ENVIRONMENTAL SCIENCES & PRACTICES

Environmental Sciences & Practices

JANUARY - JUNE, 2024

VOL. 2 No. 1

https://www.mlsjournals.com/Environmental-Science-Practices

ENVIRONMENTAL SCIENCES & PRACTICES

Environmental Sciences and Practices

Vol. 2 ● Núm. 1 ● Junio – June - Junho 2024

https://www.mlsjournals.com/Environmental-Science-Practices

SUMARIO / SUMMARY / RESUMO

Editorial

In the phase of the COVID 19 Pandemic; We had havoc worldwide, which obviously affected our processes, fortunately in the recovery period it was also an opportunity to strengthen our editorial ecosystem, with the incorporation of responsible associate editors from institutions of Ibero-American representation, all of them prestigious, such as the Autonomous University from the State of Mexico; The Inter-American Center for Environmental and Territorial Development and Research of the University of the Andes, in Mérida Venezuela; ; Vilaseca Consultores, leaders in environmental services in Spain and Europe and the Interdisciplinary Center for Research and Studies on Environment and Development of the National Polytechnic Institute in Mexico; All of them recognized in the Ibero-American field and that today marks a watershed in the history of our Publication, in this issue with six articles of importance in the context of the events of the planet in environmental matters, such as the agricultural issue, the occupation of the territory and its territorial environmental planning, new teaching-learning models and new technological tools in this context are the topics today; Also consider the rational use and use, with a sustainability approach of fossil fuels and the trends with a prospective approach, of the European city model in the Latin American context, are topics of great impact for the rational use of our resources and think about the design of products and processes from a sustainable approach to have as a “sine qua non condition; the environmental variable as a priority!”

We have in the foreground of the articles published today, on “Sustainable agricultural development to optimize productivity through good soil management in Benguela-Angola”; The research is based on an exhaustive review of the literature using the qualitative documentary method, consulting national and international authors, as well as national educational plans and programs. The main objective of this research is to evaluate the state of the soils in the province of Benguela-Angola and propose strategies to improve the quality of arable soils. This would contribute to sustainable agricultural development and encourage environmentally friendly soil management practices. The Benguela-Angola region offers great opportunities to improve soil quality and achieve sustainable production. The results obtained highlight the urgent need to implement preventive and corrective measures to stop soil contamination and remediate already affected soils. The implementation of sustainable agricultural practices is proposed, such as organic agriculture and the responsible use of chemicals. In addition, the adoption of soil conservation techniques is suggested, such as crop rotation, planting vegetative covers and building terraces. Implementing the proposals mentioned above, in collaboration with farmers, industries, local governments and communities, can make a significant difference. The adoption of sustainable agricultural practices, proper waste management, protection of natural vegetation areas and community awareness are key elements to achieve sustainable production and optimize productivity through proper soil management in the study region.

Secondly; “Mendoza from a geological perspective applied to urban planning from the 16th to the 18th century”; A historical geological hazard zoning was developed through the occurrence data documented in the historical records analyzed. Five units were obtained, resulting in the area with the occurrence of potentially harmful processes that includes the urban area of the founding City of Mendoza. This is located in the area of alluvial cones and fans of the Mendoza River, that is, it is part of the environment where the discharge of sedimentary material from the foothills of the Andes is generated. Consequently, the acting processes were: floods, alluvium, salinity and active faulting through the Cerro de la Cal fault, whose trace crosses the city. In short, framing the environmental processes of a city from urban geology is essential to establish the threats or dangers and potential damages that affect or may affect the territory.

The third article within the teaching-learning processes is about the “Learning styles of engineering students at the National Autonomous University of Honduras UNAH”; It allows us to visualize how the Engineering students of the National Autonomous University of Honduras UNAH. The determination of students' learning styles opens a gap so that educational experiences can be built through study plans and activities. curricular and extracurricular activities that benefit learning, to train better engineers who contribute to the solution of the enormous problems that overwhelm the Honduran population, in areas such as forestry, agronomic, industrial, chemical, electrical, mechanical, systems and agroindustrial. A significant correlation at 0.001 was found between the active, reflective and pragmatic style, concluding in relatively low values in the levels associated with learning styles, which defines great possibilities for the design of appropriate learning experiences in careers.

The Fourth article emphasizes the "Importance of incorporating sustainable values in the professional practice of design" considering design as one of the professional practices with the greatest environmental impact due to the weight played by the decisions made when configuring the world. material, reflected in the damage generated by the objects resulting from the design process: mountains of everyday products that are manufactured by the millions, causing the depletion of planetary resources and generating all types of emissions and toxic waste throughout their life cycle. life. The analysis is carried out taking as a reference the ISO 14006 standard, governing ecodesign concepts. The methodology used detailed background research on sustainable design and its strategies, a diagnostic questionnaire conducted with industrial designers, with at least two years of work experience, working in small and medium-sized companies, and an in-depth interview conducted with a panel. of experts, who helped define the problem, confirm the findings obtained and, from their experience, guide the process of incorporating sustainability into professional design work.

The fifth article on the "Technical evaluation of the installation of a biorefinery in Costa Rica to obtain bioethanol from forest residues from sawmills in the northern part of the country"; The study consists of the technical evaluation to install a biorefinery in Costa Rica. Waste from sawmills located in the northern part of the country, 30 kilometers around Boca Arenal, San Carlos, is quantified and a mass balance is carried out from secondary sources and using the chemical process simulator DWSIM version 7.5. 5, to produce ethanol for the purpose of mixing with gasoline consumed in Costa Rica. The methodology consists of a non-experimental, transectional or transversal design, and for a population of 24 sawmills, 20 interviews were applied from which it was obtained that 40,447 tons are produced annually, and under the thermochemical modality, using all waste as raw material. From the sawmills in the study area, 16,414.30 kilograms of ethanol per day (20.84 cubic meters per day) are obtained, with a purity of 99.8% v/v, thus managing to supply 5.16% of the gasoline mixed with ethanol. They are consumed in Costa Rica, with residual syngas and methanol as secondary products. Given the availability of raw materials and technologies for the conversion of biomass into ethanol, the installation of a biorefinery in Costa Rica is technically feasible, and it is favorable to take into account other lignocellulosic sources such as fractions of urban waste, agricultural waste and industrial waste; in addition to other geographical regions, it is essential to carry out a financial feasibility study for the biorefinery, to determine the viability of the project.

Finally, the sixth article with a prospective approach on the "Analysis of Guatemala City applying the European model of smart cities"; An analysis of five parameters that make up a smart city adapted to Guatemala City is presented. These parameters were extracted from the European Smart Cities Model found in the report "Smart Cities: Classification of large European cities". Due to the uncertainty surrounding the global meaning of a smart city, the parameters proposed to cover the topic at all consist of: Economy, Population, Governance, Mobility and Environment. Each of these will be evaluated with three indicators selected based on the availability of the data required for the analysis, which is currently available for Guatemala City. Next, the status of each parameter is based on an analysis and development based on official qualitative and quantitative data extracted from the corresponding ministries, public entities and reports from non-profit organizations. Once the collection of information has been concluded and the final state of each of the five parameters in the body of the work has been determined, the conclusions chapter summarizes the gaps and limitations for the adaptation of the Model to this particular city. Finally, recommendations are included for the dissemination of this study and its possible adaptation for other cities with characteristics similar to those of Guatemala City.

Finally, our thanks to our International Scientific Committee; integrated by the Universidad Internacional Iberoamericana, Puerto Rico; from the Autonomous University of Chapingo, Mexico; to the CEPA Foundation and FLACAM, Argentina; to the Center for Biological Studies, Environment and Natural Resources A.C, Mexico; to the Autonomous University of the State of Mexico and to the Paraibana Academy of Engineering and the Federal University of Paraíba, both of the latter in Joao Pessoa Brazil.

Dr. Miguel Ángel López Flores
Editor Jefe / Editor in chief / Editor Chefe

ENVIRONMENTAL SCIENCES & PRACTICES
http://mlsjournals.com/Environmental-Science-Practices

(2024) Environmental Sciences & Practices, 2(1), 7-21.

Sustainable agricultural development to optimize productivity through good soil management in Benguela-Angola

Desarrollo agrícola sostenible para optimizar la productividad a través del buen manejo del suelo en Benguela-Angola

Alejandro Cruz Arafet
Higher Polytechnic Institute Benguela, Angola
(valeforxaca@gmail.com) (https://orcid.org/0009-0007-1163-7495)
Roberto Cruz Acosta
Higher Polytechnic Institute Benguela, Angola
(roberto.acosta@ispbenguela.com) (http://orcid.org/0000-0002-7282-8857)

Manuscript information:

Received/Recibido: 25/09/23
Reviewed/Revisado: 15/01/24
Accepted/Aceptado: 25/01/24

ABSTRACT

The research is based on an exhaustive review of the literature using the qualitative documentary method, consulting national and international authors, as well as national educational plans and programs. The main objective of this research is to evaluate the state of the soils in the province of Benguela-Angola and propose strategies to improve the quality of arable soils. This would contribute to sustainable agricultural development and encourage environmentally friendly soil management practices. The Benguela-Angola region offers great opportunities to improve soil quality and achieve sustainable production. The results obtained highlight the urgent need to implement preventive and corrective measures to stop soil contamination and remediate already affected soils. The implementation of sustainable agricultural practices is proposed, such as organic agriculture and the responsible use of chemicals. In addition, the adoption of soil conservation techniques is suggested, such as crop rotation, planting vegetative covers and building terraces. Implementing the proposals mentioned above, in collaboration with farmers, industries, local governments and communities, can make a significant difference. The adoption of sustainable agricultural practices, proper waste management, protection of natural vegetation areas and community awareness are key elements to achieve sustainable production and optimize productivity through proper soil management in the study region.

Keywords:
Agricultural development, sustainability, soils, agricultural production.

RESUMEN

La investigación se basa en una revisión exhaustiva de la literatura utilizando el método cualitativo documental, consultando autores nacionales e internacionales, así como planes y programas educativos nacionales. El objetivo principal de esta investigación es evaluar el estado de los suelos en la provincia de Benguela-Angola y proponer estrategias para mejorar la calidad de los suelos cultivables. Esto contribuiría al desarrollo agrícola sostenible y fomentaría prácticas de manejo del suelo

Palabras clave:
desarrollo agrícola, sostenibilidad, suelos, producción agrícola.

	respetuosas con el medio ambiente. La región de Benguela-Angola ofrece grandes oportunidades para mejorar la calidad del suelo y lograr una producción sostenible. Los resultados obtenidos resaltan la necesidad urgente de implementar medidas preventivas y correctivas para detener la contaminación del suelo y remediar los suelos ya afectados. Se propone la implementación de prácticas agrícolas sostenibles, como la agricultura orgánica y el uso responsable de productos químicos. Además, se sugiere la adopción de técnicas de conservación del suelo, como la rotación de cultivos, la siembra de coberturas vegetales y la construcción de terrazas. La implementación de las propuestas mencionadas anteriormente, en colaboración con agricultores, industrias, gobiernos locales y comunidades, puede marcar una diferencia significativa. La adopción de prácticas agrícolas sostenibles, la gestión adecuada de residuos, la protección de áreas de vegetación natural y la concienciación comunitaria son elementos clave para lograr una producción sostenible y optimizar la productividad a través del manejo adecuado del suelo en la región de estudio.

Introduction

Agriculture plays a crucial role in society by providing the food necessary to satisfy the basic needs of human beings, thus becoming the most important economic sector. In Angola, important changes have been implemented in recent years with the aim of reducing the economy's excessive dependence on mineral resources and oil, and promoting the development of other sectors, where agriculture plays a decisive role.

However, there is a trend in the country towards an almost doubled annual expansion of the cultivated area towards natural and marginal areas. This expansion is mainly due to the low yields obtained per unit area. Unfortunately, in most cases, this expansion leads to significant environmental damage, such as soil erosion, salinity, desertification, deforestation, and threats to biodiversity and water scarcity.

Addressing these challenges is critical to ensure the sustainability of agriculture in Angola. Proper management of natural resources and careful planning are required to minimize negative impacts on the environment. In addition, it is necessary to implement sustainable agricultural practices that increase yields per unit area without compromising soil health and biodiversity.

Agriculture in Angola plays a key role in the country's economic development. However, it is necessary to address the challenges related to the expansion of cultivated area in natural and marginal areas, which entails significant environmental damage. The implementation of sustainable agricultural practices and the proper management of natural resources are key to ensuring the long-term sustainability of agriculture in Angola.

Soil, as a fundamental resource for the survival of mankind and other species, provides 95% of the food we consume. Despite its importance, its environmental protection has long been neglected. Insufficient attention has been paid to the threat posed by human activities to soil, an increasingly scarce and invaluable natural resource due to its central role in the interaction between the geosphere and the biosphere. Soil degradation leads to the loss of ecosystem services, which has serious consequences.

In this context, soil protection has become increasingly important in Angola, in line with Africa's efforts to achieve a sustainable territory. The Angolan government has made a strong commitment to soil preservation and is working on the implementation of increasingly advanced sustainability criteria in various areas, such as land use and urban planning, agriculture, livestock, forestry, management of natural areas and remediation of contaminated soils.

To coordinate these interventions, Angola has developed the Soil Protection Strategy, established by Presidential Decree No. 177/20 of June 23. This strategy, approved by the Ministry of Agriculture and Fisheries, proposes to meet the objectives set by working in a collaborative and coordinated manner with all stakeholders involved in the protection of this natural resource. The strategy addresses the most pressing environmental concerns, such as climate change and biodiversity loss, and integrates them with traditional challenges, such as the loss of water and air quality. The resulting approach is a combination of integrative concepts that allow environmental protection to be addressed while incorporating social and economic aspects.

The challenge is to rehabilitate degraded soils and minimize land degradation and occupation in net terms. Healthy soils are essential for achieving climate neutrality, a circular and clean economy, reversing biodiversity loss, ensuring healthy food, protecting human health and combating desertification and land degradation. Humans and other species that inhabit the Earth need direct contact with the soil and terrestrial ecosystems.

It is essential to take measures to protect and preserve the soil as a vital resource. Angola is committed to this task and has established a comprehensive strategy that addresses environmental challenges and promotes collaboration between different sectors. Only through the rehabilitation of degraded soils and the adoption of sustainable practices can we ensure a healthy and sustainable future for our planet.

Despite the launching of the RETESA (Rehabilitation of Land and Management of Pasture Areas in Smallholder Farming Systems in Southwest Angola) project by the United Nations Agency, which is recognized as a starting point for the development of activities focused on the promotion and management of pasture areas, the reality is that Angola continues to face significant soil loss due to erosion. According to the advisor of the United Nations Food and Agriculture Fund (FAO), it is estimated that the country loses around 20 million tons of soil per year, which is equivalent to a loss of capacity to feed approximately 50,000 people.

Land for agricultural production is often obtained through the traditional slash-and-burn process of native forests. This practice, known as slash-and-burn agriculture, has long been employed and is considered the first step in the transition from a society based on food gathering to a society that produces its own food (Zhang, Y., Ram, MK, Stefanakos, EK and Goswami, DY (2012)). Although still practiced in several regions of the world, this technique has significant negative impacts on the environment.

Slash-and-burn agriculture is economically viable and offers advantages to farmers by allowing them to prepare new land for planting and other agricultural activities. However, it also has serious consequences for the environment. It decreases biodiversity and increases soil erosion, thus contributing to the problem of deforestation and soil impoverishment. Fires resulting from this practice often get out of control and spread, destroying large areas of forest.

Alterations to the natural land cover due to human activities also influence the hydrological system. Some land use changes do not immediately alter the hydrologic response, but occur progressively over time (Schulze, 2003 cited by Wartbuton, 2012). The practice of slash-and-burn to obtain agricultural land has economic and cultural advantages for farmers, but also has negative impacts on the environment, such as reduced biodiversity and increased soil erosion. It is important to promote sustainable agricultural practices that minimize these impacts and promote the conservation of natural resources.

Degradation of vegetation cover and deforestation of woody plants and shrubs are processes widely linked to desertification. Desertification is defined as land degradation in arid, semi-arid and dry areas, which occurs as a result of climatic changes and/or human activities (UNCCD 1994 cited by Dawelbait and Morari 2012). In these regions, natural resources such as land, water and vegetation are extremely fragile and highly susceptible to degradation (CCD/UNEP 1995). Population growth and the increasing demand for food, feed and energy have generated a series of interconnected economic, social and environmental problems related to soil degradation. In essence, desertification is the result of land degradation.

Currently, one of the main challenges related to inadequate soil management lies in poor conservation practices, especially with regard to land preparation, fertilization, crop rotation and association, as well as irrigation. (Giraldo, S. C. (2016)). Through the proper use and management of the chemical, physical and biological properties of the soil, together with the implementation of conservation practices, it is possible to guarantee its balance and recovery, thus increasing its fertility and avoiding degradation problems and, consequently, food shortages. Soil degradation currently represents a considerable threat to the future of humanity, which is of great concern to the scientific community and poses the triple challenge of intensifying soil conservation in an appropriate manner in order to maintain its balance and fertility, which contributes to guaranteeing food availability and preserving natural resources for future generations. It is necessary to implement sustainable soil management practices, promoting education and awareness of the importance of soil conservation.

It is essential to integrate sustainable land management into all agricultural, pastoral and forestry development initiatives in southwest Angola. This involves not only the rehabilitation of grazing areas through improved pasture and herd management, but also the implementation of project monitoring strategies and dissemination of best practices. In addition, the capacities of farming communities must be strengthened to reduce the impact of land degradation processes and achieve their rehabilitation.

The objective of this research is to evaluate the state of soils in the province of Benguela-Angola and to develop strategies to improve the quality of arable soils. This study aims to contribute to sustainable agricultural development and promote environmentally friendly soil management practices.

Method

This research is the result of a thorough review of the literature following the method: Qualitative documentary. Several national and international authors and even national educational plans and programs were consulted, an exploratory-descriptive research was conducted, with the main objective of this research is to assess the state of soils in the province of Benguela-Angola and propose strategies to improve the quality of arable soils. In this way, it seeks to contribute to sustainable agricultural development and promote environmentally friendly soil management practices.

Characteristics of Benguela Province

Benguela, a city and municipality located in the province of Benguela, western Angola, is recognized as the capital of the province. The municipality is made up of only the headquarters municipality, which is divided into six zones. According to population projections prepared by the National Institute of Statistics for 2018, Benguela has a population of 623,777 inhabitants and a territorial area of 2,100 km^2, making it the most populous municipality in the province and the tenth most populous in the country. . It is bordered to the north by the municipality of Catumbela, to the east by the municipalities of Bocoio and Caimbambo, to the south by the municipality of Baía Farta and to the west by the Atlantic Ocean.

Its climate is dry and hot in the coastal zone, with an average temperature of 24.2 degrees Celsius. Minimum Celsius and maximum 35 degrees Celsius. Vegetation is concentrated in the western part of the province and from time to time this part has been greatly reduced in the coastal zone due to deforestation. There are approximately 1 million hectares of potential agricultural land, and it can produce a variety of products thanks to its fertile soil and water resources. The main products are bananas, corn, potatoes (reindeer and sweet potatoes), wheat, coconut, beans, fruits, citrus fruits, mangoes, sugar cane, etc.

The province of Benguela has a high agricultural and livestock potential, which has been historically proven. This is due to a unique soil structure and a favorable climatic diversity, combined with a hydrographic network of enviable quality. With about one million hectares of arable land, the province has great capacity for the development of agricultural activity in this area. Benguela represents an important agricultural region in Angola, with great potential for the development of agricultural and livestock activities. It is known nationally for the variety of its production and for cattle breeding, where it ranks fourth. It currently cultivates an area of approximately 214,000 hectares and the main products amount to some 247,000 tons.

In addition, the average annual temperature in Angola is around 20 degrees Celsius, with lows of 14 degrees and highs of 28 degrees. These moderate temperatures, together with 12 to 13 hours of daylight, provide a favorable environment for the development of various crops and agricultural activity in general.

Soils in Angola are characterized by being predominantly loamy, clayey and sandy. These soil types provide a suitable base for agriculture and other uses. Average annual rainfall in Angola is around 1100 mm, although there are regions where figures can reach 2500 mm. These favorable rainfall conditions contribute to soil fertility and crop growth.

The predominant soils in the Benguela locality are mainly of the ferralitic type, but paraferralitic and lithosols are also present. The latter, although not very representative, are associated with the lower part and the base of the mountain slopes (Diniz 1993; cited by Matas et al., 2007). Paraferralitic soils and lithosols have significantly higher fertility than ferralitic soils and are mainly used for drought crops such as wheat.

In addition, alluvial soils associated with the larger valleys are also found in the Benguela region. These soils, known as "nakas" and "mbalas" by local farmers, are relatively fertile areas that are exploited mainly during the dry season through regulated irrigation of the water table. Vegetables and corn are grown in these areas, taking advantage of the existence of numerous water sources on the mountain slopes (Ramos Noriega, M. I. (2019)).

It is important to highlight the diversity of soils and agricultural characteristics of the Benguela locality. The ferralitic, paraferralitic and lithosol soils present in the region offer different possibilities for the development of sustainable agricultural practices. It is essential to implement soil conservation and water management strategies, as well as to take advantage of soil fertility to ensure long-term agricultural production (Diniz 1993; Matas et al., 2007; Sardinhas 2006).

In summary, Angola has loamy, clayey and sandy soils, with average annual rainfall of around 1100 mm, average annual temperatures of 20 degrees Celsius and 12 to 13 hours of daylight. These conditions are favorable for agriculture and food production in the country.

It is essential to implement strategies and policies that promote the rehabilitation of agricultural activity in Benguela. This involves mine clearance and deactivation, as well as the implementation of support and training programs for farmers to promote sustainable land use and maximize the province's agricultural potential.

According to the Food and Agriculture Organization of the United Nations (FAO), Angola is among the five countries with the greatest agricultural potential in the world. The country has 58 million hectares of arable land, equivalent to an area larger than France. However, only 10% of this land is currently in use, mainly due to the lack of adequate irrigation systems.

In the province of Kwanza del Sur, the country's largest agricultural facility is located at 1,400 meters above sea level in the highlands. With an area of 10,000 hectares, only one third of this area is currently under cultivation. Despite this, 50 different species are currently produced in this area, generating an annual turnover of US$5 million.

It is important to note that, although large private landowners represent approximately 15% of agricultural producers in Angola, they manage to exploit about half of the country's arable land (Table 1). This underscores the need to promote investment in the agricultural sector and encourage the participation of small farmers to take full advantage of Angola's agricultural potential.

Figure 1

Arable land (% of land area) - Angola

Benguela, Angola's vegetable garden

Agricultural production in this region is diverse and abundant (Table 2). The main crops include sisal, cotton, sugar cane, arabica coffee, avocado, banana, potato, sweet potato, sesame, macundé bean, sunflower, guava, papaya, mango, passion fruit, massambala, massango, corn, aromatic plants, vegetables, castor beans, tobacco, eucalyptus and pine.

Approximately 1 million hectares of the total area of 39,826.83 km² are suitable for agricultural activity. Rehabilitation programs are currently being implemented to improve infrastructure to support agriculture, livestock and irrigation. Priority is given to the cultivation of corn, beans, bananas, palm and various vegetables. Gross production is estimated at 80,000 tons.

In addition, we seek to rehabilitate irrigation systems in the interior of the province to benefit farmers. Agricultural inputs are being distributed and training is being provided to support and strengthen agricultural production in at least 6 inland municipalities.

Data provided by medium-sized farms reveal that this region is betting on large-scale food production. Despite the crisis, the local market is flooded with vegetables and this has stimulated the entrepreneurial capacity of farmers.

Benguela has the ideal climatic conditions to be considered the best area in the country (Table 3), and even in the world, for banana production. It is estimated that large producers in the area release around 15,000 tons of bananas per year. This crop occupies most of the agricultural land in the Benguela valleys, where another 200 small and medium-sized producers also work, mainly in the Culango and Canjala valleys.

Figure 2
NDVI profile compared to LTA (1984-2015) and previous year

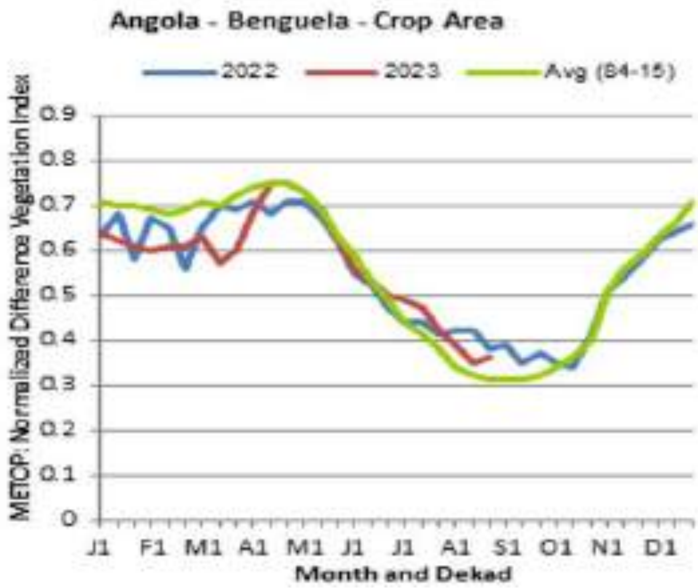
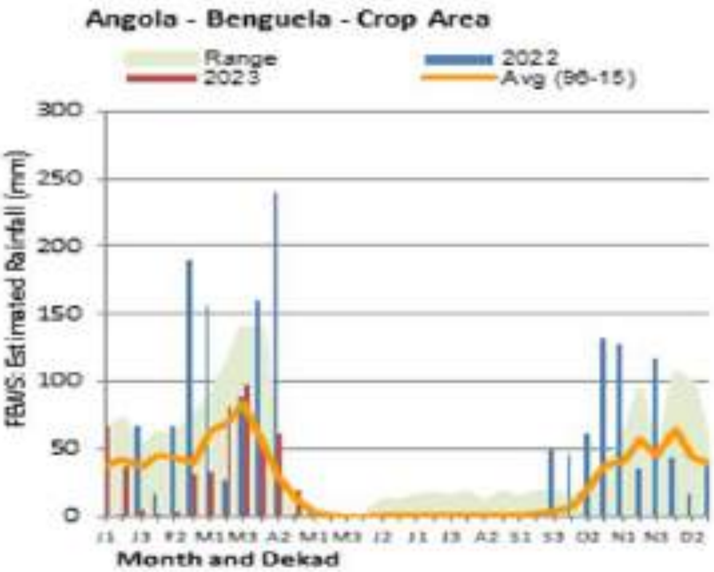


Figure 3
Estimated rainfall compared to LTA and previous year



The NDVI Profile compared to LTA is a tool that compares the long-term moving average (LTA) of the Normalized Difference Vegetation Index (NDVI) with the current NDVI, allowing to identify anomalies in the vegetation over time.

However, the goals for Benguela are even more ambitious. Over the next three years, the province plans to reach an annual production of at least 24,000 tons of bananas. Experts assure that, by reaching 50,000 tons, the country's needs could be met and a continuous flow of exports to the world's most demanding markets could be guaranteed.

