from stem base to tip, plant stem thickness (mm), number of petioles, number of primordia, fresh foliage weight (kg) and number of bunches. In addition, the average monthly temperature under the shade of the pecan trees was recorded. In economic terms, the rate of return on total income and the benefit/cost ratio were calculated.

Experimental design and statistical analysis

For the statistical analysis, an analysis of variance (ANOVA) was implemented under unstructured treatments (Rubio and Jimenez, 2012) using the statistical package SAS version 9.4 (SAS Insittute Inc. 2016). When the ANOVA declared statistical significance between treatments, the Tukey's mean comparison test was used. All analyses considered a significance level of 95%, i.e. α=0.05.

Economic management

Through the agrocost methodology used by Fideicomisos Instituidos en Relación con la Agricultura (FIRA, 2024), which consists of a digital register of production costs in an agrocost of production scheme for agricultural crops in specific areas. The production cost structure considers the actual expenses incurred by the producer during the production cycle, such as cultural work, labour, irrigation, inputs (fertilisers and chemicals) and harvesting processes. Subsequently, for the economic analysis, economic viability was evaluated using the financial indicators ROI and B/C Ratio according to Ortega et al (2023).

Results

Agronomic variables

Temperature

The temperature was recorded using two Elitech RC-51 devices, one located under the shade of pecan nut trees and the other in the open field. The readings were recorded from 23-04-2023 to 27-05-2023, obtaining an average temperature of 20.6 ˚ C under the cover of pecan nut trees and 25.1 ˚ C in the open field.

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Plant height (PA)

ANOVA showed statistical differences between the varieties evaluated with respect to the PA parameter (P<0.05). Figure 1 shows that the variety Morocco obtained the greatest height with 33.2 cm followed by the variety Turko with 32.3 cm. Tukey's test showed that these two varieties are statistically equal with respect to this variable and different with respect to the other three varieties. Similarly, the varieties Líder (30.8 cm), Long national (30.7 cm) and American long standing (30.1 cm) were statistically similar to each other. The results of the present study are different from those reported by Duwal et al. (2019) who evaluated eight coriander varieties at the Institute of Agriculture and Animal Science in Nepal and found no statistical difference in PA parameter. These researchers reported plant heights ranging from 39.1 cm in the variety Khusboo to 46.7 cm in the variety IKO-BR-50, which are higher than those found in the study reported here. Vega Diaz (2012) reported that the five varieties evaluated in the region of Araucania, Chile, did not present statistical differences in the PA parameter, however the heights were similar to those obtained in the present study, reporting values ranging from 29.925 for the santos variety to 30.9 for the Moggiano and Comun varieties. Researchers Peneva and Krilov (1977) pointed out that the growth of coriander is affected by the length of the day rather than by temperature, suggesting that studies should be carried out to determine this effect under the conditions in which the present study was carried out.

Box 1

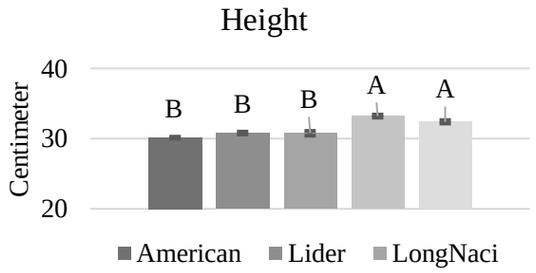

Figure 1

Final height (cm) of five coriander varieties produced in a pecan nut orchard

Source: Own elaboration

Stem thickness

The ANOVA showed statistical differences for the stem thickness variable in the five varieties evaluated (P<0.05).

Figure 2 shows that the American long standing variety obtained the greatest stem development with 6.68 mm followed by the Long national variety with 6.4 mm, Líder with 6.25 mm, Morocco with 6.2 mm and finally the lowest thickness was noted in the Turko variety with 5.4 mm. The Tukey test identified that the American long standing variety was superior to all the other varieties with respect to this variable, while the Turko variety was the least thick of this group. It is important to mention that Hernández (2003) reported a significant genotype-environment interaction between four coriander materials (Criollo de Ramos, Marroqui, Sun master and Slow bolt). This author mentioned that leaf area and stem thickness were similar in the first 45 days of growth in the four genotypes evaluated; however, from that date onwards, there was a clear difference between the genotypes evaluated. On the other hand, Balanta Lara (2017) in his evaluation of the variety Unapal precoso, without and with fertilisation, the plant showed an average thickness of 5.29 and 5.79 mm respectively, highlighting the benefits of fertilisation.

Box 2

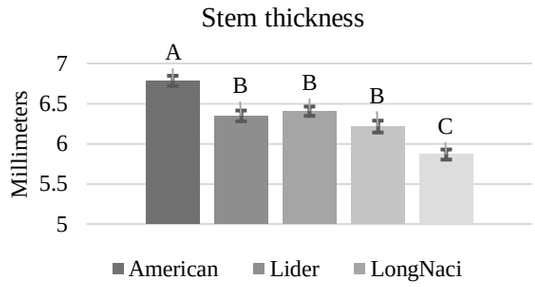

Figure 2

Stem thickness (mm) of five coriander varieties produced in a pecan orchard

Source: Own elaboration

Number of petioles

ANOVA identified statistical differences among the five coriander varieties evaluated (P<0.05). Figure 3 shows that the highest number of petioles was found in the variety Morocco with 7.38, followed by the varieties Long Nacional with 7.28 and American long standing with 7.23. The Tukey test confirmed that these three varieties are statistically equal with respect to this variable, while the varieties Líder (6.78 petioles) and Turko (6.53 petioles) obtained the lowest number of stems.

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Vega Diaz (2012), in his evaluation of five cultivars (varieties) of coriander, reports that there were no significant differences, however, presents values similar to those obtained in this study, with the Bonanza variety registering the lowest number with 6 petioles per plant and the common variety the highest number with 7 petioles per plant.

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Box 3

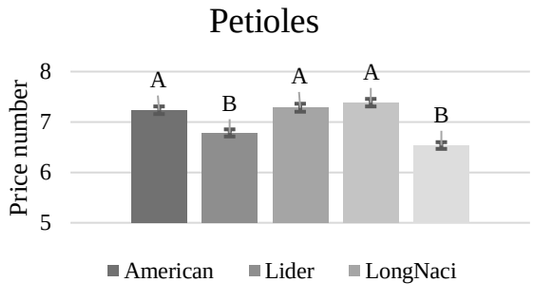

Figure 3

Number of petioles in five varieties of coriander produced in an orchard with pecan nut

Source: Own elaboration

Fresh weight yield of coriander

ANOVA detected significant differences for the yield obtained by five coriander varieties (P<0.05) evaluated in a pecan nut orchard. For the estimation per hectare, a total area of 0.8 hectares was considered, because the remaining 0.2 hectares of land is dedicated to walnut cultivation. Figure 4 clearly shows that the variety American long standing averaged the highest yield with 13.1 t ha-1 and the variety Líder came second with 12.0 ton ha-1. The variety with the lowest yield was Turko with 10.9 ton ha-1 and with average yields were the national Long variety (11.4 ton ha-1) and the variety Morocco (11.8 ton ha-1).

Researchers Duwal et al. (2019) evaluated eight coriander varieties at the Institute of Agriculture and Animal Science in Nepal and found that the variety IKO-BR-50 produced the highest yield with 15.46 ton ha-1, which is higher than that obtained in this study. However, these researchers also evaluated the variety American long standing and reported a yield of 12.66 ton ha-1 which is similar to the yield reported for this variety, in the present study (13.1 ton ha-1). Surya et al., (2018) tested four genotypes (CO-1, CO-2, CO-3 and Cr-4) of coriander and one variety (Arka Isha) under two conditions; open field and protected.

These authors reported statistical differences between growing conditions and between genotypes/variety. The highest yields were in the treatments under protected conditions and the highest yield was with the variety Arka Isha with 14.13 g plant-1.

Box 4

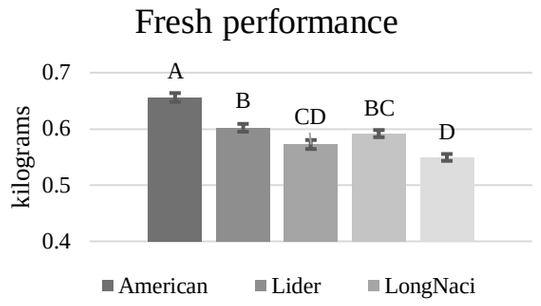

Figure 4

Fresh yield of five coriander varieties evaluated in a walnut orchard

Source: Own elaboration

Number of bunches

ANOVA identified statistical differences between the five coriander varieties evaluated (P<0.05).

For the estimation per hectare a total area of 0.8 hectares was considered, for the variety American Long Standing 108,698.26 bunches were estimated, presenting the highest yield, while the variety Turko presented the lowest yield with 80,818.70 bunches.

Box 5

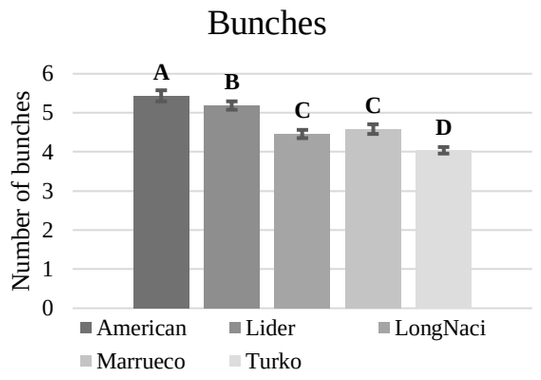

Figure 5

Number of bunches of five coriander varieties evaluated in a walnut orchard

Source: Own elaboration

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Table 1 shows the costs associated with the concepts and activities carried out in relation to the establishment, growth, development and harvest of the coriander variety that presented the highest fresh yield and number of bunches, which based on the agronomic results was the American Long Standing variety with 13.1 ton $^{ha-1}$ and 108,698.26 bunches $^{ha-1}$.

The total cost is also shown in table 2, considering an interest rate of 11.25% per annum, applied to the amount described as bankable, giving a total production cost of $127,959.00.

Box 6

Table 1

Production Costs per Ha

Concept	Finan.	No finan	Total
Land preparation	7200	0	7200
Sowing	9800	0	9800
Fertilization	7210	0	7210
Irrigation	4500	0	4500
Crops	1600	0	1600
Pest, weed, and disease control	12929	0	12929
Harvesting, selection, and packing	38039	0	38039
Goods transportation	0	14756	14756
Miscellaneous	2500	20000	22500
Total	83778	34756	118534

Source: Own elaboration

Box 7

Table 2

Production Costs

Date	Financeable	Interes rate	Interests	Non financeable	Total
jan-dec 2023	83778	11.25%	9425	34756	127959

Source: Own elaboration

Economic profitability

FIRA's agro-cost methodology was used to determine the profit ($/ha), considering the commercial presentation of coriander (bunches).

Three estimates were made based on variable prices and yields (minimum, probable and maximum).

The prices considered correspond to those usual in a normal harvesting season, while the most probable yield was determined in this study, considering a range of plus or minus one tonne for maximum and minimum. The prices established are: minimum price per bunch of coriander is $1, representing the lowest extreme under supply and demand conditions. The likely price is set at $1.5 per bunch, reflecting the most realistic estimate under typical market circumstances. Finally, the maximum price is $2 per bunch, indicating the highest value it could reach under favourable conditions.

In relation to yields, the following quantities are established: 99,570 bunches, equivalent to a yield of 12 ton/ha; 108,698 bunches, corresponding to a yield of 13.1 ton/ha; and 116,165 bunches, associated with a yield of 14 ton/ha. Table 3 shows the profits ($/ha) based on yield and table 4 shows the profits ($/ha) based on production costs, generating a profit of $35,088.00 in the most likely price and yield scenario.

Box 8

Table 3

Profit per ha based on yield

UTILITY ($/HA)

YEAR 1	Selling price ($/ton)						
YIELD (BUNCHES/HA)	1.00	1.17	1.33	1.50	1.67	1.83	2.00
99570	-28389	-11462	4469	21396	38323	54254	71181
102308	-25651	-8259	136070	25503	42895	59265	76657
105046	-22913	-5055	139711	29610	47468	64275	82133
108698	-19261	-782	144568	35088	53567	70958	89437
110606	-17353	1450	147106	37950	56753	74450	93253
113344	-14615	4653	150748	42057	61325	79461	98729
116165	-11794	7954	154499	46289	66037	84623	104371

Source: Own elaboration

Box 9

Table 4

Profit per ha per Cost of Production

UTILITY ($/ha)

Year 1	Selling price ($/ton)						
Total cost ($/ha)	1.00	1.17	1.33	1.50	1.67	1.83	2.00
108459	239	18718	36109	54588	73067	90458	108937
114959	-6261	12218	29609	48088	66567	83958	102437
121459	-12761	5718	23109	41588	60067	77458	95937
127959	-19261	-782	16609	35088	53567	70958	89437
134459	-25761	-7282	10109	28588	47067	64458	82937
140959	-32261	-13782	3609	22088	40567	57958	76437
147459	-38761	-20282	-2891	15588	34067	51458	69937

Source: Own elaboration

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Based on the total costs and probable income obtained, we proceeded to calculate the benefit-cost ratio and other concepts, which show the economic viability for the American Long Standing variety, generating as a result a B/C ratio of 1.27 and an ROI of 27%. These values indicate a positive economic viability, although the B/C ratio is lower than that reported by Cuvi Ramírez (2023) in his study on the evaluation of coriander cultivation with different fertilisers and nitrogen levels. In this study, the following B/C ratios were obtained: 1.50 for fertilisation with UREA, 1.47 for ammonium nitrate, 1.49 for Ferthigue, under a medium fertilisation level, and 1.22 for the control.

Thus, the author shows that there is a way to improve economic efficiency through the optimisation of fertilisation and agronomic management practices.

Box 10

Table 5

Compendium of economic viability information, American Long Standing variety.

Concept	Valor
Probable yield (Ton/ha)	13.10
Probable yield (Bunches/ha)	108698
Probable price ($/Bunch)	1.50
Weight per bunch (gr)	120
Probable income ($/ha)	163047.00
Total cost ($)	127959.00
Cost-benefit ratio	1.27
Probable utility ($/ha)	35088.00
Cost (Ton/ha)	9767.86
Return on Investment (ROI)	27%

Source: Own elaboration

Conclusions and recommendations

From the present study it is concluded that there are differences in the agronomic performance of the evaluated varieties, being superior the performance of the variety American long standing. In addition, this variety showed a positive economic viability, confirming that coriander has potential as an alternative crop under the cover of pecan nut. It is recommended to continue with research that adds value to the coriander crop, taking advantage of its medicinal and nutritional benefits, in order to expand and diversify the economic opportunities offered by this crop.

Declarations

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Authors' contribution

Ontiveros-Gómez, Guadalupe: I contributed the project idea and research development.

Guigón-López, Cesar: I contributed with the development of the research, data analysis, revision and editing.

Magaña-Magaña, José Eduardo: I contribute with revision and editing.

Olivas-García, Jesús Miguel: I contribute with the research method, data analysis.

Availability of data and materials

Data sets used or analysed during the current study are available from the corresponding author upon reasonable request.

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Abbreviations

FIRA	Fideicomisos Instituidos en Relación con la Agricultura (Trusts related to agriculture)
CANACO	National Chamber of Commerce
ROI	Return of Investment (Retorno de la Inversión)
B/C	Benefit-Cost Ratio
SIAP	Agri-food and Fisheries Information System
FAO	Food Agriculture Organization

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Article

Gender gaps in the perception of human labor rights among the staff of a Higher Education dependency

Brechas de género en la percepción de los derechos humanos laborales en el personal de una dependencia de Educación Superior

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Abstract

Objective: Explore the perception of the staff of a higher education unit regarding knowledge of Human Rights and gender, as well as their experience regarding them. Methodology: a study was carried out with a cross-sectional design, with staff from a higher education unit. This work contributes to understanding gender gaps from the perception of the personnel with whom we work, since each approach contained in the questionnaire induces them to reflect and evaluate their current situation; In the medium and long term, it is expected that the results obtained will provide elements that can be translated into Public Policies so that Higher Education institutions can translate them into promoting a healthy work environment and thus contribute to the intention of mainstreaming the gender perspective. in college.

Gender gaps in the perception of human labor rights among the staff of a Higher Education dependency		
Goals	Methodology	Contribution
Explore the perception of the staff of a higher education unit regarding knowledge of Human Rights and gender.	Cross-sectional design, with staff from a higher education institution.	Understand gender gaps from the perception of the personnel who work in a higher education institution and develop public policies that translate into actions for a healthy work environment.

Gender Gaps, Human Rights, Higher Education Institution

Resumen

Objetivo: Explorar la percepción del personal de una dependencia de educación superior sobre el conocimiento de los Derechos Humanos y género, así como su experiencia respecto a los mismos. Metodología: se llevó a cabo un estudio con un diseño transversal, con personal de una dependencia de educación superior. Este trabajo contribuye a entender las brechas de género desde la percepción del personal con el que se trabaje, ya que cada planteamiento contenido en el cuestionario los induce a reflexionar y valorar su situación actual; a mediano y a largo plazo se espera que los resultados obtenidos aporten elementos que puedan traducirse en Políticas Públicas para que las instituciones de Educación Superior los traduzca en acciones que fomenten un ambiente laboral saludable y de este modo se contribuya con la intención de transversalizar la perspectiva de género en la Universidad.

Brechas de Género en la percepción de los Derechos Humanos laborales en el personal de una dependencia de Educación Superior		
Objetivo	Metodología	Contribución
Explorar la percepción del personal de una dependencia de educación superior sobre el conocimiento de los Derechos Humanos y género.	Diseño transversal, con personal de una dependencia de educación superior.	Entender las brechas de género desde la percepción del personal que labora en una institución de Educación superior y se elaboren Políticas Públicas que se traduzcan en acciones para un ambiente laboral saludable.

Brechas de género, Derechos Humanos, Institución de Educación Superior

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Introduction

Trejo Sánchez (2017) suggests that, in order to construct the concept of human rights from a gender perspective, it is important to analyses the national and international legal framework on labor human rights and gender equality in Mexico, in addition to studying the conceptual framework on gender, gender perspective and labor human rights. As early as 2015, Natividad Sánchez pointed out that in Mexico, gender equality gaps in labor matters still existed despite the reform to the Federal Labor Law that Felipe Calderón Hinojosa presented to the Chamber of Deputies on 1 September 2012 (Natividad, 2015).

Trejo Sánchez (2017: 141) defines labor Human Rights as "all those human rights linked to the world of work, whose purpose makes possible minimum satisfactory working conditions, that is, those that respect the dignity of people". "Human rights at work are rights to benefits, like all social human rights". Labor rights protect against discrimination and exploitation in the workplace; they require, for their realization in time and space, existing and viable legal instruments, whose regulation is based on national and international standards.

She also points out that, in order to represent human rights from a gender perspective, it is first necessary to point out her proposed concept of human rights from this perspective. Thus, she considers them to be: "Those prerogatives that ensure the protection of and respect for human dignity, which must be enjoyed without distinction based on gender, and which aim at substantive equality in order to favor the integral development of the person". To this end, it is necessary to address three elements that it encompasses, which are inescapable in human rights from a gender perspective, and these are: human dignity, the elimination of discrimination based on gender and substantive equality (Trejo, 2017: 164).

In this sense, the gender perspective constitutes a tool that seeks to show the differences between women and men that occur because of the cultural differences assigned to human beings, rather than because of their biological determination.

The gender perspective, although it is a tool of analysis that focuses on determining the differences between men and women, as well as their needs, should also be interested in improving the living conditions of both genders and, therefore, seek to transform the position of women in relation to that of men, their community and society in general (Trejo, 2017: 138).

Still today, in both first world and underdeveloped countries, women continue to be socially and professionally segregated, and although they are already occupying high-level executive positions, there are still differences that separate men from women in terms of salary and representation in the political, social and economic structure at a global level that make discrimination towards women evident (Gómez et al., 2022).

Based on the above, it is pointed out that the use of a gender perspective raises the need to carry out actions such as: 1) the equitable redistribution of productive and reproductive activities between the sexes; 2) the fair valuation of the different jobs performed by women and men, especially those related to raising children, caring for sick people and domestic tasks; and 3) the modification of social structures, mechanisms, rules, practices and values that reproduce inequality; the strengthening of women's management and decision-making power (Trejo, 2017: 138).

Therefore, the search for gender equality should result in the integral development of the person, regardless of sex, race, culture or religion, which is expected to have an impact on the eradication of violence against women (Gómez et al., 2022).