On the domestic market, approximately 70% of the tomatoes, onions and bananas sold in Luanda come from Benguela, while 20% come from Namibe and 10% from other nearby areas. The Cavaco Valley, the most productive in the province, is where the most ambitious and competitive bets are being made, and where they are increasingly taking the lead in vegetable production.

Today, farmers in this area use modern machinery, seeders, automatic irrigation systems, bulldozers, graders and other advanced equipment. This guarantees the continuity of the banana business even when there is a generational change and the land passes into the hands of the new generations, who find incentives not to abandon the land and continue with the business.

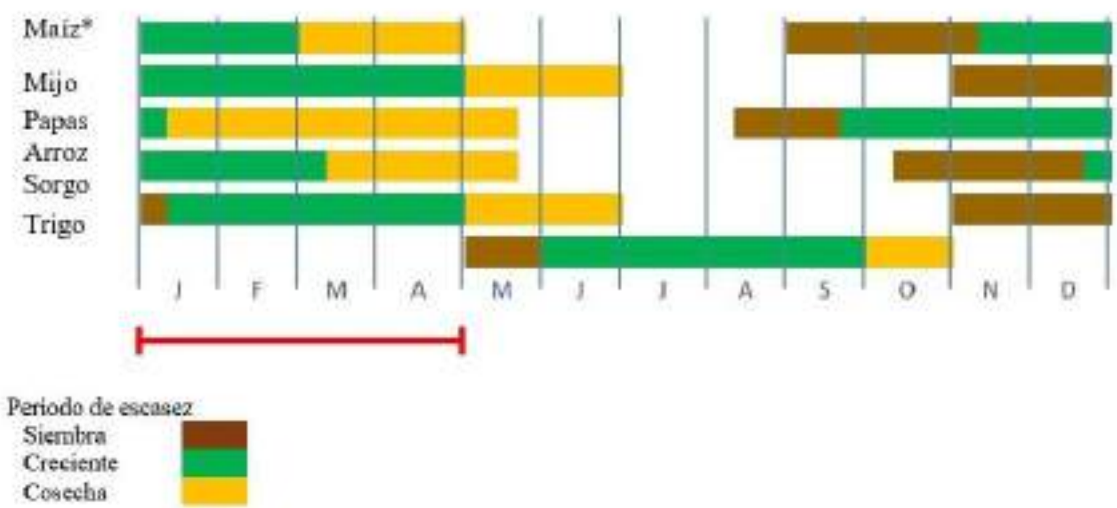
A key factor in the success of agricultural production in Benguela is water. The rehabilitation of the Dungo dam, in the municipality of Cubal, by the Provincial Government of Benguela, has been fundamental in guaranteeing the availability of water for irrigation of the extensive agricultural areas. Twenty years later, farmers in the region have renewed hopes for a return to large-scale production of bananas, onions, tomatoes and corn (which has recently experienced high demand) on the 2,500 hectares of cultivated land.

Results

Cereal production in 2022 was slightly above the five-year average, especially for coarse grains. The main cereal harvest concludes in July and, although official data are not yet available, favorable weather conditions in the main cereal producing areas indicate higher yields (Figure 1). However, in the southern provinces, irregular rainfall and high temperatures have negatively affected cereal production.

Figure 4

*Crop calendar (*main food crop)*



Source: Source: FAO/GIEWS.

In the 2022/23 trading period (April/March), it exceeded the average, which is mainly due to the need to meet about 40% of domestic grain demands. Wheat and rice imports, which represent the largest proportion of cereal imports, increased by 4% and 17%, respectively, compared to the average of the last five years.

As for food inflation, a slowdown was observed in 2022, although levels remain high. The annual headline inflation rate was estimated at 21% in July 2022, the lowest level since mid-2020. Unlike neighboring countries, the country has benefited from high world oil prices, due to its status as an exporter, which has supported an appreciation of the national currency and helped curb inflation caused by imports. In addition, the government's implementation of the Strategic Food Reserve Plan has contributed to stabilizing domestic food supply and containing price increases, thus alleviating inflationary pressure.

Grain production was above average in 2022, along with an increase in grain imports to meet domestic demand. Although the rate of food inflation has slowed, it remains high, but measures have been implemented to contain price increases and stabilize the domestic food supply.

Angola: Soil loss and contamination in agriculture

In Angola, it has been revealed that the country loses about 20 million tons of soil per year due to erosion, which is equivalent to a loss of capacity to feed 50,000 people. This worrying situation was made known by Paulo Vicente, advisor to the United Nations Food and Agriculture Organization (FAO), during a conference in Namibe.

The agricultural perimeter of Catumbela, located north of Benguela City, has 3,317 hectares of arable land. The main crops grown in this area are corn, vegetables and bananas, with a total of 520 hectares of corn, 539 hectares of vegetables and 193 hectares of bananas. However, the low flow of the Catumbela River, due to the lack of rainfall, has negatively affected crops in the region.

In addition, agricultural activities in the region have contributed to soil contamination. Hazardous chemicals such as pesticides, persistent organic pollutants, lead and mercury have been used, posing a risk to both environmental and human health. Although the use of these chemicals is banned or controlled in developed countries, their illegal dumping in Africa remains a major challenge for environmental pollution management.

The use of pesticides in agriculture is considered the main factor contributing to soil contamination. Significant levels of endosulfan and Dichloro, Diphenyl, Trichloroethane (DDT) have been detected in the soils of state farms in Ethiopia, and are attributed to historical agricultural practices in the area. In Burkina Faso, endosulfan and profenofos have been found in soils used for cotton production.

Although DDT is banned for agricultural purposes in the region, exceptions have been granted for its use in malaria vector control. However, DDT is sometimes diverted from its intended purpose and sold on the local market for use in agriculture.

Burial of obsolete pesticides in the past has also been a source of soil contamination. This practice can be a diffuse source of groundwater contamination by infiltration. According to the World Bank, about 50,000 tons of obsolete pesticides were identified in Africa in 2018.

Soil loss and pollution in agriculture pose a serious threat to food security and sustainable development in Angola. It is essential to implement sustainable agricultural practices, promote the responsible use of chemicals and encourage soil conservation and restoration to protect natural resources and ensure the well-being of future generations.

As a possible solution, we should begin to respect existing national and international alliances and agreements:

The Global Soil Alliance (GSA) was established in 2012 with the aim of promoting closer and more effective collaboration between stakeholders. Its mandate is to improve the governance of limited soil resources worldwide, ensuring soil health and productivity to ensure food security and support other vital ecosystem services. The WHA recognizes the sovereign right of each state over its natural resources and strives for sustainable land management.

The Voluntary Guidelines for Sustainable Soil Management (VGSSM) were approved by the FAO Council in 2016 and provide technical and policy recommendations for achieving sustainable soil management. These guidelines identify ten threats to soil functioning and health, including soil contamination, and propose a set of principles to minimize and control these threats.

The International Code of Conduct on Pesticide Management, adopted by FAO members in 2013, sets voluntary standards of conduct for all stakeholders involved in the use of pesticides. The objective of this code is to ensure the rational use of pesticides and to serve as a basis for countries with no or weak legislation to regulate the quality and suitability of pesticide products.

The Global Action Plan on Antimicrobial Resistance, endorsed by the WHO Assembly in 2022, aims to combat antimicrobial resistance, which poses a threat to human and animal health and hinders medical advances in the treatment of infectious diseases. This plan establishes five goals to combat antimicrobial resistance, including increasing awareness, reducing the incidence of infections and optimizing the use of antimicrobial drugs.

The Bamako Convention on the Ban of the Import of Hazardous Wastes into Africa and the Management of Wastes within Africa was adopted within the framework of the Basel Convention. Its main objectives include banning the import of potentially hazardous waste, including radioactive waste, and properly managing waste already present in Africa. However, its acceptance and application have been limited, leading to the Libreville Declaration on Health and Environment in Africa in 2008, promoted by WHO. This declaration seeks to establish a legislative framework, build capacity to address the problems, initiate and coordinate applied research, and ensure effective implementation and follow-up at the national level.

It is essential to improve communication mechanisms on the causes, risks and preventive actions of soil contamination among all stakeholders, especially the general public. The actions undertaken by the Global Soil Partnership following the Global Soil Pollution Symposium and on the occasion of World Soil Day 2023 have demonstrated a strong interest in this topic.

Realizing the importance of professional practices, it is essential to address these challenges and work together to ensure sustainable soil management and protect our natural resources for future generations.

Priority actions to prevent and stop soil contamination and to remediate contaminated soils may include:

Implement appropriate management measures in industrial and agricultural activities to minimize the release of pollutants into the soil. This may include the use of cleaner technologies, the application of good agricultural practices and the promotion of sustainable production methods.

Establish strict environmental regulations and standards to control and monitor soil contamination. This may include the implementation of soil quality monitoring and evaluation programs, as well as sanctions for those who do not comply with established standards.

Promote environmental education and awareness to encourage responsible land management practices. This may include training farmers, industries and local communities on the importance of protecting and conserving soil quality.

Encourage research and development of innovative technologies and methods for the remediation of contaminated soils. This may include the use of bioremediation techniques, where living organisms are used to degrade contaminants, or the application of specific amendments and treatments to restore soil quality.

Establish long-term monitoring programs to evaluate the effectiveness of prevention and remediation actions. This will allow for continuous adjustments and improvements in the strategies implemented.

Promote organic agriculture and gardening: Promoting farming practices without the use of toxic chemicals, such as pesticides and synthetic fertilizers, helps prevent soil contamination. The use of organic techniques, such as crop rotation and composting, improves soil health and reduces reliance on harmful chemicals.

Promote proper waste management: Implement recycling and composting programs to reduce the amount of waste that ends up in landfills. Proper disposal of wastes, including chemicals and hazardous materials, prevents them from contaminating soil and groundwater.

Protect areas of natural vegetation: Conserving and protecting natural ecosystems, such as forests and wetlands, helps maintain soil quality. These areas act as natural filters, absorbing and filtering pollutants before they reach the soil and water.

Promote the responsible use of chemical products: Promote the responsible use of chemical products in industrial and domestic activities, avoiding their release into the soil. This involves the proper use and safe storage of chemicals, as well as the adoption of safer and less toxic alternatives.

Implement erosion control measures: Soil erosion is an important cause of contamination, as it can carry sediments and pollutants into nearby water bodies. Implementing erosion control measures, such as planting vegetative covers, terracing and soil conservation, helps prevent soil loss and associated pollution.

It is important to emphasize that these actions must be carried out in a coordinated manner among different actors, including governments, industries, farmers, scientists and society in general, in order to achieve effective results in soil protection and conservation. Collaboration and commitment from all are essential to address the challenges of soil contamination and create a sustainable environment for future generations.

Strategies for sustainable soil management

In the area of sustainable soil management, a number of key actions have been identified to promote harmonization of standard operating procedures in laboratory methods for soil contaminant analysis. This includes the development of standardized threshold levels of soil contamination, which will allow the establishment of clear criteria for assessing and monitoring soil quality.

It is also essential to promote the inclusion of soil contamination in conventional soil survey data and information in national and global soil information systems. This will help to improve the overall understanding of the challenges and solutions related to soil contamination.

In addition, greater investment is required in specific research on emerging contaminants, addressing aspects such as their detection, fate in the environment, risk assessment and remediation. This will allow the development of effective strategies to meet the new soil contamination challenges.

Regarding the monitoring of point and diffuse soil contamination, it is necessary to establish and strengthen national, regional and global inventory and monitoring systems. This will provide up-to-date and reliable data on soil quality and facilitate informed environmental management decisions.

In parallel, it is essential to establish and strengthen national biosurveillance and epidemiological surveillance systems to identify, assess and control damage and diseases attributable to soil contamination. These systems will be essential to implement preventive actions and mitigate negative impacts on human health and the environment.

To strengthen international cooperation in sustainable soil management, the creation of the Global Soil Pollution Monitoring and Information System is being promoted. This initiative will facilitate the exchange of best practices, data and experiences among countries, promoting joint actions to address global challenges related to soil contamination.

Effective implementation to prevent and remediate soil contamination

It is essential to enforce international agreements on chemicals, persistent organic pollutants, residues and sustainable soil management. This involves ensuring compliance with the Voluntary Guidelines for Sustainable Soil Management and the International Codes of Conduct for the Sustainable Use and Management of Fertilizers and Pesticides.

It is also proposed to establish a system of incentives and recognition for efforts to stop soil contamination. This can include eco-labeling and compliance with schemes such as the Voluntary Guidelines for Sustainable Soil Management, offering a distinctive label to agricultural products that apply sustainable soil management practices.

It is necessary to advocate for a global commitment to prevent, stop and remediate soil contamination, in line with the goals of Zero Pollution/Towards a Pollution-Free Planet. Regional efforts and objectives, such as the European Green Pact, can be used as a basis for establishing clear goals and concrete actions in this area.

It is important to improve national and international regulations on industrial and mining emissions, promoting environmentally friendly production processes. This will contribute to significantly reduce soil contamination generated by these activities.

The implementation of policies that promote the "right to repair" and discourage the planned obsolescence of manufactured materials is also key to reducing waste, including electronic waste. Likewise, the use of single-use articles should be discouraged and reduced, especially in materials and food packaging.

It is necessary to implement adequate waste collection and green management policies that promote recycling and ensure proper treatment of different types of waste within and between countries. This will help reduce waste generation and minimize its impact on the soil and the environment in general.

In the area of sustainable agricultural soil management, policies should be implemented to reduce dependence on agrochemicals and promote the control of irrigation water quality and organic residues. This will minimize the negative impacts of agriculture on soil quality and contribute to the production of healthier and more sustainable food.

It is essential to develop and include in national reporting mechanisms soil contamination targets and indicators related to the achievement of the Sustainable Development Goals. This will make it possible to effectively evaluate and monitor progress in sustainable soil management and ensure accountability in this area.

Finally, there is a need to expand sustainable nature-based and environmentally sound management and remediation technologies, such as bioremediation. These technologies offer effective and environmentally friendly solutions to address soil contamination and restore soil quality in a sustainable manner.

In conclusion, sustainable soil management requires a series of strategic and technical actions, ranging from the harmonization of operational procedures to the implementation of concrete policies and actions. With the collaboration and commitment of all sectors involved, it is possible to prevent and remediate soil contamination, thus protecting our health and the environment for future generations.

Discussion and conclusions

. The objective of the research was to evaluate the state of soils in the province of Benguela-Angola and to develop strategies to improve the quality of arable soils, in order to achieve sustainable production and optimize productivity through good soil management.

During the assessment, several problems affecting soil quality in Benguela-Angola were identified, such as erosion, organic matter degradation, salinization and chemical contamination. These problems represent a significant challenge for food security and sustainable development in the region.

The results obtained highlight the urgent need to implement preventive and corrective measures to stop soil contamination and remediate already affected soils. To achieve this, the implementation of sustainable agricultural practices, such as organic agriculture and the responsible use of chemicals, is proposed. The adoption of soil conservation techniques, such as crop rotation, planting cover crops and terracing, is also suggested.

In addition, it is essential to promote proper waste management and protect areas of natural vegetation, such as forests and wetlands, which act as natural filters and help maintain soil quality.

The Benguela-Angola region has great potential for improving soil quality and achieving sustainable production. The implementation of the above solution proposals, together with the collaboration of farmers, industries, local governments and communities, can make a significant difference.

Education and environmental awareness also play a key role in this process. It is important to train farmers and the community in general on proper soil management practices and the benefits of soil conservation to achieve sustainable production and optimize productivity.

Urgent measures are needed to improve soil quality in Benguela-Angola. The implementation of sustainable agricultural practices, proper waste management, protection of natural vegetation areas and community awareness are key to achieving sustainable production and optimizing productivity through good soil management in the region.

References

África. Texto con anexos. Suiza, 71p. http://www.fecomol.org/pdf/Convencion_de_las_Naciones_Unidas_de_la__Lucha_Contra_la_Des.pdf

CCD/PNUMA. 1995. Convención de las Naciones Unidas de Lucha contra la Desertificación y la Sequía , en particular en Dawelbait, M. y Morari, F. (2012). Monitoring desertification in a Savannah region in Decreto Presidencial N° 177/20 de 23 de junio. https://faolex.fao.org/docs/pdf/ang196090.pdf

Diniz, E. S., Amaral, C. H., Sardinha, S. T., Thiele, J., & Meira-Neto, J. A. A. (2021). Phylogenetic signatures in reflected foliar spectra of regenerating plants in Neotropical forest gaps. Remote Sensing of Environment, 253, 112172. http://148.207.151.236:8080/xmlui/handle/123456789/374.

Elsevier. Vol 80, pages 45-55. https://www.sciencedirect.com/science/article/abs/pii/S0140196311003971 Giraldo, S. C. (2016). La ciencia del suelo, un reto para la Ingeniería Ambiental en Colombia. Revista Cintex, 21(2), 9-15. https://revistas.pascualbravo.edu.co/index.php/cintex/article/view/14

Goswami, K., Choudhury, H.K., Saikia, J. (2012). Factors influencing farmers adoption Instituto Nacional de Estadística (INE) https://www.ine.gov.ao/of slash and burn agriculture in North East India. Forest Policy and Economics Vol 15, pages 146-151, DOI: 10.1016/j.forpol.2011.11.005.

Ramos Noriega, M. I. (2019). Experiencia en integración de la cadena de valor maíz en la región Montaña del Estado de Guerrero. http://148.207.151.236:8080/xmlui/handle/123456789/374

Salazar, W. L. B., & Montoya, D. H. (2014). Los costos ambientales en la sostenibilidad empresarial. Propuesta para su valoración y revelación contable. Contaduría Universidad de Antioquia, (65), 173-195. https://revistas.udea.edu.co/index.php/cont/article/view/24400

Dawelbait, M., & Morari, F. (2012). Monitoring desertification in a Savannah region in Sudan using Landsat images and spectral mixture analysis. *Journal of Arid Environments*, *80*, 45-55. https://www.sciencedirect.com/science/article/abs/pii/S0140196311003971

Zhang, Y., Ram, MK, Stefanakos, EK and Goswami, DY (2012). Síntesis, caracterización y aplicaciones de nanocables de ZnO. Revista de Nanomateriales , 2012 , 1-22. https://www.hindawi.com/journals/jnm/2012/624520/

ENVIRONMENTAL SCIENCES & PRACTICES
http://mlsjournals.com/Environmental-Science-Practices

(2024) Environmental Sciences & Practices, 2(1), 23-39.

Mendoza from a geological perspective aplied to urban planning from the 16Th to the 18Th century

Mendoza desde una perspectiva geológica aplicada al urbanismo del siglo XVI al XVIII

Natalia Lourdes Mazzeo
Environment, Argentina
(ntlmazzeo@gmail.com) (https://orcid.org/0009-0000-7236-9171)

Manuscript information:

Received/Recibido: 27/12/23
Reviewed/Revisado: 15/02/24
Accepted/Aceptado: 15/03/24

Keywords:
urban planning, urban geology, environment, history.

ABSTRACT

This research has been of interest to identify the past geological and environmental processes that triggered and accentuated the ecological, social and historical transformations of the urban sector of Mendoza between the sixteenth and eighteenth centuries. In the present research, the following were taken as objects of analysis: geological processes, topography, hydrogeological management and land use. These variables were measured through indicators such as the use of natural resources, alluvium, floods, seismic events, landforms and erosive agents. The techniques of documentary and content analysis were used, in addition to the observation technique, in order to gather the necessary resources to obtain data for the analysis of each variable.
A historical zoning of geological hazards was elaborated, through the occurrence data documented in the historical records analyzed. Five units were obtained, resulting in the area with potentially damaging processes occurring in the urban area of the foundational city of Mendoza. This is located in the area of cones and alluvial fans of the Mendoza River, i.e. it is part of the environment where the discharge of sedimentary material from the foothills of the foothills is generated. Consequently, the processes involved were: floods, alluvium, salinity and active faulting through the Cerro de la Cal fault, whose trace crosses the city. In short, framing the environmental processes of a city from urban geology is essential to establish the threats or hazards and potential damage that affect or may affect the territory.

Palabras clave:
urbanismo, geología urbana, medio ambiente, historia.

RESUMEN

Ha sido de interés identificar los procesos geológicos y medio ambientales del pasado que desencadenaron y acentuaron las transformaciones ecológicas, sociales e históricas del sector urbano de Mendoza entre los siglos XVI y XVIII. En la presente investigación se tomaron como objetos de análisis: los procesos geológicos, la topografía, el manejo hidrogeológico y el uso del suelo. Estas variables fueron medidas a través de indicadores como el uso de recursos naturales, aluviones, inundaciones, eventos sísmicos, formas del relieve y agentes erosivos. Se utilizaron las técnicas del análisis documental y de

contenido, además de la técnica de la observación, con el propósito de recabar los recursos necesarios para obtener datos de análisis de cada variable.
Se elaboró una zonificación histórica de peligrosidad geológica, a través de los datos de ocurrencia documentados en los registros históricos analizados. Se obtuvieron cinco unidades, resultando el área con ocurrencia de procesos potencialmente perjudiciales la que comprende el casco urbano de la Ciudad fundacional de Mendoza. Esta se emplaza en la zona de conos y abanicos aluviales del río Mendoza, es decir que forma parte del ambiente donde se genera la descarga del material sedimentario del piedemonte precordillerano. Por consiguiente, los procesos actuantes fueron: inundaciones, aluviones, salinidad y fallamiento activo a través de la falla Cerro de la Cal, cuya traza atraviesa la ciudad. En suma, enmarcar los procesos ambientales de una ciudad desde la geología urbana es fundamental para establecer las amenazas o peligros y los daños potenciales que afectan o pueden afectar al territorio.

Introduction

The urban development of Mendoza took place within a growth that involved the interaction between society and the natural environment. The dynamics of this process is presented in three stages marked by different events and events in the founding history of the city. Initially, a pre-Hispanic period (prior to the 16th century) where the inhabitants belonged to local cultures, with little impact on the demand for the natural resource. Then the foundation process was installed, manifesting the interest of colonization and exploration of the territory (XVI-XVII centuries) progressing towards a consolidation of a society in an effective way between the XVII-XVIII centuries, to give place, in the XVIII century, to the process of growth and urban expansion. The city of Mendoza began to transform itself into an urban ecosystem increasingly dependent on natural resources for its subsistence. In this sense, environmental issues should be analyzed as a symbiosis of social and natural sciences, contextualizing the topographic, geological, economic, political, and anthropic situation in the history of a region that was the axis of communication between two worlds (Spain and the American colonies) and its strategic link as a transportation network since its foundational beginnings. It is for this reason that the city of Mendoza serves as an example to address the development of its city and how it varied according to its degree of urbanization in these historical times. This issue has been studied from an environmental, archaeological and social history perspective by Chiavazza (2012), Prieto, and Chiavazza (2005), Prieto (1989), Prieto et al. (2012), Prieto (1997), Abraham and Prieto (1991), Abraham and Prieto (1981).

The main motivation of this work is to approach the historical environmental processes of this city from a geological point of view applied to urban planning. How are geological and environmental processes linked to the morphological characteristics of the city of Mendoza consolidated between the 16th and 18th centuries?

We will take into account that every urban system is surrounded by ecosystems of various types (vegetation, soil, crops, grazing fields, water basins) which, when integrated, form the necessary support for its subsistence. Within this framework, we intend to analyze the role played by this settlement in the exploitation of resources and its direct link with natural phenomena associated with floods, earthquakes and alluvium. Thus, the present work would show the changes that urban activity has developed to adapt to the new circumstances of its ecosystem. Associated with this approach, we also contribute from a geological-environmental perspective to geological risks in order to predict and prevent natural phenomena that may harm the population or the settlement of a population in a given geographical site.

Method

The research design to be followed is non-experimental, using the bases of projective type research, whose objective is to describe, analyze and explain how geomorphological and environmental processes are linked to the morphological characteristics of the city of Mendoza consolidated between the 16th and 18th centuries.

Through qualitative analysis, we intend to address and study the variables involved in the geomorphological and environmental processes that occurred in the urban sector of Mendoza, such as geology, topography, hydrogeology, and soil.

As can be seen in the table of operationalization of variables (Table 1), we intend to use the techniques of content analysis, documentary, and observation. The data obtained through these techniques will be recorded by means of measuring instruments.

As shown in Table 1, the research strategy is based on understanding and interpreting the natural scenarios that took place in the process of urban expansion through the reconstruction of the paleoenvironment and natural resources from a diachronic environmental perspective. By resorting to the methodology of environmental history, which is fundamentally aimed at obtaining reliable ecological data from historical sources.

Natural indicators such as vegetation distribution and coverage, local flora and fauna species, droughts and extraordinary precipitation, the increase and decrease of river flows, swamps, alluvial channels, soil erosion, floods, alluvium, and the analysis of seismic events will be tracked. With respect to anthropic indicators, we will investigate settlements, occupation and abandonment of land, use of natural resources, introduction of new plant and animal species, new crops, construction of canals and/or drains, and water use.

For the description of the population situation, historical documents from the Chapter Acts of the Cabildo of Mendoza, the General Archive of the Nation and the General Archive of the Indies (Seville) Spain, corresponding to the 16th, 17th, and 18th centuries, will be taken into account.

A basic task will be to express the categories associated with the processes (relief, geomorphology, soil, vegetation, geological processes, lithology and Quaternary deformations) and their relationships in space through cartographic representation. Maps will be made based on current knowledge of the geomorphology, vegetation cover, soil, and neotectonic deformations acting in the area and will be compared with historical documentation, information materials obtained from archaeological finds, and characteristic plans of the study period.

The cartographic representation of the current state of the ecosystems involved will be carried out through the analysis of satellite images, 3D reliefs (DEM) and longitudinal profiles of the different sites of interest to be analyzed.

Table 1
Table of operationalization of variables

Variables	Indicators	Techniques	Measuring instruments
Geological Processes	Use of natural resources. Alluvium. Flooding, Seismic events and quaternary deformation.	**Documentary analysis**	Database and software storage.
		Content analysis	Baseline, log charts and category classification.
		Observation	Geological mapping, Gis software (QGIS)
Topography	Natural relief elevations. Occupied surfaces. Relief shape. Relief morphologies.	**Content analysis**	Record charts and category classification
		Remarks	Thematic mapping and geological mapping. Gis software (QGIS).
Hydrogeological Management	Construction of canals and drains. Location. Proximity to urban sectors. Water use.	**Documentary analysis**	Database and software storage.
		Content analysis	Baseline, log charts and category classification.
		Observation	Geological mapping, Gis software (QGIS)
Land uses	Crops. Occupied surfaces. Erosive agents. Land occupation and abandonment.	**Documentary analysis**	Database and software storage.
		Content analysis	Baseline, log charts and category classification.
		Observation	Geological mapping, Gis software (QGIS)

Note: Adapted from Mazzeo 2021

Results

The aim is to achieve a historical zoning of geological hazards, through the occurrence data documented in the historical records analyzed for the sector called "the foundational area of the city of Mendoza", located in the current city of Mendoza, Argentina (Figure 1). The foundational city is located in the area of the fourth section of the capital of this province (Figure 2). It covers an area of 25 blocks around the current Pedro de Castillo square, to the west of the Cacique Guaymallén canal (Chiavazza, 2009). (Figure 3).

Geological hazard can be understood as the probability of occurrence of a potentially damaging phenomenon (geological process) within a given period and in a specific area. Varnes (1984).

The following elements were basically used for the zoning: geological processes, lithology, geomorphology, information about recurrences and intensity or magnitude of the processes, and characteristics of the triggering agents. (Figure 4). The zoning is at a local scale since we only wish to present the hazards associated with the study sector.

For a better understanding, it was classified into the following units (Gonzáles et al., 2002) (Figure 5):

• **Area with occurrence of potentially damaging processes**. This area includes the urban area of the Foundational City of Mendoza (Figure 3). It is located in the sector of cones and alluvial fans of the Mendoza River (Figure 6 and Figure 7), where the discharge of sedimentary material from the Precordilleran foothills is generated. Processes: floods, alluvium, salinity and active faulting through the Cerro de la Cal fault, whose trace crosses the city.

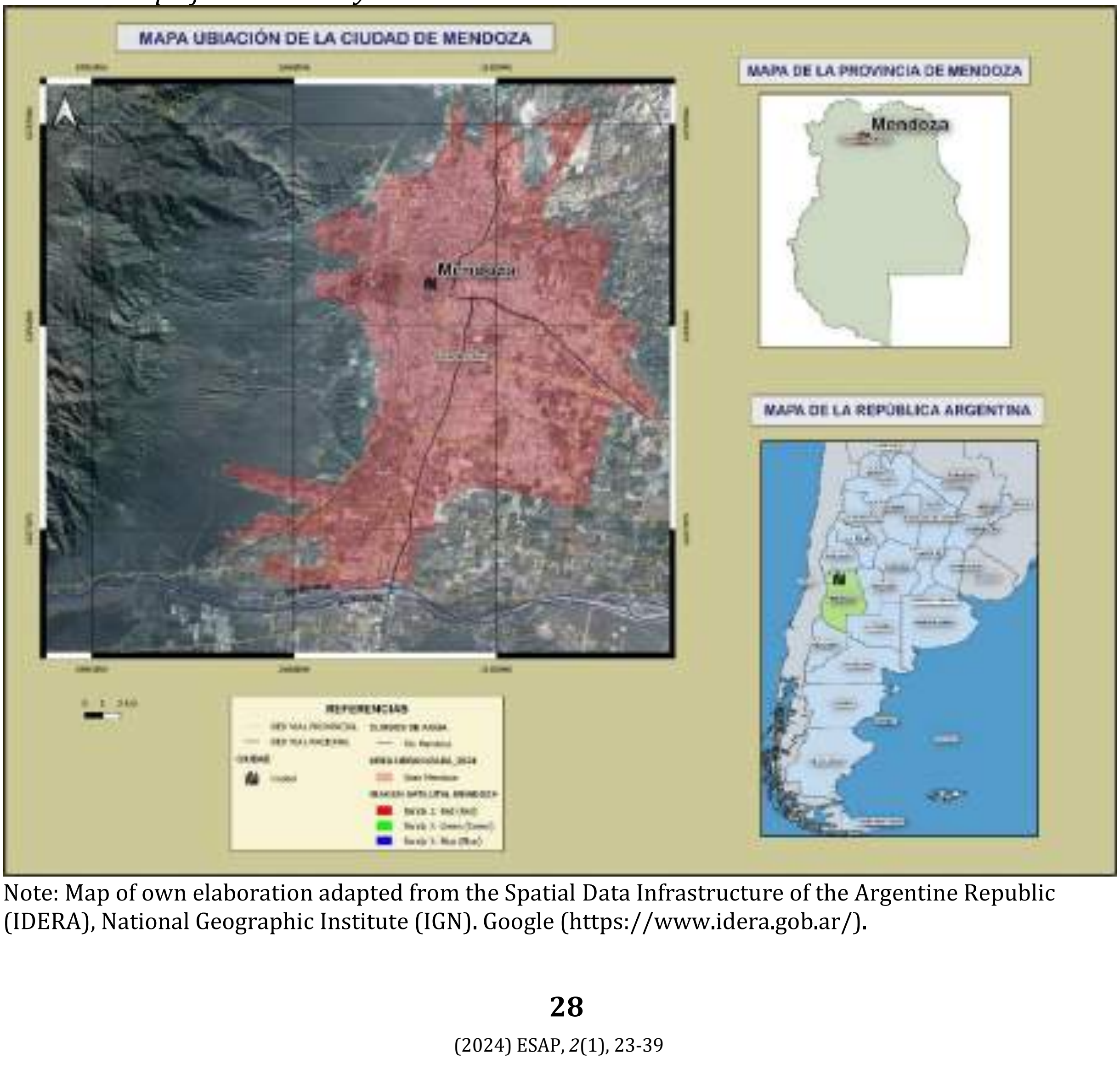
• **Area with occurrence of moderately damaging processes**. The archaeological site, Memorial de la Bandera site, is located there. The zone includes small areas distributed in the southwest and northeast whose geological environments are similar to the area described above. Processes: floods, alluvium and salinity.

• **Area with occurrence of moderately to slightly damaging processes**. The Arroyo Tulumaya archaeological site (PA70) is located. It includes the foothills of the Precordillera, the central sector of the Maipú Cone, and a large part of the Tulumaya and Rosario Plains (Figure 7). Processes: erosion (carcavation) and fluvial sedimentation, flooding, liquefaction, and salinization.

• **Area with occurrence of slightly damaging processes.** It occupies part of the Tulumaya plain and the Huanacache lagoons. The most important processes are: erosion (carving) and fluvial sedimentation, liquefaction and salinization.

• **Area where no harmful processes have been detected**. It coincides with flat or low slope and height reliefs, in resistant rocky massifs. (Figure 10)

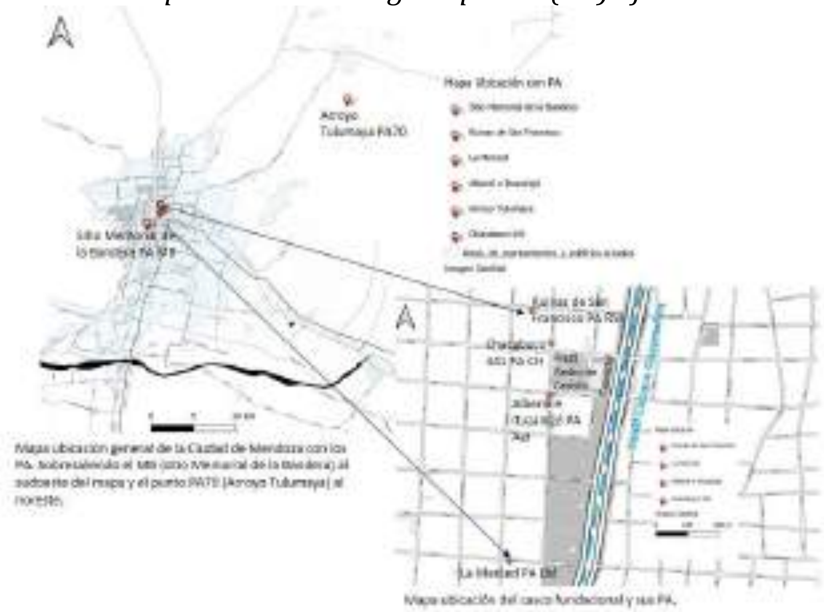
Figure 1.
Location map of Mendoza city



Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), National Geographic Institute (IGN). Google (https://www.idera.gob.ar/).

Figure 2

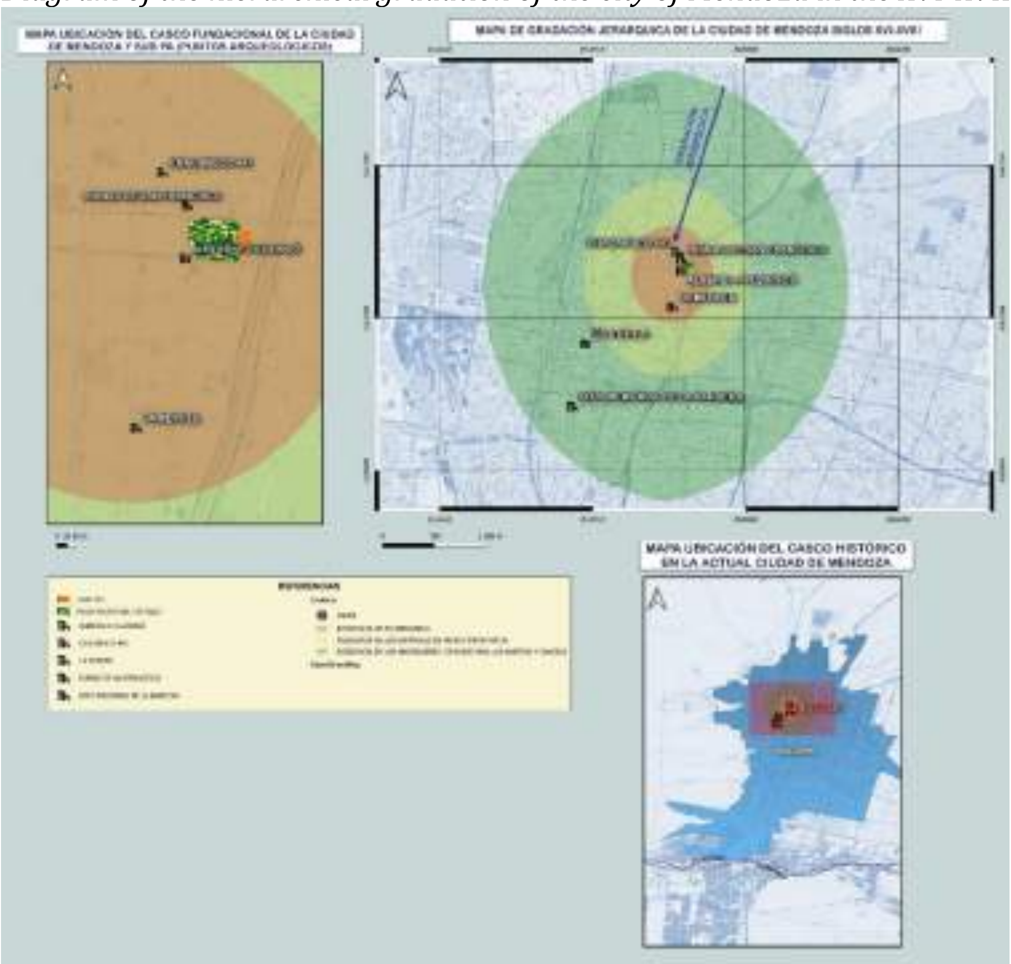
Location map with archaeological points (AP) of the urban center and its periphery



Note: Own elaboration adapted from Chiavazza (2012).

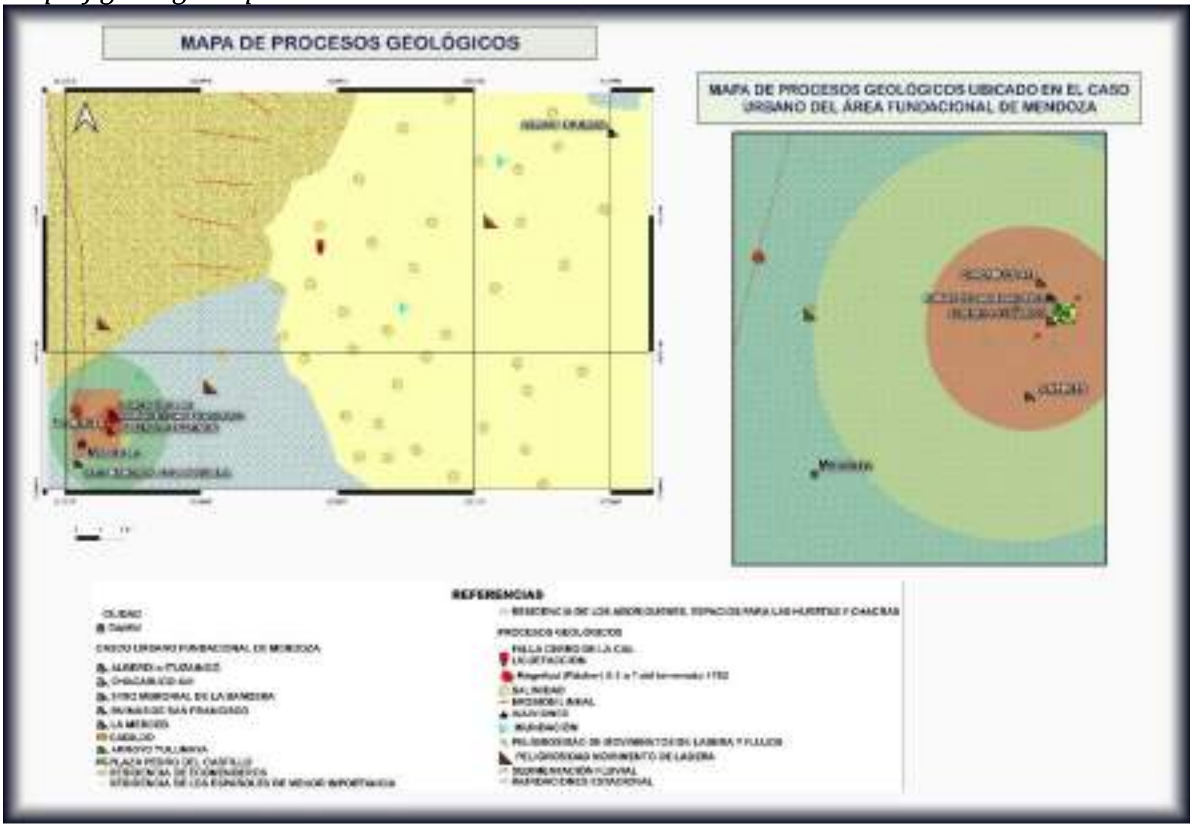
Figure 3

Diagram of the hierarchical gradation of the city of Mendoza in the XVI-XVIII centuries



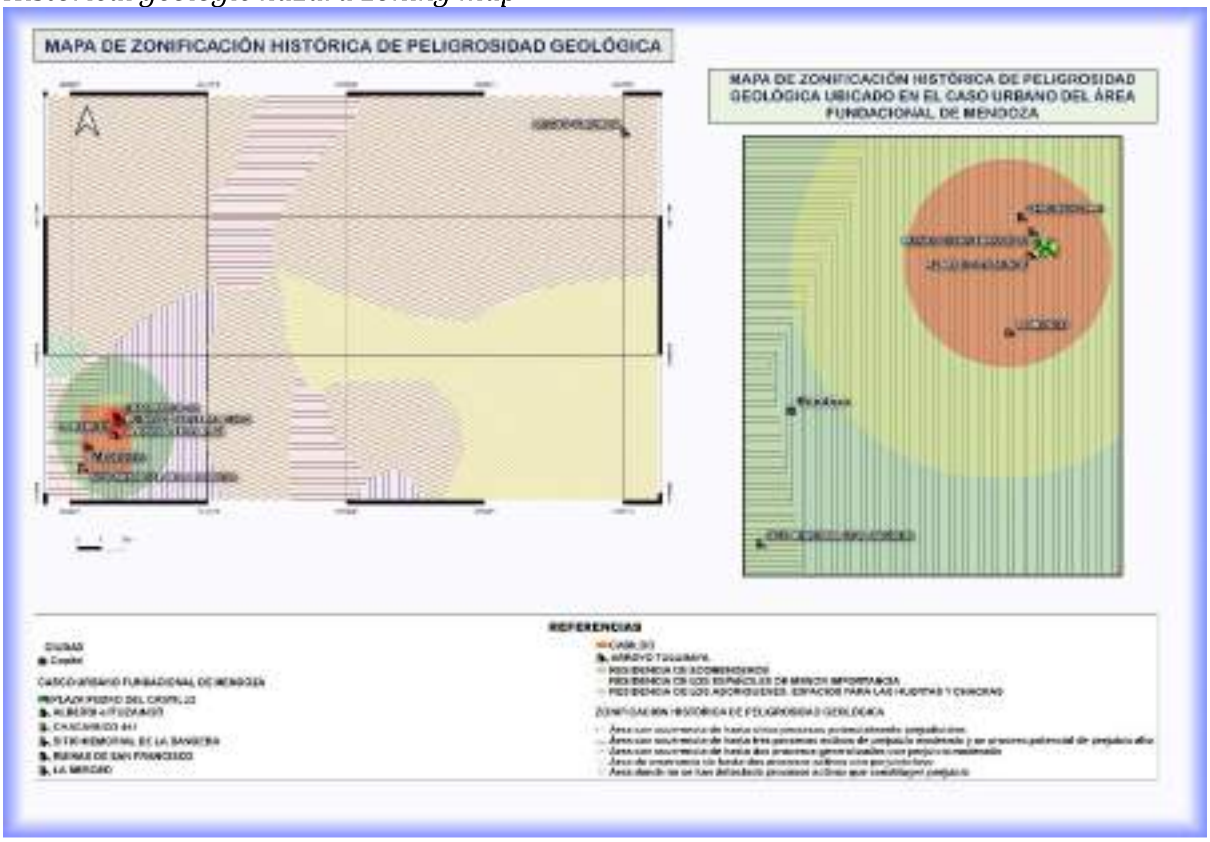
Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), National Geographic Institute (IGN). Google (https://www.idera.gob.ar/).

Figure 4
Map of geological processes



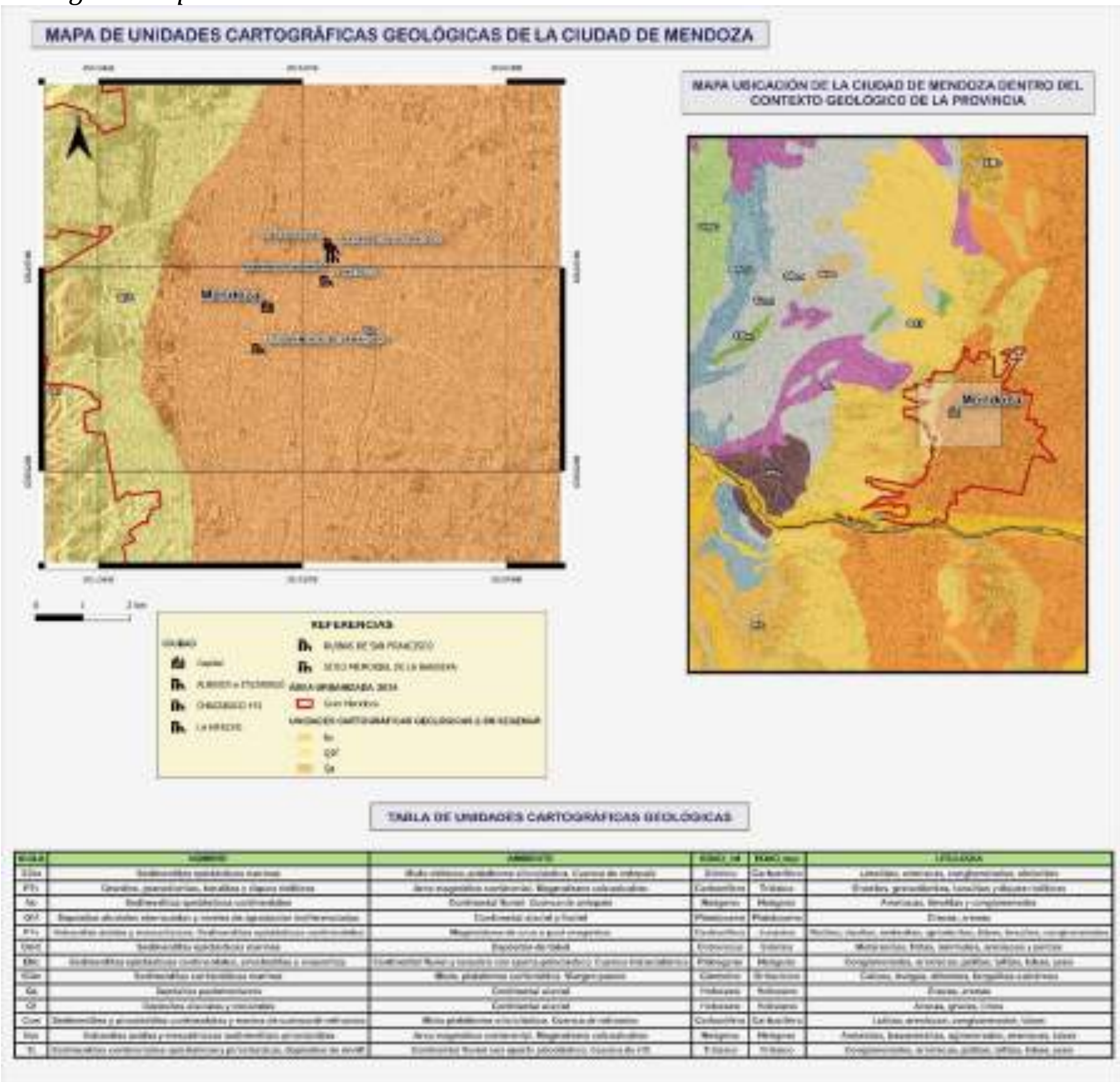
Note: Own elaboration adapted from González et al. (2002).

Figure 5
Historical geologic hazard zoning map



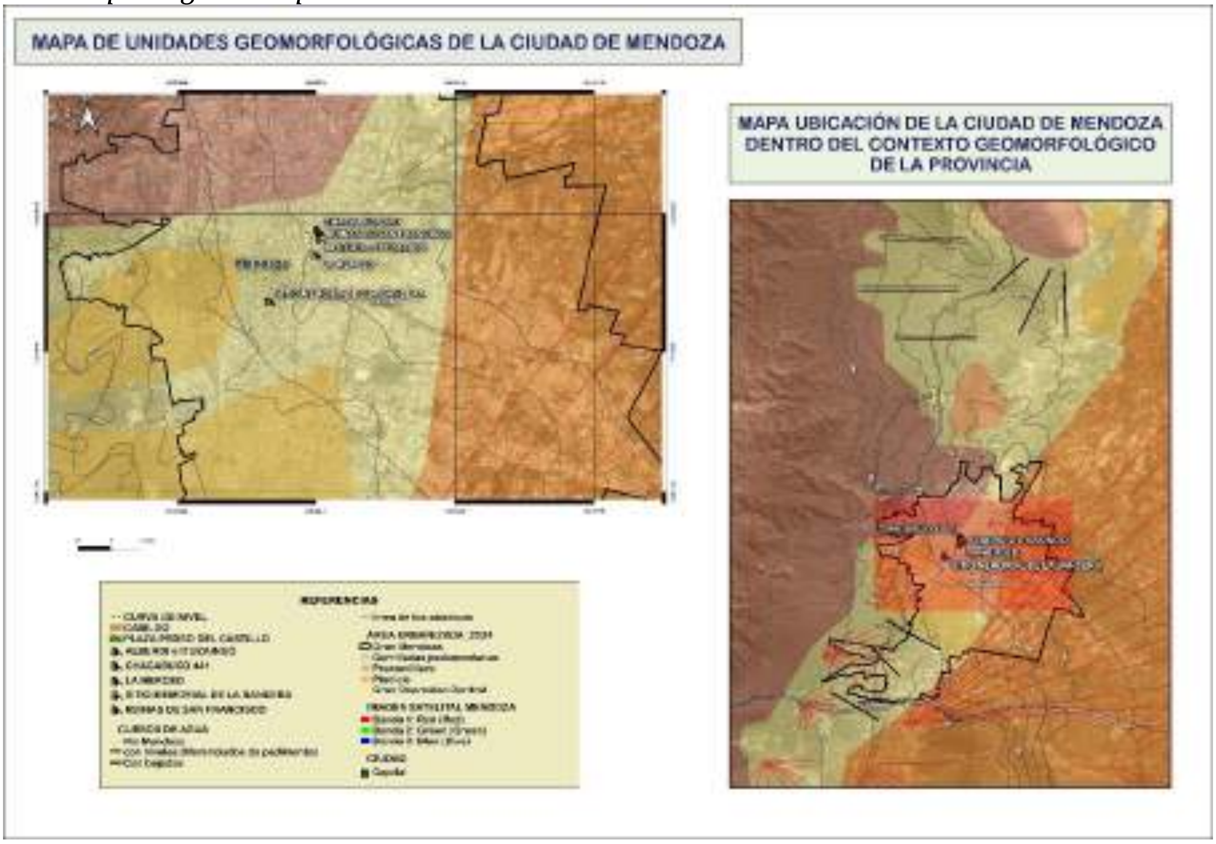
Note: Own elaboration adapted from González et al. (2002)

Figure 6
Geological map



Note: Own map adapted from Servicio Geológico Minero Argentino (SEGEMAR) Google (https://www.argentina.gob.ar/economia/segemar).

Figure 7
Geomorphological map



Note: Own elaboration Adapted from Abraham (1996).

Another factor that intervened in the natural conditions of the terrain were the climatic fluctuations (periods of higher or lower humidity) accompanied by rises and falls in temperature, also these influenced the life of the inhabitants of the new city, especially in the economic aspect (droughts, the appearance of plagues and pests). The positive or negative trends in rainfall should also be taken into account, which not only affected economic activity, but also caused floods and large mudflows or torrents of mud, causing serious damage to the population (Figure 8).

Figure 8
Alluvium in Mendoza XVII-XVIII centuries

Note: Adapted from Prieto (1989). History of the occupation of space and the use of natural resources in the foothills of Mendoza (p.152).