Buedo (2015) states that gender inequality in the labor market is rooted in the collective construction of women and men, as well as in the links between production and reproduction, where gender is constructed. Based on these, an unequal collective allocation and a different value is placed on the roles played by men and women, which affects their chances of entering and remaining in the labor market. In addition, cultural perceptions of what women and men do, with regard to the valuation of their actions and capabilities, are transferred to the work environment.

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This results in the sexual segmentation of work, which is evidenced by the fact that women do not have the same possibilities of access to the labor market as men (Pasos and Asián, 2018).

In 2015, Buedo conducted a socio-critical analysis of the labor process in order to elucidate aspects related to the anticivilization that women have experienced and continue to experience throughout their lives. She tries to understand the masculine and feminine in different contexts or social conditions, "understanding that women and men are not collectives or groups, but subjects of analysis due to the fact that the historical process is understood from a gender perspective, from which the fundamental aspects for coexistence in society are understood" (Buedo, 2015; 65).

Buedo stresses that although we are in a society that shows progress, it still remains marked by patriarchy, and that, today, this situation of need and inequity is just beginning to change, because despite the shaping and updating of socio-political models, towards more humanitarian and egalitarian quotas, we continue to find a reality that biases, differentiates, and treats people differently depending on their origin, academic level, sex or gender" (Buedo, 2015: 74); or, as Yuan, F. et al. (2023) the presence of female executives and the employment relationship has been little researched.

The Centro de Investigaciones Regionales "Dr. Hideyo Noguchi" is a dependency of the Universidad Autónoma de Yucatán; it has 145 basic and contract employees (Table 1).

Box 1

Table 1

Staff working at the Centro de Investigaciones Regionales "Dr. Hideyo Noguchi"

Personal	Women	Men	Total
	No. (%)	No. (%)	No. (%)
Base	67 (57.3)	50 (42.7)	117 (100.0)
Contract	13 (46.4)	15 (53.6)	28 (100.0)
Total	80 (55.2)	65 (44.8)	145 (100.0)

Source: Retrieved from the archive of the Administrative Coordination of the Regional Research Centre

The Centro de Investigaciones Regionales "Dr. Hideyo Noguchi" is one of the units that seeks to position itself in the Health Sciences Campus. Its position within the Autonomous University of Yucatán has a lot to do with its growth, not only in terms of its involvement with schools and faculties, but also in terms of its staff (Andueza et al. 2016). For this reason, carrying out studies on Human Rights with a Gender Perspective within this agency is fundamental as it allows us to have an approach on the knowledge and perception that the staff has about Human Rights and gender, as well as their experience with respect to them, which is the objective of this work.

Methodology

The study was designed as a cross-sectional study in which all staff of the Unit were invited to answer a survey on Gender and Human Rights at the Autonomous University of Yucatan. The questionnaire was divided into four sections: 1) contextualization of the staff; 2) general data of the participant; 3) items for research purposes and 4) glossary of terms. The first section indicated the objective of the study; the second section collected information on the type of staff, type of contract and gender of the participants; the third section consisted of a total of 16 items and the fourth section was a glossary of terms to assist in the process of applying the questionnaire and to promote a better understanding of the information that was intended to be collected.

Results

The distribution of participants by category type and gender is shown in Table 2:

Box 2

Table 2

Distribution of participants by category and sex

Sex	Category			Total
	Academic	Administrative	Manual	
Men	22 (62.9%)	5 (14.3%)	8 (22.9%)	35 (100.0%)
Women	30 (65.2%)	13 (28.3%)	3 (6.5%)	46 (100.0%)
Total	52 (64.2%)	18 (22.2%)	11 (13.6%)	81 (100.0%)

Source: Survey on Gender and Human Rights at the Autonomous University of Yucatán. sample=81

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From the information obtained it can be seen that the participation of staff by category was distributed as follows: 64.2% (52) academic, 22.2% (18) administrative and 13.6% (11) manual, which made a total of 81 people, i.e. 55.86% agreed to participate in the study. In the gender distribution, there were 46 women (56.8%) and 35 men (43.2%); in both the men's and women's groups, the highest percentage was of academic staff. It should be noted that all staff at the Research Centre are full time. To the question: "Do you know what your human rights are in the workplace? 62.5% said yes. By gender, 30 (66.7%) women and 20 (57.1%) men indicated that they were aware of them; by category, it was the female administrative and academic staff who said they were more aware of them, while among manual staff the situation was reversed, with more men (75%) indicating that they were aware of them. It is striking that more than a third (37.5%) do not know about human rights in the workplace (Table 3).

Box 3

Table 3

Gender and Human Rights

Participants	Yes No. (%)	No No. (%)	Total
Men	20 (57.1)	15 (42.9)	35 (100.0)
Women	30 (66.7)	15 (33.3)	45 (100.0)
Total	50 (62.5)	30 (37.5)	80 (100)

Source: Survey on Gender and Human Rights at the Universidad Autónoma de Yucatán. sample=80

Likewise, from a list of options, they were asked to select the three main ones they associate with the word "Human Rights in the workplace" and the most frequent were: "non-discrimination" with 70%, "equality" with 53.1% and "equity" with 51.9%. On the other hand, the words: fight against impunity and justice were chosen with 5% or less, in all three staff categories.

For the study, the association with Discrimination, Equality and Equity shows that there is knowledge or at least an idea of what Human Rights are.

To evaluate the perceptions, items were applied focused on knowing the Guarantees (4,5,13), the exercise, (6,8,9) and obstacles (7,10,11,12) that the institution offers to maintain a healthy working environment.

The World Health Organisation's (2010) definition of a "healthy work environment" was used as a basis, which states that it is one in which workers and managers collaborate in a process of continuous improvement to promote and protect the health, safety, well-being of workers, the sustainability of the work environment and gender equality, in their physical, psychosocial and physical health space.

They were asked about their perceptions of the guarantees that the institution offers to maintain a healthy work environment through three questions, question 4 was: Do you consider that in your unit there is a healthy work environment? the answers are shown in table 4:

Box 4

Table 4

Healthy work environment

Sexo	**Always** No. (%)	**Generally** No. (%)	**Sometimes** No. (%)	**Never** No. (%)	Total No. (%)
Men	5 (14.3)	18 (51.4)	9 (25.7)	0	32 (100.0)
Women	10 (21.7)	25 (54.3)	11 (23.9)	0	46 (100.0)
Total	15 (18.5)	43 (53.1)	20 (24.7)	0	78 (100.0)

Source: Survey on Gender and Human Rights at the Autonomous University of Yucatán. sample=78

The results show that 54.3% of women and 51.4% of men consider the working environment to be generally healthy; however, 24.7% said sometimes. Analysis of the data by category shows similar percentages for academic staff, 54.5% for men and 53.3% for women.

Among administrative staff, the perception is higher among men (80%) than among women (53.8%) who answered the option generally; however, among manual staff the opposite is true, with 25% of men and 66.7% of women indicating this option. It seems that for manual men the environment is less favorable than for the others. In question 5 they were given a list of Human Rights to indicate the ones they consider to be the most important. 90.1% considered the right to just, fair and satisfactory working conditions, 88.9% indicated dignified and respectful treatment, 80.2% indicated health and safety at work, 77.8% indicated freedom of religion.

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They were also asked to indicate, from a list of options, those in which they consider that there are equal opportunities for women and men in their workplace.

The top three options selected were: benefits with 63%, opportunities for advancement in management positions with 60.5% and promotion with 58.8%, followed by equal pay with 58%, scholarships with 51.9%, income with 44.4% and none with 8.6%. It is worth noting that 90.9% of academics consider that there are equal benefits, but 56.7% of female academics do not; likewise, 69.2% of administrative women and 66.7% of manual women agree with academics on equal benefits.

In order to find out the main rights that are exercised freely in the department, they were asked to indicate from a list of options, those that they consider that they exercise freely in their work environment; the data are shown in Table 5.

Box 5

Table 5

Human rights exercised in the work environment

Human Rights	**Sex**	**Yes** no. (%)	**NO** no. (%)	**Total** no. (%)
Dignified and respectful treatment	Men	24 68.6%	11 31.4%	35 100.0%
	Women	31 67.4%	15 32.6%	46 100.0%
	Total	55 67.9%	26 32.1%	81 100.0%
Right to health	Men	19 54.3%	16 45.7%	35 100.0%
	Women	30 65.2%	16 34.8%	46 100.0%
	Total	49 60.5%	32 39.5%	81 100.0%
Religious freedom	Men	19 55.9%	15 44.1%	34 100.0%
	Women	28 60.9%	18 39.1%	46 100.0%
	Total	47 58.8%	33 41.3%	80 100.0%

Source: Survey on Gender and Human Rights at the Autonomous University of Yucatán sample=80

According to the results, dignified and respectful treatment is the most freely exercised in the unit (67.9%); men 68.6% and women 67.4%.

By category and sex, more academic (81.8%), administrative (60%) and manual (37.5%) men reported this, compared to women in the three categories, 73.3%, 61.5% and 33.3% respectively.

The Human Right to Health was the second most recognized option with 60.5%; men reported it at 54.3% and women at 65.2%. By category and gender, female academics and administrative staff indicated it the most, 70% and 61.5%, respectively, compared to male academics and administrative staff who indicated it at 63.6% and 40% respectively. In contrast, 37.5% of male manual workers and 33.3% of female manual workers reported it.

As for religious freedom, although it was the third most recognized option with a total percentage of 58.8%; 60.9% of women and 55.9% of men reported it; it is striking that, by category and sex, among manual staff, 71.4% of men and 66.7% of women indicated that this right is not exercised.

The third question regarding the guarantees was to indicate how the exercise of human rights is promoted in the workplace:

It is striking that the perception of the majority of the staff, regardless of sex, indicated that the options provided in the study are NOT promoted; the percentages above 90% were: they are not considered as a transversal part of the planning and budgeting processes, there are no protocols for urgent attention to workers, a culture of reporting human rights violations is not promoted, friendly solutions are not promoted in the case of human rights violations as a form of reparation for damages, they are not promoted through dissemination campaigns, there are no mechanisms for expressing disagreement without fear of reprisals.

All staff agree on the perception that these human rights are not promoted in the workplace, regardless of category and gender (Table 6).

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Box 6

Table 6

Human Rights that are NOT promoted in the workplace

Promoting human rights in the workplace	**Women** no. (%)	**Men** no. (%)	**Total** no. (%)
Unmet needs of workers are identified.	37 (80.4)	29 (82.9)	66 (81.5)
c It is promoted through outreach campaigns	44 (95.7)	30 (85.7)	74 (91.4)
It is promoted through training.	34 (73.9)	31 (88.6)	65 (80.2)
They are expressly incorporated into employment contracts	38 (82.6)	26 (74.3)	64 (79)
They are considered as a cross-cutting part of the planning and budgeting processes.	45 (97.8)	35 (100)	80 (98.8)
Protocols are in place for the urgent care of workers.	44 (95.7)	35 (100)	79 (97.5)
Promoting a culture of reporting human rights violations	42 (91.3)	33 (94.3)	75 (92.6)
Promoting gender equality	28 (60.9)	13 (37.1)	41 (50.6)
Non-discrimination on the basis of status is promoted.	33 (71.7)	21 (60)	54 (66.7)
The University is promoted as a safe space free of violence for the university community.	28 (60.9)	20 (57.1)	48 (59.3)
Mechanisms are in place for people with disabilities (hearing, audiovisual, motor or intellectual), older adults, sexual diversity, or any other condition, to exercise their rights as university employees.	37 (82.2)	30 (85.7)	67 (83.8)
The work-life balance is promoted.	37 (80.4)	26 (74.3)	63 (77.8)
Amicable solutions are promoted in cases of human rights violations as a form of reparation.	44 (95.7)	31 (88.6)	75 (92.6)
Mechanisms exist for expressing dissent without fear of reprisals.	41 (89.1)	33 (94.3)	74 (91.4)
None of the above	36 (78.3)	33 (94.3)	69 (85.2)

Source: Survey on Gender and Human Rights at the Autonomous University of Yucatan

From a list of options, the staff selected those that could hinder the exercise of human rights in the workplace. Ignorance had the highest percentage (61.7%), followed by indifference (58.0%), fear (38.3%) and social pressure (27.2%).

Of the responses regarding lack of knowledge by category and sex, the highest percentage was among administrative and manual women (61.5% and 100%) compared to men (40% and 37.5%), respectively.

Indifference was reported by 40% of men and 69.2% of women administrators. In the case of manuals, 75% of men and no women reported it, which shows a different perception according to category and gender.

Of the participants who said that fear is an obstacle to the exercise of human rights, more than 45% of academics and administrative staff said that fear is an obstacle to the exercise of human rights, with no difference by sex. Manual staff, regardless of gender, reported it in less than 15%.

Social pressure maintains a similar trend to fear, in terms of category and gender.

Conclusions

The Centro de Investigaciones Regionales is a unit made up mostly of women, both in the academic and administrative staff, which is reversed in the manual staff, where the majority are men; this can be explained by the functions themselves or by uses and customs linked to the forms of organization of the institutions, therefore, the knowledge and perception of Human Rights are not the same in all circumstances of space and time as stated by Gómez et al.

Although the workplace is a space where people spend a considerable part of their time, and labor institutions should provide minimum satisfactory working conditions, as Trejo Sánchez (2017) points out, we continue to find a reality that biases, differentiates, and treats people differently depending on their origin, academic level, sex or gender.

In this regard, the perception of equal opportunities between men and women in the workplace showed that just over 60% perceive equality in benefits and opportunities for promotion in management positions; however, by category and gender, the percentages are notoriously different, with men reporting this much more than women, both academic and administrative. It seems that equal opportunities are different for women.

This situation is an area of opportunity that needs to be addressed in order to promote equal opportunities regardless of gender.

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In relation to the perception of guarantees, more than 80% indicated that they have heard about human rights in the workplace, only slightly more than 60% reported knowing their rights and slightly more than 50% considered that the working environment is generally healthy. The perceptions by gender and by category were also different, which gives rise to the opportunity to implement strategies to raise awareness of human rights and improve the working environment as a space of respect for human dignity, as one of the elements referred to by almost 90% of the staff was dignified and respectful treatment, and more pointed out by women. Regarding the exercise of human rights, the most frequent were dignified and respectful treatment, the right to health and religious freedom; however, the percentages were less than 70%, with different proportions between men and women; the procedures to follow when any of the human rights are violated are to report it to the superior, and those who reported it the most were women, in particular, those of the administrative staff.

The promotion of the exercise of human rights in the workplace is an issue that is not promoted in the workplace, as a very high percentage of participants pointed out. In this respect, it will be necessary for the authorities to carry out a thorough review of the conditions that give rise to this perception and to contribute to planning actions aimed at reversing the perception and achieving a healthy working environment where human rights can be exercised.

Ignorance, indifference, fear and social pressure are conditions that can hinder the exercise of human rights, especially for female academic and administrative staff. Likewise, academic degree, job position, opinions and the fact of being a man or a woman were considered as a reason for discrimination, the latter referred to more by women from manual and academic staff, which is in agreement with authors such as Trejo Sánchez (2017) and Natividad (2015) who point out the differences between men and women due to cultural differences.

The interest in receiving training in gender and human rights is a positive aspect to plan actions such as workshops, conferences, courses aimed at all the staff of the unit and thus contribute to the University's interest in mainstreaming the gender perspective.

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Declarations

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Authors' contribution

Andueza-Pech, María Guadalupe: Contributed with the idea of the paper, responsible for the research and organization of the data collection.

Rodríguez-Angulo, Elsa María: Contributed with the analysis of the information and search for bibliographic material.

Ojeda-Rodríguez, Ricardo: Contributed to the analysis of the information and preparation of the results.

Cambranes-Puc, Luis Humberto: Contributed to the analysis of information and elaboration of results.

Availability of data and materials

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Article

Adaptation of agricultural practices for the sustainability of sugarcane production in the Northern Huasteca Region in Response to Climate Change

Adaptación de prácticas agrícolas para la sostenibilidad de la producción de caña de azúcar en la Región Huasteca Norte frente al Cambio Climático

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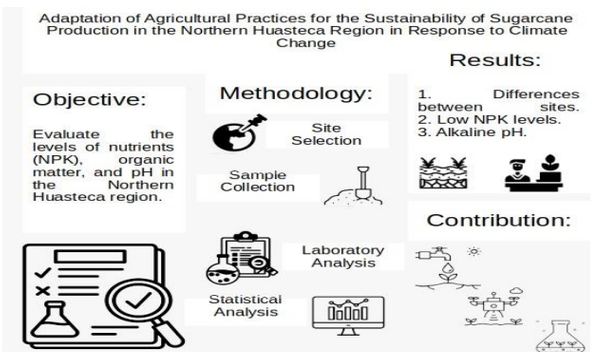
Abstract

Climate change poses significant challenges to agricultural production, requiring the adaptation of practices to ensure the sustainability of crops like sugarcane. This study focuses on the Huasteca Norte region of San Luis Potosí, Mexico, evaluating nitrogen, phosphorus, potassium, organic matter, and soil pH levels at 13 cultivation sites. Data reveal suboptimal NPK levels at most sites, indicating the need for improved nutrient management. Proposed strategies include the use of controlled-release fertilizers, efficient irrigation, and cover crops to enhance nutrient and water retention in the soil. The results highlight the importance of adopting a proactive and adaptive approach to agricultural management to address the challenges of climate change and ensure the sustainability of sugarcane production in the region.



Agriculture practices, Sustainability, Sugar cane

Resumen

El cambio climático impone desafíos significativos a la producción agrícola, requiriendo la adaptación de prácticas para asegurar la sostenibilidad de cultivos como la caña de azúcar. Este estudio se centra en la región Huasteca Norte del Estado de San Luis Potosí, México, evaluando los niveles de nitrógeno, fósforo, potasio, materia orgánica y pH del suelo en 13 sitios de cultivo. Los datos revelan niveles subóptimos de NPK en la mayoría de los sitios, indicando la necesidad de mejorar la gestión de nutrientes. Se proponen estrategias como el uso de fertilizantes de liberación controlada, riego eficiente y cultivos de cobertura para mejorar la retención de nutrientes y agua en el suelo. Los resultados subrayan la importancia de adoptar un enfoque proactivo y adaptativo en la gestión agrícola para enfrentar los retos del cambio climático y asegurar la sostenibilidad de la producción de caña de azúcar en la región.

Prácticas agrícolas, Sostenibilidad, Caña de azúcar

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Introduction

Sugarcane production in the Northern Huasteca Region of Mexico, an essential agricultural activity that has been historically important and has undergone various social and economic transformations (Pereda, 2016), faces significant challenges due to current agricultural practices and the effects of climate change. The latter is severely affecting agricultural production in the region, with increases in temperature, rainfall variability and extreme events such as prolonged droughts, which put the productivity of sugarcane crops at risk (Linnenluecke et al., 2018; Marin et al., 2013; Biggs et al., 2011; Zhao & Li, 2015). These changes directly impact soil quality and the availability of essential nutrients for sugarcane growth. In addition, the increase in extreme weather events, such as storms and floods, is causing increased soil erosion, decreasing soil fertility and its capacity to retain water and nutrients (Sundara et al., 1990; Castro et al., 2023).

In the Huasteca Potosina, agricultural soils present various limitations that affect their fertility. Soil degradation, mainly due to prolonged monoculture practices and lack of adequate nutrient management, is a recurrent problem (Castro et al., 2023).

Current agricultural practices are not only depleting soil resources, but also increasing its vulnerability to climate change. Soils show organic matter depletion, acidification and nutrient imbalances, which negatively affect the productivity of sugarcane crops (Kandhro et al., 2021). Organic matter is crucial for soil health as it improves soil structure, increases water holding capacity and facilitates nutrient availability. However, the reduction of organic matter due to intensive agricultural practices is leading to a decline in soil quality in the region (Castro et al., 2023; Dinka & Dawit, 2019).

Prolonged droughts and rainfall variability are increasingly frequent phenomena due to climate change and represent a considerable challenge for agriculture in the region. Lack of adequate water not only reduces crop productivity, but also exacerbates soil degradation and loss of essential nutrients (Linnenluecke et al., 2018; Biggs et al., 2011; Zhao & Li, 2015).

This scenario raises an urgent need to review and improve current agricultural practices to ensure the long-term sustainability of agricultural production in the Huasteca Potosina. Inefficient irrigation practices and excessive use of chemical fertilisers are contributing to soil salinisation and water pollution, further aggravating the situation (López Álvarez et al., 2015; Kusumawati et al., 2019).

A critical analysis of the elements that make up soil fertility in the region reveals that organic matter, soil pH and levels of nutrients such as nitrogen (N), phosphorus (P) and potassium (K) are key parameters that require proper management. Organic matter is crucial for water and nutrient retention, and its depletion significantly reduces the soil's capacity to support healthy crops (Castro et al., 2023).