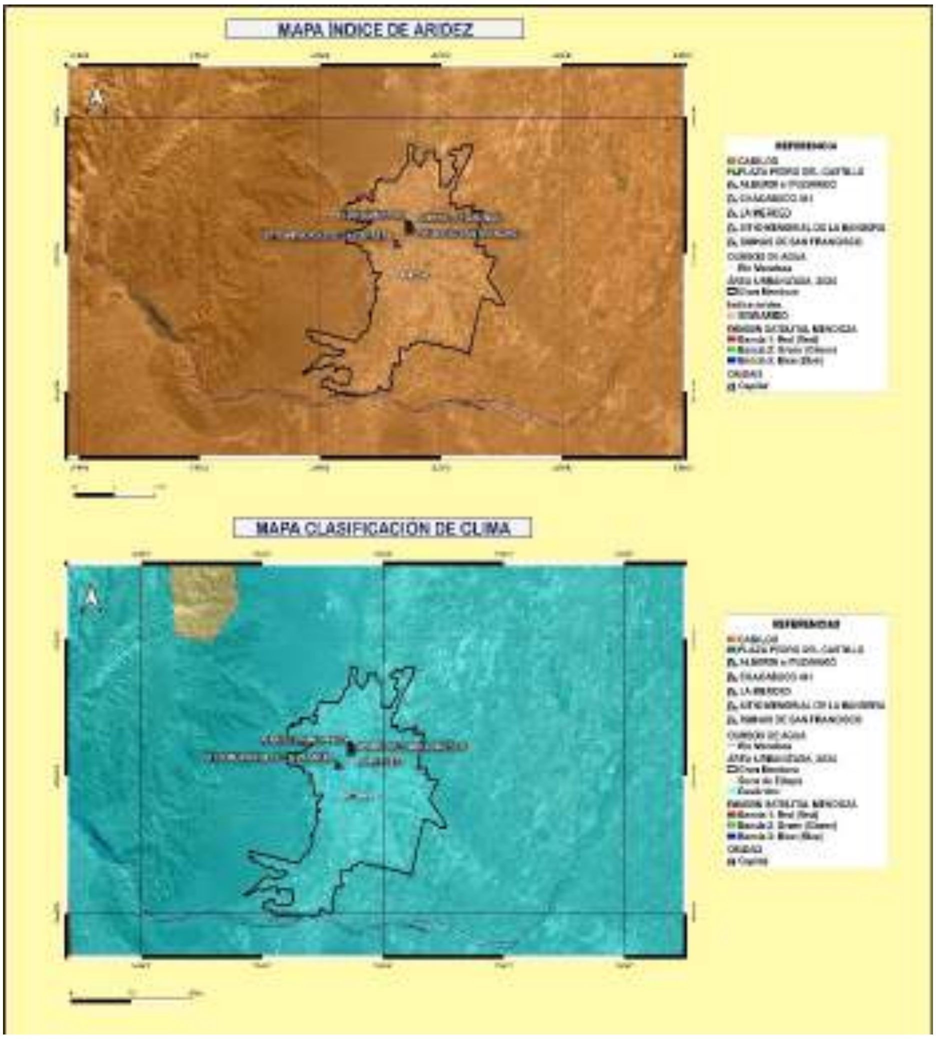
Floods have covered and currently cover large areas of the city of Mendoza, as shown in Figure 4, due to the large flood plains of the Mendoza River located to the southeast (Figure 7). The factors are mainly geomorphology (wide flood plains) and lithology (fine deposits) (Figure 6). Triggering factors are generally torrential summer rainfall and snowmelt (increased inflow causing overflows). Although they are not excessive, when concentrated in a short period of time their effects are more important. Historically, the rains that present serious damage are those greater than 40 mm/h. (Figure 9). Another factor is the excessive increase in temperatures, which causes a considerable increase in the flow, due to the thawing of snow, in the headwaters of the basins. Gonzáles et al. (2002).

It is recorded that the floods began to damage the city of Mendoza from 1661-70, but it was not until 1720-30 (beginning of the 18th century) when their quantity and intensity began to increase, and it was then that the disappearance of buildings and crops located near the riverbed was feared. (Prieto et al., 2008).

The written documentation of that time also mentions the suffering of the floods in the foundational area as detailed by Bárcena et al (1990 p. 22):

> According to the minutes of the town council, the damage to which the city was subjected to the rains is reflected: The house and jail suffered water damage since 1609, which shows, as we have seen, its location in the middle of the water evacuation line towards the so-called Zanjón or zanjón channel. The chapter minutes of the time have numerous references to these periodic landslides produced by the rains or flooding of the ditch. This was aggravated during the beginning of the 18th century, when the ditch, deepened by the diversion of other waters into its course, endangered not only the Cabildo but also the very existence of the city.

Figure 9
Map of Mendoza's climatic conditions



Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), Ministry of Environment and Sustainable Development. Google (https://www.idera.gob.ar/).

The study area has been characterized by seismic activity since the end of the 18th century, which does not mean that such activity did not occur previously. This seismic activity mainly affected the colonial urban area and its surroundings. Damage to structures (houses) caused by this phenomenon was mainly induced by ground surface movements and liquefaction. (Figure 4).

The eastern foothills of the foothills coinciding with the development of an important historical seismicity. The quaternary structures are linked to the seismic activity of the area and are the surface manifestation of the deformations that suffered and suffer as a consequence of an earthquake. (Figure 7).

On May 22, 1782, the Santa Rita earthquake occurred in the city of Mendoza. Schávelzon (2007, p. 10-11) describes what happened through the following account of a religious temple:

> The rooms or dwellings of the school suffered much damage and especially its corridors, which were almost completely ruined, having opened in the middle, until most of the materials that closed them at the bottom fell, so that it was necessary to demolish what had not yet fallen.

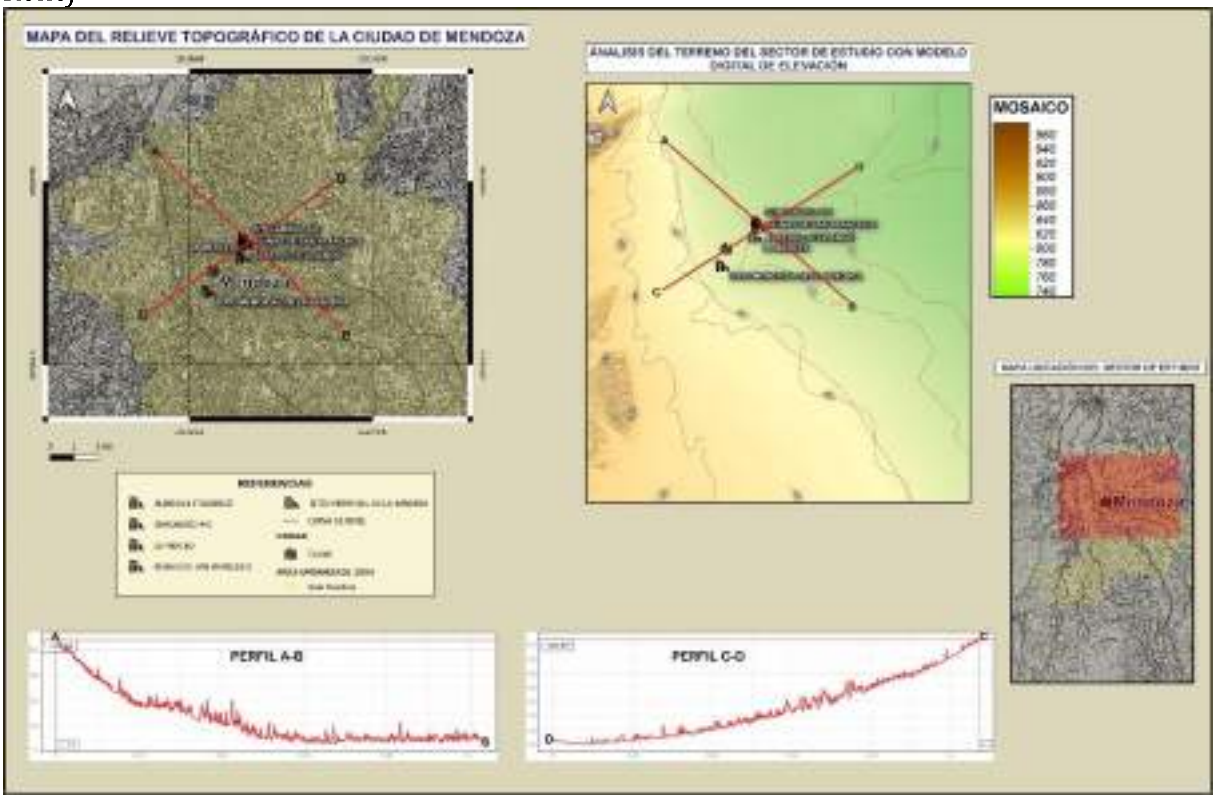
As shown in Figure 7 and Figure 10, the most relevant geoforms for the development of these flooding and alluvial processes are the central depression and the plains. Geomorphologic environments whose erosion factors are rainfall, which is enhanced by the slope and the high degradability of the surface materials. (Figure 11).

Anthropic erosion was very marked by the advance of overgrazing, unsuitable settlements, the use of carts and the felling of trees for fuel and industrial production that was beginning to develop with the wine industry. The desertification process accentuated even more the action of floods and alluviums that affected the city, due to the marked impoverishment of the vegetation cover, accelerating even more the runoff of water towards the urban area of the city.

The urbanization process that affected the city of Mendoza from its foundation in 1561 until the end of the 18th century is strongly characterized by its cattle and agricultural expansion associated with the fattening of cattle during the winter season. Thus, the period went from a period of adaptability (1561) to a period of destructuring (1561- 1700) and finally to a period of competition for natural resources (1700- 1830) (Abraham and Prieto, 1981) (Figure 12).

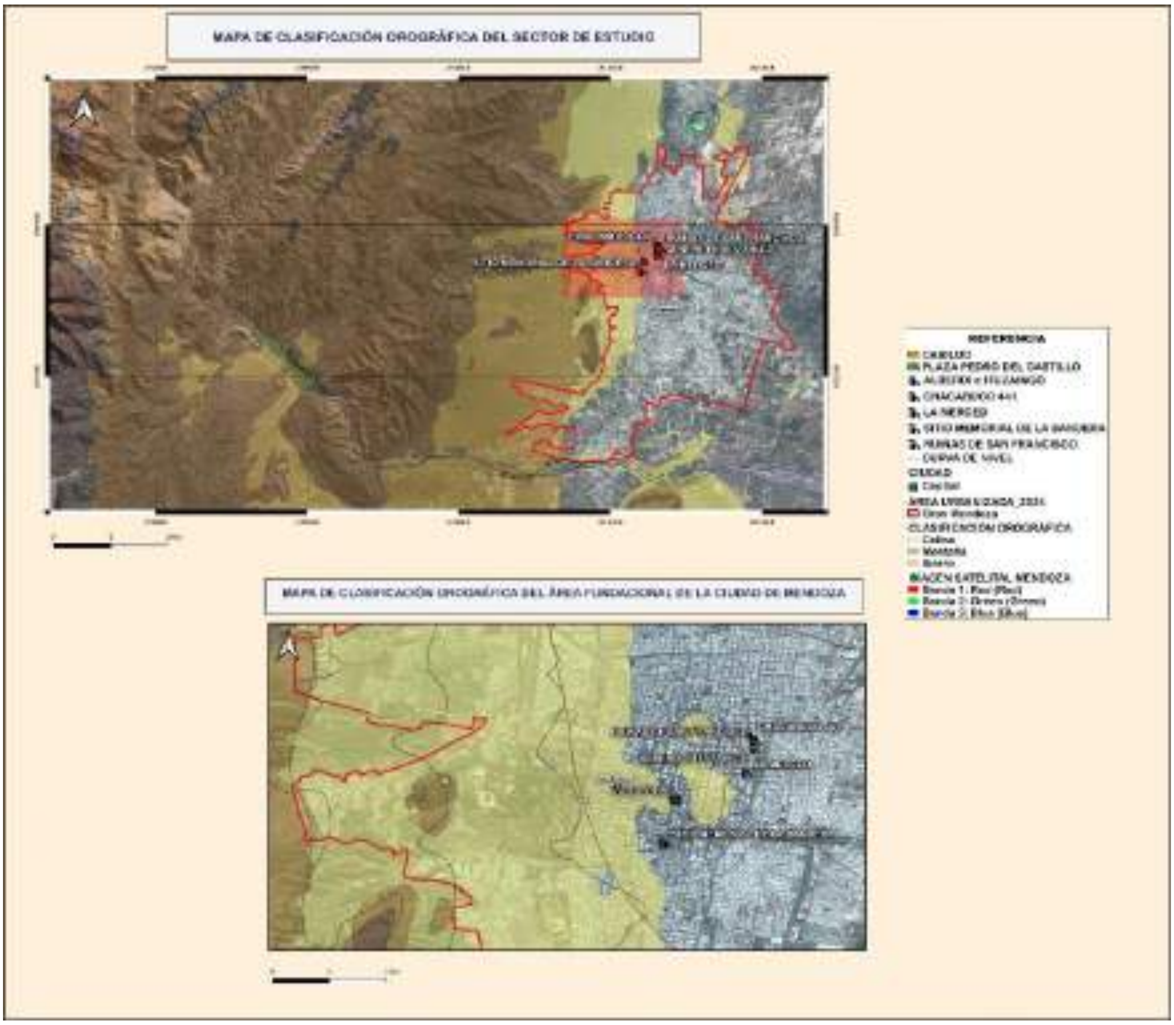
It is evident that the results of the urbanization process generate in space a new configuration of physiognomies called landscapes. These spaces (urban) and adjacent areas (peripheral-rural) are characterized by a strong dynamism that causes rapid changes in their physical, biological and human components. Alberto (2009)

Figure 10
Relief



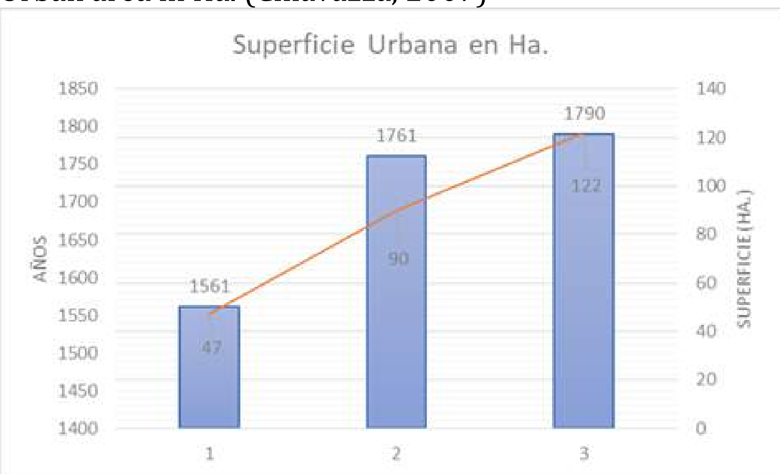
Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), National Geographic Institute (IGN). Google (https://www.idera.gob.ar/).

Figure 11
Orography



Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), Ministry of Environment and Sustainable Development. Google (https://www.idera.gob.ar/).

Figure 12
Urban area in Ha. (Chiavazza, 2007)



Note: Adapted from Chiavazza (2007). Theoretical bases for the archaeological analysis of religious spatiality and the processes of cultural transformation in the city of Mendoza during the colony (p.241).

Discussion and conclusions

The objective of this study was to rank and order most of the environmental events raised by Chiavazza (2012), Prieto and Chiavazza (2005), Prieto (1989), Prieto et al. (2012), Prieto (1997), Abraham and Prieto (1991), Abraham and Prieto (1981), as geological processes and zoned in a context of geological environment (lithology, geomorphology, relief, seismicity).

These results show that the geological and environmental processes that affected the foundational city of Mendoza between the 16th and 18th centuries are not monocausal. They usually respond both in the present and in the past to multiple origins.

Two key elements that favored the geological hazard of the study site stand out: one linked to morphostructural and tectonic factors, where the natural physiognomy of the relief of the study area stands out (low slope, important active fault systems, good permeability due to the fact that it is formed mostly by the sediments provided by the large floods of the Mendoza River in the summer season), and the other element, is related to the climate and its climatic variations (temperature and humidity), which also participates directly with the episodes of important river flows due to the thaw cycles in the summer seasons.

However, it is estimated that the direct cause of these processes being classified as dangerous had to do fundamentally with an anthropic factor inherent to an urban establishment "the city".

As a consequence of overgrazing, firewood extraction, the opening of roads and the indiscriminate felling of shrub vegetation, erosion processes were accelerated and their capacity to slow down surface runoff increased, thus increasing the frequency of alluvial floods. Prieto (1989, p. 151) states the following:

> There is a notable absence of information on alluvions during the second half of the sixteenth century and throughout the seventeenth century, when there were only 5 in the whole century. During the 18th century, 17 major floods have been recorded, causing numerous damages (1.7 floods per decade).

Through the vision of applied geology, an attempt was made to provide an approximation of the natural events and phenomena that occurred in a historical space, which was crucial for the development of a society. This information allows to have a key record of the geological-environmental evolution of a city, to predict future natural phenomena and to anticipate or prevent them if possible. It is important to take these historical records as a key to understanding and analyzing the future behavior of the terrain in the face of erosion, landslides, floods and seismic events.

References

Abraham, E.M., Prieto, R., (1981). Enfoque diacrónico de los cambios ecológicos y de las adaptaciones humanas en el Ne árido mendocino. Cuadernos del CEIFAR 8:109-139.

Abraham, E.M., Prieto, R., (1991). Contributions of historical geography to the study of processes of landscape change. The case of Guanacache, Mendoza, Argentina. Nº 11: ps. 309-336. Bamberger Geographische Schriften. Mendoza: Proyecto Lada-Fao.

Abraham, E.M., (1996). Mapa Geomorfológico de la Provincia de Mendoza en escala 1:500.000. En el Atlas básico de Recursos de la región Andina Argentina. Informe Final.

Alberto, J., (2009). Geografía y crecimiento urbano. Paisajes y problemas ambientales. Revista digital geográfica, 11 (6), ISSN 1668-5180.

Bárcena, J.R., Schávelzon, D., (1990). El cabildo de Mendoza, Arqueología e Historia para su recuperación.

Chiavazza, H. (2012). Procesos sociales y ambientales en el sector urbano de Mendoza entre los siglos XV-XVIII: Arqueología urbana e historia ambiental.

Ferro, C. (2016). Análisis filológico de las actas del cabildo de Mendoza (siglos XVI y XVII). Universidad Nacional de Cuyo.

Gascón, M. (2001). La transición de periferia a frontera: Mendoza en el siglo XVII. Andes, núm. 12. Universidad Nacional de Salta, Argentina.

González, M., González Díaz, E., Sepúlveda, E., Regairaz, C., Costa, C., Cisneros, H., Bea, S., Gardini, C., Pérez, I. y Pérez, M. (2002). Carta de Peligrosidad Geológica 3369 –II, Mendoza, Provincias de Mendoza y San Juan. Boletín N° 324, SEGEMAR, 178 p., Bs. As.

IDERA. Instituto De Datos Espaciales de la República Argentina. https://www.idera.gob.ar/

IGN. Instituto Geográfico Nacional. https://www.ign.gob.ar

Mazzeo, N. L. 2021. Procesos ambientales y geomorfológicos de tiempos históricos en el oasis norte de Mendoza. Trabajo /Proyecto Final Especialización en Gestión de Proyectos de Arquitectura y Urbanismo, Universidad Europea del Atlántico (España)-FUNIBER. pp: 1-67.

Mazzeo, N.L. Beca creación (2021), Fondo Nacional de las Artes. Tema: Los núcleos urbanos como agentes transformadores de ambiente: cambios en el contexto de urbanización y del medio ambiente de la Ciudad de San Luis entre los siglos XVII y la actualidad.

Michieli, C. (2014). Proceso fundacional de las ciudades de Cuyo en el siglo XVI: Mendoza, San Juan de la Frontera y San Luis (Argentina).

Michelini, J y Davies, C. (2009). Ciudades intermedias y desarrollo territorial: un análisis exploratorio del caso argentino. Grupo de estudio sobre desarrollo urbano. Documento de trabajo GEDEUR nº 5. Madrid.

Prieto, M. del R. (1989). Historia de la ocupación del espacio y el uso de los recursos naturales en el piedemonte de Mendoza. En Roig et. al. (1989). Detección y control de la desertificación, IADIZA-Conicet, UNEP; Mendoza.

Prieto, M. del R. (1997). Formación y consolidación de una sociedad en un área marginal del reino de Chile: la provincia de Cuyo en el siglo XVII. En: Anales de Arqueología y Etnología, No. 52-53, p. 17-366. Dirección URL del artículo: https://bdigital.uncu.edu.ar/14877.

Prieto, M. del R. and Chiavazza, H. (2005). Aportes de la Historia ambiental y Arqueológica para el análisis del patrón de asentamiento huarpe en el oasis norte de Mendoza. Anales del Instituto de Arqueología y Etnología 59-60: 163-196. Facultad de Filosofía y Letras, U.N.Cuyo. Mendoza.

Prieto, M.R., Rojas, F., Castillejo, T., Hernández, F., (2012). Procesos ambientales y construcción del territorio a partir de un estudio de caso: la ciénaga del Bermejo, oasis Norte de Mendoza 1810-1930. En: Revista de Historia Americana y Argentina, Vol. 47, No. 2, Tercera época, p. 175-207.

Prieto Olavarría, C. A., Chiavazza, H. D. (2015). Cambios en contextos de colonización: Opciones económicas y transformaciones tecnológicas en el norte de Mendoza entre los siglos XV y XVII (Rca. Argentina).

Schávelzon, d. (2007). Historia de un Terremoto: Mendoza, 1861. Centro de Investigaciones Ruinas de San Francisco. Área fundacional de Mendoza. Municipalidad de Mendoza. Dirección URL del artículo: http://www.danielschavelzon.com.ar/?page_id=827&file=Area+Fundacional+de+Mendoza%2F

Varnes, D.J. (1984). Landslide Hazard Zonation—A Review of Principles and Practice. IAEG Commission on Landslides, Paris, 63.

ENVIRONMENTAL SCIENCES & PRACTICES
http://mlsjournals.com/Environmental-Science-Practices

(2024) Environmental Sciences & Practices, 2I(1), 41-59.

Learning styles of engineering students at the National Autonomous University of Honduras

Estilos de aprendizaje de los estudiantes de ingeniería de la Universidad Nacional Autónoma de Honduras UNAH

UNAH

Marco Antonio Ramos Espinal
Autonomous University of Honduras, Honduras
(marco.ramos@unah.edu.hn) (https://orcid.org/0000-0003-1389-4026)

Manuscript information:

Received/Recibido: 28/07/23
Reviewed/Revisado: 03/01/24
Accepted/Aceptado: 15/01/24

Keywords:
learning style, active, reflective, pragmatic.

ABSTRACT

The present investigation serves to elucidate the way that Engineering students of the National Autonomous University of Honduras UNAH learn. The UNAH is the largest University and the one that occupies the first place in Honduras, it is a public one and with a constitutional mandate to govern higher education in the Honduran territory. Determining the learning styles of students opens a gap so that educational experiences can be built through study plans and curricular and extracurricular activities that benefit learning, that better engineers are trained to help solve problems huge amounts that overwhelm the Honduran population, in areas such as forestry, agronomy, industrial, chemical, electrical, mechanical, systems and agro-industrial. The design used is non-experimental and cross-sectional with a stratified random sample with data collection through Google Forms. The establishment of the learning style was carried out using the CHAEA questionnaire of Honey-Alonzo and analysis of variance in two factors and multiple was used to find the differences in the learning styles by careers, place of birth and place of residence, also, it was The discriminant equations were built and the Pearson correlation coefficient was calculated, a significant correlation was found at 0.001 between the active, reflective and pragmatic styles, concluding in relatively low values in the levels associated with the learning styles, which defines great possibilities. for the design of appropriate learning experiences in careers.

Palabras clave:
estilo de aprendizaje, activo, reflexivo, pragmático.

RESUMEN

La presente investigación sirve para dilucidar sobre la manera que los estudiantes de Ingeniería de la Universidad Nacional Autónoma de Honduras UNAH, aprenden. La UNAH es la Universidad mas grande y la que ocupa el primer lugar en Honduras, es una pública y con un mandato constitucional de rectorar la educación superior en el territorio hondureño. La determinación de los estilos de aprendizaje de los estudiantes abre una brecha para que se puedan construir las experiencias educativas a través de planes de estudio y actividades curriculares y extracurriculares que beneficien el aprendizaje, que se

	formen mejores ingenieros que coadyuven con la solución de los problemas ingentes que agobian a la población hondureña, en área como la forestal, agronómica, industrial, química, eléctrica, mecánica, sistemas y agroindustrial. El diseño utilizado es no experimental y transversal con una muestra aleatoria estratificada con recolección de información a través de Google Forms. El establecimiento del estilo de aprendizaje se realizó usando el cuestionario CHAEA de Honey-Alonzo y se utilizó análisis de varianza en dos factores y múltiple para encontrar las diferencias en los estilos de aprendizaje por carreras, lugar de nacimiento y lugar de residencia, también, se construyeron las ecuaciones discriminantes y se calculó el coeficiente de correlación de Pearson, se encontró correlación significativa a un 0.001 entre el estilo activo, reflexivo y pragmático, concluyéndose en valores relativamente bajos en los niveles asociados a los estilos de aprendizaje, lo cual define grandes posibilidades para el diseño de experiencias de aprendizaje apropiadas en las carreras.

Introduction

It includes the presentation of the paper and the analysis of the literature on the subject, with special emphasis on previous research that justifies the study and that will be contrasted in the discussion of the results.

All text is in 12-point Cambria font, single-spaced and with no spacing between paragraphs. The National Autonomous University of Honduras (UNAH) is the largest university in Honduras with an enrollment of more than 80 thousand students(UNAH, 2023b) the majority of its courses are undergraduate, with a smaller number of postgraduate degrees, in 10 faculties, and several regional centers. Engineering careers are developed in several centers, mainly in the CU University City, located in Tegucigalpa, Department of Francisco Morazán and in the Sula Valley, Department of Cortés, in the city of La Ceiba, Department of Atlántida and in the city of Choluteca, in the Department of the same name. It is said with great certainty that a considerable percentage of the engineers working in the Honduran territory graduated from the UNAH, even many of those who direct engineering careers in other private or public universities, were also graduates of the UNAH or had some relationship with it.

On September 19, 1847, the university was solemnly inaugurated in a public ceremony headed by President Juan lindo and Rector José Trinidad Reyes. The UNAH gained autonomy on October 15, 1957 by decree number 170, which defined the first organic law of the University. Article 160 of the Constitution of the Republic establishes that the UNAH has the exclusive right to organize, direct and develop higher and professional education in the country.

In 1881, the faculty of sciences was incorporated, which was to offer civil engineering studies for a duration of five years. In 1904, the engineering faculty was founded with 11 students, and it was named the school of topographical engineering. In 1920, the first reform of the civil engineering curriculum was made, in 1959 the semester studies began, and in 1960 the building where the School of Engineering is currently located was built. In 1967 new careers were created and in 1968 the enrollment and hiring of full-time professors in the technical careers of chemical and electrical mechanical engineering was achieved. The UNAH has an industrial information center created in 1975 and in 1981 the Industrial Engineering program was created, and in 2003 the Systems Engineering program was incorporated. In 2021, the curriculum for the Master's degree in Environmental Engineering was registered with the General Secretariat of the UNAH (UNAH, 2023a)

In the development of engineering careers, the question arises as to how students learn, and how they manage to make that learning become a source of memories that will help them for much of the rest of their lives (Ojeda & Herrera, 2013, p. 166). Of course, there is no one way, and even someone who at some point learns one way may later in his or her own life learn another way. But it is not only the ways in which they learn that are influential, but also how they are taught (Chowdhury, 2015) Learning is best conceived of as a process and not in terms of the products that can be obtained from such activity (Kolb, 2014)this represents a basic idea of experiential learning theory, which rests on different epistemological and philosophical views from behaviorist theory (Schunk et al., 2012). Tocci (2013) states that "cognitive, affective and physiological traits" are associated with the concepts that students define and therefore the dominant learning style defines the best way to learn.

A subject that is developed in a way that is contrary to the learning style of a student will surely cause him/her greater difficulty to study and learn it, and would limit the scope of the objective set out in the curriculum to train professionals, specialists, researchers, etc., with the minimum required characteristics, considering that both classroom and distance or online training are considered, which can have a great impact even to improve language skills (Kuzmina et al., 2021).

It is considered that success in learning is not only achieved with teachers who are highly trained in the subject they serve, but who adequately express their social and human competencies, who set their teaching objectives well, who respect and motivate students, who build appropriate evaluation mechanisms according to the way in which their students learn best (Arias Gallegos, 2011).

Tulsi et al., (2016) found that engineering students prefer active, sensitive, and sequential styles of learning. On the other hand, the CHAEA questionnaire, Honey, Alonzo questionnaire of Learning Styles, was based on the contributions of Honey and Mumford, used in Spain by Alonso, Gallego & Honey, establishing four Learning Styles: Active, Reflective, Theoretical and Pragmatic (Alonso et al., 1997, p. 110)the knowledge of learning styles becomes a tool to propose new and better teaching strategies (Molina-Cabello et al., 2023, p. 1)also, evidence is found on the treatment given to students in their learning, which could imply the reinforcement of the use of differentiated strategies depending on the learning style of each student (Rofiq & Pratiwi, 2023, p. 1).

But we do not think only of the traditional teaching that has been used in countries such as Honduras, that is, the traditional model in which the teacher is like the only source of light in knowledge. In addition to repeating the teaching of subjects confined in books, perhaps classics and others not, some very old and others the same but with updated versions, which of course is fabulous, but it also requires modifications even of paradigms both in the way of learning and teaching as could be observed in the post pandemic, where the intensive use of internet, devices, etc., requires new ways and both for teaching and learning.

In the teaching ecosystem, a new way of learning and teaching called education 4.0 where the new needs of students and teachers (ras) converge to make the process more effective (Gueye & Exposito, 2023), references of institutions that seek to reinforce knowledge in the area of engineering and previous mathematics subjects, as is the case of the Coimbra Engineering Institute and its Center for Engineering Mathematics Support (CeAMate) according to learning styles (de Almeida et al., 2023).

Design of experiments for learning, in which the student is allowed to develop their subjects in different ways, with the proper construction of experiments and pre and post evaluation, according to the idea of identifying learning styles to improve education in engineering (Yesilevskiy et al., 2022). Consequently, knowing the learning style, which is more or less stable during a good part of life, the next step is the construction of experiences according to that reality, because the main objective is to achieve new memories, that is, new knowledge, which applied to the good, serves as a basis for the construction of a better society (Haltas, 2022, p. 1). The barriers that the teacher has, i.e. their mental blocks, the diversity of ways of learning in a single room or even in a virtual space, pose a problem of adaptation or adjustment of the teacher, how to harmonize so that the teaching is effective for everyone (Bhogayata & Jadeja, 2022)

Regarding learning styles, Honey and Munford, based on Kolb's approaches, define them as active, reflective, theoretical and pragmatic, with some features indicated in Table 1 below.

Table 1

Traits of learning styles according to Honey and Mumford

Features	Features
Assets	They are fully involved, open-minded, non-skeptical and enthusiastic about new tasks.
Reflective	They like to observe from different perspectives, they gather and analyze data carefully, they are detailed and prudent, they evaluate alternatives before taking any action and they already know the situation well.
Theoreticians	They identify with complex theories, tend to perfection by analyzing and synthesizing, seeking rationality and objectivity
Pragmatists	Practical application of ideas, looking for the positive in order to experiment, they act quickly and confidently, impatient in search of a solution.

Note. Authors' own source, adapted from Alonso et al., (1997) According to Ojeda y Herrera, (2013)the term style is used in psychology in relation to the way in which each individual performs an activity" and in the context of learning, style refers properly to education, it implies the way of obtaining knowledge. According to Smith, (1982) five elements that help learning, namely:

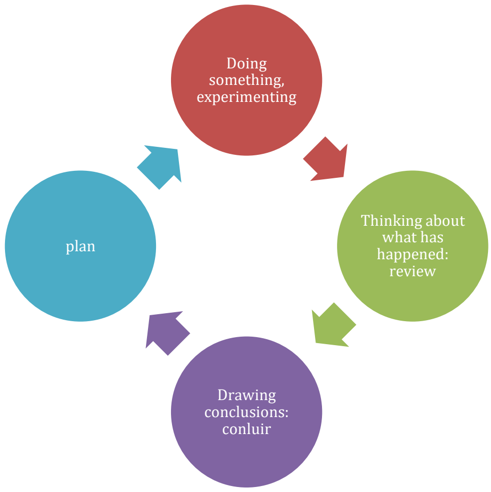
1. Learning is lifelong, we learn with the family, at school, with friends, always, as long as life lasts there is learning
2. Personal learning
3. Learning processes are associated with changes
4. Human development is intimately linked to learning
5. Learning and experience go hand in hand

According to the points indicated, some elements involved in learning can be established, as shown in Figure 1.

Figure 1
Elements in a learning situation

The figure shows the involvement of the environment, what the young people learn, the attitude and of course the emotions, with what a student finally does, and in the case of the results obtained from Honey Alonzo's questionnaire. These are approximately the same in each of the styles, probably so that students can learn in almost any circumstance(Alonso et al., 1997, p. 179)the phases are illustrated in Figure 2,

Figure 2
Learning cycle



Note. Diagram of the elements involved in learning, taken from (Alonso et al., 1997, p. 179)

The teacher's task is not an easy one, however, Martínez, Geijo y otros (2009) citing Alonso et al., (1997), define a series of teaching behaviors that favor each of the learning styles, and Table 2 summarizes the information:

Table 2
Behaviors that favor learning styles

Assets	Reflective	Theoretical	Pragmatic
1. Attending to spontaneous questions	1. Develop few topics with the students.	1. Activities should always be super structured	1. Learning techniques
2. Be up to date	2. Address issues with students in detail and depth	2. All work, tasks, etc., must have clear purposes	2. Doing tasks that are related to each other
3. Show genuine interest in students	3. Require students to review exercises before submitting them	3. Applying work pressure to students	3. Everything must be shown with practical examples
4. Accept and understand what you feel	4. Pay no attention to the superficial	4. Let everything in the class be questioned	4. Bringing subject matter experts into the classroom
5. Frequently come up with new content and projects	5. Do not make them explain something in public without prior explanation	5. Do not promote activities charged with emotions and feelings	5. Reducing explanations by practical activities that enhance learning
6. Promoting and encouraging innovative activities	6. Do not ask questions in class if not previously announced	6. Maintain a calm and orderly climate	6. Building viable and useful projects
7. Requiring students to search multiple paths with feasible solutions	7. Explain slowly, allowing time for reflection	7. Establish with precision the theoretical framework of the positions within the class	7. If something works well, it is because it is useful
8. Constantly varying activities	8. Encourage the collection of information for analysis	8. Assessing in public what students think and reason about	8. Search for shortcuts that lead to a solution
9. Students must invent problems and come up with solutions	9. Allow ample time for the tests to be carried out	9. Do not emphasize trivial or superficial issues	9. Work more on procedures than on theoretical explanations
10. Contribute new ideas, even if they clash with precepts	10. Do not proceed with activities unless the possibility of analysis has been exhausted	10. Consult on criteria and principles	10. Show that the important thing is that things work
11. Encourage teamwork	11. Establish timely academic planning at the beginning of each term.	11. Demanding works explained in detail, informing each procedure.	11. Creating great learning experiences
12. Continuous research	12. Every job you do should be created at the draft level for review prior to submission	12. Explanations must be logical and follow a clear order	12. Enhancing realism and practicality
13. Breaking routines	13. Explain in detail	13. Avoiding open problems	13. Valuing the result over the procedure
14. Make short theoretical presentations	14. Insist on listening first and then formulating an opinion	14. Insist that students be logical and avoid expressing ambiguities	14. Decrease the time of theoretical explanation.
15. Use different methods of presenting the subject	15. Arguing from rationality always	15. Academic planning must be completely linked, defining a common thread in everything that happens in the classroom.	
16. Working on problems obtained from the environment	16. The quality of the presentation of reports and assignments is unquestionable	16. To promote professional relationships more than emotional ones	
	17. Reflecting on facts or events, leaving no loose ends	17. Do not allow students to speak spontaneously	
	18. Never improvise or force them to do so		

Note. Authors' own source, adapted from (Martínez Geijo & others, 2009).

The construction of learning experiences requires a great deal of skill from the teacher but more from the will to carry them out, the great objective is to take advantage of the personal characteristics of each student and as far as possible create the conditions that allow each student to make the most of them. Countries like Honduras, mired in poverty and backwardness, require engineers to solve problems at the lowest cost and to benefit the majority. To achieve this, or at least get closer to a possible solution, the UNAH must synchronize its administrative and academic aspects, giving priority to the latter, since it is even a constitutional obligation to direct higher education in order to contribute to solving the enormous problems that afflict the population.

All of the above implies giving priority and flexibility to the construction of curricula in accordance with the reality of the needs of science, society, the productive sectors and all the forces that make up society. It cannot be that an institution with such an obligation cannot overcome the administrative formalities and not provide educational solutions, i.e. timely offers. The construction of adequate experiences also requires the vocation of the teacher, it is archaic and stale thinking to postpone for the sake of postponing students, just because the only light of the world is the teacher, must leave, disappear from university classrooms, comprehensive education but focused on the student is the basis for progress and improve conditions.

Nor should the petty interests of sectors linked to education give way to the empire of knowledge, it is not possible to stop the advancement of the public university for political and private interests and arrangements that only aim at unbridled enrichment, sacrificing the quality of education for accumulation in the style of savage capitalism, leaving thousands of young people on the sidelines and depriving them of access to the best possible education.

It seems that the hidden interest is not to let them advance, in that sense it is important to indicate that teachers of stale thinking, too, must learn again to discard their misconceptions and be forgers of better people, or get out of the way because they are in the way.

The most important thing in the UNAH is not its authorities, nor its buildings, nor its professors, nor anyone else but the students. The establishment of learning styles in the framework of the theory constructed by Honey Alonzo, allows an adequate and fast way to formulate a research with the current tools of the Internet and allows to give lights to improve the process especially of teaching, adapting to new achievements and taking advantage of the bonus of youth that students have, since we are talking about young people whose ages range between 18 and 25 years mostly, and who demand that the arbitrary and perhaps orthodox methods of teaching are adjusted even if it is little by little, but that define a gap for the construction of a better university.

Beyond academic planning, curricula or study plans are required that in their methodological components emphasize the way of teaching, not only in the content and topics to be covered, which are important, but cannot be served in the same way always and to everyone, therefore, it requires a hard work of the teacher to plan how to achieve the construction of new memories and link them with the previous ones and thus achieve new knowledge, that is the most difficult part, that is the complicated part, how to design these activities that at least benefit the majority, since not everyone learns the same way, but the majority will be benefited, or else how can we expect the country to have better prepared children if the way to do it is just one more activity, perhaps poorly served or constructed and that has forced the student to think that the only important thing is to pass the course and get a degree, this last thought is probably the responsibility of the teacher, who transmits only that, in the worst of the cases, the most regrettable ones by the way, who serves the subject, does not have the adequate formation, and avoids questions, reacts with violence or assaults the students wanting to make them feel bad, as if the deficiency of the one who teaches should be borne by them. In the case of learning styles measured through the Honey Alonzo questionnaire, it is suggested to improve the styles when the active one obtains scores lower than 9, the reflective one when it is lower than 14, the theoretical one lower than 10 and the same for the pragmatic one (Alonso et al., 1997, pp. 180–190)

Method

The learning style of engineering students enrolled in the first academic period of 2023 at the National Autonomous University of Honduras was established through a non-experimental, cross-sectional design. Considering as the target population all students enrolled in the various careers of the Faculty of Engineering, which is developed in several study centers as shown in Table 3,

Table 3

Students enrolled in the School of Engineering careers

University Center	Number of students enrolled
Central Regional University Center CURC	551
Centro Universitario Regional del Litoral Atlántico CURLA	365
Centro Universitario Regional del Litoral Pacifico CURLP	421
Northeastern Regional University Center CURNO	181
Tecnológico de Danlí, UNAH-TEC Danlí	193
Central Regional University Center CUROC	352
CU University City	4593
Distance Education Learning Resource Centers (CRAED) in several cities in Honduras	10
Cloth I.T.S.T	2
UNAH Sula Valley	2497
UNAH TEC-Aguan	102
UNAH VS-Telecentro Cortés	1
Total	9268

Note. *Adapted from information provided by the Dirección de Ingreso Permanencia y Promoción DIPP of the UNIVERSIDAD NACIONAL AUTÓNOMA DE HONDURAS UNAH, 2023, (UNAH, 2023b)*

From the total population, stratified random sampling was developed in one stage by sending the questionnaire to those selected using the Google Forms platform, which is hosted at the address: https://forms.gle/vN7vRdCMyFHBSRqp6the details of the sample are shown in Table 4:

Table 4
Sample size

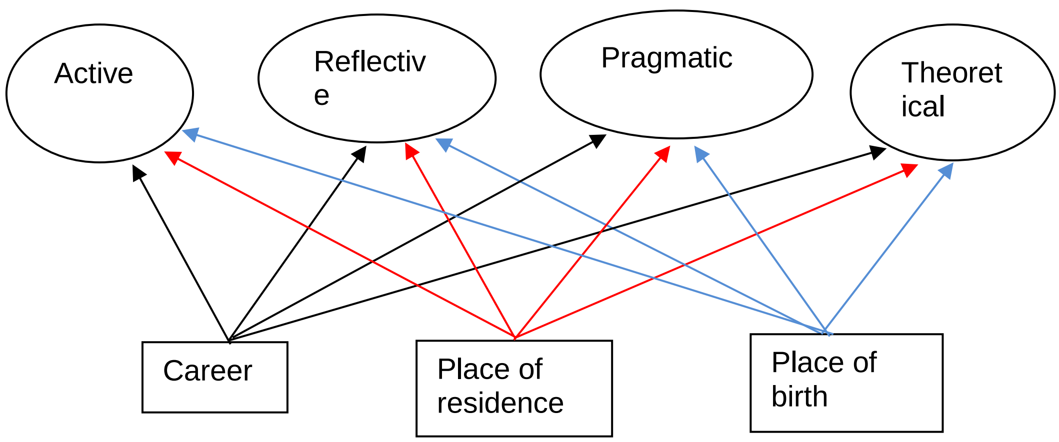
Career	Sample Size	Response obtained
Agroindustrial Engineering	60	15
Agricultural Engineering	13	1
Civil Engineering	49	32
Industrial Electrical Engineering	71	64
Systems Engineering	100	44
Forestry Engineering	3	1
Industrial Engineering	41	73
Industrial Mechanical Engineering	31	58
Chemical Engineering	25	82
Grand Total	392	370

Note. Own elaboration using stratified sampling (Mendenhall et al., 2006, p. 94)

As can be seen, the value defined in the sample was not achieved, but the analysis was performed with the information collected. The analysis of the data consisted of establishing the learning style of the students through the use of the graph associated with the Honey Alonzo questionnaire, then it is of interest to know if there is a difference between the values obtained in each learning style by the students of each career, so a two-factor analysis of variance is performed with a sample by group and also, by place of birth through the Department, said extreme is also verified with a two-factor analysis of variance and a sample by groups. To verify the existence of differences in each of the leadership styles, a multiple variance analysis was performed, using as factors the career studied, place of birth and place of residence, and the differences found are verified with a discriminant analysis as shown in Figure 4,

Figure 4

Multiple variance analysis, determination of differences in learning styles of UNAH engineering students



Note. This figure shows the multiple analysis on the value of learning styles**.**

In order to determine the relationship that may exist between the academic index of the students and their manifest learning style, the study of the relationship is proposed through a linear regression model, and the corresponding correlation coefficient is calculated. Student participation includes various regions of the country, with the highest participation in the

Department of Francisco Morazán, where the University City (CU) is located, as shown in Figure 5:

Figure 5

Geographical distribution in the Republic of Honduras, of responses from Engineering students at UNAH

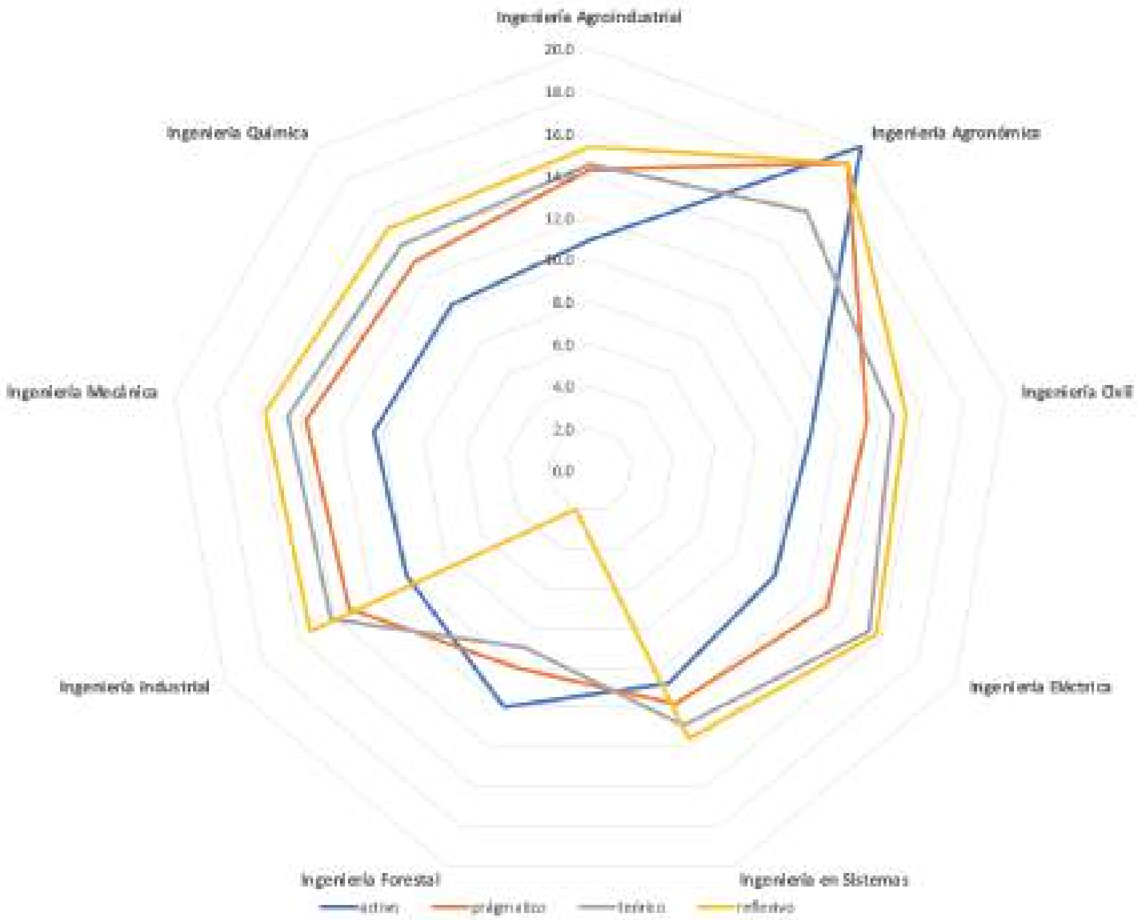
Note. This figure shows the political and geographic distribution of the Republic of Honduras in its 18 Departments, and the number of students who responded to the questionnaire. Own elaboration based on the data collected.

Method

Figure 6 shows the learning style based on the Honey Alonzo questionnaire for each of the careers

Figure 6

Learning styles of engineering students at the UNAH



Note. This figure shows the learning styles of the students of the Faculty of Engineering of the UNAH, enrolled in the first period of 2023, in the different careers. Own elaboration based on the data collected

Table 5 shows the result of the average value of the responses of the engineering students, which establishes their position in relation to the questionnaire items, as shown below:

Table 5

Assessment of learning style by career

Career	*Active*	*Pragmatic*	*Theoretical*	*Reflective*
Agroindustrial Engineering	10.9	14.3	14.53	15.3
Agricultural Engineering	20.0	19.0	16.00	19.0
Civil Engineering	10.7	13.3	14.56	15.2
Electrical Engineering	10.1	13.0	15.30	15.7
Systems Engineering	10.8	11.8	12.93	13.6
Forestry Engineering	12.0	10.0	9.00	2.0
Industrial Engineering	10.0	13.2	14.19	15.3
Mechanical Engineering	10.4	13.7	14.57	15.7
Chemical Engineering	10.2	12.9	13.91	14.9

Note. *Own elaboration based on the answers obtained*

By performing the two-factor analysis of variance and one sample per group, the following results were generated as shown in Table 6, Analysis of Variance of two factors of leadership styles versus race and Table 7, Analysis of Variance of leadership styles versus Department of Birth,

Results

Table 6

Two-factor analysis of variance of learning style versus career

Origin of variations	Sum of squares (SC)	Degrees of freedom(gl)	Mean squares	F	Pr(>F)
Careers	216.157765	8	27.0197206	5.22707447	0.000737703**
Style	32.0360222	3	10.6786741	2.06583278	0.131428286
Error	124.060466	24	5.16918607		
Total	372.254253	35			

Note. *Own elaboration based on the data collected, ** significant difference at 0.001*

Table 7

Two-factor analysis of variance of learning style versus Department of Birth

Origin of variations	*Sum of squares*	*Degrees of freedom*	*Mean squares*	*F*	*Pr(>F)*
Department	58.7289931	12	4.894082758	2.279454097	0.028065091
Styles	275.4598958	3	91.81996528	42.76580646	5.89567E-12
Error	77.29349739	36	2.147041594		
Total	411.4823863	51			

Note. Own elaboration based on the data collected

After performing a multiple variance analysis, taking learning styles as dependent variables, and career, place of birth and place of residence as predictor variables, the results of the variance analysis are shown in Table 8,

Table 8

Result of multiple variance analysis, learning style versus career, place of birth and place of residence

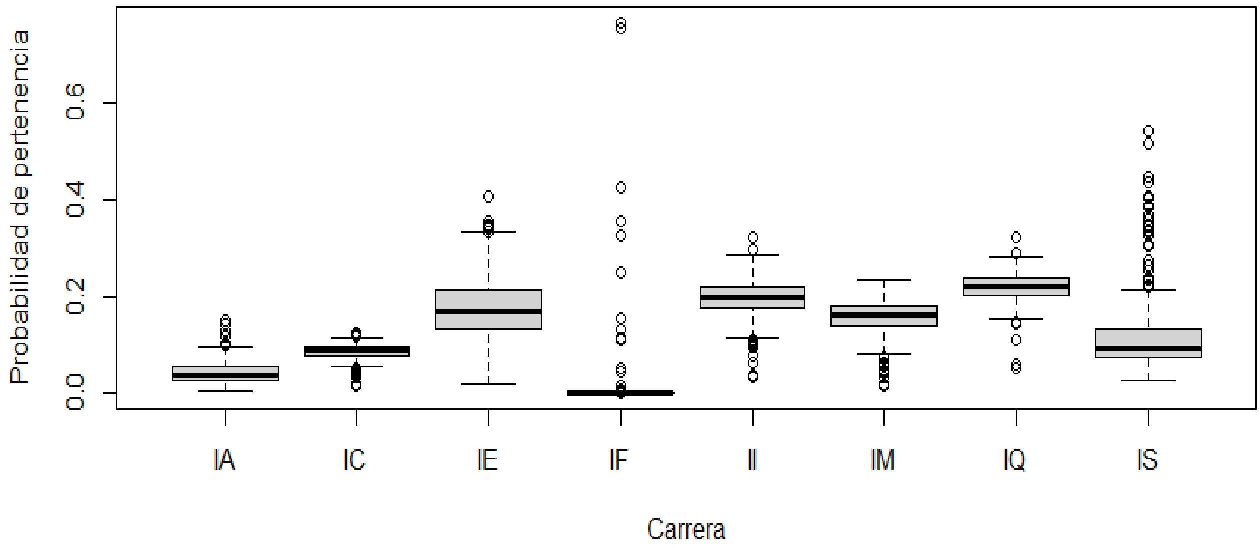
Source of variance	gl	Pillai	Approx F	Num Df	den Df	Pr(>F)
Career	8	0.21875	1.8151	32	1004	0.003912**
Place of residence	52	0.68733	1.0015	208	1004	0.484985
Place of birth	57	0.76199	1.0363	228	1004	0.357091
Residuals	251					

Note. Own elaboration based on data collected, ** difference significant at 0.001

To study the significant difference in learning style due to career, a multiple discriminant analysis was performed, obtaining the results shown in Figure 7.

Figure 7

Behavior of learning styles across centroids of predicted probabilities of belonging versus careers



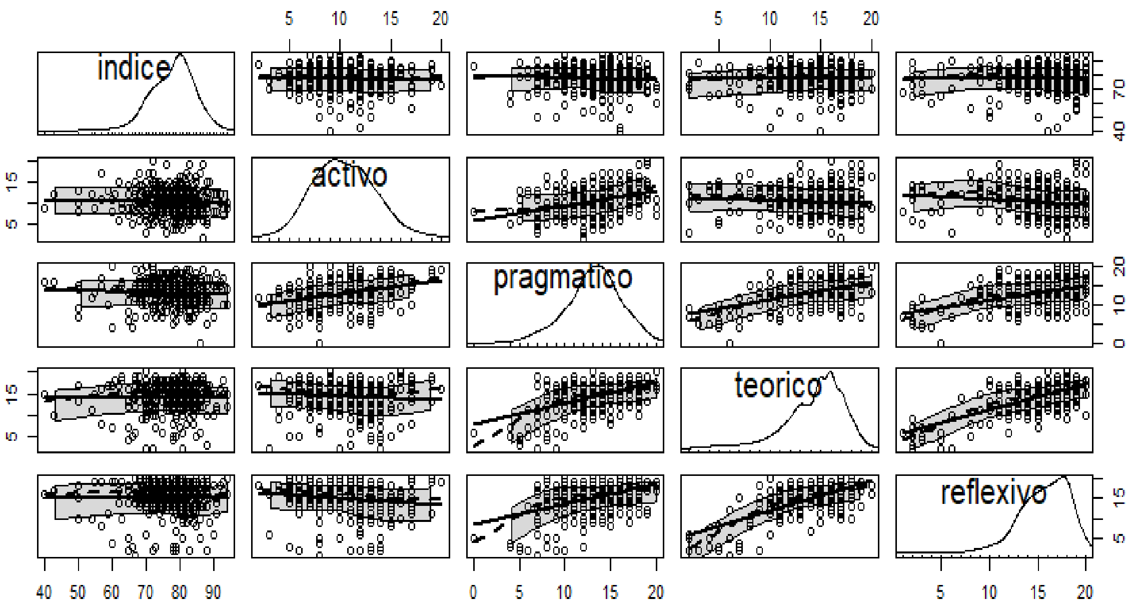
Note. This figure shows the centroids of the discriminant functions.

For each career, where IA is Agroindustrial Engineering, IC is Civil Engineering, IE is Electrical Engineering. IF Forestry Engineering, II Industrial Engineering, IM Mechanical Engineering, IQ Chemical Engineering and IS Systems Engineering, the centroids were calculated to know the location of the style of each career.

Figure 8 below shows the scatter plots of the academic index variable and the students' learning styles.

Figure 8

Data behavior of index styles and learning styles of UNAH engineering students



Note. This figure shows both the histograms and the relationship between each pair of variables, indicating that it is not linear, prepared from the data collected.