Soil acidification, which affects nutrient availability, is another critical problem that needs to be addressed through more sustainable soil management practices (Kandhro et al., 2021). Imbalance in N, P and K levels, often caused by over- or under-application of fertilisers, also contributes to declining soil fertility (Pang et al., 2021; Zhang et al., 2019).

Assessment of these parameters at 13 sites in the Huasteca Potosina has revealed that current agricultural practices are not sustainable and are leading to progressive soil degradation. Soils show low levels of organic matter and imbalances in NPK levels, reflecting compromised soil fertility and reduced capacity to support agricultural production (Sundara et al., 1990; Dominy et al., 2002; Pang et al., 2021).

These problems are closely linked to monoculture practices and inefficient use of fertiliser and water resources (Castro et al., 2023; Kusumawati et al., 2019; Mitter et al., 2021). Monoculture, in particular, is associated with decreased soil biodiversity and increased pests and diseases, which in turn reduce crop productivity (Dominy et al., 2002; Madamombe et al., 2024).

It is crucial to recognize the need to implement sustainable agricultural practices that improve soil health and increase soil resilience to climate change.

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Strategies such as the use of controlled-release fertilizers, efficient irrigation techniques and the incorporation of cover crops can significantly improve soil structure, increase organic matter and reduce erosion (Kandhro et al., 2021; Dinka & Dawit, 2019; Mitter et al., 2021). The use of controlled-release fertilizers allows a gradual release of nutrients, improving their efficiency and reducing the need for frequent applications (Dinka & Dawit, 2019; Pang et al., 2021). Efficient irrigation techniques, such as drip irrigation, optimize water use and improve crop resilience to drought (Castro et al., 2023; Hussen, 2022). Cover crops improve soil structure, increase organic matter and reduce erosion, contributing to long-term sustainability (Kusumawati et al., 2019; Madamombe et al., 2024). In addition, crop rotation can help break pest and disease cycles, improve soil structure and increase biodiversity, which in turn improves the resilience of the farming system (Haque et al., 2023).

The incorporation of advanced technologies, such as remote sensing and the use of in-field sensors, can also play a crucial role in the sustainable management of sugarcane production. These technologies enable real-time monitoring of soil and weather conditions, facilitating informed and timely decisions to optimise agricultural management practices (Shukla et al., 2020; Haque et al., 2023; Pensado, et al., 2022). Integrating these technologies with traditional agricultural practices can offer a holistic and effective approach to meet the challenges of climate change (Kandhro et al., 2021; Madamombe et al., 2024). For example, soil moisture sensors can provide accurate data on soil water content, allowing farmers to adjust their irrigation practices to maximise water use efficiency (Shukla et al., 2020; Hussen, 2022). In addition, it is important to consider the role of education and training in promoting sustainable agricultural practices. Training programs for farmers can provide the knowledge and skills needed to implement sustainable and adaptive management practices. These programs should include modules on nutrient management, efficient water use, soil conservation and climate change adaptation, among other relevant topics (Dinka & Dawit, 2019; Hussen, 2022). The creation of farmer-to-farmer knowledge-sharing networks can also facilitate the dissemination of successful practices and innovation in farm management (Dominy et al., 2002; Pang et al., 2021).

Continuing education and training in the use of new technologies and sustainable practices are essential to improve the adoption of these practices among local farmers (Zhang et al., 2019; Mitter et al., 2021).

Collaboration between research institutions, local governments and farmer organizations is one strategy to develop and implement innovative and effective solutions to address the challenges of climate change in agriculture (Marin et al., 2013; Zhang et al., 2019; Mitter et al., 2021). Further research is needed to assess the impact of extreme weather events on sugarcane production and the effectiveness of integrated water resources management strategies. It is also crucial to investigate the long-term sustainability of different fertilization practices and how to overcome barriers to adaptation through increased institutional support and resources for farmers (Hussen, 2022). Cooperation between these different actors can facilitate the implementation of more sustainable agricultural policies and practices that benefit both farmers and the environment (Kusumawati et al., 2019).

The aim of this article is to provide a critical analysis of the elements that shape soil fertility in the Huasteca Potosina under the current agricultural model. Emphasis will be placed on the vulnerability of the region to climate change, prolonged droughts and current agricultural practices. Through this analysis, the aim is to raise awareness among farmers of the imperative need to adopt sustainable agricultural practices that will maintain economic systems without collapsing the environment. By providing evidence-based guidance, this article aims to help sugarcane farmers understand and address the challenges of climate change with effective and sustainable strategies, thus promoting agricultural production that is both economically viable and environmentally responsible.

Methodology

Selection of Sampling Sites

Sampling sites were selected following rigorous scientific criteria to ensure that the samples were representative of the characteristics of the Northern Huasteca Region.

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Variability in soil types, land use and environmental conditions were considered. Specific criteria included edaphic heterogeneity, spatial distribution of agricultural practices and accessibility of sites.

Thirteen sites strategically distributed in five different municipalities were selected, covering a wide range of agricultural conditions typical of the region. Figure 1 shows the location map of the sampling sites, clearly indicating the distribution and specific characteristics of each site.

Box 1

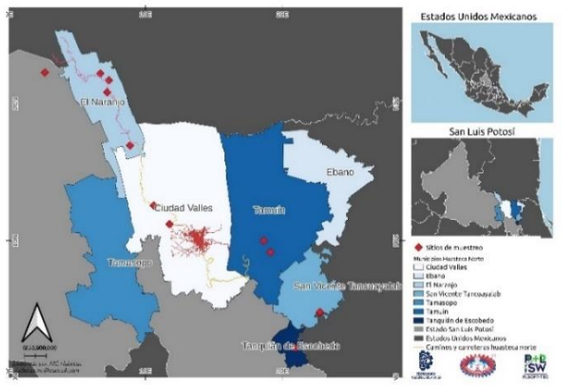

Figure 1

Map of the location of sampling sites in the Huasteca Potosina region

Sampling

Soil samples were collected following standardized protocols to minimize contamination and ensure sample integrity (ISO 10381-1, 2002). At each site, composite samples were taken from several sub-samples collected at different depths (0-30 cm), mixing them appropriately to obtain a representative sample from each location. Samples were labelled and stored under controlled conditions until analysis at the Environmental Research and Monitoring Laboratory of the Tecnológico Nacional de México Instituto Tecnológico de Ciudad Valles.

The labelling of the samples included key elements such as the sampling site code, the date of collection, the depth of the sample and the name of the collector.

In addition, each label contained a QR code to facilitate traceability and access to detailed information on sampling conditions and procedures followed.

Organic Matter Analysis

Quantification of organic matter in the soil was carried out by the calcination method using a muffle (Nelson & Sommers, 1996). This method involves the combustion of organic matter at high temperatures (550°C) until a constant weight is reached. Initially, the dried soil samples were weighed and then placed in a muffle furnace. After complete combustion of the organic matter, the samples were reweighed, and the organic matter content was determined as the weight loss after calcination. This procedure is widely recognised for its accuracy and reliability for the determination of soil organic content (Heiri et al., 2001).

Determination of soil pH

Soil pH was measured by solubilizing the soil in a distilled water solution, following the method described by McLean (1982). For this, a suspension of soil and water was prepared in a ratio of 1:2.5 (weight/volume), and the mixture was stirred for 30 minutes.

Subsequently, the suspension was allowed to stand and the pH of the supernatant solution was measured using a calibrated pH meter. This method is standard for the evaluation of soil pH and provides consistent and reproducible results.

NPK analysis

The determination of nitrogen (N), phosphorus (P) and potassium (K) levels in the soil was carried out using the NPK HI3896 kit, which allows the simultaneous measurement of these essential nutrients using colorimetric techniques specific to each (Johnston & Richards, 2003).

Soil samples were prepared according to the kit instructions, and readings were taken following the procedures indicated by the manufacturer. Specific chemical reactions within the kit produce colour changes in the presence of the nutrients, which are then measured and interpreted to quantify N, P and K levels.

The results obtained provide an accurate assessment of NPK levels in soil samples, fundamental to the interpretation of soil fertility and health at sampling sites.

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Statistical analysis of the data

The data obtained were statistically analyzed using Google Colab with Python, ensuring a collaborative and reproducible environment for data analysis. Various statistical techniques were employed to analyse the data and assess the spatial and temporal variability of soil properties. Initially, the assumptions of normality and homogeneity of variance were checked using Shapiro-Wilk and Levene tests, respectively (Shapiro & Wilk, 1965; Levene, 1960).

To compare the levels of %MO, pH, N, P and K between the different sampling sites, one-way analysis of variance (ANOVA) was applied and where necessary because the assumptions of normality or homogeneity of variance were not met, equivalent non-parametric tests (Kruskal-Wallis) were performed, followed by Tukey's post hoc tests to identify significant differences between means (Tukey, 1949). In addition, principal component analysis (PCA) was used to identify patterns and relationships between measured variables and sampling sites, providing a holistic view of the data structure. (Jolliffe, 2002).

All statistical analyses were performed using Python libraries such as NumPy, pandas, SciPy and Scikit-learn, facilitating efficient calculations and data visualization. Statistical results were presented in the form of tables and graphs, highlighting significant differences and trends observed in the data (Oliphant, 2006).

This methodology ensures that the data obtained are representative and reliable, providing a solid basis for the assessment of soil conditions in the Northern Huasteca Region and their relationship to the sustainability of sugar cane production in the face of climate change.

Results

Organic Matter and Soil pH

The results obtained show significant differences in soil pH and organic matter (%MO) levels (Figure 2 and Figure 3) between the municipalities of the Northern Huasteca region.

Box 2

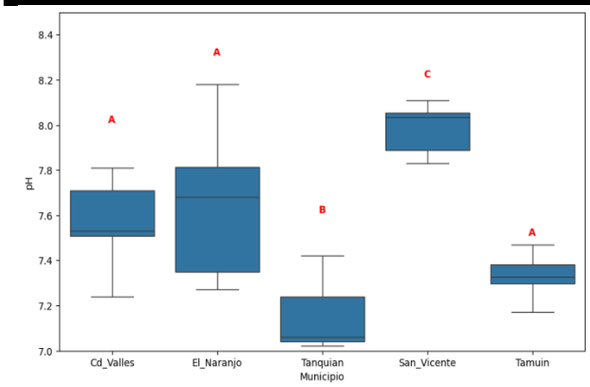

Figure 2

Distribution of pH by municipality (Northern Huasteca Region). Note: Different letters indicate statistically significant differences ($p<0.005$)

Box 3

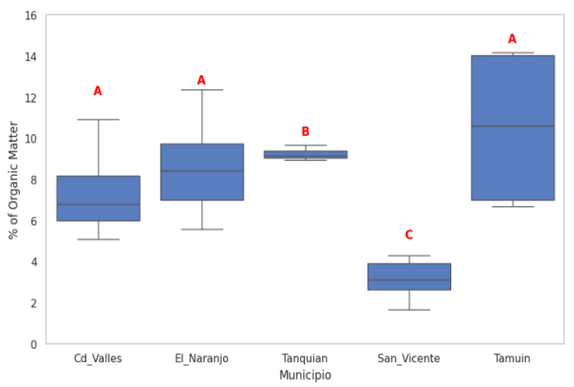

Figure 3

Distribution of % organic matter by municipality (Huasteca Norte Region). Note: Different letters indicate statistically significant differences ($p<0.005$)

Table 1 summarises the average organic matter and pH values of the 13 sites located in the five sampled municipalities. Tamuín presents the highest average organic matter content (10.50%) with a standard deviation of 3.92%, while San Vicente shows the lowest content (3.14%) with a standard deviation of 0.99%.

In terms of pH, San Vicente has the highest average value (7.99) with a standard deviation of 0.12, and Tanquián presents the lowest pH (7.17) with a standard deviation of 0.22.

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Box 4

Table 1

Distribution of % organic matter by municipality (Huasteca Norte Region). Note: Different letters indicate statistically significant differences (p<0.005)

Municipality	Mean MO (%)	Std MO (%)	Mean pH	Std pH
Cd. Valles	7.43	2.08	7.55	0.19
El Naranjo	8.68	2.11	7.64	0.30
San Vicente	3.14	0.99	7.99	0.12
Tamuín	10.50	3.92	7.33	0.10
Tanquián	9.25	0.36	7.17	0.22

Analyses of variance (ANOVA) for %MO and pH (Tables 2 and 3) confirm that the differences observed between municipalities are statistically significant, with p-values less than 0.00005 in both cases.

Box 5

Table 2

ANOVA for %MO

Source	Sum of Squares	df	F	p- valor
Municipality	192.8386	4	9.1720	0.00004
Residual	178.7103	34	-	-

Box 6

Tabla 3

ANOVA para pH

Source	Sum of Squares	df	F	p-valor
Municipality	1.9286	4	9.1806	0.00004
Residual	1.7857	34	-	-

Organic matter is crucial for soil health as it improves soil structure, retains moisture and nutrients, and promotes biological activity (Lal, 2004). High levels of organic matter in Tamuín could be related to more sustainable agricultural practices or less intensification of land use.

In comparison, studies in other tropical regions have shown that the addition of organic residues and the use of cover crops can significantly increase soil organic matter (Ghimire et al., 2017). Soil pH is also an important indicator of soil fertility. pH values close to neutral (6.5-7.5) are ideal for the availability of most nutrients (Brady & Weil, 2008). The results show a variability in pH that could be influenced by the application of alkaline or acidic amendments, soil management practices, and intrinsic soil characteristics at each site.

Nitrogen (N), Phosphorus (P) and Potassium (K) levels

The determination of nitrogen (N), phosphorus (P) and potassium (K) levels in the soil was carried out using the NPK HI3896 kit, which allows the simultaneous measurement of these essential nutrients by means of colourimetric techniques specific to each one. Soil samples were prepared according to the kit instructions, and readings were taken following the procedures indicated by the manufacturer. The results obtained are qualitative on a scale ranging from 1 (Very low presence) to 4 (Very high presence), and indicate that all sites have suboptimal presence of the NPK nutrients required for sugar cane cultivation.

Similar studies have shown that NPK deficiency in agricultural soils is common in tropical regions, affecting crop productivity (Fageria & Baligar, 2008). Low availability of these nutrients may be due to leaching, soil erosion and insufficient fertilizer application. To improve soil fertility, it is essential to adopt nutrient management practices that include balanced fertilizer application and the use of biofertilizers (del Pozo et al., 2019).

Analysis of variance (ANOVA and Kruskal-Wallis)

Analysis of variance (ANOVA) revealed significant differences in %MO, pH, N, P and K (Kruskal-Wallis) between sampling sites ($p < 0.05$). Tukey's post hoc tests indicated that Tamuín is significantly different from other municipalities in terms of organic matter and pH. Likewise, San Vicente showed significant differences in N and K levels compared to other sites as shown in Table 4.

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Box 7

Table 4

Non-Parametric Tests (Kruskal-Wallis)

Variable	Kruskal-Wallis statistic	p-valor	Significant
N	2.2472	0.6904	No
P	8.0000	0.0916	No
K	5.5000	0.2397	No

Principal Component Analysis (PCA)

Principal component analysis (PCA) identified clear patterns in the relationship between measured variables and sampling sites. The first two principal components explained 75% of the total variability in the data. The first component was highly correlated with N and K levels, while the second component showed a strong correlation with pH and organic matter. Figure 4 presents the PCA biplot, highlighting the grouping of the sampling sites according to their edaphic characteristics.

Box 8

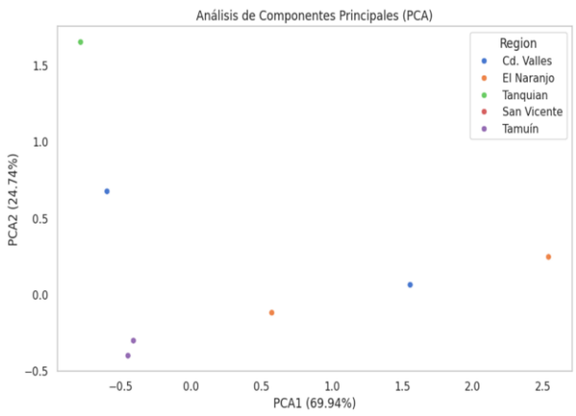

Figure 4

Principal Component Analysis (PCA) in municipalities of the Huasteca Norte region

These patterns suggest that variability in soil properties is influenced by multiple factors, including soil management practices and site-specific environmental conditions. Previous studies have shown that principal component analysis is an effective tool for identifying and explaining spatial variability in soil properties (Shukla et al., 2006).

Conclusions

This study has revealed significant variations in soil properties, specifically in the levels of organic matter (%MO), pH, nitrogen (N), phosphorus (P) and potassium (K), in the Northern Huasteca region. The results underline the need to adopt more sustainable and adaptive agricultural practices to face the challenges of climate change and improve the productivity of sugarcane crops.

In terms of organic matter, Tamuín presented the highest levels, while San Vicente showed the lowest. Organic matter is fundamental to soil health, as it improves soil structure, retains moisture and nutrients, and promotes biological activity. High levels of organic matter in Tamuín suggest more sustainable agricultural practices, while low levels in San Vicente indicate possible soil degradation. To improve organic matter in areas with low levels, it is essential to consider the addition of organic residues and the use of cover crops, practices that have been shown to be effective in other studies (Ghimire et al., 2017).

Soil pH varied significantly between municipalities, with San Vicente showing the highest values and Tanquian the lowest. pH values close to neutral are ideal for the availability of most nutrients (Brady & Weil, 2008). Variations in pH can influence nutrient availability and thus crop productivity. The alkalinity observed in St Vincent may be negatively affecting the availability of certain nutrients, requiring adjustments in soil management practices, such as the application of acid amendments.

Soil levels of nitrogen, phosphorus and potassium were suboptimal at all sampling sites, indicating a general deficiency of these essential nutrients. Low NPK availability may be due to leaching, soil erosion and insufficient fertilizer application.

This deficiency is a common problem in tropical regions and significantly affects crop productivity (Fageria & Baligar, 2008). To address this deficiency, the adoption of nutrient management practices including balanced fertilizer application and the use of biofertilizers is recommended (Del Pozo et al., 2019).

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Analysis of variance (ANOVA) revealed significant differences in %MO, pH, N, P and K levels among sampling sites. Tukey's post hoc tests confirmed that Tamuín is significantly different from other municipalities in terms of organic matter and pH. San Vicente also showed significant differences in N and K levels compared to other sites. These findings highlight the importance of adapting soil management practices to the specific conditions of each municipality to maximise soil fertility and crop productivity.

Principal component analysis (PCA) identified clear patterns in the relationship between measured variables and sampling sites. The first two principal components explained 75% of the total variability in the data, with the first component highly correlated with N and K levels, and the second component showing a strong correlation with pH and organic matter. These patterns indicate that variability in soil properties is influenced by multiple factors, including soil management practices and site-specific environmental conditions (Shukla et al., 2006).

This study provides an assessment of soil conditions in the Northern Huasteca region and suggests the need to implement sustainable and adaptive agricultural practices to improve soil health and increase resilience to climate change. The adoption of practices such as the addition of organic residues, the use of cover crops, and the balanced application of fertilisers can significantly improve soil fertility and crop productivity. In addition, the use of advanced technologies, such as remote sensing and in-field sensors, can facilitate real-time monitoring of soil and weather conditions, optimizing agricultural management practices. Collaboration between farmers, researchers and policy makers will be crucial to develop and implement these strategies, thus ensuring the long-term sustainability of agricultural production in the Northern Huasteca region.

Declarations

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Authors' contribution

Each researcher's contribution to each of the points developed for this paper is listed below:

Lorenzo-Márquez, Habacuc: Designed the project idea, methods and applied research techniques. He designed the instrument for the collection of information in the field, supported the field sampling and laboratory analysis, carried out the data analysis and systematization of results, as well as writing the article.

Wong-Arguelles, Cynthia: Supported in the application of the research methods and techniques, contributed to the laboratory analysis and the revision of the article.

Acosta-Pintor, Dulce Carolina: Contributed to the research design, type of research, laboratory analysis, analysis of data collected in sampling and writing of the article.

Mojica-Mesinas, Cuitláhuac: supported field sampling, data collection and laboratory analysis. Worked on the writing of the article.

Availability of data and materials

All data used for this research were derived from our own data analysis, no information from third parties was used.