As shown in the figure, the index shows a linear relationship with the four learning styles, with data concentrations that show a relationship close to a linear one, so it becomes important to know this style as an element that allows establishing curricular experiences to improve learning with repercussions in the performance of future engineers.

The correlation coefficients calculated are shown in Table 9:

Table 9

Pearson's correlation coefficients between the index and learning styles

Variable	Index	Active	Reflective	Pragmatic	Theoretical
Index	1	-0.04	0.01	-0.06	0.02
Active	-0.04	1	-0.014	0.35	-0.09
Reflective	0.01	-0.14	1	0.43	0.66
Pragmatic	-0.06	0.35	0.43	1	0.47
Theoretical	0.02	-0.09	0.66	0.47	1

Note. Own elaboration based on the data collected.

The p values are shown in Table 10.

Table 10

P-values of Pearson's correlation coefficients between the index and learning styles

Variable	Index	Active	Reflective	Pragmatic	Theoretical
Index		0.4705	0.8395	0.2416	0.7264
Active	0.4705		0.0060*	0.0000*	0.0929
Reflective	0.8319	0.0060		0.0000*	0.0000*
Pragmatic	0.2416	0.0000	0.0000		0.0000*
Theoretical	0.7264	0.0929	0.0000	0.0000	

Note. *Own elaboration based on the data collected. * significant values at 0.001*

Discussion and conclusions

Finally, the conclusions of the article will be presented in a last section, followed by the main conclusions. Where appropriate, limitations and proposals for continuity will be included. From the data collected in the sampling process, it was possible to determine the learning style for each of the engineering careers that are developed in the UNAH, in the case of Agroindustrial Engineering, students have characteristics of pragmatic, theoretical and reflective styles with higher values, in the case of the active its value was lower, in fact, the active style showed a significant negative correlation with the reflective style and showed no relationship with the theoretical style; however, the reflective, pragmatic and theoretical styles showed significant direct relationships, which indicates that they enhance teaching, as shown in Table 2, behaviors that favor the styles identified in the students. In the case of Agronomy Engineering, relatively high scores were obtained in the four styles, so that the work to be done to improve learning can be oriented in the four directions, differentiating and at the same time complicating the work of the teachers; on the other hand, Civil Engineering obtains its lowest value in the active style, followed by the pragmatic, and scarcely higher values in the theoretical and reflective styles.

Despite the above, the results offer great opportunities for improvement in the teaching process, since at low levels, the implication is to work on strengthening teaching in the four ways marked by the identified styles,

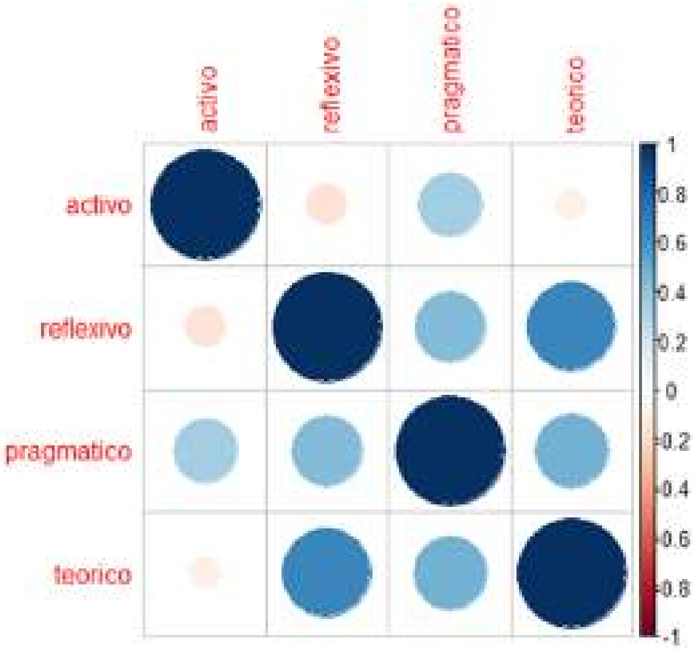
A similar situation to that of Civil Engineering was detected in Electrical Engineering with the possibility of establishing teaching and learning methodologies oriented to the four styles. One strategy that can be followed by the faculty and the authorities of the Academic Departments and the Dean's Office is to emphasize the construction of classes that involve the development of activities that offer opportunities for all students to make the most of the subjects they take. In the case of Systems Engineering, the values presented are low in all four styles, offering great opportunities for intervention through the design of appropriate experiences. Forestry Engineering requires a bold strategy and implementation to achieve significant learning in students, and for Industrial Engineering, Mechanical Engineering and Chemical Engineering, the values obtained are very similar, so there are important opportunities for intervention favoring the four learning styles.

An important concern that is elucidated by the results obtained is that, when performing the two-factor analysis of variance with a sample per group, a significant difference is found only in terms of careers, not style, i.e., when evaluating styles by style, engineering students have similar traits, but differences are found in terms of careers. The same did not happen in the case of the two-factor analysis of variance considering careers and place of birth represented by the Department, no differences were found. In spite of the above, a multiple variance analysis was performed considering the defined styles and as factors career, place of residence and place of birth, finding significant differences only in the careers. As shown in Figure 7, after constructing the discriminant functions, similarities can be found in careers such as Agricultural Engineering, Forestry Engineering and Civil Engineering, and another large group could be defined by Electrical Engineering, Industrial Engineering, Mechanical Engineering, Mechanical Engineering and Systems Engineering.

Although the values of the correlations between the academic index reported by the students do not reflect a significant relationship with the values of the learning styles, it is observed that the frequency graphs are close to normality, which gives rise to further parametric inferences of the same and other variables, a significant relationship was found between the active, reflective and pragmatic style, as shown in Figure 9 below.

Figure 9

Correlations of learning style values of UNAH engineering students



Note. This figure shows both the Pearson correlation coefficients of the values of each learning style, own elaboration from the data collected.

As a conclusion, it is established that for the active style, it should be reinforced to try new things, compete in teams, solve problems, dramatize, lead debates, find problems, try different methods, for the reflective style, design observation activities, work without pressure, investigate exhaustively, collect information, get to the bottom of the issues addressed, analyze in detail and synthesize,

Also, the requirement of detailed reports, in the case of the theoreticians, defining strongly structured schemes, working methodically, questioning with skepticism, testing methods and the logic of the resolution, and for the pragmatists, experimenting, showing shortcuts and results, the system must work because it must work, exemplifying abundantly since the training of engineers requires a lot of practical activity that helps to build adequate experiences. (Alonso et al., 1997, pp. 158–162).

The result of this research generated a snapshot at a given moment, a good alternative could be to follow up groups throughout their stay in the career, and thus build data that reflect the variation of learning styles in engineering students of the UNAH.

References

Apellido, A. A., Apellido, B. B, y Apellido, C. C. (Fecha). Título del artículo. *Nombre de la revista*, *volumen*(número), pp-pp. Alonso, C. M., Gallego, D. J., & Honey, P. (1997). *Los estilos de aprendizaje: Procedimientos de diagnóstico y mejora* (Vol. 221). Mensajero Bilbao, España.

Arias Gallegos, W. L. (2011). Estilos de aprendizaje en estudiantes universitarios y sus particularidades en función de la carrera, el género y el ciclo de estudios. *Revista de Estilos de Aprendizaje*.

Bhogayata, A., & Jadeja, R. B. (2022). Influence of Learners' Diversity on the Pedagogical Practices in Engineering Education: A Meta-Analysis of Teachers' Reflections. *Journal of Engineering Education Transformations*, *36*(Special issue 2), 566–574.

Chowdhury, R. K. (2015). Learning and teaching style assessment for improving project-based learning of engineering students: A case of united Arab Emirates university. *Australasian Journal of Engineering Education*, *20*(1), 81–94.

de Almeida, M. E. B., Branco, J. R., Margalho, L., Cáceres, M. J., & Queiruga-Dios, A. (2023). An Individual Work Plan to Influence Educational Learning Paths in Engineering Undergraduate Students. *Springer Proceedings in Mathematics and Statistics*, *414*, 285–293. www.scopus.com

Gueye, M. L., & Exposito, E. (2023). *Education 4.0: Proposal of a Model for Autonomous Management of Learning Processes: Vol. 13821 LNCS*. www.scopus.com

Haltas, I. (2022). Teaching from Multiple Angles: Aligning the Teaching Materials and Activities with Preferred Learning Styles of the Students. *ASEE Annual Conference and Exposition, Conference Proceedings*. www.scopus.com

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.

Kuzmina, N. N., Korotkova, E. G., & Kolova, S. M. (2021). Implementing E-Learning in the System of Engineering Students Training. *Proceedings of the 2021 IEEE International Conference "Quality Management, Transport and Information Security, Information Technologies", T and QM and IS 2021*, 818–823. www.scopus.com

Martínez Geijo, P. & others. (2009). Estilos de enseñanza: Conceptualización e investigación (en función de los estilos de aprendizaje de Alonso, Gallego y Honey). *Revista de Estilos de Aprendizaje*.

Mendenhall, W., Scheaffer, R. L., & Lyman Ott, R. (2006). *Elementos de muestreo*. Ediciones Paraninfo, SA.

Molina-Cabello, M. A., Thurnhofer-Hemsi, K., Molina-Cabello, D., & Palomo, E. J. (2023). Are learning styles useful? A new software to analyze correlations with grades and a case study in engineering. *Computer Applications in Engineering Education*, *31*(3), 537–551.

Ojeda, A. F. O., & Herrera, P. J. C. (2013). Estilos de aprendizaje y rendimiento académico en estudiantes de ingeniería en México. *Revista de estilos de aprendizaje*, *6*(11).

Rofiq, Z., & Pratiwi, H. (2023). The influence of collaborative strategies and cognitive styles on the results of learning to read machinery engineering images. *AIP Conference Proceedings*, *2671*. www.scopus.com

Schunk, D., Meece, J., & Pintrich, P. (2012). *Motivation in education: Theory, research, and applications: Pearson Higher Ed*.

Smith, R. M. (1982). *Learning how to learn: Applied theory for adults*. Open University Press Great Britain.

Tocci, A. M. (2013). Estilos de aprendizaje de los alumnos de ingeniería según la programacion neuro linguística. *Revista de estilos de aprendizaje*, *6*(12).

Tulsi, P. K., Poonia, M. P., & Anupriya. (2016). Learning styles and achievement of engineering students. *IEEE Global Engineering Education Conference, EDUCON*, *10-13-April-2016*, 192–196. www.scopus.com

UNAH. (2023a). *Facultad de Ingeniería UNAH*. https://www.facebook.com/ingenieria.unah.edu.hn/posts/pfbid0241xAjEMvnjRycxg6qEXnFf2WitcteBQwPdDFiESEcMJzR1Eic9WPYdYMKxytV3hYl

UNAH. (2023b). *Informe de Matricula en Ingeniería, DIPP*.

Yesilevskiy, Y., Thomas, A., Oehrlein, J., Wright, M. A., & Tarnow, M. (2022). Introducing Experimental Design to Promote Active Learning. *ASEE Annual Conference and Exposition, Conference Proceedings*. www.scopus.com

ENVIRONMENTAL SCIENCES & PRACTICES
http://mlsjournals.com/Environmental-Science-Practices

(2024) Environmental Sciences & Practices, 2(1), 61-74.

The importance played by the professional education of industrial designers when incorporating ecodesign practices within the professional practice of design

La importancia que juega la formación profesional del diseñador industrial para incorporar el ecodiseño dentro de su práctica profesional

Antonio Solórzano Cisneros
Autonomous University of Mexico, Mexico
(antonio.solorzano@doctorado.unini.edu.mx) (http://orcid.org/0000-0002-8667-6508)
Eduardo May Osio
Itescam, Mexico
(eduardo.may@unini.edu.mx) (http://orcid.org/0000-0003-0782-3002)

Manuscript information:

Received/Recibido: 18/03/23
Reviewed/Revisado: 17/01/24
Accepted/Aceptado: 25/01/24

Keywords:
design, sustainability, ISO 14006 standard.

ABSTRACT

The design activity has been marked as one of the professional practices with the greatest environmental impact due to strategic decisions made while crafting the material world, thus reflected in the damage that resulting objects coming from the design process generate: mountains of everyday us products that are manufactured by the millions, causing the depletion of planetary resources and generating all kinds of emissions and toxic waste throughout their life cycle. The results presented here are based on a doctoral investigation whose objective was to locate and describe how external factors reduce the effectiveness of the decisions taken during the design process; the present study centers on the part that professional formation plays. The study was centered on the industrial designer located in Mexico City and the metropolitan area, taking as a reference, the ISO 14006 standard, which governs the eco-design concepts to better understand the design processes it manages. The methodology used a detailed header research on sustainable design and its strategies, a diagnostic questionnaire carried out to industrial designers, with at least two years of experience working in small and medium-sized companies and an in-depth interview carried out within a panel of experts, who helped defining the problem, confirming the findings and, from their experience, guiding the process of incorporating sustainability into the professional designer´s work.

Palabras clave:
diseño, sustentabilidad, norma ISO 14006.

RESUMEN

La actividad de diseño ha sido marcada como una de las prácticas profesionales de mayor impacto ambiental debido al peso que juegan las decisiones tomadas al momento de configurar el mundo material, reflejado en el daño generado por los objetos resultantes del proceso de diseño: montañas de productos de uso cotidiano que se fabrican por millones provocando el agotamiento de los recursos planetarios y generando todo tipo de emisiones y residuos tóxicos a lo largo de su ciclo de vida. Los resultados presentados parten de una investigación de carácter doctoral cuyo objetivo fue localizar y describir aquellos factores externos que reducen la efectividad en las tomas de decisiones a lo largo del proceso de diseño relacionadas con el cuidado medio ambiental; este artículo se centra en el peso que juega la formación profesional. Se hizo el estudio en diseñadores ubicados en Ciudad de México y zona conurbada, tomando como eje transversal la Norma ISO 14006, rectora de los conceptos de ecodiseño, para entender que procesos de diseño son gestionados por la misma. La metodología recurrió a una investigación de cabecera detallada sobre el diseño sustentable y sus estrategias, un cuestionario diagnóstico realizado a diseñadores industriales, con al menos dos años de experiencia laboral que trabajan en pequeñas y medianas empresas y una entrevista a profundidad realizada a un panel de expertos, quienes ayudaron a delimitar la problemática, confirmar los hallazgos obtenidos y desde su experiencia guiar el proceso de incorporación de la sustentabilidad al trabajo profesional de diseño.

Introduction

Everything that exists in the modern world is the result of an act of design (Norman, 1999), the physical manifestation of culture, where the lack of empathy with the natural world is reflected and where every decision, unconsciously irresponsible, that is taken in the process of construction and diffusion of products comes from such activity and the role played by the designer marks him as the main responsible (Capra, 1992, Papanek, 2005). Design is considered the material transformation of the world, suggesting that it is a practice that consists of diagnosing a problem, interpreting and analyzing it to develop creative ways to overcome it (Boehnert, 2018), implying by definition that the designer executes such actions, and therefore, responsible for the consequences, giving rise to the consideration that no activity causes greater harm than the way in which the material world is designed and manufactured (Papanek, 2005), when its ethical and moral work, is to create responsible products that incorporate efficient technologies in their life cycle, avoiding the degradation of natural systems but instead shows only a lack of adequacy to interact harmoniously with our natural environment, which makes design one of the activities with greater responsibility towards the environment (Capra, 2015).

Enzo Manzini (1992) states that it is the lack of a professional ethic that adapts to real problems and new sensitivities, specifically the environmental issue, offering new horizons to design and the opportunity for transformation, based on the values of an industrial society within a sustainable context.

Design is a powerful tool that has allowed the transformation of the natural state of existing environments towards preferred, although sometimes hyper-artificial and unsustainable states (Buchanan, 2001) that result in resource depletion, pollution and health problems among others, putting at risk the quality of life of future generations. Because design has fallen into an inability to generate lasting values, becoming obsolete, dangerous and unsustainable (Norman, 1999) has marked the practice of design as the main responsible. According to several authors (Papanek, Buchannan, Boehnert, Manzini, Thakara) more than 80% of environmental decisions are made during the conceptualization and design stage of the design process. For this reason, it is said that the problem of sustainability is a design problem (Thackara, 2005) and although there are strategies focused on minimizing the damage produced by design practices (e.g. eco-design), they are inefficient and insufficient to achieve the objectives of sustainable development, assuming that design has the ability to develop products that consider environmental factors, transforming the professional practice of design (Ehrenfeld, 2015).

The designer has the ability to implement the necessary changes, redirecting his or her efforts to transform the system he or she determines should be designed (Boehnert, 2018), mitigating the environmental damage derived from the professional practice of design. There are several concepts derived from the so-called eco-design, whose objective is to reduce the impact in the design practice; this concept was born within the so-called industrial ecology under the tenor of "*doing more with less*", a perspective rooted under guidelines proposed by neoliberal policies, where the important aspect is the economic and not the environmental. This limits the real scope that strategies such as the one mentioned above could have, because their main scope lies in the recycling of resources and the optimization of raw materials, without contemplating stages that produce a great environmental impact, such as obtaining the primary resource itself, its use and final disposal, which in the opinion of several authors, are processes that fail due to the lack of an integral vision that goes beyond the limits imposed on the professional work of the designer, who should go beyond and turn his profession into an innovative and creative activity based on solid scientific foundations that allow him to solve human needs and at the same time stop the planetary degradation caused by poorly designed objects and services.

This research arose from the concern to understand how the professional training of the designer affects their performance in addressing an environmental problem, as well as to describe what are the obligations that every designer has, their skills, limitations and competencies, where the ISO 14006 standard played an important role in mapping the design processes managed by it, under the principles of the so-called eco-design. This standard becomes an important reference because it indicates exactly which processes the industrial designer is responsible for, lists them and suggests a series of recommendations to systematically reduce the impact by reducing material resources and energy.

This type of studies are carried out with the future objective of guiding the critical decisions taken during the design process, responding to the demands of a society interested in both the conservation of nature and the preservation of its lifestyle, in order to incorporate, subsequently, to the design work, different alternatives to achieve this objective, improving processes, instilling ethical values and integrating a cultural vision, turning this challenge into one of a strategic nature that contemplates all those involved (Chávez, 2016). Another objective of the doctoral research was to recognize the designer and the role he plays in the transformation and construction of the artificial world that surrounds us and the context within which design projects are developed.

This article presents part of the results obtained from a research conducted during the months of February to May 2021, which revolved around the design activity and its relationship with the environmental decisions taken during their professional work.

Method

Research design

As mentioned, this article presents a small portion of a doctoral research, where the main objective was to document the situation of design in Mexico City and the surrounding area, to understand the factors inside and outside the industry and to delimit the professional profile of graduates from universities that teach design or similar careers. In order to meet the proposed objectives, various tools were used, both qualitative and quantitative, taking as a starting point a mixed research, descriptive-explanatory type, whose objective was to relate the different actions and decision making, which lead to a cause and effect relationship between what the designer does (direct internal factors) and its effect on environmental damage; On the other hand, we sought to locate and understand those indirect external factors that affect the way in which the designer makes his decisions, determining both the indirect variables (decision-making capacity, manufacturing requirements, customer requests, etc.), and those direct variables (training, knowledge, professional development, etc.) and the role they play in determining the degree of environmental impact derived.

A diagnostic questionnaire was used to parameterize and quantify, as far as possible, the characteristics of such broad and ambiguous areas as the type of environmental management in companies, the implementation of eco-design strategies, environmental performance, responsibility based on the position according to the organizational chart and the objectives pursued by companies that hire industrial designers in Mexico City and the surrounding area, this information was nourished and corroborated by means of an extensive consultation of diverse sources of information and a series of in-depth interviews with a panel of experts, in order to define indicators and quantifiable concepts as parameters.

This questionnaire was nurtured thanks to the participation of a panel of experts, through the tool of the unstructured in-depth interview, which made use of an inquiry technique known as "laddering", directing the interviewee in the direction necessary to delve into the issues relevant to the confirmation and complementation of the information gathered during the bibliographic research stage, and whose results were the basis for the generation of the diagnostic questionnaire. The three research tools were analyzed through data triangulation for final data interpretation and conclusions.

Participants; population, sample, and selection of key stakeholders

A mixed research, such as the one proposed in this document, starts with a small number of informants; in a participatory observation and qualitative interview, the number of informants is not known beforehand, but cases are added as the research progresses.

A maximum variation sampling is proposed, focused on those cases recognized as usual within the context under investigation, with the purpose of describing and understanding the central themes or characteristics of the actors interviewed; the informants that best represent the reality under study. It is also a non-probabilistic convenience sampling, since our main actor must cover a specific profile of essential characteristics defined by the nature of the study and be perfectly adapted to the proposed model.

The organizational chart of the companies with a design department was decisive at the time of selecting the sample population, the industrial designers, and the job descriptions in accordance with the Human Resources departments, and under these criteria, the selection of the objective population on which the questionnaire will be implemented was made.

The sample population presented was selected for its position within the organizational chart, as well as the power in critical decision-making and experience within the company, being the main actor, the industrial designer who develops his professional work within the field of product development and manufacturing industry in micro, small and medium enterprises in Mexico City and its suburbs.

Primary Sampling

The diagnostic questionnaire was applied to 106 industrial designers working in industries or companies located in Mexico City and its suburbs, who met the selection profile and agreed to participate by answering the questionnaire.

The criteria for the selection and inclusion of industrial designers to whom the diagnostic questionnaire was carried out, providing the most relevant information, were as follows:

- Industrial Design interns working as scholarship holders: This profile is taken into consideration because it is a common practice in the industry to hire interns who are in the last years of their career, in order to develop their internships or obtain professional experience.
- Recent college graduates starting their professional careers: Young graduates are more aware of the knowledge acquired during their training, so the information provided by them will be of vital importance, especially when it comes to understanding whether there is a relationship between what they have learned in their studies and their professional work.
- Junior Designers: Designers with less than 3 years of work experience, young designers who already have the necessary experience to be performing efficiently within a company, and who already know the processes within the company.
- Senior Designers: Designers with work experience greater than 3 years, who may or may not be able to fill a management type position due to experience. This profile is important because they already master a series of processes and tools thanks to their work experience; they are able to identify a methodological process inherent in the practice.
- Designers with an additional degree (specialty, master's, doctorate, etc.). Those who, in general, may or may not be able to fill a management position based on their qualifications. If any, they are able to identify the most advanced procedures and strategies that are not so obvious to designers without this degree of education.

The second part of the experiment consisted of in-depth interviews with a panel of experts: 15 specialists were interviewed. The purpose of the interview was to understand the context within which the work of the industrial designer is developed in Mexico, the historical background that frames the evolution of the professional work, the academic professional training, the competencies and the graduate profile, the current situation of the Mexican designer, the relationship between the industrial designer and sustainability in Mexico, and to define the profile for a new type of integral designer.

The criteria for the selection of the specialists were:

- Academy leaders with more than 10 years of experience involved in the teaching of the discipline, curricula and the definition of graduate profiles.
- Design theorists with several publications related to the fundamental aspects of the discipline.
- Industry leaders, both in the area of customer relations, design company management and production managers involved with product design and manufacturing projects (complementary sampling).

Complementary sampling: A group of secondary actors, who have direct interference with the work of the industrial designer and, therefore, with the results of the design processes, were identified during the questionnaire. These profiles will complement the profile of specialists who completed the panel.

The interview with these actors focused directly on the academic training of the industrial designer, design procedures, management of design teams and the implementation of environmental strategies within companies, as well as knowledge of standards and their practical application within the design industry.

These profiles, despite having an external participation, had a crucial role in defining the development of the projects, occupying positions located at the upper ends of the organization charts, interviewed in order to understand the level of direct impact that their positions have on the design processes.

The complementary sampling consisted of: 1) company general managers, 2) sales managers and their sales team, who express the customer's needs and serve as part of the panel of experts in the interview stage, and 3) managers of the product design and development areas.

Instruments

The questionnaire and its results: As mentioned, this instrument, consisting of 35 diagnostic questions, was applied to 106 industrial designers who met the established ideal profile and was applied online during the months of March and April 2021, using the "Google Survey" tool. One of its main objectives was to diagnose the degree of knowledge related to the concepts of sustainability, climate change, the impact of the profession and the different methodological tools available to them, ending with the identification of those variables that affect environmental performance.

Among the objectives covered by the questionnaire, two stand out: Identify the direct and indirect factors that affect decision making when developing a project; and to understand the role played by the academic training of designers and its relationship with the knowledge of strategies, causes and consequences.

The questionnaire addresses criteria of relevance and importance of the different factors related to the implementation of environmental strategies, the knowledge of these and the formation of competencies related to the sustainable aspect during the professional training of the respondents.

Analysis and Results Obtained

The questionnaire was divided into three blocks, defined as professional training, knowledge about the existence of ISO 14006 and the implementation of strategies focused on reducing the environmental impact within their workplace.

For practical purposes, we present the most relevant results of the section related to professional training, questions 27 to 31 of the diagnostic questionnaire, whose objective was to understand if university studies play an important factor when making decisions regarding issues related to environmental impacts.

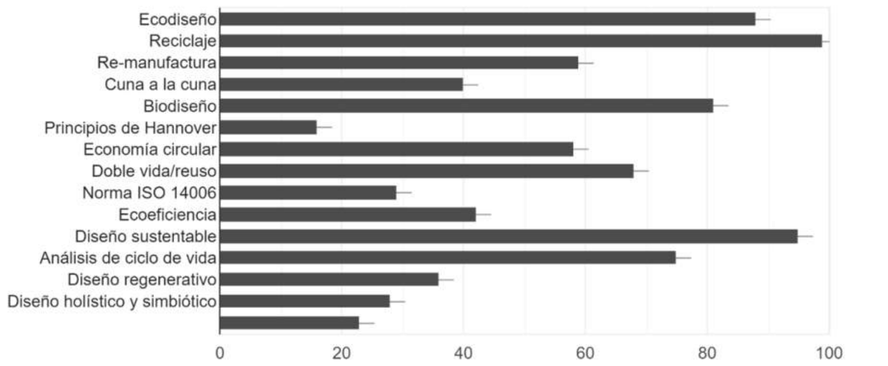
Results

The following are some of the most representative data obtained during the application of the questionnaire to designers and their opinion about the processes they carry out and their environmental impact and the relationship between professional training.

The questionnaire focused on understanding, first, the professional work and labor situation in Mexico City and its suburbs, the second part was to understand the role of academic studies and their training; finally, they were asked about the incorporation of environmental strategies in their workplace. The focus of this article is to understand the part of the industrial designer's professional training.

First, questions were asked about the type and knowledge of environmental strategies. The designers claimed to be familiar with the following environmental management tools: Recycling (93.33%); Sustainable design (88.57%); Ecodesign (81.90%); Biodesign (75.23%); Life cycle analysis (68.57%); the concept of double life and reuse (60%). Interestingly, although many designers claim not to know about the causes and consequences of climate change and the role played by industry, the vast majority claimed to know about various preventive strategies, implying that during their professional training, they had to cover such topics, at least theoretically, but the various subjects did not connect with each other, providing only information, a cultural breviary on environmental issues, but without any practical value at the time of addressing a design project.

Figure 1
Knowledge of environmental strategies



Another important question asked was whether they were able to identify which processes within the industry generate some type of environmental damage; the results obtained, as shown in graph 2, were as follows: in first place the designers identified the selection of materials as the main aspect of environmental damage (70.47%), in second place they identified the selection of manufacturing processes (69.52%); packaging design (59.04%); transportation as the next factor (53%) and, lastly, the selection of finishes (40%).

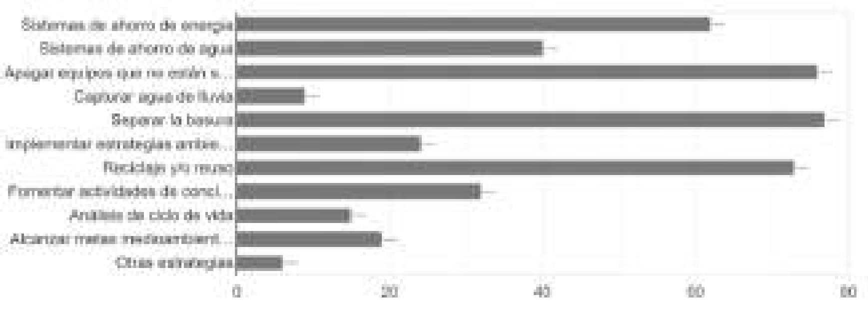
Figure 2

Design processes that generate the greatest environmental damage

To understand environmental responsibility within the companies, we asked about the incorporation of sustainable strategies in the workplace, with the following results: four main responses: turning off disused equipment (63.80%); separating garbage (59.04%); recycling strategies (56.19%) and using energy saving systems (51.42%). It can be concluded that most of the companies that hire designers do not implement strategies in the designer's work, they only use traditional strategies that seek to reduce the direct impact of the company.

Figure 3

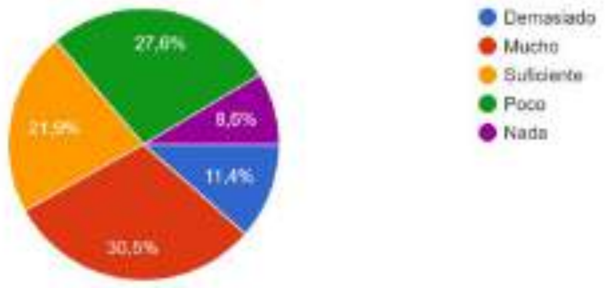
Incorporation of environmental strategies in the workplace



Another block of questions focused on understanding whether the designers consider that the decisions made within their workplace are related to the environmental element, obtaining the following results: 30.5% answered that decisions are closely related to environmental issues, 27.6% said that the company's decisions have little relation, 21.9% confirmed that they are sufficiently related to environmental issues, 11.4% said that these decisions have too much weight, and 8.6% said that they have no relation at all. Almost a third of the designers confirm that the decision-making process within the company has a lot to do with the issue of environmental damage and very closely, those who consider that it has very little to do with it, showing that opinion is divided as to the role that decision-making plays when carrying out a project.

Figure 4

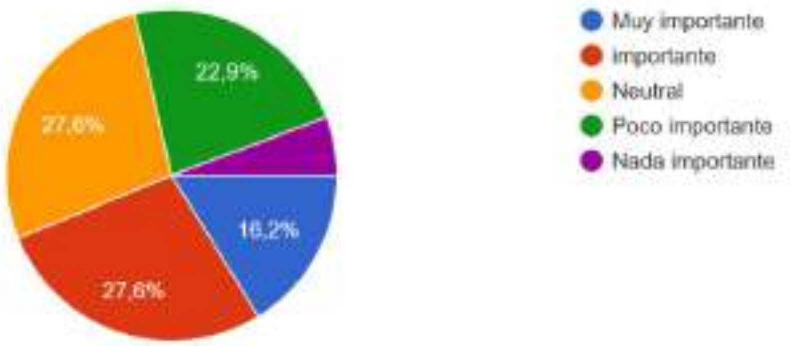
Importance given to the environmental factor in strategic decision-making



As well as the weight given to environmental values in decision making, we also asked about the degree of importance given to sustainability in business processes: 27.6% say it is important, another 27.6% say the company is neutral to these factors, 22.9% say it is not very important, 16.2% say it is very important and 5.7% say it is not important at all. This information was a recurring theme during the interviews with the experts, and indeed, in Mexico City, most of the companies that hire industrial designers do not give importance to the environmental element if it is not requested by the client. One of the reasons derives from the competition that exists between companies and for those customers who ask for the best price, punishing the environmental element. The results are shown in the following graph.

Figure 5

Degree of importance of sustainable values in companies.



The in-depth interview to the panel of experts, descriptive-evaluative phase, complemented the exercise and whose objective was to contextualize the situation of the Mexican designer within the industry, providing the guidelines under which the diagnostic questionnaire was structured and corroborating the results of the bibliographic documentation stage, in order to understand the dynamics that are generated in the work environment and the current situation of design in Mexico and through the triangulation of information, understand and describe the relationship that exists between the factors that affect the environmental performance of the designer, such as: professional training; requested requirements; the limitations, both technical and technological; indirect factors that affect decision making; the development of design projects and how is it that from such knowledge, to give greater meaning to the results derived from professional training, seeking to create new synergies that nurture the work of design.

Different series of interviews were carried out; the first block of interviewees corresponds to those experts within the theoretical, historical and academic areas; the second block was carried out with leaders of Mexican companies that hire designers and actors within them who are the ones who interpret the client's wishes and transmit the information and objectives of the design projects. The last block of interviews focused on designers who work professionally in companies that implement ecodesign strategies in their processes or are environmental consulting firms operated by designers. As a result of this second phase, qualitative portion of the experiment, and whose purpose I seek to cover with the following objectives:

• Contextualize the situation of the Mexican designer within companies, their relationship with clients, projects and the way in which sustainable requirements could be integrated into their processes, as well as the challenges presented by the industry that hires industrial designers, with the purpose of proposing a new professional profile that will serve as a basis for universities to generate a new curriculum.

• Outline the current professional profile of the Mexican industrial designer, his or her procedures, practical tools, competencies and challenges, in order to analyze whether education truly covers the required profile.

• Understand the role played by the study plans and the incorporation of subjects related to sustainability within their academic projects, thus understanding the dynamics generated between theoretical knowledge and practical application, helping to discover areas of opportunity for the introduction of such topics in the professionalizing exercises.

• Through a historical analysis, understanding how the discipline of industrial design was introduced in Mexico, its development over time and how the specific profile of the design professional was defined; the historical context becomes valuable to locate and focus macro trends that reflect this new spirit of the younger population that seeks to be friendly and responsible with the environment.

Due to the limitations resulting from the pandemic caused by COVID-SARS2, these interviews had to be adapted to a variation of the DELPHI method with an in-depth interview. Also, through the interviews, we sought to contextualize the environment in which the industrial designer works in Mexico and to understand the current situation, the historical background, cultural, social and economic variables that affect the work of the designer, as well as to delimit the scope and limitations when incorporating strategies to prevent environmental damage.

The panel of experts consisted mainly of academics from the main design universities in Mexico (UNAM, Universidad Iberoamericana, Instituto Tecnológico de Monterrey, UAM Azcapotzalco and Xochimilco, Universidad La Salle, EDINBA and Universidad Panamericana), and who at some point were involved in making decisions to create or update the curricula; another profile of the interviewees was that of historians who have analyzed the evolution of design in Mexico, highlighting personalities of Mexican design such as Dr. Oscar Salinas, creator of the DESIGNIO publishing house, Dr. Julio Frias, former coordinator of the Arts and Sciences postgraduate program at UNAM, creator of the "Diseña México" award, Dr. Sandra Molina of CyAD at UAM, coordinator of scientific publications at that university, Aldo Pérez Jaimes, Coordinator of the Innovation and Design Engineering program at Universidad Panamericana and Ariel Méndez, from Universidad Iberoamericana, as well as Ana Charfen and Reneé Harari, specialists in design management and foresight.

Each in-depth interview was unstructured, based on some guiding questions, which were developed during the time of the interviews to delve deeper into the subject matter, adapted according to the profile, professional experience and specialty of each of the experts.

Conceptual and Pragmatic Reflections of the Research

The research yielded different results, depending on the approach considered. The following is the information obtained, which revolves around the designer, his activity and the environmental values within his practice: first, an efficient and effective designer must have a complex and comprehensive profile that allows him to take advantage of the methodological resources at his disposal, as well as different types of thinking to adapt to different activities.

The panel of experts made up of industry leaders mentioned that the current business and industrial environment presents designers with a much greater challenge: in Mexico, designers who decide to work within a company live governed by the needs posed by the national industry and within which, the designers they employ are forced to respond to the needs of the predominant economic system with little or no decision-making power, directly affecting decision making that revolves around sustainable values, and this results in a lack of control over the decisions that are made in the projects; this is the reason why a designer who seeks to propose alternatives that can generate a positive change, must be able to read, interpret and transfer various factors, mainly economic, political, environmental and cultural, reflecting them as an economic advantage for his company, and not as an added or ethical value, and to achieve this, the designer who considers incorporating an ethic of sustainable character from within the industry must count mainly on bosses and clients with enough openness to change the course of the projects and incorporate sustainability.

There are other challenges that the specialists interviewed mentioned, coinciding in the existence of these two: understanding where the designer stands, from a local and global perspective, understanding globalized systems and diverse cultural phenomena, and through this knowledge, offering solutions that provide a global vision; a second challenge is that the designer must leave behind the individualistic posture that characterizes him, integrating himself into interdisciplinary work teams, where the designer and his language can become a point of convergence of ideas, where the contributions of a team composed of professionals from different areas of knowledge are synthesized, becoming mediators and integrators, both challenges are evident in Mexico, where sustainable objectives are elements that are not well founded and for which the Mexican industry is not prepared to achieve them.

As for the environmental factor, the panel of experts confirmed that both the client and the industry seek to turn the problem around through deception, the typical case is to make something appear to be what it is not in order to overcome a filter, such as an environmental requirement that is not covered in its entirety, but it is also necessary to consider that an environmentally responsible client is not a guarantee of sustainability either, added to this, the supply of environmentally friendly materials is another important factor in Mexico, since there are few suppliers of healthy materials and those that do offer them are usually either too expensive or of low quality.

Discussion and Conclusions

If, in fact, these studies prove a problem within the academy itself, when training these professionals, not only the thematic content should be rethought, but also the scope that these subjects play. It is worrying to see that prestigious universities, such as the Universidad Iberoamericana, the first university to offer this career in Mexico since 1955, is eliminating sustainable subjects from its program, giving more weight to technical training that covers the professional profile required by companies; this is also a reflection of a major problem, where the labor environment is the one that dictates professional training. In the panel of experts interviewed, many indicated that these subjects hinder professional training, because it is difficult to incorporate these elements in the training exercises, while others, shielded by the need to prepare new professionals who face other types of problems, which are within the competence of the industrial designer.

And although it is serious that design students lack the minimum knowledge necessary to address a complex issue such as sustainability, the big problem stems from the industry itself and the clients it serves; if the designer does not address it adequately, it is because there are several factors, both internal and external, intimately linked to their professional work and where company leaders and clients do not align their own objectives with the objectives of a sustainable agenda, here the key is in the values that revolve around an ethic focused more on economic issues than on environmental ones, and therefore, are reflected in the people who work in the industry.

Other factors, for example, mentioned by the panel experts is the importance of the fact that the designer leaves behind discourses that are rooted in archaic, simple and linear design thinking. Here professional training should focus on creating a new profile, a more competitive one whose main characteristic is to live immersed in the context, and whose function is to be a translator and configurator of all the components of a complex system, including the environmental one, through prospective and collaborative actions, generating the necessary components and an efficient reading of use to give a true sense and utility to things, thus reducing the impact that may derive from an inadequate use of the products resulting from the design process. These designers must pilot the integration of their ideals, becoming the standard that marks the way and the times, becoming a faithful reflection of the variety of cultures and thoughts within which they cohabit.

The designer must generate the filters that give the required effectiveness to transdisciplinary exploration and complex systematization, including all the participants of this complexity, including the environment within it, transforming himself to meet a new reality, that of a world that due to planetary limitations and the multiple existing crises, tends towards dematerialization, focusing its efforts towards the design of services, experiences and social innovation. Donald Norman (2007) emphasizes the need to return to a design that is neither ephemeral nor outdated, but rather to a more lasting design, a design of truly necessary and not banal objects, a social and responsible design that addresses real problems, reinventing itself, just as during the Industrial Revolution, when industry was the guiding axis, the new guiding axis is the need derived from the world crisis, which forces us to take a sustainable attitude, where the traditional vision of design becomes obsolete.

Professional training must generate designers who are restless, disruptive and capable of approaching systemic thinking, always seeking to propose a real change, and they will achieve this by detaching themselves from the traditional industry to become entrepreneurs with a highly developed social and environmental conscience and who bring new values to their proposals, aligning themselves with the real needs of users, their life context and the quality of planetary life, they must understand the need to reduce the scale of their projects and generate real value; they must also be integral designers who develop within the administrative, logistical, financial, communication, sustainable and life cycle fields, skilfully applying the tools of design thinking to solve all kinds of problems without losing their ability to express themselves through objects, because if they are only problem solvers or are completely devoted to administrative issues, they cease to be designers.

Especially in Mexico, a designer is required to respond to real needs derived from their own context, seeking a positive impact from their work, and this is where the effective teaching of useful and practical strategies can be achieved; the university must help the student to develop new skills, transforming the discipline of design from the critical and prospective reflection of it.

The designer who manages to create interesting, relevant and innovative projects, will be characterized by becoming a co-participant of the reality in which he/she lives, soaking in the real planetary needs, so it is important that the designer develops within the collective work and the person to person relationship, experiencing first hand the context within which he/she wants to make a contribution, which requires a comprehensive vision and synthesis capacity based on empathy, implementing good practices, sharing the knowledge generated together with others, thus sowing the seed of true sustainability.

Currently, the traditional designer is completely anonymous, this anonymity provided by being an employee of a company, shields him from making ethical decisions when designing, therefore, he does not show any guilt or desire to change the way he does things, either because he lacks knowledge or because he aligns himself with what is requested; this designer, by moving up the hierarchy to positions where he could generate a change, perpetuates the disdain with which sustainability is approached, always in favor of economic gain.

But what about the other designer, the one who, despite living in anonymity, wants to make the right decisions and is committed to the planet? This designer must overcome limitations such as the weight of the economic point of view, one that focuses on savings and unlimited development where the main objective of companies is to generate profits through poor products derived from the cheapest possible manufacturing, regardless of the final destination of these designs or the ethical responsibility that should be taken towards the planet, factors that directly affect the sustainable innovation that the designer could bring, one who does not have enough tools to achieve a positive change at the environmental level and can not bring a major change from his position within the company.

But the designer must be trained from their academic training to introduce a real change, but above all to create an environmental awareness and empathy with the environment in which they live, fortunately today designers are exposed to a constant global media bombardment that allows them to see everything that happens in the world and the consequence of our actions. They are aware of the effects of their lifestyles and decisions, and seek to incorporate a positive change through their work, taking the reins by becoming leaders that guide companies by demonstrating that a business can be profitable, ethical, conscious and build their discourse transversally within the different stages of project development, and the only way to achieve this is through the implementation of sustainable values in each of the stages of their work and the life cycles of what they design.

The ideal designer, who manages to incorporate these values, starting from a resilient vision, becoming an individual who has the need to guarantee the quality of life, preserving its integrity and cycles; a new designer, resilient and symbiotic, who pursues the integral protection of ecosystems and their regeneration, social equity, community participation and the concern for generating welfare futures for all living beings and who also has a broad understanding of the planetary limits and natural adaptive cycles, as well as their practical application (Sanchez, 2013).

These designers must be negotiators of value, facilitators of thoughts, visualizers of the intangible, navigators of complexity, mediators and coordinators of exploration; some of the tools they resort to are resilient thinking, biophilia, biomimetics, and a deep understanding of the concepts of symbiosis, which must be taught in their training, not only at university, but from the moment they enter a school for the first time.

In conclusion, the professional training of the designer should focus on achieving the planetary quality of life and assign due importance to subjects focused on the teaching of the critical environmental situation we live in and be able to address it from the tools of the discipline, redirecting the design towards a comprehensive, resilient vision that manages to balance ethical, economic, technological, and environmental issues.

Throughout this doctoral research project it was possible to demonstrate the problems that exist in Mexico at the time of implementing strategies that guide design companies to meet the objectives of sustainable development from the work of the industrial designer, one of the main reasons being an education whose focus is centered, on the one hand, on policies and solutions proposed by developed countries, where technological advances, culture, and size of their economies are advantageous compared to developing countries such as Mexico, and on the other hand, on the generalized apathy that exists in the industry and its clients, to incorporate healthy alternatives in their products.

The ISO 14006 standard is very practical when it comes to identifying areas of opportunity and the steps to follow under the ecodesign recommendations, but it is difficult to adapt it to a Mexican environment, where the industry is not as evolved as that of the First World countries, where this standard was born. We must accept the reality in which Mexican companies live, where many of them work with reduced budgets in the race to be competitive by offering the cheapest price, at the expense of their own growth and development. This forces companies to look for another way to become responsible with the planet and the industrial designer, with proper training, can help to achieve an efficient change in the right direction through small corrective steps, starting with environmental awareness from the companies and their workers.

References

Boehnert, J. (2018). *Design, Ecology, Politics: Towards the Ecocene*. Blooms-bury Press.

Buchanan, R. (2001), Design and the new learning. *Design Issues Vol. 17, No. 4* (autumn), pp. 3-23

Capra, F. (2006). *La trama de la vida*. Anagrama.

Chávez, J. et al. (2016). Liderazgo y cambio cultural en la organización para la sustentabilidad. *Telos 18*(1), pp. 138-158.

Lumsakul, P., Sheldrick, S. y Rahimiford, S. (2018). Sustainable codesigns of products and production systems. *Procedia Manufacturing 21*, pp. 854-861.

Manzini, E (1992), Prometheus of the Everyday: The ecology of the artificial and the designer's responsibility. *Design Issues 9*(1), pp. 5-12.

Norman, D. (1999). Affordances, conventions, and design. *Interactions 6*(3), pp. 38-42.

Norman, D (2007). Three challenges for design. *Interactions 14*(1), pp 46–47 https://doi.org/10.1145/1189976.1190002

Papanek, V. (2005), *Design for the real world: Human Ecology and Social Change*. 2nd revised edition. The Chicago Review Press.

Sánchez, D. (2013), The wonder of design with-in nature: towards and ecotechnic future. 10th European Academy of Design Conference, Centre for the Study of Natural Design, University of Dundee.

Thackara, J. (2005). *In the bubble; designing in a complex World*. The MIT Press

MLS JOURNALS

ENVIRONMENTAL SCIENCES & PRACTICES
http://mlsjournals.com/Environmental-Science-Practices

(2024) Environmental Sciences & Practices, 2(1), 75-89.

Simulation of a process to obtain bioethanol from forestry residues from sawmills in the northern part of Costa Rica

Simulación de un proceso de obtención de bioetanol a partir de los residuos forestales de los aserraderos de la zona norte de Costa Rica

Osvaldo Antonio Chavarría Acuña
Environment, Costa Rica
(osvachavarria@gmail.com) (https://orcid.org/0000-0002-0303-7314)

Manuscript information:

Received/Recibido:21/10/22
Reviewed/Revisado: 21/12/23
Accepted/Aceptado:17/01/24

Keywords:
Sawmills, biorefinery, biomass, gasoline, ethanol.

ABSTRACT

The focus of this project is the technical evaluation of the installation of a biorefinery in Costa Rica. This includes sawmill residues from the country's north, 30 kilometers around Boca Arenal, San Carlos, and performing a mass balance from secondary sources and the DWSIM 7.5.5 chemical process simulator for ethanol production to blend with Costa Rican gasoline. The methodology makes use of a non-experimental, transactional, or transversal design. Twenty interviews were conducted for a population of 24 sawmills producing 40,447 tons of lumber per year, producing 16,414.30 kilograms of 99.8% v/v purity ethanol daily (20.84 cubic meters per day). As a result, the ethanol produced can supply 5.16% of the gasoline consumed in Costa Rica, as well as syngas residual and methanol as secondary products. The installation of a biorefinery in Costa Rica is technically feasible due to the availability of raw materials and technologies for the conversion of biomass into ethanol, and it is advantageous to consider other lignocellulosic sources such as fractions of urban waste, agricultural waste, and industrial waste, as well as other geographic regions around the country. To determine the viability of the project, a financial feasibility study for the biorefinery installation is required in other stages of project planning.

Palabras clave:
aserraderos, biorrefinería, biomasa, gasolinas, etanol.

RESUMEN

El estudio consiste en la evaluación técnica para instalar una biorrefinería en Costa Roca. **S**e cuantifican los residuos de los aserraderos ubicados en la zona norte del país, 30 kilómetros a la redonda de Boca Arenal, San Carlos, y así realizar un balance de masa a partir de fuentes secundarias y mediante el simulador de procesos químicos DWSIM versión 7.5.5, para producir etanol con el propósito de mezclar con las gasolinas consumidas en Costa Rica. La metodología consiste en un diseño no experimental, transeccional o transversal, y para una población de 24 de aserraderos, se aplicaron 20 entrevistas de donde se obtuvo que anualmente se producen 40,447 toneladas, y bajo la modalidad termoquímica, utilizando como materia prima todos los residuos de los aserraderos de la zona de estudio, se obtienen 16,414.30 kilogramos de etanol por día (20.84 metros cúbicos por día), con una pureza del 99.8 % v/v, logrando

	de esta manera abastecer mezclar con etanol el 5.16 % de las gasolinas que se consumen en Costa Rica, teniéndose como productos secundarios syngas residual y metanol. Al haber disponibilidad de materia prima y tecnologías para la conversión de biomasa en etanol, técnicamente es factible la instalación de una biorrefinería en Costa Rica, siendo favorable tomar en cuenta otras fuentes lignocelulósicas como fracciones de residuos urbanos, residuos agrícolas y residuos industriales; además de otras regiones geográficas, siendo imprescindible llevar a cabo un estudio de factibilidad financiera para la biorrefinería, para determinar la viabilidad de proyecto.

Introduction

Costa Rica has historically been highly dependent on fossil fuels in the transportation sector. From an environmental point of view, hydrocarbons represent a major problem, since combustion produces gases such as carbon dioxide, carbon monoxide, sulfur dioxide and nitrogen oxides (E-education, 2022). These gases cause the greenhouse effect, causing global warming, causing sea levels to rise and the poles to melt (National Geographic, 2022), and also cause acid rain, acidifying soils and bodies of water, altering the conditions of living beings (Castro, 2019).

In order to mitigate the impact of gasoline emissions, RECOPE (2020) (Refinadora Costarricense de Petróleo) proposed blending them with bioethanol, with the disadvantage of needing large extensions of land for sugarcane cultivation, and of being a first generation biofuel as its raw material is a source of human consumption.

By changing the raw material to residual forest biomass, it is possible to propose a model for the use of its lignocellulose, through the installation of a biorefinery, which is conceptualized in the framework of the transformation of biomass in an optimal way, to produce various products, and at the same time be self-sufficient and without being dangerous for the environment (Hingsamer and Jungmeier, 2019), therefore, a biorefinery can be defined as any plant that contemplates the necessary equipment to carry out unitary processes and operations of biomass conversion to produce food, chemicals, materials, fuels, heat and/or electricity (Ray et al., 2021).

By properly using waste as feedstock, it constitutes a second-generation biorefinery, whose raw materials come from crops, but not food, being the raw material mainly agricultural and forestry residues, so it has a great advantage over first-generation ones, as it does not compete with human consumption Chávez-Sifontes (2019).

The transformation of lignocellulosic biomass into ethanol can be carried out by biochemical conversion, where the biomass is first separated into cellulose, hemicellulose and lignin, and then the sugars are converted by enzymatic reactions. Enzymes, which can be yeast, fungi or bacteria, digest the sugar to produce, in addition to ethanol, carbon dioxide, hydrogen and other products (Dahiya, 2020).

The other way is through a thermochemical process, the controlled reaction of biomass is carried out in a solid state, which is volatilized so that, in this way, other materials can be produced either solid, liquid and gaseous, and is characterized by undergoing little or in the absence of oxygen, and regulated by pressure and temperature (IRENA, 2018).

Compared to biochemical conversion, thermochemical conversion offers greater advantages, as it contemplates a wide variety of feedstocks, including wood, as well as higher conversion and energy efficiency, and shorter reaction times (Chandraratne and Daful, 2021).

Studies have shown different results for ethanol from biomass. Technical, economic and environmental evaluations to produce bioethanol in a biorefinery from residual biomass, yielded results between 0.14 - 0.22 kg of bioethanol / kg of biomass through biological conversion (Demichelis et al., 2020).

In another variant, with a dilute sulfuric acid pretreatment, 191.96 kg of ethanol were obtained from 1000 kg of sugarcane bagasse (Dionísio et al., 2021).

This study aims to simulate the process of a biorefinery in Costa Rica to produce bioethanol so that it can be blended with gasoline to reduce the impact caused by atmospheric emissions.

Chacón (2012), studied the same area of the present project: 30 km around Boca Arenal de San Carlos, in order to determine the situation of sawmill waste in the region, with respect to the waste generated, while suggesting measures to improve the use of waste for energy purposes, determining that the study area generates about 80,000 tons of waste per year.

Therefore, as the northern region is a region with a significant amount of forest residues, it is justified to study the biomass supply in order to propose a process and a mass balance using secondary sources to produce second-generation bioethanol.

To have an idea of the benefit of obtaining ethanol under the proposed scheme, the capacity of the plant obtained was determined, to be used as a blend in the gasoline consumed in Costa Rica, replacing MTBE, which is the oxygenate that has been used in recent years, for which it was necessary to consider the consumption of gasoline, and the amount of ethanol that it is technically possible to blend with hydrocarbons.

For this purpose, we considered what was determined by López (2019), who conducted several tests at the Center for Electrochemistry and Chemical Energy (CELEQ) of the University of Costa Rica, and determined that, using blends of 10% ethanol, without MTBE or ETBE, the physicochemical properties of the gasolines are suitable for use, considering among several aspects that, no phase separation problems (ethanol - water) were found in the temperature range of study (0 °C - 40 °C).

In relation to consumption, RECOPE, which acts as the hydrocarbon marketing monopoly in Costa Rica, determined that in an average scenario for 2022, it was estimated that 1,414,320 m^3 (RECOPE, n.d.) of super and regular gasoline would be consumed, a figure that was used as a reference to determine the amount that could be blended with the ethanol in the simulation process.

The research is consistent with the National Decarbonization Plan, established by the Government of Costa Rica (2019), which among several points, promotes blending national ethanol with gasoline; in addition, it is part of the instruments of the Organization for Economic Cooperation and Development (OECD, 2020), which recommends that countries promote cleaner fuels and renewable energy sources, while promoting development in harmony with the environment and a circular economy.