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Abbreviations

ANOVA	Analysis of Variance
ISO	International Organization for Standardisation
K	Potassium
N	Nitrogen
NPK	Nitrogen, Phosphorus, Potassium
OM	Organic Matter
P	Phosphorus
PCA	Principal component analysis
pH	Hydrogen potential
PRODEP	Programme for the Professional Development of Teachers
QR	Quick Response Code

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Discussions

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Article

Macroeconomic determinants of financial fraud and identity theft

Determinantes macroeconómicos del fraude financiero y robo de identidad

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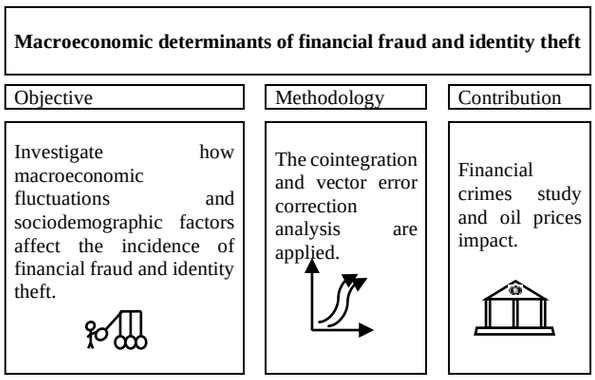
Abstract

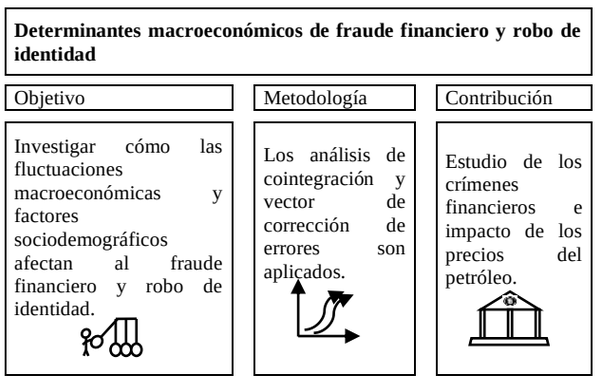
This study concentrates on the environment of financial institutions and investigates how macroeconomic fluctuations and sociodemographic factors affect the incidence of financial fraud and identity theft in the pre-covid era. Using quarterly records of the incidence of these variables provided by a major financial institution in Mexico from 1999 to 2019, we modelize financial crimes of fraud and identity theft. Macroeconomic and sociodemographic variables are employed. Oil prices are a new variable added to the analysis of financial crimes that have an impact on oil-exporting economies such as Mexico. The cointegration and vector error correction analysis is applied. Our findings show that the unemployment rate, oil prices, GDP per capita and gender have a significant impact in the short and long term on fraud and identity theft incidence. The Toda-Yamamoto test shows evidence of Granger-causality from inflation and the stock market towards these financial crimes.



Financial crime, macroeconomic, causality

Resumen

Este estudio se centra en el entorno de las instituciones financieras e investiga cómo las fluctuaciones macroeconómicas y los factores sociodemográficos afectan la incidencia del fraude financiero y el robo de identidad en la era pre-covid. Datos trimestrales de una importante institución financiera de 1999 a 2019 son utilizados. Los precios del petróleo son una nueva variable agregada al análisis de los delitos financieros que tienen un impacto en las economías exportadoras de petróleo como México. Se aplica el análisis de cointegración y corrección de errores vectoriales. Nuestros hallazgos muestran que la tasa de desempleo, los precios del petróleo, el PIB per cápita y el género tienen un impacto significativo en el corto y largo plazo en la incidencia del fraude y el robo de identidad. La prueba de Toda-Yamamoto muestra evidencia de causalidad de Granger de la inflación y el mercado de valores hacia estos delitos financieros.



Crimen financiero, macroeconómico, causalidad

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Introduction

Two main theoretical approaches explain the determinants of crime: the sociological and the economic. The sociological approach proposes that the criminal behavior of the individual is governed by individual characteristics, family factors and social structure (Butkus et al., 2019) or even when in the company of peers (Engel, 2023). The economic approach proposes that crime is the product of a utility maximization process where the individual chooses between committing a crime or a legitimate activity comparing its expected benefits with its costs as mentioned by Ehrlich (1973) and Becker (1968). This approach opens the door to the inclusion of macroeconomic factors that can modify benefits and opportunities in legal activities and maximize utility in the direction of illegal ones (Cerulli et al., 2018).

Fraud and identity theft crimes in financial institutions have not received attention in terms of their macroeconomic determinants in the literature review (Mangala and Soni, 2023). Fraud is considered any financial transaction not recognized by the customer made from their accounts in which identification is not necessary (Bolton and Hand, 2002). Identity theft occurs when one person obtains data or documents belonging to another (victim) and then passes himself off as the victim to steal money (Koops and Leenes, 2006). These crimes represent over 70% of total financial claims in countries such as Mexico causing monetary losses, investigation costs, external penalties, deterioration of institutional reputation and financial damage to clients. Knowledge of their determinants is crucial to mitigate these negative effects. Indeed, some authors hightlight that a type of crimes as corruption has a mixed effect into firm growth and innovation (Goedhuys et al., 2016; Sheng et al., 2019). It is well known in the literature that macroeconomic fluctuations and sociodemographic characteristics affect the incidence of non-financial crimes, but do these factors affect financial fraud and identity theft crimes? If so, does the impact contribute to increasing or reducing their incidence? The interest in the answers to these questions is heightened by the recession started in 2020 in different countries due to the SARS-Cov-2 pandemic, and the strong fluctuations in oil prices due to Russian-Saudi Arabian oil price war in 2020 and the recent Russo-Ukrainian war.

To answer the two questions above, data from a large financial institution in Mexico are taken to study the effects of macroeconomic fluctuations and sociodemographic characteristics on the incidence of financial fraud and identity theft per 100,000 individuals. The macroeconomic variables considered in the study are the unemployment rate, petroleum prices, inflation, GDP per capita, and economic growth. Petroleum prices are a new variable of interest as a determinant of financial crime, particularly in fraud and identity theft, that has not been deployed in previous analyses and is relevant in oil-exporting countries. Sociodemographic factors such as gender and level of urbanization are also considered in the study.

Using the cointegration and vector error correction analysis, our findings show that the unemployment rate and oil prices have a positive and negative impact on fraud and identity theft incidence, respectively, in the short and long term. The GDP per capita shows a negative impact on fraud and identity theft in the long term and a positive only for identity theft in the short term. Gender shows a significant negative impact on the incidence of both crimes in the short and long term. The Toda-Yamamoto test by its part shows evidence of Granger-causality from inflation and the stock market towards these financial crimes. Consequently, the contributions of this study are twofold: in a theoretical way, to show a new macroeconomic variable such as oil prices has an impact on fraud and identity theft incidence. In a practical way, the implementation of this methodology to real data works well in financial institutions to identify the increase of fraud and identity theft cases and apply mitigating measures to their determinants.

This article is organized as follows. In the “Literature review and hypotheses” section, we present the literature on determinant factors of financial and non-financial crimes, and hypotheses to prove. The "Data" section presents and describes the variables and sources of data. The "Methodology" section shows the econometric techniques implemented. The "Results and discussions" section describes the main results and findings. The article ends with the " Conclusions " section presenting the main findings.

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Literature review and hypotheses

As mentioned before, few articles study the determinant factors of crime in financial institutions. For example, Agarwal and Liu (2003) study how the unemployment rate affects credit card delinquency. They prove that the unemployment rate has a positive effect of between around 1.9 percentage points and 2.8 percentage points depending on the specification. Hartmann-Wendels et al. (2009) analyze the determining factors of the risk that a debt cannot be enforced because the identity of the person incurring the debt cannot be ascertained. They use individual features such as gender, nationality, marital status, telephone, age, occupation, overdraft and urban characteristics. The results of the regression suggest that fraud risk is sensitive to nationality, gender, marital status, age, occupation, and urbanization. Along the same lines, Reyns and Henson (2015) identify determinants for online identity theft and find that online banking, among others, is an important factor in exposure to this type of crime. In some cases, the crime does not come from external entities but can be caused internally by the institution. Avortri and Agbanyo (2020) prove that pressure on credit placement staff and poor remuneration have an impact on the incidence of financial fraud. Achim and Borlea (2020) study how cultural factors, religion, tax morale, trust in the state, or the happiness condition of individuals influence economic and financial crimes. This study is applied to European Union countries. A last related study is Mangala and Soni (2023) where the authors mention that pressure to sell products, the perceived opportunity to commit fraud and rationalization to justify offensive behavior can lead bank staff to commit financial fraud.

However, the literature on the determinants of non-financial crimes for different societies/countries is extensive. For example, a recent study by Gokmenoglu et al. (2022) shows that rapid urbanization and high-rate unemployment are influential factors in increasing crime rates. On the contrary, real GDP growth and progress in the rule of law reduce crime rates. The coming sections describe the most common non-financial crime determinants already studied in the literature that may explain the factors involved in financial fraud and identity theft crimes.

All existing empirical studies show that the determinants of crime can be classified into three main categories: economic, sociological and deterrence. These three categories are described below.

Economic approaches to the determinants of crime

The first group of determinants that could condition crimes are the economic ones. The main variables used are the following: unemployment, inflation, GDP/GDP per capita/economic growth and income inequality.

-*Unemployment*. By far the most widely used economic variable as a determinant of crime is the unemployment rate. Studies such as those of Cantor and Land (1985) have shown the positive and negative effects of the unemployment rate on crime (homicide, robbery, burglary, larceny, and motor vehicle theft). They argue that, on the one hand, the positive effect is because unemployed individuals look for alternatives to obtain income such as crime. On the other hand, the negative effect is due to a greater number of workers in the labor market with resources available to steal.

This ambiguity coincides with what was explained in Field (1990). This article states that wealth may be an incentive to crime simply because, with prosperity, there are more goods available to steal and at the same time, wealth may be a disincentive to crime because wealthy people have less need to steal. Cohen and Land (1987) report a negative effect of unemployment on motor vehicle theft rates and a positive effect on homicide rates. Studies such as those by Lee (2018) show that the unemployment rate can have an ambiguous (positive/negative) impact on crime depending on the apprehension rate. Nordin and Almén (2017) argue that property and violent crime are affected, in a different way, by the unemployment rate. On one hand, long-term unemployment has a strong positive effect on violent crime, while total unemployment affects only property crime.

Other studies such as Devine et al. (1988), Tang and Lean (2007), Tang (2009), Tang (2011) and Mittal et al. (2019) show evidence that the unemployment rate has only a positive impact on non-financial crimes as homicide, robbery and burglary, etc.

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In the context of economic crisis, Bell et al. (2015) use data from the US and UK to show evidence that recessions can lead to substantial and persistently higher rates of criminal behavior resulting from higher entry-level unemployment rates. In economic recessions with mass layoffs, Bennett and Ouazad (2018) suggest that, in transitions between employment and passive benefits and between active benefits and social assistance, crime spikes, and generates an associated social cost.

- *Inflation.*

Inflation is usually used as an indicator of good health in the economy. Consequently, high inflation is associated with difficult times in the economy that push people to perform criminal acts. Some of the first studies including inflation as a determinant of crime are carried out by Brenner (1976), Land and Felson (1976) and Devine et al. (1988) that prove a positive link between homicide rates, property (but not violent), robbery, burglary and inflation.

Allen (1996) argues that studies usually focus on the effect of the unemployment rate, ignoring the effects that inflation has on criminal activities. In the long term, inflation reduces the purchasing power of consumers and the cost of living increases. Consequently, individuals cannot maintain their lifestyle at the same level, opting, in some cases, for illegal activities to obtain resources (Tang and Lean, 2007). Tang (2009) includes the unemployment rate and inflation in the same model to investigate their effects on property and violent crimes. Using annual data from 1970 to 2006 in Malaysia, he finds that inflation has a positive effect on these types of crimes.

Teles (2004) and Gillani et al. (2009) point out that monetary and fiscal policies impact crime through inflation, specifically when prices increase, reducing the real income of individuals. Nunley et al. (2016) use annual data from 1950 to 2010 in the US and obtain a stable, positive impact of inflation on all forms of property crime (larceny, burglary, motor vehicle theft, and robbery). They deduce that this positive effect can be either via income, because inflation lowers the real income of thieves, or by raising the per-unit reward for theft. Rosenfeld and Levin (2016) link inflation to crimes committed for monetary gain through its effect on the market for stolen goods.

When prices of stolen merchandise increase due to inflation, they become more attractive to consumers and criminals, encouraging an increase in the theft of goods. The same results are obtained later when the same study is replicated in a sample of 17 U. S. cities between 1960 and 2013 (Rosenfeld et al., 2019). Other studies such as Adekoya and Abdul (2016) and Hazra and Cui (2018) also confirm the positive effect of inflation on crime. Recently, Rosenfeld and Vogel (2023) corroborate a significant association between inflation and homicide rates partially mediated by acquisitive crime.

- *GDP/GDP per capita/Economic growth*

GDP per capita is a common measure of economic affluence. It is also an indicator of economic development and conditions the context as social influence (Van Gelder and Nagin, 2023). This indicator can have two links to crime. If economic affluence increases as income disparity decreases, the incentive to commit a crime is likely to decrease. On the other hand, if the increase in economic affluence is accompanied by an unequal distribution of income, the incentive towards crime may emerge (Debnath and Das, 2017).

Rosenfeld and Fornango (2007) use GDP per capita as a measure of aggregate economic activity and find that GDP per capita has a significant negative impact on robbery and larceny crimes. Detotto and Otranto (2012) obtain a similar effect using the Gross Domestic Product (GDP) from Italy as a business cycle proxy proving the hypothesis that the crime rate follows a cycle. Especially, they show that a rise in economic performance is associated with a decrease in the total crime rate. Muloka et al. (2016) obtain a different result by taking economic growth as a determining variable.

They show that economic growth has a positive effect on the incidence of criminal activities in the short and long term. This study follows the economic reasoning that stable and growing economies tend to produce more crime since there is more wealth available to be stolen and vice versa. Kizilgol and Selim (2017) obtain results that also follow this logic but using GDP per capita and the crimes recorded by the police for the EU 28 and Turkey in 2001-2010.

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The effect of economic growth is not significant in this study. Kathena and Sheefeni (2017) use quarterly time series data over the period 2000Q1 to 2015Q4 in Namibia to show a bidirectional causality between crime rate and economic growth. They also prove that an increase in crime rates does indeed result in a decline in economic growth. The same positive effect between economic growth and criminal activities is obtained by Mulok et al. (2018) for Malaysia. Studies such as those of Latimaha et al. (2019) prove a negative relationship between the GDP per capita and all types of street crime (murder, rape, injuries and robbery) rates in Malaysia.

- *Income inequality*

Income inequality can be a catalyst for crime. Lower-income individuals may feel jealousy and envy and be pushed to acquire wealth from upper social classes in a criminal way. Kelly (2000) uses the ratio of mean to median households as a proxy of income inequality and data from 1991 FBI Uniform Crime Reports to prove that inequality has a strong positive and robust impact on violent crime and null on property crime. This article argues that individuals with economic disadvantages have more incentives to commit a crime in areas with high inequality.

Fajnzylber et al. (2000) introduce the Gini index as a measure of income inequality and obtain a positive significant effect on violent crime. Jennings et al. (2012) use statistics on recorded crime in England and Wales from 1961 to 2006 to confirm a null effect of income inequality on property crime. Later, Baharom et al. (2013) show a positive relationship between inequality and general crime by analyzing 21 countries, with data spanning from 1960 to 2001. Enamorado et al. (2016) estimate the effect of income inequality on crime in the context of Mexico's drug war. They prove that, for the period from 2007 to 2010, an increment of one percentage point in income inequality measured by the Gini index represents an increase of more than 6 homicides per 100,000 inhabitants in Mexican municipalities. Other more recent studies such as those of Kang (2016), Coccia (2017) and Buonanno and Vargas (2019) also show that socioeconomic inequality is one of the factors that generate high rates of property and violent crime.

From South Africa, Büttner (2022) find robust evidence for a significant and positive relationship between income inequality within precincts and local rates of violent crime. Moreover, education and housing inequality combined with racial heterogeneity are also positively correlated with crime.

Sociological approaches to the determinants of crime

Social and demographic characteristics of a population could affect the incidence of criminal activities. Age is a variable commonly related to crime. The pattern observed shows an increase in crime rates with age until a peak is reached in the teenage years, with a slow decline afterwards (Farrington, 1986). This is confirmed in the study by Nunley et al. (2011) which proves that the percentage of the young population is a robust predictor of the large swings observed in the U.S. murder rate for the period 1934–2006. Köber et al. (2022) find that younger people were almost as fearful as older people in the most disadvantaged neighbourhoods, but older people were considerably more fearful than younger ages in better-off neighbourhoods. Thus, age is a variable related to crime but mediated by other factors such as wealth.

Lafree et al. (1992) incorporate educational attainment and family stability in the study of rates of robbery, burglary, and homicide for blacks and whites. For white people, they found that crime rates declined as family income and educational attainment increased. In contrast, crime rates among black people showed a positive relationship with family stability and educational attainment. Igbinedion and Ebomoyi (2017) also find a negative relationship between education and crime rates. They suggest that education not only makes people risk-averse, but also indirectly alters an individual's decision to adopt criminal behavior. With the same arguments, Esedo et al. (2017) analyze white-collar crime in Nigeria to obtain a negative effect between education and crime rates. In Mexico, Gleditsch et al. (2022) corroborate that crime can be reduced by strengthening the education system.

Regarding gender, the universal belief held by criminologists is that women are less likely to commit a crime than men (Steffensmeier and Allan, 1996).

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Using an experiment, Reed and Rorie (2023) find that "gender identity influences the likelihood of crime perpetration even when one's opportunity to commit crime is held constant". Masih and Masih (1996) introduce urbanization as a determining variable of crime and find that burglary and vehicle theft are positively affected by the growth of urbanization. Other sociodemographic patterns related to crime are found by Gaviria and Pages (2002).

They explain that in Latin American countries the typical victims of property crime come from the middle and upper classes and live in large cities or with high population growth. In South Africa, Blackmore (2003) analyzes 15 crimes across the 9 provinces of South Africa over 8 years and finds that most crimes are positively affected by the degree of urbanization, the ratio of women to men, and drug possession offences. Haider and Ali (2015) examine the determinants of crime in Pakistan in the period 2010-2011. Their results suggest a positive and significant impact of population density on crime, meaning that dense and populated areas provide more chances for criminals to commit crimes. In contrast, they find that crime in Pakistan is negatively affected by education levels, suggesting that as education levels increase incentives to commit crimes decline.

The same result for population density is obtained by Anwa et al. (2015). Poverty is a variable that also has an impact on crime. Poverty is a denial of choices and opportunities, and a violation of human dignity. The poor lack of basic capacity to participate effectively in society. In this situation, individuals are more likely to opt for illegal activities than legal work (Kuhe et al., 2016).

Kuhe (2016) uses annual data from Nigeria for the period 1970-2015 to determine that the crime level is positively affected by the level of poverty. The same positive impact is obtained by Hassan et al. (2016) and Asghar et al. (2016) for Pakistan. Subsequently, Amin and Ahmad (2018) incorporate ethnic diversity and social exclusion in the analysis of determinants of crime in Pakistan in the period 1970-2015. Their results show a positive and significant impact on property, violent crime rates, and overall crimes in Pakistan.

Deterrence approaches to the determinants of crime

The deterrence factors are those aimed at containing criminal activities in society. These can be laws, police numbers, the number of arrests, etc. Meera and Jayakumar (1995) analyze the determinants of crime in developing countries, introducing as deterrence factors prison overcrowding, police development expenditure and size of the police force. They find that the first two are positively related to criminal activities while the size of the police force is not significant. Ralston (1999) also obtains positive effects by taking as a deterrent variable the white arrest rate. Imrohoroglu et al. (2000) introduce police expenditure to study its relationship to criminal activities using a general equilibrium model.

They show that increasing the level of expenditure on police protection reduces crime, although at a decreasing rate. In other articles such as those by Keshavarz and Markazi (2011), deterrent factors may not be significant for some crimes in the presence of certain sociodemographic and economic conditions. Frederick et al. (2016) use a balanced panel dataset of the 67 counties in Pennsylvania over the period from 1990 to 2009 to show that clearance and arrest rates contribute to criminal deterrence.

Adekoya and Abdul (2016) incorporate other interesting deterrent variables such as domestic investment, prosecution, and punishment in the analysis of determinants of crime for Nigeria in the period 1970-2013. Their results show that domestic investment and prosecution contribute to reducing criminal activity while punishment only causes a significant impact in the long term.

Recently, in many developed countries, the connection between crimes and immigration rates has been discussed. An empirical paper by Tufail et al. (2022) in the period 1988-2018 across 30 OECD countries show that no statistical evidence exists to relate an increase in the number of immigrants to the rise of any kind of crime. Curiously, an increase in foreign prisoners reduces all kinds of crimes.

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Developing hypotheses

The economic recession due to the SARS-Cov-2 pandemic, and the strong fluctuations in oil prices due to Russian-Saudi Arabian oil price war in 2020 and the recent Russo-Ukrainian war are three complex scenarios. Intuitively, you would think that the economic recession due to the coronavirus pandemic could be accompanied by high unemployment rates, a decrease in stock market, an economic slowdown, and higher levels of inflation that could increase the incidence of financial fraud and identity theft. This effect may be exacerbated by a reduction in GDP per capita and reductions in oil prices triggered by events such as the economic war between Russia and Saudi Arabia. On the other hand, the increase in oil prices due to events such as the war between Russia and Ukraine can mitigate the negative effects of the price decrease in oil-exporting countries (Neely, 2022).

From this scenario and the variables presented in the literature review of previous sections, we have decided to consider in the analysis the following economic and sociodemographic factors:

Unemployment rate: this is one of the most used in prior literature but also because this factor has an ambiguous (positive/negative) impact on non-financial crimes.

Inflation rate and GDP per capita: these factors are including as the purchasing power of clients.

Economic growth: this variable is considered as a measure of a country's wealth.

Oil prices: this is a new variable, never considered in analyzing the determinants of crimes.

Gender: this variable is used in prior literature and is incorporated in this study to confirm whether men are more likely to commit financial crimes as occurs in non-financial ones.

Urbanization level: this variable is a proxy of population density.

Bearing in mind all the above-mentioned literature, our hypotheses are as follows:

H1: Macroeconomic fluctuations in the unemployment rate, inflation, and economic growth positively affect the incidence of financial fraud and identity theft. This means that any increase of these variables in one unit may cause an increase in the incidence of fraud and identity theft and vice versa.

H2: Fluctuations in oil prices and GDP per capita negatively affect the incidence of financial fraud and identity theft. In other words, any increase of these variables in one unit may cause a decrease in the incidence of fraud and identity theft and vice versa.

H3: The level of urbanization is expected to have a positive effect on the incidence of these crimes and a negative one in terms of gender. That is to say, the higher the urbanization level the more likely the incidence of fraud and identity theft and vice versa. On the other side, is expected to see less crime when the proportion of women over men is small enough and vice versa.

Some or all the variables from the hypotheses mentioned are expected to be significant in the short and long term. The unemployment rate and inflation may produce short-term effects on the incidence of these crimes through direct interaction with the consumer. The same effect occurs in the long term. Economic growth, GDP per capita and oil prices may show effects that are more noticeable in the long term due to their indirect interaction with individuals. Regarding sociodemographic variables, their effects are expected to show in the long term, since social and demographic changes are slow and not as abrupt as some macroeconomic fluctuations.

Data

This study uses quarterly records of the incidence of these variables provided by a major financial institution in Mexico from 1999 to 2019 to model financial crimes of fraud and identity theft. The period was selected based on the information available on fraud and identity theft cases in the financial institution. Macroeconomic and sociodemographic variables are employed in the same periods and are taken from several sources. Moreover, we want to know the effect of the variables chosen on financial crimes during and before the effect of the coronavirus era.

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As the worldwide pandemic has been a rare effect on many macroeconomic variables (Wang et al., 2023), we have not considered more recent years.

Bank of Mexico provides statistics about the country's macroeconomic and financial indicators in daily, monthly, quarterly, or annual periods from Mexico. Time series of the unemployment rate, oil prices, stock market, GDP and inflation are taken from this source. The unemployment rate and GDP are available quarterly. The unemployment rate is included as an indicator of the level of legal activities performed by individuals in society. It is assumed that when an individual earns income from a non-legal activity, they may be performing informal work or illegal activities. GDP is expressed at 2013 prices and is used to obtain the GDP per capita and quarterly economic growth. GDP per capita is introduced as an indicator of individual wealth and economic growth as a measure of economic affluence. The quarterly inflation rate is obtained through the monthly series of the INPC (Consumer Price Index). This variable acts as the purchasing power of consumers and the cost of living. Oil prices are provided daily and in U.S. dollars. These prices are deflated using the U.S. consumer price index and the quarterly data is obtained as the average of the daily data. Oil prices are introduced as a measure of incoming wealth for the economy in the context of an oil-exporting country. Finally, the stock market is included also as a measure of wealth and is obtained on a monthly basis. The quarterly observations are calculated as the average of the monthly data.

Deterrent factors have a strong mitigating impact on crime incidence. In addition to the usual containment measures implemented by the government (police force, laws, regulations, etc.), financial crimes have internal mitigating factors aimed at minimizing the incidence of crime. Examples of these are requiring secret codes for any transaction, recognition of official identifications, fingerprints and digital signatures for transactions in a branch, restriction of operations with a certain amount and type of currency, asking questions in financial operations carried out by telephone, etc. In this study, governmental and internal deterrent factors are not considered due to the lack of available data for the period of analysis.

The data from the urbanization level was extracted from the National Survey on Occupation and Employment (ENOE) survey, carried out by the National Institute of Statistics and Geography (INEGI) every month in Mexico. From this source, the quarterly total population is used to express the incidence of fraud and identity theft per 100,000 individuals. The survey also provides the number of individuals in 4 levels of urbanization: rural, low urban, medium urban and more urbanized. The influence of urbanization is considered through the proportion of individuals in the more urbanized areas over the total population. The effect of gender is introduced as the proportion of women over men formed with the statistics reported by INEGI. Table 1 shows the initial variables contemplated for the study.

Box 1

Table 1

Explicative variables in the analysis

Unemployment rate	It is the number of unemployed individuals over the active total population.
Oil prices	Prices per barrel in US dollars.
Inflation	Inflation rate obtained through the Consumer Price Index.
GDP per capita	GDP of the country over total population.
Economic growth	Quarterly economic growth obtained with the GDP.
Gender	Proportion number of women over men.
Urbanization Level	Number of individuals in the more urbanized areas over the total population.

Source: Own elaboration

Methodology

We use cointegration theory to model the incidence of financial fraud and identity theft per 100,000 individuals, and the unemployment rate, petroleum prices, inflation, stock market, GDP per capita, economic growth, gender, age, and level of urbanization as explanatory variables.

To implement the mentioned theory, first, it is necessary to check whether the variables are stationary. For this, the Augmented Dickey-Fuller (ADF) stationarity test is implemented (Dickey and Fuller, 1981). We have chosen this method as it is currently used by the financial institution since 2020 for fraud prevention area.

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This test considered the following autoregressive model,

$$\Delta y_t = \alpha_0 + \delta y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t \quad [1]$$

Where $\delta = -(1 - \sum_{i=1}^{p} \alpha_i)$, $\beta_i = \sum_{i=1}^{p} \alpha_i$, y_t is the variable to be tested, Δ the difference operator and ε_t the error. The parameter of interest for the test is δ. The null hypothesis is to test whether $\delta = 0$. If the "t" statistic exceeds the critical Dickey-Fuller value, the null hypothesis is rejected indicating that the series is stationary. If the null hypothesis is not rejected, the series contains a unit root.

Second, if the series are not stationary, we proceed to check whether they are integrated of the same order "d". A time series is said to be integrated of order "d", denoted $I(d)$, if it becomes stationary after first being differentiated "d" times.

Third, once all the variables are integrated in the same order, the Johansen cointegration test is used to obtain long-term relationships among them (Johansen, 1991). The Johansen test considers the following vector autoregression model (VAR) of order "p", according to Enders (1995)

$$Y_t = \gamma + \theta_1 Y_{t-1} + \ldots + \theta_p Y_{t-p} + \varepsilon_t \quad [2]$$

Where Y_t is the $k-$ vector of non-stationary variables integrated of the same order $I(d)$, θ is a matrix of $k\ x\ k$ parameters and ε_t is a $k-$dimensional vector of white noise.

By rewriting equation 2, we obtain the following structure:

$$\Delta Y_t = \gamma + \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad [3]$$

The term ΠY_{t-1} is called the error correction term. The rank of Π is determined to obtain cointegration relationships in the long term. If the rank of Π is complete, any linear combination of the variables is stationary, and the model adjustment should be made with the variables in levels. If the rank of Π is null, then there is no cointegration relationship. If Π has a reduced rank, $r < k$, then there are r cointegration vectors, in which $0 < r < k$.

The Johansen cointegration test computes two statistics: trace and maximum eigenvalue statistics. The trace statistic for the null hypothesis of r cointegrating relationships is computed as:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{k} \ln(1 - \lambda_i) \quad [4]$$

The maximum eigenvalue test aims to test the null hypothesis that the number of vectors is r , $H_0{:}r$, against the alternative hypothesis of the existence of $r+1$ cointegrating vectors, $H_1{:}r+1$. The statistic is expressed as follows:

$$\lambda_{max}(r, r+1) = -T \sum_{i=r+1}^{k} \ln(1 - \lambda_{r+1}) \quad [5]$$

Once the existence of a long-run relationship among the variables is detected, the short-term effects of variables can be obtained by applying the Vector Error Correction Model (VECM). The VECM is a restricted VAR, where the restriction is on the existence of a long-run relation of the series and all endogenous variables that are used in the differenced form.

If some of the variables do not meet the requirements to be considered in the Johansen test, the Toda-Yamamoto (1995) method is applied to find out whether there is granger causality towards financial crimes.

Results and discussions

Johansen Cointegration Test and Vector Error Correction Model

When applying the Augmented-Dickey Fuller stationarity test at 0.05 significance level, it was found that incidence of identity theft and fraud, unemployment rate, oil prices, GDP per capita and gender were integrated of order 1, $I(1)$.

Conversely, the inflation, economic growth and urbanization level resulted stationary, $I(0)$. The results of the Augmented-Dickey Fuller test on the original time series and its first difference are shown in Table 2.

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Box 2

Table 2

Augmented Dickey-Fuller test (H0: Non-stationary, Ha: Stationary)

Variable	Original (p-value)	First differece (p-value)
Identity theft	0.1442	0.0100
Fraud	0.0794	0.0100
Unemployment rate	0.7429	0.0169
Oil Prices	0.7973	0.0100
GDP per capita	0.1297	0.0100
Gender	0.5594	0.0104
Economic growth	0.0178	0.0000
Urbanization level	0.0100	0.0000
Inflation	0.0300	0.0100

Source: Own elaboration with R software

From the above, it follows that the variables to be included in Johansen's cointegration test are the incidences of fraud and identity theft, unemployment rate, oil prices, GDP per capita and gender.

To identify the optimal lag length for our VAR specification the Schwarz information (SIC) criterion and the Hannan-Quinn (HQC) criterion are used. From the optimal lags obtained by the two criteria, the smallest lag is selected. According to Ventzislav and Lutz (2005), for quarterly VAR models, the Hannan-Quinn Criterion (HQC) appears to be the most accurate criterion with the exception of sample sizes smaller than 120, for which the Schwarz Information Criterion (SIC) is more accurate. The results are shown in Table 3.

Box 3

Table 3

Schwarz information (SIC) and Hannan-Quinn (HQC) criterion results. LR – Statistic of LR modified sequential test. *Indicates lag order selected by the criterion

VAR for fraud incidence and explanatory variables			LR	VAR for identity theft incidence and explanatory variables			LR
Lag	HQC	SIC		Lag	HQC	SIC	
0	11.30	11.39		0	0.139	0.2286	
1	4.98	5.51	579.4	1	-5.70	-5.17	541.71
2	3.974	4.95*	154.5	2	-6.68	-5.70*	152.13
3	3.61*	5.03	103.0	3	-6.84*	-5.41	86.59
4	3.86	5.74	53.2*	4	-6.77	-4.90	68.46*

Source: Own elaboration

In this way, the VAR is well specified so that the residuals do not have serial correlation at the selected lag length. Then, the Johansen cointegration test is applied to the variables to see if there is any cointegration relationship among them. As can be seen in Table 4, the trace and maximum eigenvalue tests reject the null hypothesis of non-integration among the variables at 5% significance for the cases that include fraud and identity theft. The trace tests indicate that there is at least one cointegration vector that defines the long-term relationship among the variables. This result is confirmed by the maximum eigenvalue test.

Box 4

Table 4

Trace and maximum eigenvalue tests for cointegration among variables. * denotes rejection of the null hypothesis at the level of 5%

Cointegration test with fraud incidence.				Cointegration tests with identity theft incidence.			
Trace Test				Trace Test			
Null	Alternative	Test statistic	Critical value (5%)	Null	Alternative	Test statistic	Critical value (5%)
r= 0	r>0	87.52*	76.07	r= 0	r>0	89.51*	76.07
r≤ 1	r>2	41.41	53.12	r≤ 1	r>1	39.35	53.12
r≤ 2	r>3	22.57	34.91	r≤ 2	r>2	21.13	34.91
r≤ 3	r>4	9.55	19.96	r≤ 3	r>3	8.25	19.96
r≤ 4	r>4	3.04	9.24	r≤ 4	r>4	2.73	9.24
Cointegration test with fraud incidence.				Cointegration tests with identity theft incidence.			
Maximum Eigenvalue Test				Maximum Eigenvalue Test			
Null	Alternative	Test statistic	Critical value (5%)	Null	Alternative	Test statistic	Critical value (5%)
r= 0	r=1	46.11*	34.4	r= 0	r=1	50.16*	34.4
r= 1	r=2	18.85	28.14	r= 1	r=2	18.22	28.14
r= 2	r=3	13.02	22	r= 2	r=3	12.88	22
r= 3	r=4	6.51	15.67	r= 3	r=4	5.52	15.67
r= 4	r=5	3.04	9.24	r= 4	r=5	2.73	9.24

Source: Own elaboration in R software

Table 5 shows the first cointegration vector, normalized to the financial crimes. Therefore, the coefficients should be interpreted with the opposite sign to that shown in the table.

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Box 5

Table 5

Cointegration vector normalized to the financial crimes. Estimations made in R software. The symbol "*" expresses that the coefficient is significant at 10%, "**" at 5% and "***" at 1%

Coefficient			Coefficient		
Financial Fraud	1	T-statistic	Identity Theft	1	T-statistic
Unemployment rate	-53.76***	-3.06	Unemployment rate	-0.24***	-3.65
Oil prices	18829.08***	7.71	Oil prices	0.02***	6.99
GDP per capita	4.63***	10.49	GDP per capita	25.77***	3.79
Gender	2261.27**	2.47	Gender	8.01**	2.30
Constant	-5437.18***	-6.31	Constant	-13.25***	-4.04

Source: Own elaboration

From Table 5 it is observed that in the long term, the unemployment rate has a significant positive impact (-53.76 it is observed in the cointegration vector but 53.76 is used for interpretation) on the incidence of financial fraud and identity theft. The result of the unemployment rate coincides with the positive effect on credit card delinquency obtained by Agarwal and Liu (2003). It also coincides with the positive effect obtained by Bell et al. (2015), Mittal et al. (2019) and Bennett and Ouazad (2018) on property and violent crime. This implies that in a period of recession when unemployment rates increase, individuals may find more benefit from carrying out illegal activities in financial institutions such as credit card cloning, identity theft, execution of transactions not recognized by clients and financial extortion.

The negative and significant effect of GDP per capita on financial fraud and identity theft is in line with that shown by Rosenfeld and Fornango (2007) in robbery and larceny crimes, and Latimaha et al. (2019) in all types of street crime (murder, rape, injuries and robbery). According to this, when the recession is accompanied by a decrease in GDP per capita, criminals may be more interested in committing fraud and identity theft crimes to get extra income due to a reduction of their personal income.

The same table shows that oil prices have a negative significant effect on the incidence of fraud and identity theft. In the oil price war between Russia and Saudi Arabi, drastic falls in oil prices were observed, even reaching negative numbers related to the low demand for oil caused by the sudden closure of companies. This drop-in price has a direct impact on the income of exporting countries such as Mexico, where oil sales represent about 33 per cent of its tax revenue.

When tax revenues are reduced, the government of the exporting country may experience a reduction in federal and sub-federal public spending, affecting investments in sectors such as education, health, social programs, public security, and business creation.

Thus, falls in oil prices may provoke an increase in financial crimes because individuals who do not see opportunities presented by the government in the sectors that previously existed may choose to carry out illegal activities, further aggravated by limited spending on public safety. The opposite effect will occur in the presence of events such as the war between Russia and Ukraine where rising prices are observed.

As for sociodemographic variables, in the long term, gender exhibits a negative effect as established in Steffensmeier and Allan (1996) about the involvement of males in most crimes.

Another visible result from Table 5 is that financial fraud and identity theft show similar reactions (same sign) to macroeconomic fluctuations and sociodemographic characteristics in the long term. These similarities may be justified by the fact that criminals in financial systems usually carry out several crimes at once.

In a few minutes, they may be performing card cloning, a transaction with a hacked account, transactions for the theft of app keys, or telephone extortion, without any physical exposure.

These offenders are not limited by physical effort, face-to-face action, or the time required to commit non-financial crimes such as assault with a weapon, car theft, or kidnapping.

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From the aforementioned, we have that hypothesis 1 is partially fulfilled by the positive significant effect of the unemployment rate and the absence of economic growth and inflation in the analysis. Hypothesis 2 is completely fulfilled by the negative effect of GDP per capita and oil prices. Hypothesis 3 is also partially fulfilled by the significant negative effect of gender, and the absence of the urbanization level in the analysis. The long-term impacts of macroeconomic variables are present as expected.

The long-term relationship among the variables, shown by the cointegration vector in Table 5 is used as an explanatory variable of the vector error correction representation. The vector error correction modelling allows us to identify the direction of Granger causality among variables and distinguish between "short-run" and "long-run" causality. The coefficients of the VECM for financial crimes in relation to the explanatory variables are shown in Tables 6 and 7. The coefficients are interpreted with the signs that appear in the following table.

Box 6

Table 6

VEC coefficients for fraud incidence**.** Estimations made in R software. The symbol "*" expresses that the coefficient is significant at 10%, “**” at 5% and "***" at 1%

Variable	Coefficient	Standard Error	T-statistic
ECT(-1)	-0.8569***	0.187	-4.573
ΔFraud (-1)	-0.74***	0.143	-5.172
ΔUnemployment Rate (-1)	96.66*	57.479	1.682
ΔOil Prices (-1)	-5.65***	1.796	-3.149
ΔGDP per capita (-1)	7134.94	5415.670	1.317
ΔGender (-1)	-7278.31**	3329.438	-2.186

Source: Own elaboration

Box 7

Table 7

VEC coefficients for identity theft. Estimations made in R software. The symbol "*" expresses that the coefficient is significant at 10%, “**” at 5% and "***" at 1%

Variable	Coefficient	Standard Error	T-statistic
ECT(-1)	-0.8477***	0.173	-4.88
ΔFraud (-1)	-0.79***	0.129	-6.151
ΔUnemployment Rate (-1)	0.42**	0.186	2.274
ΔOil Prices (-1)	-0.02***	0.006	-3.041
ΔGDP per capita (-1)	42.31**	17.596	2.405
ΔGender (-1)	-21.31*	12.436	-1.714

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Tables 6 and 7 show the adjustment degree of the error correction terms (ECT) that expresses how fast the variables converge in the long-term equilibrium. This value is -0.8569 and -0.8477 for fraud and identity theft, respectively, being negative and significant at a level of 1%. For fraud, the -0.8569 means that approximately 85.69% of the discrepancy between the current value and the long-term equilibrium is adjusted each quarter. For identity theft, the percentage of adjustment is 84.77%. Turning to details, it is observed that the unemployment rate, lagged in the first difference, has a significant positive impact on the incidence of fraud and identity theft in the short term, the same sign as that observed in the long term.

The positive and significant effect of GDP per capita on identity theft, lagged in the first difference, is opposite to the negative sign observed in the long term. This may indicate that in the short term, the impact of GDP per capita is in line with that established by Kizilgol and Selim (2017) in homicide, violence and other non-financial crimes. It also seems to follow what Debnath and Das (2017) set, an increase in economic affluence is accompanied by an unequal distribution of income that can incentive crime emergence. This dynamic would not be alien to an economy such as Mexico, which historically has been one of the most-unequal regions in the world and whose inequality has increased over the years (Reyes et al. 2017). According to this, when the recession is accompanied by a decrease in GDP per capita in the short-term, criminals may be less interested in committing identity theft crimes due to a reduction of assets in the victim's financial accounts. Faced with such an economic situation, delinquents might change their objective towards non-financial crimes according to what is shown by Rosenfeld and Fornango (2007) and Latimaha et al. (2019).

Finally, the oil prices and gender, lagged in first difference, show that same sign as that observed in the long term for both financial crimes.

Toda and Yamamoto Causality Testing

To explore whether there is a causal effect of the variables that were not incorporated in the Johansen test towards financial crimes, we implement the approach of Toda and Yamamoto (1995).

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The stock market will be added in this analysis, taking advantage that the GDP per capita with which it is highly correlated, is not present at this stage of the study. This method is appropriate when the series has a different order of integration or with an order of integration greater than 2. It also has the advantage of not requiring a Johansen cointegration pretesting to be applied.

This approach consists in estimating an augmented VAR of order "k" with "d" additional lags, where "d" is the maximum order of integration of the variables in the analysis. The "k" value is the optimal lag length of the VAR model determined by some measures such as the Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), Final Prediction Error (FPE) and Hannan-Quinn (HQC) Information Criterion.

For the present study, the specification of the increased VAR of order $(k+d)$ is the following,

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_k Y_{t-k} + \ldots + \beta_{k+d} Y_{t-(k+d)}$$

$$\text{Where} Y_t = \begin{pmatrix} Fraud_t \\ Stock\ Market_t \\ Inflation_t \\ Economic\ Growth_t \\ Urbanization\ Level_t \end{pmatrix} \text{ or } Y_t = \begin{pmatrix} Identity\ Theft_t \\ Stock\ Market_t \\ Inflation_t \\ Economic\ Growth_t \\ Urbanization\ Level_t \end{pmatrix} \quad [6]$$

The null hypothesis of non-causality of any of the macroeconomic or sociodemographic variables towards financial crimes can be expressed as follows, $H_0: Y_{it}\ does\ not\ cause\ Y_{jt}, that\ is, \delta_{ij}^{p} = 0\ para\ p = 1,2,\ldots,k$. The Wald test statistic W with an asymptotic χ^2 distribution with k degrees of freedom is used to test this null hypothesis.

For the selected variables, an optimal lag of 2 was obtained following the Schwarz information (SIC) and Hannan-Quinn (HQC) criteria.

Given that the maximum order of integration obtained is 1, the augmented VAR to estimate is of order 3. See Table 8 for the results.

Box 8

Table 8

Toda-Yamamoto Causality (Wald Tet). "**" expresses rejection of null hypothesis at 5% and "***" at 1% of significance level

Null Hypothesis	Chi-sq	P-Value	Causality
Inflation does not Granger cause Fraud	21.8	0.0000***	Granger-Causality
Economic Growth does not Granger cause Fraud	0.29	0.8600	No Causality
Stock Market does not Granger cause Fraud	10.7	0.0047**	Granger-Causality
Urbanization Level does not Granger cause Fraud	1.60	0.4400	No Causality
Inflation does not Granger cause Identity Theft	6.4	0.04**	Granger-Causality
Economic Growth does not Granger cause Identity Theft	1.5	0.4800	No Causality
Stock Market does not Granger cause Identity Theft	2.40	0.3100	No Causality
Urbanization Level does not Granger cause Identity Theft	0.85	0.6500	No Causality

Source: Own elaboration

Table 8 shows that inflation and the stock market, granger cause financial fraud, and only inflation granger cause identity theft. When the economic slowdown is accompanied by a shortage of resources, the prices of goods and services can increase causing a decrease in purchasing power. This decrease in purchasing power can push individuals into alternative activities to obtain income that in many cases can be illegal.

Regarding the stock market, this variable can have a positive or negative effect on the incidence of fraud depending on whether the individuals are investors (hold stock) or non-investors. If the stock market increases, investors can see an increment in their wealth and a decrease in their propensity to crime. On the other hand, under these same conditions, non-inventors can observe how their wealth decreases concerning the wealth of investors, causing them feelings of envy, jealousy, or anger, increasing their propensity towards crime (Huck, 2018).

Finally, the null hypothesis of the non-causality of the economic growth and urbanization level towards financial crimes cannot be rejected, thus there is no evidence that these macroeconomic variables have a causal impact on financial crimes.

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Conclusions

The objective of this study is, concentrated on the environment of financial institutions, to investigate how macroeconomic fluctuations and sociological factors affect the incidence of financial fraud and identity theft. Our results show partial and complete compliance with the hypotheses priorly established in this study. The unemployment rate has a positive impact on the incidence of financial fraud and identity theft in the short and long term. Oil prices exhibit a significant negative effect on both crimes in the short and long term. Also, the GDP per capita shows a negative impact on fraud and identity theft in the long term and positive only for identity theft in the short term. Gender shows a significant negative impact on the incidence of both crimes in the short and long term. The patterns of reactions(signs) of financial fraud and identity theft to macroeconomic fluctuations and demographic characteristics were also shown to be similar.

The positive sign in the coefficients of the unemployment rate indicates that in the face of a recession, such as the one caused by the SARS-Cov-2 pandemic, the crimes of financial fraud and identity theft might increase in the long term. This effect may be intensified in exporting countries due to the drop-in oil prices by the sudden reduction in demand as that observed in the commercial war between Russia and Saudi Arabia. With these same conditions that can cause a decrease in GDP per capita, criminals in the short term may lose their interest in identity theft due to the reduction of victims' financial assets and turn towards non-financial crimes. Then, in the long term, the same decrease in GDP per capita may cause an increase in the incidence of both financial crimes. Regarding inflation and the stock market, the Toda-Yamamoto test shows the existence of Granger causality towards financial fraud and Granger causality from inflation to identity theft. The same test shows the absence of Granger causality from the economic growth and urbanization level towards financial crimes.

Given the results obtained by this study, it is recommended that the authorities of financial institutions reinforce their internal controls and mitigating actions to minimize the incidence of financial crimes when macroeconomic conditions fluctuate outside the normal range.

It is also important to note that the results produced by this study have the limitation of not considering deterrent factors, which play an important role in stopping financial crime. In addition to the laws and penalties imposed by the government, financial institutions have their internal policies, detection systems, customer authentication processes, and various controls that can produce different levels of impact depending on the institution.

Future research is aimed at studying how macroeconomic fluctuations affect the incidence of financial crimes in non-oil exporting countries. It will also study how changes in the stock market in a model without correlated variables affect the incidence of fraud and identity theft. Additionally, we will use data from 2020 onwards to analyse the impact of the covid pandemic on the incidence of financial fraud and identity theft as well.

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Rocha-Salazar, José de Jesús: Writing - original draft, formal analysis, conceptualization, methodology, software.

Segovia-Vargas, María Jesús: Project administration, writing - review & editing, validation, funding acquisition.

Camacho-Miñano, María del Mar: Visualization, writing - review & editing, validation, resources.

Availability of data and materials

Data not available due to privacy policies of the institution. Data will be made available on request.

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Abbreviations

ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
ECT	Error Correction Term
ENOE	Encuesta Nacional de Ocupación y Empleo
FPE	Final Prediction Error
GDP	Gross Domestic Product
HQC	Hannan Quinn Criterion
INEGI	Instituto Nacional de Estadística y Geografía
OECD	Organization for Economic Cooperation and Development
SARS-COV-2	The virus that causes coronavirus disease 19 (COVID-19)
SIC	Schwarz information Criterion
VAR	Vector autoregression
VECM	Vector Error Correction Model

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Article

Incorporation of QR codes to provide information about academic conferences, register attendance, and generate certificates

Incorporación de códigos QR para brindar información sobre congresos académicos, registrar asistencia y generar certificados

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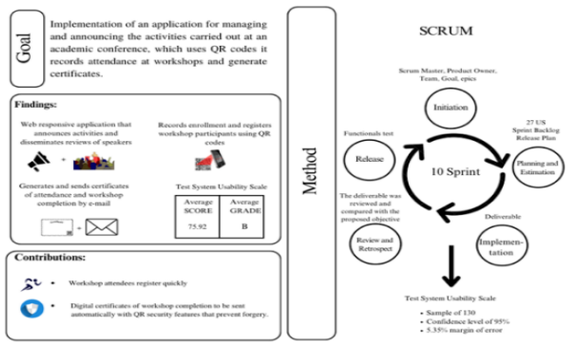
Abstract

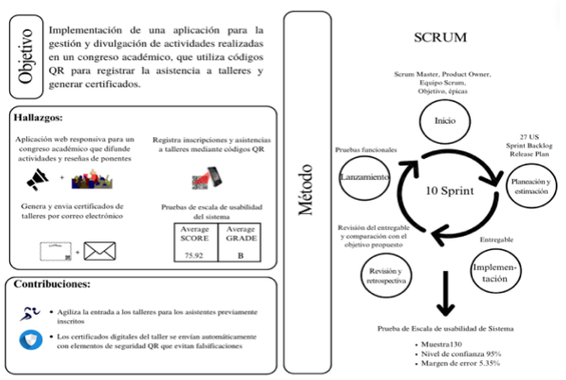
Goal: Implementation of an application for managing and announcing the activities carried out at an academic conference, which uses QR codes it records attendance at workshops and generate certificates. **Method:** The Scrum methodology was used; the requirements of the application were captured in user stories; ten Sprints were used. Functionality tests were applied and the System Usability Scale was employed to test usability. **Findings:** Responsive web application for an academic conference that allows announces activities and disseminates reviews of speakers, records enrollment and registers workshop participants using QR codes, generates and sends certificates of attendance and workshop completion by e-mail. The usability tests placed the application in the B percentile, which is considered acceptable. **Contributions:** Workshop attendees register by scanning a QR code with a smartphone; this streamlines entry for previously registered attendees, and enables digital certificates of workshop completion to be sent automatically with QR security features that prevent forgery.



QR Code, Responsive web application, Academic Conference

Resumen

Objetivo: Implementación de una aplicación para la gestión y divulgación de actividades realizadas en un congreso académico, que utiliza códigos QR para registrar la asistencia a talleres y generar certificados. **Método:** Scrum; los requisitos se plasmaron en historias de usuarios; resultaron diez Sprints. Se aplicaron pruebas de funcionalidad y se empleó la Escala de Usabilidad del Sistema para probar la usabilidad. **Hallazgos:** Aplicación web responsiva para un congreso académico que difunde actividades y reseñas de ponentes; registra inscripciones y asistencias a talleres mediante códigos QR; genera y envía certificados de talleres por correo electrónico. Las pruebas de usabilidad ubicaron la aplicación en el percentil B, que se considera aceptable. **Contribuciones:** Los asistentes al taller se registran escaneando un código QR con un teléfono inteligente; esto agiliza la entrada para los asistentes previamente inscritos y los certificados digitales del taller se envían automáticamente con elementos de seguridad QR que evitan falsificaciones.



Código QR, Aplicación web responsiva, Congreso académico

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Introduction

Public universities in the state of Hidalgo, Mexico, hold academic conferences where researchers, teachers, students, and professionals can exchange knowledge and experiences in a given area of knowledge to position them at the forefront of the field. At these events, academics disseminate the results of their research, which increases their visibility and recognition as academics; it also facilitates networking and fosters collaboration among academics, businesspersons, and organizations.

Academic conferences held at a technological university located in the state of Hidalgo, Mexico, are announced on the university's website by means of downloadable PDF files containing a list of activities. Paper sheets or Google Forms are used to register conference attendees, as well as to register attendees for the workshops held at these conferences. After a conference has concluded, certificates of recognition are generated through mail merge and then sent by e-mail in a process that can take up to a further month. In addition, forgery has been identified in some of the names on these certificates.

Therefore, an area of opportunity was identified: it would be convenient to have an application to manage these activities for academic conferences, including publicizing, managing attendance, and generating attendance certificates and certificates of workshop completion.

This article is divided into five sections: introduction, literature review, methodology, results, and conclusions and future work.

Literature review

According to the 2023 National Survey on Availability and Use of Information Technologies in Households (ENDUTIH) applied in Mexico to the population aged 6 years or older, 81.2% of the population made use of the Internet; 81.4% had a cell phone; 37.8% connected to the Internet through a smart TV, 44% through a computer, laptop, or tablet, and 97.1% through a smartphone (INEGI and ift, 2023).

These data show that more and more users are accessing websites from various different devices such as smart TVs, tablets, and computers, but especially from smartphones. These devices have different screen sizes, hence the importance of designing web applications with responsive design.

Responsive web design enables users to access website content from any device regardless of its size, screen resolution, platform, or orientation without the need to reduce, enlarge or scroll the page (Parlakkiliç, 2022). To achieve this, among other features it is necessary to adapt the design to different screen sizes, adapt images, optimize page elements such as buttons and links for mobile use, and hide non-essential elements from small screens (Bhanarkar, Paul and Mehta, 2023).

QR codes (quick response code) were created in 1994 by Masahiro Hara for the Japanese company Denso Wave to label and track vehicle parts. They have become widely used, since smartphones containing a decoder can readily scan QR codes through their cameras (Escorza, et al., 2023).

QR codes store information through a square two-dimensional dot matrix with three squares located in the two upper and lower left corners (Gallardo-Camacho, and Melendo-Rodríguez-Carmona, 2023). They have a higher storage capacity compared to other technologies (Reddy, et al., 2023). QR codes have become popular in a variety of contexts, including attendance registration.

Several recent research papers discuss the use of QR codes for managing attendance records. We cite three examples here

Liew and Tan proposed an attendance system based on QR codes, with functions to avoid attendance cheating, recording the scheduled time for a class, a registered mobile device, and geolocation (Liew and Tan, 2022).

Sujyot proposed an attendance system for educational and corporate institutions based on QR codes. Their system effectively streamlines attendance management by generating a unique QR code for each student or employee, which can be printed on an ID card or distributed via email or messaging applications (Sujyot et al., 2023).

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Research by Mustafa and Khamis produced a digital attendance management system that uses QR code technology and geolocation tracking to automate taking attendance in educational institutions (Mustafa and Khamis, 2023).

In the present paper, we propose a responsive web application for dissemination at academic conferences, which uses QR codes to track attendance at workshops offered at the conference and to generate certificates of completion.

Methodology

The Agile Scrum methodology was used to develop the application. Scrum has five iterative phases.

In the first phase, called Start, the Scrum Master, Product Owner, and Scrum Team were identified in their respective roles of designer, developer, and tester. Two types of users of the application were identified; conference attendees and administrators. Once the users and application requirements were identified, they were captured in user epics and ordered by priority in the Backlog.

This methodology enabled a responsive web application to be developed for managing the activities of the State Information Technology and Software Development Conference using QR codes to record workshop attendance and as a security element for producing workshop completion certificates.

Specifically, the responsive web application would enable the following to be carried out:

- Manage the activities of an academic conference to effectively publicize and disseminate the conference.
- Manage registration for workshops at an academic conference where the number of workshop participants is limited.
- Record attendance at the academic conference through a responsive web application.
- Use a QR code to record attendance at the workshops held at the conference.
- Automatically e-mail certificates of participation in the conference to registered attendees by e-mail.
- Send certificates of workshop completion to attendees, employing QR security to prevent forgery.
- Carry out functionality and usability tests to identify errors, and prevent or correct them, thus ensuring a quality product.

The activity diagram in Figure 1 shows the interaction and relationships between the two types of users of the application; administrators and attendees. The requirements of the application were captured in user epics.

In the Planning and Estimation phase, the user epics were then divided into 27 smaller user stories (US) that were assigned a delivery priority through the Sprint Backlog, enabling 10 sprints, and the products that should be obtained for each US were specified. This was then reflected in the Release Plan. The nomenclature used for the products (PRD) was SCR for views, PRO for processes, and PRT for on-screen or printed reports. Table 1 shows an excerpt from the 10 sprints or blocks, ordered by delivery priority. Six work blocks were defined for the administrator user and four for the conference attendee user. Table 2 shows the View Speakers US related to the Attendee user.

In the third phase, Implementation, the first deliverable, related to administrator access to the conference application, was codified.

In the next phase, Review and Retrospect, the deliverable was reviewed and compared with the proposed objective. Functionalities not specified in the first round were added if deemed necessary.

In the last phase, Launching or Closing, the deliverable underwent functional testing. Once the first sprint was concluded (administrator access), the next sprint related to the activities carried out at the conference was continued and iterated again through the five phases. The iterations were repeated until all ten sprints were completed.

At the end of the ten sprints, usability tests were carried out. The usability evaluation method was the Inquiry, which uses tests to gather information about users' perceptions of various aspects of the application, resulting in a broader picture and enabling statistical reports to be generated more conveniently (García, et al., 2019).

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A sample of 130 was selected from the population of 210 people, mainly students, teachers and administrative staff of the Information Technology Educational Program. The sample size provided a confidence level of 95% with a 5.35% margin of error.

The System Usability Scale (SUS) test was applied, which is a test commonly used to measure the usability of digital products and systems (Hyzy, et al., 2022). It has a high psychometric validity and measures ease of use through a questionnaire with 10 items (Macías, Miranda and Tapia, 2021) related to the effectiveness, efficiency, and user satisfaction of the application, measuring product usability according to the ISO 9241-11:2018 standard (Pailiacho, Garcés and Balseca, 2022). The questionnaire items were adapted to the context of the present study and are as follows:

Item 1. I think I would like using the web application for the State Information Technologies and Software Development Conference often.

Item 2. I found registration for the State Information Technologies and Software Development Conference via the application unnecessarily complicated.

Item 3. How easy was it for you to use your smartphone obtain your certificate of attendance at the State Information Technologies and Software Development Conference or certificate of completion for a workshop you attended at the conference?

Item 4. When generating my attendance certificate or workshop completion certificate, I realized that I would need help from a technical person to complete the task.

Item 5. I found that the various functions of the web application page of the State Information Technology and Software Development Conference were well integrated and adjusted to the dimensions of my smartphone.

Item 6. The content of the web application did not follow a consistent style. Furthermore, I had to zoom in to see the content of the web application for the State Information Technologies and Software Development Conference.

Item 7. I imagine that most of the attendees of the State Information Technology and Software Development Conference could easily learn how to register their attendance at the workshop using the web application and their smartphone camera to read the QR code.

Item 8. I found it very cumbersome to use the application to record my attendance at the workshops I selected at the State Information Technology and Software Development Conference.

Item 9. I think that the workshop completion certificates generated by the web application are trustworthy, since they include QR codes which prevent forgery.

Item 10. I found that selecting my workshop at the State Information Technology and Software Development Conference involved a considerable learning curve.

The programs used to create the application were HTML5 combined with PHP, the database was created in MySQL, and the code editor was Visual Code Studio.

Box 1

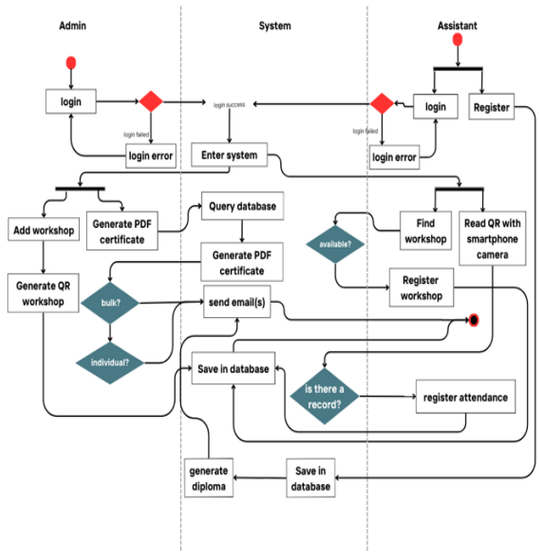

Figure 1

Conference activities diagram

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Box 2

Table 1

Release Plan (excerpt)

Priority	User	US	Time estimate (days)	Required Product ID	From	Until
Sprint 6						
14	Administrator	List of attendees	2	PRD-SCR-014 PRD-PRO-014 PRD-RPT-001	30/11/23	01/12/23
15	Administrator	Generate certificate	6	PRD-SCR-015 PRD-PRO-015 PRD-RPT-002	05/12/23	12/12/23
16	Administrator	Send certificate	5	PRD-SCR-016 PRD-PRO-016	14/12/23	20/12/23
Sprint 8						
21	Attendee	Schedule of activities	3	PRD-SCR-017 PRD-PRO-017 PRD-RPT-003	24/01/24	26/01/24
22	Attendee	Download schedule of activities	2	PRD-SCR-018 PRD-PRO-018 PRD-RPT-004	30/01/24	31/01/24
Sprint 7						
17	Attendee	View announcements	2	PRD-SCR-019 PRD-PRO-019	08/01/24	09/01/24
18	Attendee	View speakers	2	PRD-SCR-020 PRD-PRO-20	11/01/24	12/01/24
19	Attendee	View workshops	2	PRD-SCR-021 PRD-PRO-021	16/01/24	17/01/24
20	Attendee	View alumni	2	PRD-SCR-022 PRD-PRO-022	19/01/24	22/01/24

Results

The results include the following: a fully responsive web application for a conference on Information Technology and Software Development, which was held at the Technological University of the Mezquital Valley in Hidalgo, Mexico, as shown in Figure 2. By means of this application, aligned with the user stories of the attendees, the conference activities can be viewed, as well as the curriculums of the speakers, workshop participants, and alumni present at the conference (see Figure 3).

The application also allows the announcements for sport and cultural activities at the conference to be viewed, and enables attendees to register for the conference and obtain a certificate of attendance.

Box 3

Table 2

View speakers US

US	How…	I want to…	In order to …	Acceptance criteria
View speakers	Attendee	See the list of speakers	Be informed about the speakers giving talks at the conference	Show the following information about the speakers: -Academic degree -Name -Photograph -Button to see further details -Pop-up window to view speaker CV

Box 4

Figure 2

Conference home page

Continuing with attendee user stories, the application first gives the attendee access to the workshop section, then they can select their workshop according to the topic and the attendance limit for the workshop. Once the workshop is concluded, the attendee can register their presence at the workshop by means of a QR code, and finally, the application generates a PDF workshop completion certificate for workshop attendees whose attendance at the respective workshop was recorded. The QR code for the certificate contains information on the attendee and the workshop, as well as a unique identifier or registration number, as a way to avoid forged certificates. Figure 4 shows some of the application interfaces corresponding to these attendee-related user stories.

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Box 5

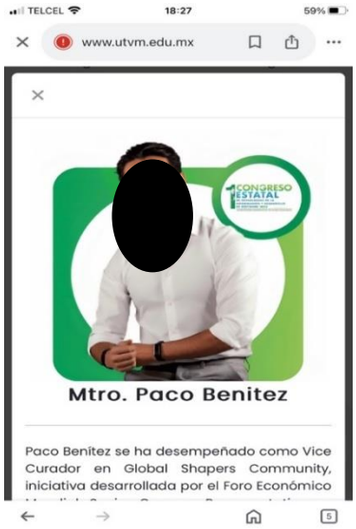

Figure 3

Speaker CV

Source: Authors

In response to administrator user stories, the application enables administrators to Create, Read, Update, and Delete (CRUD) speakers, workshop participants, alumni, activities, announcements, and workshops. Each time a new workshop is added, the application generates the QR code that will be used to register attendance at the respective workshop, as shown in Figure 5. Workshop administration is shown in Figure 6. This includes the name, attendance limit, target audience, workshop leader, and a representative image for each workshop. A part of workshop administration is the generation of workshop completion certificates. Figure 7 shows the sending of these certificates individually or in bulk.

Box 6

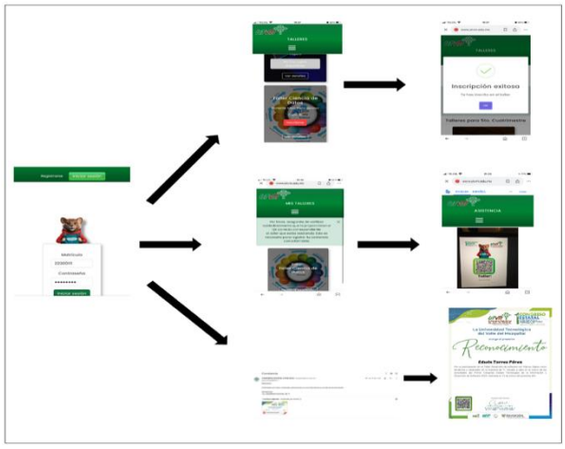

Figure 4

Application interfaces related to the workshops

After the functionality test had been applied, some adjustments were made when errors were detected and corrected. The test was then repeated. An excerpt from the test log is shown in Table 3.

Box 7

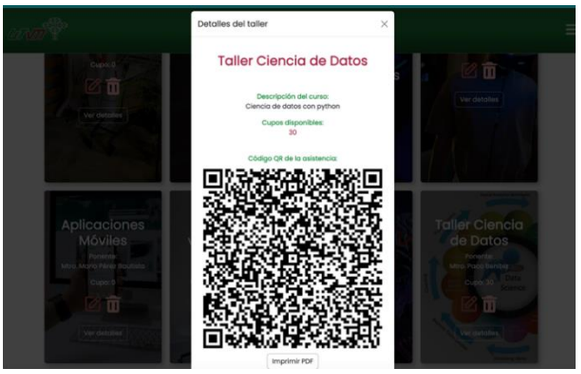

Figure 5

QR generated for a workshop

In Table 4, an excerpt from the usability tests is shown. The SUS test applied by means of Google Forms yielded a score of 75.92, which places it in the B percentile, meaning that it is acceptable.

Box 8

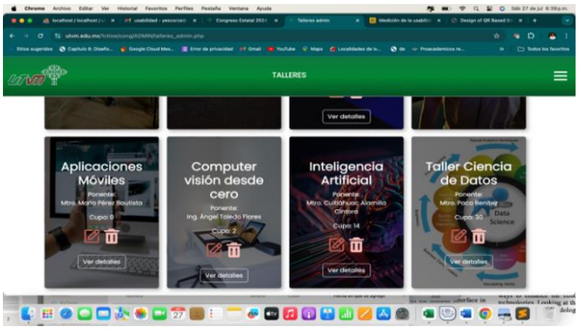

Figure 6

Administration of workshops

Box 9

Table 3

Test Log (excerpt)

Id	US	Date	Entry data/actions	Expected result	Environmental requirements for test	Special procedures required	Result obtained	Status	Severity
TCTi_014	List of attendees	04/12/2023	Administrator credentials	The administrator can see the complete list of workshop attendees	Internet connection or data	No	The administrator can see the list of workshop attendees ordered and classified by workshop	Approved	High
TCTi_015	Generate certificate	13/12/2023	Administrator credentials	The administrator can generate workshop completion certificates individually or in bulk	Internet connection or data PDF reader	List of participants whose attendance is recorded	The administrator has generated PDF workshop completion certificates individually or in bulk for participants whose attendance at the workshop is recorded	Approved	High
TCTi_016	Send certificate	21/12/2023	Administrator credentials E-mail credentials of registered attendees	The administrator can send workshop completion certificates by email.	Internet connection or data Institutional email	No	The administrator has sent the workshop completion certificate(s) by email and confirmed that the attendee(s) has/have received the email(s) with the PDF certificate as an attachment	Approved	High

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Conclusions

In this article, we have presented the implementation of a responsive web application to manage and publicize the activities of an academic conference. In this case, the application was implemented for the Information Technology and Software Development Conference held at a technological university located in the state of Hidalgo, Mexico. Our objective was achieved since, as shown in the Results section, we provide evidence of a responsive web application that that gives practical access via a smartphone to the conference schedule, the curriculums of the speakers, workshop participants, and alumni, announcements of cultural and sports activities, contact information, and sponsors. This availability facilitates the dissemination of information about the conference.

Box 10

Table 4

Test System Usability Scale (excerpt)

Average SCORE	Average GRADE
75.92	**B**

Gender	Type	Item										SUS Score	SUS Grade
		1	2	3	4	5	6	7	8	9	10		
1	1	3	1	5	3	3	2	4	3	3	3	65	C
1	1	3	1	4	2	4	2	4	2	4	3	72.5	C
2	1	3	2	5	1	4	2	5	1	5	3	82.5	A
2	1	4	1	3	1	3	1	4	1	2	1	77.5	B
2	1	3	2	5	2	5	2	5	1	4	3	80	A
2	1	2	2	4	3	4	2	3	3	4	3	60	D
2	2	5	2	5	2	4	2	3	3	5	3	75	B
2	1	3	2	2	2	4	1	5	2	4	1	75	B
2	1	5	1	4	2	4	2	4	2	4	3	77.5	B
2	2	3	2	3	2	4	2	4	2	4	3	67.5	C
1	1	3	3	4	2	4	2	3	2	2	1	65	C
2	1	5	1	5	1	4	2	3	2	4	1	85	A
1	1	3	2	4	2	4	2	3	2	3	3	65	C
2	1	3	1	5	1	5	2	3	1	3	1	82.5	A
2	1	3	1	4	2	5	2	1	2	5	1	75	B
1	1	5	1	5	1	5	1	4	2	5	1	95	A

Source: Authors

With this application, registration for the workshops is controlled by means of an attendance limit. According to availability, the application facilitates the editing and, if required, deletion of workshop information, fulfilling the first specific objective.

Since the application is responsive, conference attendance can be registered from a smartphone. Attendees can scan a QR code to record their attendance at the workshops for which they have previously registered, fulfilling the second and third specific objective.

Certificates of conference participation are generated by the application and sent automatically by email to registered attendees, as specified in the fourth objective.

Box 11

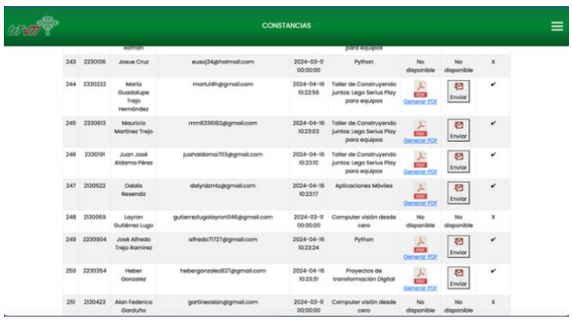

Figure 7

Administration of workshops

The results section shows how an administrator can send the workshop completion certificates by e-mail individually or in bulk. These certificates include a QR code to avoid forgery, fulfilling the fifth objective.

The application was subjected to functionality and usability tests in order to ensure a quality product. The functionality tests enabled errors in the user stories to be identified so they could be corrected, as shown in the excerpt from the test log. The SUS (usability) test placed the application in the B percentile, with a score of 75.92, which can be interpreted as indicating that the perceived usability is acceptable. This is consistent with the table of percentiles, grades, adjectives and metrics to identify SUS scores (Sauro, cited by Gamarra, Chávez, and Segundo, 2021).

In the case described in the present study, the application was developed for the Information Technology and Software Development Conference, but it can be adapted to any other academic conference held at this university. In the future, the intention is to develop a scientific papers section for the application, where authors and reviewers can be registered and papers evaluated.

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Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Escorza-Sánchez, Yolanda Marysol: Contributed to the project idea, research, programming and writing.

Mendoza-Espinoza, Héctor Eduardo: Contributed to the project idea, research method and technique and testing.

Availability of data and materials

The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

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Abbreviations

CRUD	Create, Read, Update, and Delete
ENDUTIH	National Survey on Availability and Use of Information Technologies in Households
HTML	HyperText Markup Language
ISO	International Organization for Standardization
PDF	Portable Document Format
PHP	Hypertext Preprocessor
PRD	Products
PRO	Processes
PRT	On-screen or printed reports
QR	Quick response code
SCR	Views
SUS	System Usability Scale
TV	Television
US	User Story

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Discussions

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Article

Comparative analysis of natural disasters in the Mexican Pacific: The case of hurricane Otis and its socioeconomic impact on Acapulco

Análisis comparativo de desastres naturales en el Pacífico mexicano: El caso del huracán Otis y su impacto socioeconómico en Acapulco

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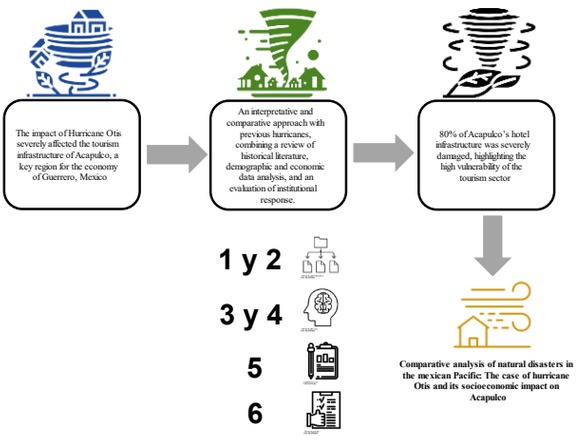
Abstract

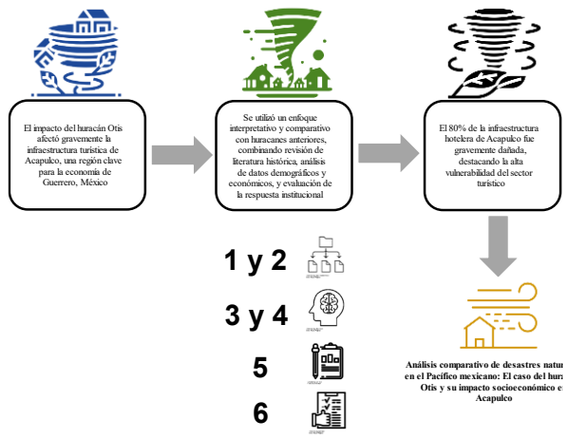
The article analyzed the impact of Hurricane Otis on the tourist infrastructure of Acapulco, a key part of Guerrero's economy. Through an interpretative approach and comparison with previous events like Pauline (1997) and Ingrid-Manuel (2013), it identified factors contributing to the vulnerability of the tourism sector to extreme weather events. The mixed methodology combined literature review, data analysis, and institutional response, revealing that 80% of hotel infrastructure was severely affected. Although recovery phases were implemented, risk communication was insufficient, exacerbating the disaster's impact. The study concludes that improving risk management, communication, and promoting policies that ensure resilient economic recovery are essential to mitigate future disasters.



Risk management, Hurricane Otis, Climate vulnerability

Resumen

El artículo analizó el impacto del huracán Otis en la infraestructura turística de Acapulco, clave en la economía de Guerrero. Mediante un enfoque interpretativo y comparativo con eventos previos como Pauline (1997) e Ingrid-Manuel (2013), identificó factores que contribuyen a la vulnerabilidad del sector turístico ante fenómenos extremos. La metodología mixta combinó revisión de literatura, análisis de datos y respuesta institucional, revelando que el 80% de la infraestructura hotelera fue severamente afectada. Aunque se implementaron fases de recuperación, la comunicación de riesgos fue insuficiente, exacerbando el impacto. El estudio concluye la necesidad de mejorar la gestión de riesgos, la comunicación y fomentar políticas que aseguren una recuperación económica resiliente para mitigar futuros desastres.



Gestión de riesgos, Huracán Otis, Vulnerabilidad climática

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Introduction

The devastating impact of Hurricane Otis on the coastal area of Acapulco, Guerrero, on October 25, 2023, has created an urgent need to analyze and understand the consequences of this event. The purpose of this research is to conduct a detailed analysis of the material damages and the social and economic implications of the hurricane, with a particular focus on aspects such as the flooding of buildings, loss of life, and the effects on essential services, including hotels, restaurants, educational institutions, and health centers.

The effects of hurricanes on coastal regions have been widely studied in geographical literature, beginning with the pioneering work of Gilbert White between 1930 and 1960, who established the distinction between "hazardous natural phenomena," "disasters," and "risks" (White, 1942 & 1974). This research aligns with a conceptual framework that integrates the study of natural and anthropogenic risks, encompassing a wide range of threats, including seismic, volcanic, slope processes, and hydrometeorological hazards (Espinosa Rodríguez, 2020).

In this context, factors such as climate change, environmental degradation, soil erosion, and vulnerability (Rodríguez, 2017) play a crucial role in the assessment of natural disasters. Previous studies on Hurricane Otis, such as that by Luz María Cruz Martín del Campo, highlighted the destruction of essential infrastructure, including electrical, hydraulic, communication, transportation, and building infrastructure, in addition to natural environments.

The magnitude of the impact was such that incidents of looting in businesses, banks, and homes were recorded, underscoring the severity of the situation and the vulnerability of the affected region. This research addresses the need to fill a gap in the scientific literature, particularly regarding the combined effects of wind and water on buildings ranging from two to fifteen stories located along Acapulco's coastline, as indicated by Ramírez-Fernández et al., (2023).

The land-sea and continental interface of Acapulco is a key area of study, where efforts have been made to understand how Hurricane Otis affected vegetation, communities, and infrastructure along its path (García-Méndez et al., 2020). The knowledge derived from this research is fundamental in supporting informed decision-making at local, national, and international levels, particularly in the context of disaster risk management and resilience against hydrometeorological phenomena (Wang & Kim, 2018).

Over the past 50 years, cyclones have caused an average of 43 deaths daily and significant economic losses, although improvements in forecasting, alerts, and risk reduction measures have considerably reduced the number of fatalities (Andrew, 2023). Finally, the relevance of this study is highlighted not only for its contribution to understanding the immediate effects of Hurricane Otis but also for its potential to influence future risk management policies and urban planning in vulnerable coastal areas.

Historical impact of tropical cyclones in Acapulco and the uniqueness of hurricane Otis. The Acapulco region has experienced a particular pattern regarding the direct impact of tropical cyclones, underscoring the uniqueness of Hurricane Otis. In 1973, Tropical Storm Claudia made landfall approximately 30 miles east of Acapulco, causing heavy rains in southern Mexico. However, aside from this event, no tropical storms or hurricanes have directly impacted within a 50-mile radius of Acapulco, according to Henson et al., (2023). This pattern suggests that direct impacts from tropical cyclones in the region are relatively rare.

Nevertheless, when these phenomena have affected the region, their consequences have been devastating. In 1997, Hurricane Pauline devastated approximately 5,000 homes due to flash floods and landslides in various areas of the port.

This phenomenon affected high-altitude zones with steep slopes in El Veladero National Park, located near the city center. As a result, most residents of Acapulco were left without electricity and water, with a loss of up to 500 lives (Rodríguez, 2017).

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In the context of recent tropical cyclones, research by Gao et al., (2022) suggested that the El Niño phenomenon in the central-northern Pacific played a crucial role in the development of these cyclones. This characterization is particularly relevant for Mexico, and especially for the Acapulco region, which has witnessed extreme climatic events.

The magnitude of the impact was such that incidents of looting in businesses, banks, and homes were recorded, underscoring the severity of the situation and the vulnerability of the affected region. This research addresses the need to fill a gap in the scientific literature, particularly regarding the combined effects of wind and water on buildings ranging from two to fifteen stories located along Acapulco's coastline, as indicated by Ramírez-Fernández et al., (2023).

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Hurricane Otis, which made landfall on October 25, 2023, is a paradigmatic example of the intensification of extreme meteorological phenomena in the region. According to the National Meteorological Service, Otis "even surpassed the intensity of Hurricane Patricia in October 2015, which impacted the state of Jalisco, Mexico" (BBC Mundo, 2023, p.1; García et al., 2024). The unprecedented intensity of Otis prompted alerts from the National Meteorological Service of the National Water Commission (CONAGUA), in conjunction with the United States National Hurricane Center and the WMO Regional Specialized Meteorological Center in Miami. These organizations warned of the possibility of catastrophic storm surges, deadly winds, and flash floods in urban areas due to the hurricane (Reliefweb, 2023, p.1).

Methodology

This article employed an investigative methodology grounded in the interpretative paradigm, focusing on understanding phenomena from the perspective of specific contexts.

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The research was designed as an exploratory and descriptive study aimed at identifying and describing the characteristics and effects of Hurricanes Pauline, Ingrid-Manuel, and Otis in the Acapulco region of Guerrero, Mexico. A combination of qualitative and quantitative techniques was used to achieve a comprehensive understanding of Hurricane Otis's impact, with the analysis rooted in the theoretical concepts of disaster geography.

Theoretical and methodological approach. The theory underpinning this study was based on the geography of natural disasters in Mexico, with a particular emphasis on the contributions of Dr. Irasema Alcántara Ayala, who conducted extensive research on earthquakes, floods, landslides, and hurricanes. This theoretical framework provided a crucial analytical foundation for examining the impact of Hurricane Otis in Acapulco, Guerrero, and was essential for territorial planning and management, encompassing infrastructure location, sustainable urban development, natural resource conservation, and natural risk mitigation.

Research phases. The study's methodology was structured into five essential phases:

First phase: Literature review. An exhaustive review of both printed and digital literature related to risk geography, disasters, tourism, and hurricanes affecting Acapulco from 1921 to 2023 was conducted (Niño-Gutiérrez et al., 2017). The review also included specialized literature on sustainability (Mercado & Ramírez, 2023) and tourism (Fernández-Palacios & Haroun, 2007). This review facilitated addressing key questions regarding the vulnerability of Acapulco Bay to flood disasters and the associated risk management and reduction methods.

Second phase: Collection of secondary data. This phase focused on collecting secondary data by examining digital archives and printed documents, both bibliographic and hemerographic, containing information on the development of Hurricane Otis and its effects on the economic, tourism, social, and environmental sectors. The goal was to balance the quality of sources focused on risk and disaster geography while identifying possible information gaps that determined the scope and limitations of the research.

Third phase: Analysis of historical hurricanes. An analysis of hurricanes impacting Mexico from 1921 to 2023 was conducted, including the creation of a 1:22,000,000 scale representation of each hurricane's trajectory that directly or indirectly passed through Acapulco. To obtain precise knowledge of the sites and neighborhoods affected by Hurricane Otis, fieldwork was carried out between November 2023 and April 2024. During this phase, tools such as cameras for visual documentation and a field logbook for collecting qualitative and quantitative data were utilized.

Fourth phase: Compilation of detailed statistics. Detailed statistics were generated on the impacts caused by Hurricanes Pauline, Ingrid-Manuel, and Otis to highlight the magnitude of these hydrometeorological catastrophes in southern Mexico. The collected information was processed at the Master's Program in Sustainable Tourism Management at the Autonomous University of Guerrero, where it was also organized into concentrated tables.

Fifth phase: Final analysis and article writing. An exhaustive analysis of the documentary information, statistics, and demographic databases was conducted. Based on this information, explanatory texts were developed, and the final manuscript of the article was drafted. During this stage, it was ensured that the employed methodology remained consistent with the objectives proposed in the study's introduction.

Sampling method. A non-probabilistic convenience sampling method was used, selected due to the exploratory nature of the study and the need to access specific information from relevant and accessible sources. This method included reviewing historical documents and hurricane records, as well as direct field observation for collecting qualitative and quantitative data in the areas affected by Hurricane Otis.

Results and Discussion

The port of Acapulco, located in the state of Guerrero, occupies a geographically privileged position in the southern portion of the Mexican Republic, bordered to the south by the Pacific Ocean.

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This state lies between the extreme geographical coordinates of 16°18’ to 18°48’ north latitude and 98°03’ to 102°12’ west longitude relative to Greenwich (INEGI, 2024). It is bordered to the north by the State of Mexico, to the northwest by Puebla, to the east by Oaxaca, and to the south by the Pacific Ocean, which spans a coastline of 500 km.

Acapulco is characterized by a warm subhumid climate with summer rains (Aw1). Torrential precipitation is concentrated from May to November, with an average of 72 cloudy days per year. The annual mean temperature is 26.5°C, with minimal thermal oscillations due to the moderating influence of the ocean. This climate, along with its proximity to the Pacific Ocean, creates an ideal tropical environment for tourism, a vital activity for the local economy since its development in the 1940s.

The physical configuration of Acapulco's coastline is of significant interest from a physiographic and geomorphological perspective. The sedimentary rocks that form the bay, composed of pulverized local gneiss and schist, gave rise to various beaches such as Manzanillo, Tlacopanocha, and Icacos, among others. The 10% slope allowed for the construction of significant tourist infrastructure, including an extensive hotel zone, restaurants, condominium towers, and residences on the alluvial plain of the coastal lowland of the Pacific Ocean (Niño-Gutiérrez et al., 2017).

The prevailing winds in Acapulco follow a west-southwest direction from January to June and a west-northwest direction in August, October, and November, with speeds ranging between 2.52 and 8.64 km/h. During this latter period, cyclones are common due to higher temperatures and lower pressure on the continent compared to the ocean, causing winds to move from the sea towards land, in accordance with Buys-Ballot’s first law.

From an administrative standpoint, tourism planning in Acapulco places fundamental importance on the landscape to ensure the stability and dynamics of vegetation and to prudently manage the scenic resources of the beach, which is essential for ecologically sustainable tourism operations. This approach has been particularly relevant for the Federal Maritime Terrestrial Zone (ZOFEMAT) (Niño et al, 2018).

In summary, the combination of a privileged geographic location, an attractive tropical climate, and rich marine biodiversity has positioned Acapulco as a key tourist destination. However, these same characteristics also make it vulnerable to extreme hydrometeorological phenomena, such as cyclones, whose frequency and severity may be exacerbated by climate change, affecting both tourism infrastructure and the natural environment. Hydrographic and marine characteristics of Acapulco bay. Acapulco bay features a limited surface hydrography, with streams that only become active during the rainy season. The local marine wave height averages 75 cm above the water surface, with periods of approximately 1.3 seconds. These hydrographic and maritime conditions are distinctive features of Acapulco’s coastal region, enhancing its appeal as a tourist destination.

Soils and ecosystems of the bay. The lithosol soil in Acapulco Bay is characterized by rocky outcrops, which have been utilized for the construction of residential and tourist condominiums up to fifteen stories high. The types of soil present include alluvial, eutric regosol, eutric cambisol, and haplic phaeozem, all of which have low porosity, limited permeability, and poor drainage. The land-sea interface features saline solonchack soils (SPP, 1981), which influence the distribution and management of coastal vegetation. The configuration of Acapulco's marine and terrestrial ecosystems—in terms of relief, soil, vegetation, climate, flora, and fauna—significantly contributes to the development of sun-and-beach tourism in the region. The local flora includes low deciduous forests and species such as coconut (Cocos nucifera L.), tamarind (Tamarindus indica L.), and amate (Ficus sp.), while the diverse marine fauna is supported by the presence of rocky reefs. This biodiversity is a key resource for tourism activities in the bay.

Cyclonic activity in the region. The tropical cyclone season in the Atlantic Ocean, affecting the eastern coast of Mexico, particularly in the states of Tamaulipas and Veracruz, extends from June to November, with a peak in September (Matías, 1998, p. 9). In the Pacific Ocean, the epicenter of cyclone formation is located in the Gulf of Tehuantepec, impacting regions from Chiapas to Baja California.

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A less frequent formation center has also been identified in the Gulf of California, affecting the surrounding coastal areas.

The primary scientific result of this study focused on cyclonic activity in the Pacific, with an emphasis on Hurricane Otis. Following Lidia, Otis recorded even stronger winds, reaching 165 mph (265.5 km/h), highlighting the notable intensification of hurricanes in the region during that period. Other significant hurricanes in the history of the Mexican Pacific include Hurricane 12 in 1957 (225.3 km/h), Madeline in 1976 (145 mph or 233.3 km/h), Hurricane Mexico in 1995 (225.3 km/h), Kenna in 2002 (140 mph or 225.3 km/h), Patricia in 2015 (150 mph or 241.4 km/h), and Hurricane Lidia in 2023 (225.3 km/h), all of which recorded extremely strong winds (Poveda, 2004).

These events underscore the importance of close monitoring of cyclonic activity in this region, which is particularly vulnerable to severe impacts. This analysis represents the first significant scientific contribution to risk geography applied to Hurricane Otis, developed by local researchers (Figure 1).

Box 1

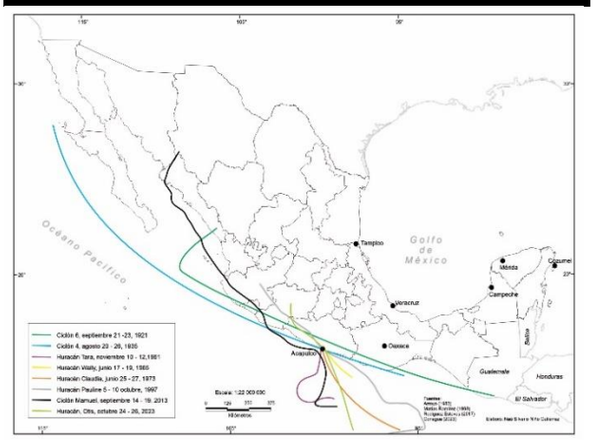

Figure 1

Hurricanes that have impacted Acapulco, Guerrero, Mexico 1921-2023

Source: Matías (1998); Arroyo (1983); Rodríguez (2017); Servicio Meteorológico Nacional-CONAGUA (2023); & Niño-Gutiérrez (2023).

Impact of hurricane Otis on tourism infrastructure. Tourism has historically been the primary source of income for the state of Guerrero, generating an economic impact of 6 million pesos in 2023, driven by a flow of 977,000 people and an average hotel occupancy rate of 65.3% (Gobierno del Estado de Guerrero, 2024).

However, Hurricane Otis severely impacted this industry, affecting 80% of the hotel infrastructure, according to the Acapulco Hotel and Tourism Business Association (AHETA). The estimated losses in infrastructure damage amounted to 15 billion dollars, as reported by the National Business Council for Tourism of Mexico.

The results highlighted both the vulnerability and resilience of Acapulco's port in the face of extreme climatic events. The tourism infrastructure, essential to the region's economy, was severely affected, underscoring the urgent need to improve disaster preparedness and response capacity.

Demographic growth and risk vulnerability. Population growth in Acapulco from 1900 to 2023 shows a significant trend that has increased the region's exposure to hydrometeorological phenomena. The municipality's population grew from 4,932 people in 1900 to 852,622 in 2023 (INEGI, 2023). This demographic increase was partly driven by the rise of commerce and the flourishing of tourism since the 1960s, which has heightened the population's exposure to risks such as hurricanes and floods.

The accelerated population growth and economic development in recent decades have exacerbated the consequences of extreme climatic events. A notable example was Hurricane Pauline in 1997, one of the most significant natural disasters in Acapulco's recent history, with devastating effects on the region (Rodríguez, 2017).

Climatic characteristics and recovery challenges. Acapulco bay, with its distinctive "shell" shape and tropical climate with summer rains (Aw), has become a world-renowned tourist icon, attracting both national and international visitors. However, its geography and climate also make it vulnerable to intense climatic phenomena. Precipitation is more frequent between June and November, with September and October being the months of highest risk for catastrophic hurricanes.

These climatic events not only affect environmental recovery but also impose high costs on the economic restoration of the affected infrastructure.

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Notable examples of these challenges include Hurricanes Pauline in 1997, Ingrid-Manuel in 2013, and Otis in 2023, which have had a lasting impact on the region.

Recovery prospects and investment opportunities. In the context of Acapulco's tourism recovery, authorities indicated that of the 284 hotel establishments, 80% had a capacity of up to 40 rooms. According to SERFIMEX, the current gap in tourism could represent an opportunity for investors in sectors such as hotels, entertainment, restaurants, and services (Figueroa, 2023).

The resilience of Acapulco and the recovery initiatives provide an opportunity to reimagine and strengthen the tourism infrastructure, promoting investments that not only restore what was lost but also enhance the region's capacity to face future climatic challenges.

Impact of hurricane Otis and comparison with previous events. hurricane Otis was compared with previous events such as Pauline in 1997 and Ingrid-Manuel in 2013, revealing a continuous pattern of significant damage in the region. This comparative analysis, presented in Table 1, represented the second scientific contribution to the geography of risk by identifying the elements that have made these hydrometeorological phenomena notorious. The findings highlighted the urgent need to develop more robust strategies for risk mitigation and post-disaster recovery in Acapulco.

Evaluation of institutional response and risk communication. Federal authorities implemented an early warning system, providing meteorological information to state and municipal governments as well as the exposed population. However, despite these efforts, the effectiveness of risk communication was deemed insufficient to prevent disasters. The failure to comply with effective communication, which involves five phases (preparation, initiation, control, recovery, and evaluation), resulted in inadequate preparedness by both authorities and the local population, exacerbating the magnitude of the disaster caused by Otis (Presidencia de la Nación, 2016; IFRC, 2023).

In response to the impact of Hurricane Otis, the phases of initiation, control, recovery, and risk evaluation were addressed through coordinated actions under a unified command involving all governmental agencies. The federal government led efforts to mitigate flood damage in critical areas of Acapulco, including Colonia Zapata, Ciudad Renacimiento, Avenida Costera Miguel Alemán, Costa Azul, Pie de la Cuesta, and Diamante (UNFCCC, 2023).

Governmental response and support for recovery. Under the leadership of Secretary Ariadna Montiel Reyes, the Federal Ministry of Welfare implemented measures for the cleaning and reconstruction of homes affected by Hurricane Otis. A total of more than 322,000 support packages were distributed in two phases, coordinated by the Ministry of Welfare, to assist families impacted by the damage in Acapulco (Secretaría de Bienestar, 2024).

At the state level, the Ministry of Inclusion and Social Welfare (SIBISO), based in Chilpancingo, coordinated public policies on social development, equity promotion, and community social services in the state of Guerrero (Gobierno del Estado de Guerrero, 2024). At the federal level, the National Institute of Transparency, Access to Information, and Personal Data Protection (INAI) instructed the Ministry of Welfare to search for and, if necessary, disclose detailed documentation of the census of people affected by Hurricane Otis in Acapulco and Coyuca de Benítez, Guerrero (Redacción El Economista, 2024).

Economic impact on the tourism sector and resilience. Hurricane Otis caused severe damage to the hotel sector, particularly along the coastal strip of Acapulco and Coyuca de Benítez. Small business owners, including those of commercial establishments, restaurants, bars, and hotels, required accessible loans to rebuild their assets. In response, the federal government, through the National Financial Institution for Welfare in Mexico, offered two support schemes. The first, aimed at microenterprises, offered amounts of 25,000 pesos at zero interest, with a 30-month term and a six-month grace period. The second scheme provided loans ranging from 30,000 to 300,000 pesos, with an annual interest rate of 6.5%, payable over 24 months with a four-month grace period (El Sol de Acapulco, 2024a).

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Additionally, insurance companies paid more than two billion dollars to owners of automobiles, businesses, and hotels in Acapulco and Coyuca de Benítez for the damages caused by Otis. This hurricane became the third most catastrophic natural phenomenon for the insurance sector in Mexico, following the Covid-19 pandemic and Hurricane Vilma (El Sol de Acapulco, 2024b).

These efforts highlighted the need for accessible loans and the importance of insurance in economic recovery, which are critical measures for the resilience of the tourism sector and the local economy.

Impact of hurricane Otis and the insurance sector's response. Hurricane Otis triggered one of the largest demands for insurance claims in Mexico's history, with 104 claims from hoteliers and 20 claims from homeowners.

As of April 15, 2024, 73 billion pesos had been paid in indemnities for losses related to automobiles, homes, hotels, restaurants, and other sectors, although some payments were still being processed (El Sol de Acapulco, 2024c). This disaster became one of the most costly natural events recorded in the country (El Sur Acapulco, 2024).

Need for investments and policies for sustainable recovery. Despite comparisons with previous studies that indicated a rapid recovery of the tourism sector following natural disasters due to effective reconstruction strategies (Poveda, 2004), findings in Acapulco suggest an urgent need for investments and policies that support a sustainable and resilient recovery.

The effects of hurricane Otis manifested in a real estate crisis and spatial segregation in areas such as Las Cruces, La Colonia Zapata, and Ciudad Renacimiento, as well as in the devaluation of residential developments, hotels, and restaurants in tourist zones like Punta Diamante (Valentín, 2024).

These results align with studies advocating for more sustainable and resilient urban planning in vulnerable areas (Zárate, 2024).

Impact of hurricane Otis on infrastructure and housing. Residents of popular neighborhoods in Acapulco, such as Renacimiento, Santa Cecilia, Simón Bolívar, Lázaro Cárdenas, Primero de Mayo, Vicente Guerrero, Los Lirios, and Benito Juárez, witnessed the severe impact of Hurricane Otis on homes, streets, bridges, and public services (El Sol de Acapulco, 2024c).

In response to the devastation, a working group was held on April 30, 2024, to facilitate the reconstruction of Acapulco post-Otis, attended by more than 50 representatives from the Dorada and Diamante zones. At this event, Julián Urióstegui Carbajal, president of the Business Coordinating Council (CCE) of Guerrero, highlighted that the Diamante area was one of the most affected, with 40 buildings and condominiums housing 8,000 apartments suffering significant damage, representing almost half of Acapulco's tourist real estate offering (El Sur Acapulco, 2024).

Prospects for resilient recovery. The study's results underscore the need to build a more resilient community in the face of current and future extreme climatic events, such as Hurricane Otis. To achieve this goal, it is essential to continue improving risk preparedness, risk communication, and the population's adaptive capacity. Laura Polanco shared this perspective, noting that Acapulco needed a catalytic project with substantial capital investment to promote a sustainable and resilient destination in the face of economic fluctuations, pandemics, natural disasters, and changes in global tourism trends.

Context of natural disasters in Mexico. "According to the EM-DAT database, 231 disasters were recorded in Mexico between 1900 and 2018" (Alcántara-Ayala, 2019, p. 4).

The most significant disasters in the country were primarily related to storms, followed by floods, earthquakes, mass removal processes, and, finally, volcanic activity. In Acapulco's coastal strip, all of these events were present, except for volcanic eruptions, maintaining a notable parallel in terms of the magnitude and frequency of such disasters at both local and national levels (Delgado-Ramos et al., 2024).

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Recommendations for infrastructure and public services. Finally, it is crucial that the future research agenda focuses on improving the provision and quality of residential, hotel, and restaurant infrastructure in Acapulco's coastal strip (Zárate, 2024). Simultaneously, it would be beneficial to maintain and even enhance municipal public services, preserve the balance of quality public green spaces along Avenida Costera Miguel Alemán Velasco, as well as in the central medians of Las Cruces, La Colonia Zapata, Ciudad Renacimiento, and Vacacional, where public transportation services could be more efficient. In this way, the present discussion remained focused on the study's objectives and the need to ensure balanced and safe urban development in Acapulco.

Conclusions

The analysis of the impacts of Hurricane Otis in Acapulco revealed the severe vulnerability of the tourism infrastructure, a fundamental pillar of the region's economy. With significant economic losses, it was estimated that 80% of the hotel infrastructure was affected, highlighting the fragility of the tourism sector in the face of large-scale hydrometeorological phenomena.

The study of Acapulco's population growth from 1900 to 2023 showed continuous growth, especially from 1960 onwards, coinciding with the rise of commerce and tourism. This population growth has increased exposure to natural disasters, as evidenced by catastrophic events such as Hurricanes Pauline (1997), Ingrid-Manuel (2013), and Otis (2023).

Despite the implementation of the phases of preparation, initiation, control, recovery, and risk evaluation, risk communication and local preparedness were insufficient to mitigate the devastating impact of Hurricane Otis. This finding reflects the urgent need to improve disaster information management and preparedness in the region.

The comparative analysis with other catastrophic hurricanes in the Mexican Pacific, such as Patricia (2015), Madeline (1976), and Kenna (2002), indicated a trend towards the intensification of hurricanes in the region. The magnitude of the damages caused by Otis, with winds of up to 165 mph, reinforces the importance of continuously monitoring and studying the evolution of these climatic phenomena.

Finally, the data on insurance and post-Otis indemnities revealed the high economic cost for the insurance sector, with over two billion dollars paid in claims. This demonstrates the considerable financial burden that natural disasters impose, consolidating Otis as one of the most costly natural disasters in Mexico's recent history.

Declarations

Conflict of interest

The author of this article declares that there are no financial, personal, academic, or professional conflicts of interest that could have influenced the research, results, or interpretation of the data presented in this study. All procedures and analyses were conducted independently and objectively, without the influence of external entities that could compromise the integrity of the scientific work performed.

Author Contribution

Niño-Gutiérrez, Naú Silverio: The author of this article has played an integral role in all phases of the research, from the conception and design of the study to the collection, analysis, and interpretation of the data. The combination of these contributions ensures that the work presented is not only a significant contribution to the field of disaster geography and urban resilience but also a reflection of the author's commitment to rigorous research and the advancement of knowledge in this area.

Availability of data and materials

Availability of data: The collected data as well as supplementary materials accompanying the publication of this research are accesible to other users. Trough request to the author.

Availability of materials: The author specify that the materials are freely available for the users to use without any restrictions or conditioned associated with Access to them. This means that the materials, such as data sets, or other resources, can be accessed and utilized by anyone interested in the research without requiring permission or facing any limitations.

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Abbreviations

CONAGUA = National Water Commission
IFRC= International Federation of Red Cross and Red Crescent Societies
INEGI = National Institute of Statistics and Geography
SMN = National Meteorological Service
SPP = Secretariat of Programming and Budget (now part of the Secretariat of Finance and Public Credit)
UNFCCC = United Nations Framework Convention on Climate Change

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Background

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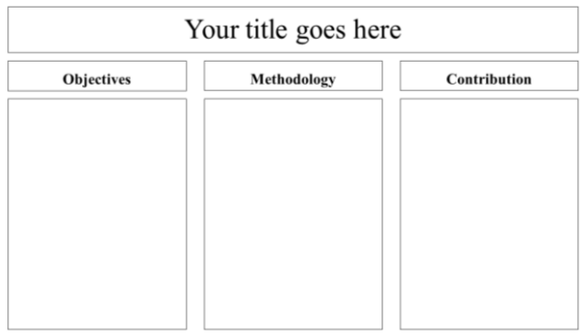

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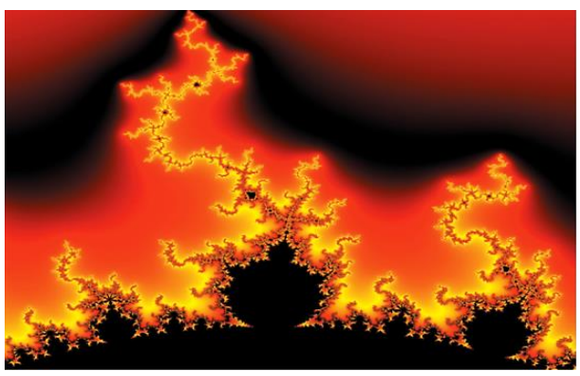

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