The objective is to evaluate the technical feasibility of installing a biorefinery in Costa Rica for the production of ethanol from sawmill forest residues, located 30 km around Boca Arenal, San Carlos, Costa Rica, in order to blend them with gasoline.

Method

The research design was non-experimental, transectional or cross-sectional, collecting information during the course of the year 2022. It was both descriptive and action-research type, since it was developed with the intention of promoting a change in the reality regarding the use of waste, for the benefit of the environment.

The population was the number of sawmills located within a radius of 30 km around Boca Arenal de San Carlos, Costa Rica, shown in Figure 1, where it was proposed to apply a census, given the relatively small number of sawmills in the area, anticipating a lack of 20% of the population due to refusal or omission of the owners, being the variable to measure, the amount of waste (biomass) in tons from sawmills, in its different physical presentations: sawdust, burucha, firewood and wood chips, where the information was obtained through face-to-face surveys or via telephone, to the personnel of the sawmills in the northern region of Costa Rica.

The survey applied to sawmill personnel was on average weekly production, workweeks per year, most common species processed, average sawmill yield, average amount of waste, whether there is waste accumulation. In addition, and more specifically on waste, we asked about the proportion of waste between sawdust, burucha, firewood and "other", and also asked about the distribution of the use given to these: self-consumption, sale, gift and accumulation.

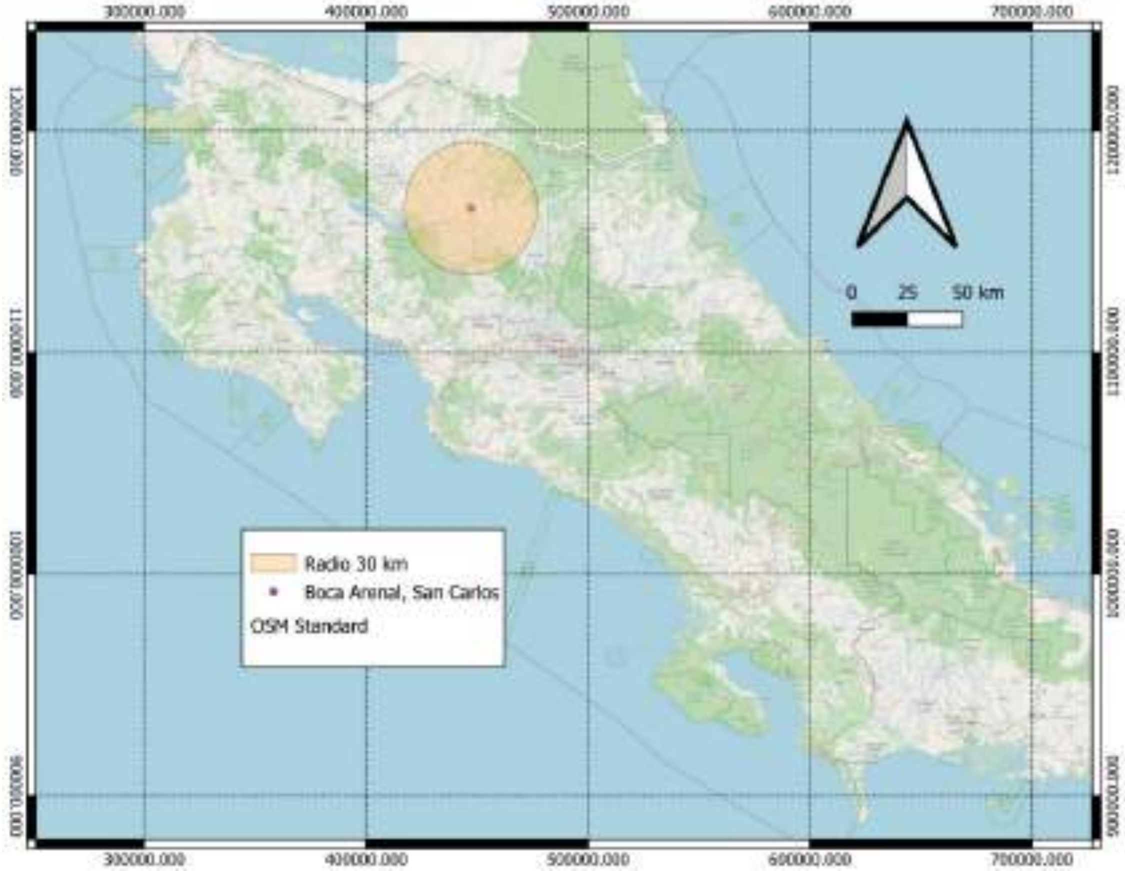
Finally, the company was asked if there is any plan or strategy for the use of waste, to what type of company it is being supplied, as well as its opinion on whether demand was being met.

To determine the sawmill population, we consulted the municipalities and the Ministry of Health of the region, and georeferenced them using QGIS software version 3.24.1, to determine which were located within the study area shown in Figure 1, whose area corresponds to a 30 km radius circle, centered in Boca Arenal, San Carlos.

Based on the current waste supply in the area, the stoichiometric thermodynamic model established by Basu (2010) was used to calculate the syngas composition after biomass gasification, and subsequently, using the DWSIM program version 7.5.5.5 and secondary sources, the processes and unit operations were determined to calculate the ethanol capacity to be produced.

Figure 1

Northern sector of Costa Rica where the research is delimited by the shaded circle, and centered in Boca Arenal de San Carlos, CRTM05 coordinates 447,131.622 longitude - 1,164,932.971 latitude



Results

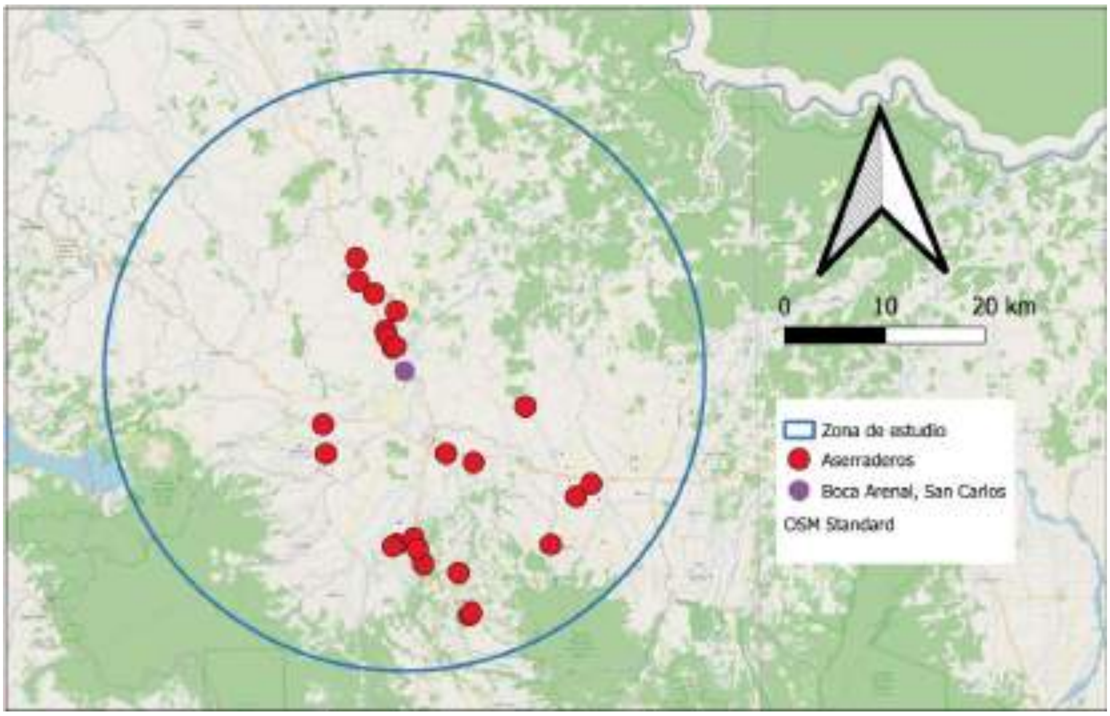
A total of 24 sawmills were located, whose location is shown in Figure 2 and the coordinates are shown in Table 1, where 100% were located in the canton of San Carlos. Information was obtained from 20 of these, obtaining that 35,338,632 PMT (Tico lumber inches) are processed annually, where 1 m^3 is equivalent to 362 PMT in roundwood, and also, 1 m3 is the same as 462 PMT in sawnwood (Barrantes and Ugalde, 2018).

The average sawlog yield was 55%, with Vochysia guatemalensis, Cordia alliodora and Vochysia ferruginea being the most common species traded, and working practically all year round. Details on the type of waste and its disposal are shown in Table 2, which shows similar proportions of waste, with the exception of burucha, and firewood being the predominant type;

and as for the disposal of waste, the vast majority (94 %) was sold, while 3 % was used for self-consumption, 2 % was accumulated in establishments, and only 1 % was given away.

Figure 2

Location of the sawmills interviewed, in CRTM05 coordinates



As for the plan or strategy for the use of waste in the sawmills, it was linked to their self-consumption (for wood drying, for example), with 35% responding that they do have a plan, while 65% indicated that they do not.

Most of the establishments have the Ticofrut company as a client for the sale of firewood, while sawdust was commonly sold to farms that had activities such as dairies and poultry farms. Other companies mentioned that purchased residues in different presentations were Cemex, Del Oro, Agrep Forestal and Agrofertilizantes Nerking.

Finally, the interviewees were asked whether, in their personal opinion, the waste is meeting the demand of the customers who buy their waste. The majority, 80% answered yes, 10% said no, while the remaining 10% said they did not know.

Table 1

Location of sawmills in coordinates CRTM05

Name of establishment	Length	Latitude
Aserradero Laraco	453852.966	1155698.201
Aserradero San Gerardo	446388.007	1170961.132
Aserradero Flor y Fauna	459132.155	1161193.906
Aserradero Atenas	445317.583	1169012.186
Aserradero Arcoiris	452176.858	1144670.679
Maderas de Sucre	453150.124	1140399.309
Aserradero Arjima	445995.262	1147634.517
Aserradero Aguas Zarcas	461427.997	1147345.077
Aserradero Muelle	451136.463	1156615.271
Aserradero Las Nieves	444217.158	1172753.887

Aserradero Bolaños	445943.236	1167326.261
Aserradero La Loma	453391.416	1140648.280
Aldequezul	447737.452	1148215.423
Aserradero Santa Rosa	442642.379	1174006.644
Aserradero Buenos Aires	445462.252	1168404.192
Tarimas Acuña y Ávila	445629.505	1147433.677
Maderas Cultivadas	442505.156	1176332.426
Tarimas del Norte	448680.262	1145593.404
Holystone Group	439129.584	1156815.792
Aserradero El Milagro	464061.439	1152082.678
HC Maderas	465565.487	1153326.342
Maderas y Molduras San Jorge	438879.674	1159737.696
Norte Madera	446240.771	1167397.932
Maderas y Molduras Acual	448102.884	1147133.559

Table 2

Breakdown of waste produced according to its classification and disposal

Type of waste	Tons per year
Sawdust	13,095
Burucha	2,587
Firewood	13,271
Chips	11,494
Use - disposition	
Self-consumption	1,183
For sale	38,066
Gift	270
Accumulation	928
Total	40,447

Mass Balance

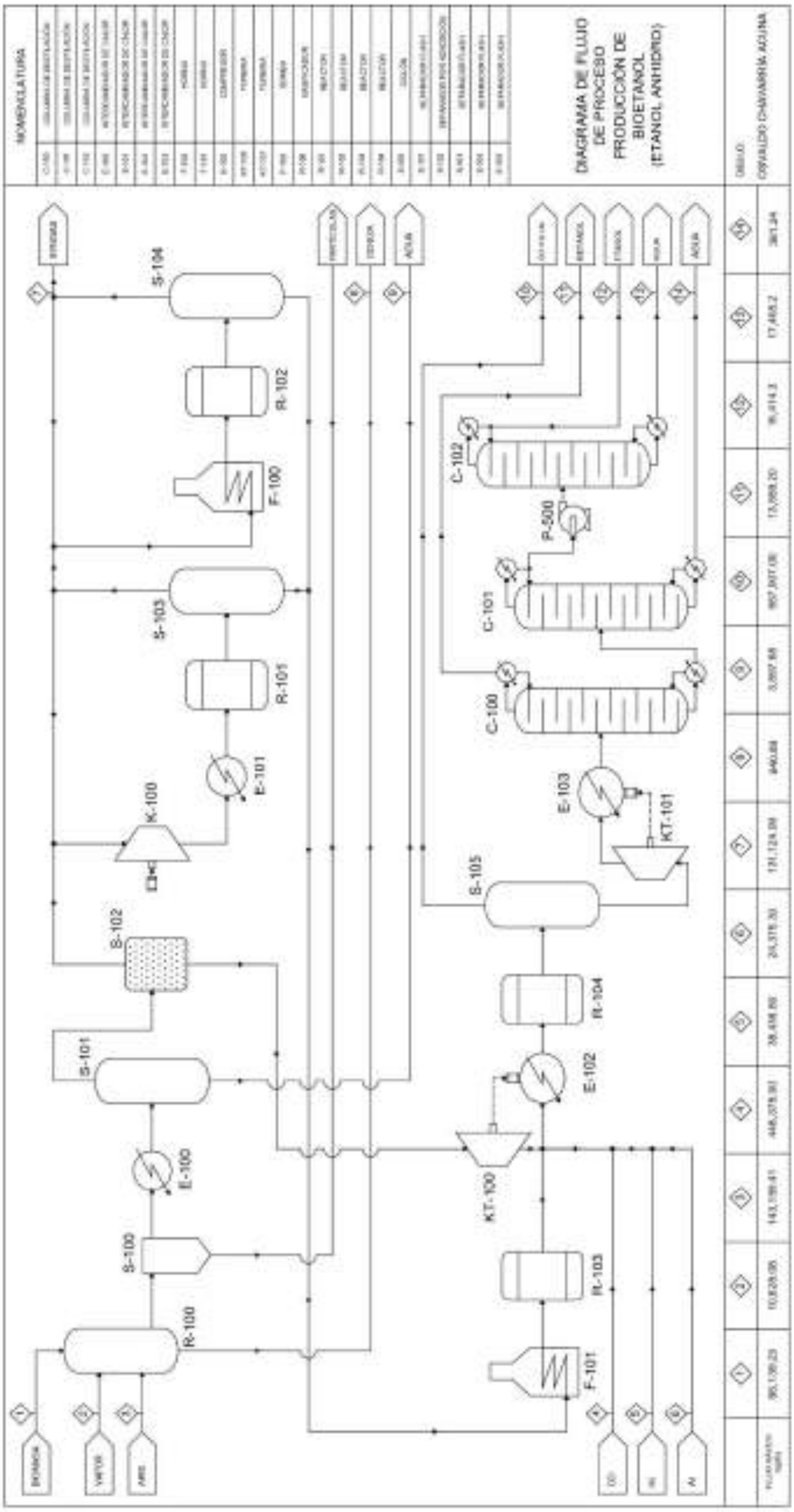
In order to prepare the mass balance, the total sum of the wastes was considered: 40,447.09 ton/year, as well as moisture values: 32.0 %, 50.0 % and 32.5 %, for sawdust, firewood and burucha respectively, as obtained by Chacón (2012), cited by Chacón, Coto and Flores (2018); while 49.0 % of the wood chips, were obtained through the services of the Agronomic Research Center of the University of Costa Rica, working with an average humidity of 42.8 %.

Elemental analysis of 50.295 % C, 6.085 % H, 42.498 % O, 0.136% N, 0.018 S and 0.969 % ash was assumed, whose values are averaged from various species by Gaur and Reed (1998), cited by BEF (2022); and it was assumed that the plant would operate 350 days per year, considering some shutdowns for maintenance and holidays.

Figure 4 shows the complete process flow diagram with mass balance values.

Figure 4

Anhydrous ethanol production process flowchart



First, using the thermodynamic model in equilibrium - stoichiometric, by means of the minimization of the Gibbs free energy established by Basu (2010), we have the following chemical reaction:

$$CH_aO_bN_c + dH_2O + e(O_2 + 3.76N_2) \rightarrow n_1C + n_2H_2 + n_3CO + n_4H_2O + n_5CO_2 + n_6CH_4 + n_7N_2$$

Assuming a temperature of 1500 K and 1229.45 kg/hour of steam-air gasifying agent 50:50, in the R-100 reactor, 9,141.46 kg of syn gas/hour were obtained, with the values shown n_i Table 3. The molecular formula of the biomass resulted: $CH_{1.441512}O_{0.634299}N_{0.002319}$.

Table 3

n_i values of syngas using the stoichiometric model of Basu (2010)

Variable	Value n_i
n1: C	0.00000
n2: H_2	0.83000
n3: CO	0.83000
n4: H_2O	0.10400
n5: CO_2	0.17000
n6: CH_4	0.00000
n7: N_2	1.60400

Subsequently, the water is separated from the light gases by the S-101 flash separator. One of the drawbacks of these gases is the large proportion of CO in relation to the rest of the gases, which is why it was decided to install an S-102 separator that works with an adsorption system of activated carbon and CuCl, prepared with $CuCl_2$, considering that Gao et al. (2018) succeeded in recovering up to 92.9% of CO from syngas, obtaining close to 100% CO purity after desorption of the separated gas.

Therefore, in the present process a S-101 separator system was proposed, such as the one mentioned above, which operates in an ideal way, assuming that 90% of the CO from the syngas leaving the R-100 reactor is recovered, so that the separated CO can be used later, thus configuring the R-101 and R-102 reactors with CO/CO2 ratios close to 0.3 for both, using the kinetic model of Van den Busshe and Froment (1996).

Using the same model, but adapted to units of pressure in Pa, and reaction rate in $kmol \cdot kg^{-1} \cdot s^{-1}$, at 50 bar and 180 ˚C, a stream of 35,607.20 kg/day was obtained, with a purity of 69.2 % m/m methanol, and a purge constituting a residual of 131,124.00 kg/day, allowing the transformation of syngas into methanol through the hydrogenation of carbon dioxide, where the reverse of the gas-water exchange reaction (RWGS) is also involved (Lücking, 2017):

$$CO_2 + 3H_2 \leftrightarrow H_2O + CH_3OH$$

$$CO_2 + H_2 \leftrightarrow CO + H_2O$$

Then, the formation of dimethyl ether continues, which can be obtained by acid catalysis (Brunetti et al., 2020) from methanol:

$$2\ CH_3OH \rightarrow CH_3OCH_3 + H_2O$$

The kinetics is modeled according to the Arrhenius equation with coefficients A_i=200034.17 and B_i=80840 (Singh, n.d.). Operating at 50 bar and 365.65 ˚C, it allows a conversion of almost 100 % of methanol, and is carried out in the R-103 reactor

Subsequently, dimethyl ether, together with carbon monoxide and hydrogen obtained from syngas, in the R-104 reactor, ethanol and methanol were obtained as main products (Li et al., 2010) as follows:

$$CO + CH_3OCH_3 \rightarrow CH_3COOCH_3$$

$$CH_3COOCH_3 + 2\ H_2 \rightarrow CH_3CH_2OH + CH_3OH$$

$$CO + 2H_2 + CH_3OCH_3 \rightarrow CH_3CH_2OH + CH_3OH$$

A selectivity of 46.16 % was obtained for methanol, 42.08 % for ethanol, while the remainder corresponds to a mixture of carbon dioxide, methyl acetate and ethyl acetate.

Finally, the ethanol was purified by means of three distillation columns, operating the first two at 1 atm (C-100 and C-101), and the third (C-1-2) at 10 bar to break the azeotropic mixture, thus obtaining anhydrous ethanol, with a purity of 99.8 % v/v, at a flow rate of 16,414.30 kg/day (20.84 m^3/day).

Amount of blending in gasoline in relation to the ethanol produced

Comparing the average scenario for 2022, of 1,414,320 m^3 determined by RECOPE (s.f.) of super and regular gasoline consumption, with the proposed plant whose capacity is 20.84 m^3/day (7,294.0 m^3/year, operating 350 days per year), means that 5.16 % of gasoline would be supplied with the ethanol produced in the plant during 2022.

Discussion and conclusions

The development of the conversion of biomass into ethanol in this study was by thermochemistry, given the advantages it offers, since it contemplates a wide variety of raw materials, including wood, in addition to greater efficiency in the conversion and energy, and shorter reaction times (Chandraratne and Daful, 2021), the same modality used by companies such as Enerkem, which has made substantial inroads in the production of products and fuels from waste (Elías, n.d.).

There are several aspects to consider when using biomass in a processing plant. One of them is the moisture content, since, during gasification, it is mainly carbon, hydrogen and oxygen, and to a lesser extent nitrogen and sulfur, that react with the gasifying agent to produce syngas, which is the start of the process to reach ethanol.

In the present project, it was determined that, of the 40,447 tons, a considerable proportion: 42.8 % corresponds to moisture, while the remaining is the biomass that enters the plant for conversion.

Under the proposed scheme, 3.32 kg syngas / kg biomass was produced; but if 22 kg/h hydrocarbon-enriched biomass is used, 41.76 kg/h can be generated, i.e., 1.9 kg syngas / kg biomass, using a non-stoichiometric gasification model between 900 ˚C - 1000 ˚C, and air as gasifying agent. (Caballero et al., 2019).

Rodriguez et al. (2010) obtained 583 kg/h of syngas from 833 kg/h of biomass (0.7 kg of syngas / kg of biomass), based on a chemical equilibrium approach, similar to the one developed in the present project, where some of the assumptions that were used in common are: the reactions are in thermodynamic equilibrium, it is carried out at atmospheric pressure, nitrogen is inert, as well as ash, so it is not involved in the chemical reactions, and the gases produced are only CO_2, CO, H_2, CH_4, N_2 and H_2O, and that in addition, the gasifying agent is a combination of steam and air. Two differences between that research and the present project were that Rodriguez et al. (2010) used 850 ˚C, and industrial sludge as a biomass source.

Therefore, the amount of syngas to be obtained differs according to the system and the conditions used. Even so, and for the purpose of designing a gasifier, it is convenient to consider some preliminary aspects. For example, if a downdraft gasifier is used, it facilitates a continuous flow of syngas, and allows processing biomass with high moisture contents, as well as being of simple design and low cost (Caballero et al., 2019).

Another aspect to take into account is the physical form of the raw material that is introduced into the reactor, because although it is true that sawdust, firewood, burucha and chips are all wood, but in different physical presentations, it should be foreseen that the reactor has the versatility to process all forms of biomass, or, alternatively, install a mechanism, either internal or external, that allows the raw material to be uniform and can even be adapted for drying it, when necessary, thus facilitating the management of the range of operating conditions of the reactor.

The amounts of steam and air used were selected to achieve maximum biomass conversion, so that there would be no unconverted carbon in the products (n_1=0), and on the other hand, the advantage of using a high temperature: 1500 K, allowed the amount of methane to be negligible in the syngas composition, and for practical purposes, CH_4 could be omitted in the next stage of the process.

Although the model used does not quantify solid particles that can be derived in the R-100 gasifier, in the flow diagram it was decided to place the S-100 cyclone downstream of the reactor, so that later, by means of the S-101 separator, the non-condensable gases (CO, CO_2, N_2, H_2) are separated from the condensable ones, of which it is mainly steam, and may contain small traces such as methanol, acetic acid, acetone and tars (Chandraratne and Dafulal), thus achieving a conditioning of the syngas for the next phase.

The next stage consists of converting the syngas into methanol, in which one of the ways to obtain it is through the hydrogenation of carbon dioxide, both gases contained in the syngas, for which the model of Van den Busshe and Froment (1996) was used, whose results are comparable with industrial processes (Luyben, 2010, Chen et al..., 2011, cited by Lüking, 2017), and furthermore, the same $Cu/ZnO/Al_2O_3$ catalyst characteristics employed by Van-Dal and Bouallou (2013) were used, which are, density: 1,775 kg_{cat}/m^3, particle diameter: 5.5 mm and porosity: 0.4.

Van-Dal and Bouallou (2013) simulated a plant to absorb CO_2, in which, they transformed it into methanol, achieving a 33 % CO_2 conversion, based on the kinetic model of Van den Busshe and Froment (1996) mentioned above, using the Aspen Plus simulator. Similarly, Nwani (n.d.), using the same kinetic expressions, but with the DWSIM simulator, also achieved a 33% CO_2conversion.

The process shown in Figure 4 works with a two-reactor system: R-101 and R-102 with double recycling, to transform syngas into methanol, in which, considering the amount of CO_2 entering and leaving the system, a conversion of 82% was obtained, which represents a considerably higher value than the simulations described in the previous paragraph.

The stream in the flowsheet, called "syngas", may well be used in a variety of ways, for example, for power generation, syngas, biofuels and waxes production through Fischer-Tropsch processes (Genia Bioenergy, 2022), or even retrofitting an additional reactor to increase methanol production, thus making it a three-reactor system instead of a two-reactor system.

Subsequently, in the R-103 reactor, the transformation of methanol to dimethyl ether is carried out, which at the outlet pressure of the methanol production section (50 bar) and the same operating temperature of 365.65 ˚C employed by Singh (n.d.), excellent conversion values of almost 100 % were obtained.

For the conversion of DME in the R-104 reactor, it is recommended to use the operating conditions studied by Li et al. (2010), to obtain ethanol: 493 K, 1.5 MPa, and a feed ratio 1/47.4/1.6/50 - DME/CO/Ar/H_2, to favor conversion to ethanol, which in the present process gave a selectivity of 46.16 % and 42.08 % for methanol and ethanol respectively, values that are very close to the 46.30 % and 42.2 % reported by Li et al. (2010).

It should be noted that the CO separated from the S-102 system was used as a reagent for the R-104 reactor, but it was insufficient to meet the 1/47.4 - DME/CO ratio indicated in the previous paragraph, which is why it was necessary to implement an additional CO stream to feed the aforementioned reactor.

Similarly with the CO stream implemented to feed the R-104 reactor, it was necessary to propose additional H_2 and Ar streams, of which CO and H_2 constitute excess reactants and Ar an inert, and which are separated in the S-105 separator, with the possibility of recirculating them to feed the R-104 reactor, or installing an additional system to produce additional methanol from the excess CO and H_2.

The final phase consists of the purification of ethanol, which is mixed with methanol, water, methyl acetate and ethyl acetate. For this purpose, three distillation columns were used.

The first column, C-100, separates mainly methanol with a purity of 96 %, the remainder being small amounts of methyl acetate and ethyl acetate, which were produced as by-products in the R-104 reactor. This stream, designated as number 11 in Figure 4, is of great importance, since it opens up possibilities for its use. One of them is to recycle it to the R-103 reactor to produce more DME, and thus more ethanol.

Another form of utilization is to purify methanol for commercialization, so that it functions as a raw material for other materials and products, which include: adhesives, paints, LCD screens, automotive manufacturing, sealants, lubricants, plastics, ethyl-propylene, polypropylene, medium-density fiberboard, plywood, in addition to the area of fuels - biofuels: biodiesel, MTBE, DME (Methanol Institute, 2022).

The bottoms of the C-100 column constitute the feed for the C-101 column, where the ethanol is partially purified. Both columns C-100 and C-101 were configured with the NRTL thermodynamic model and operate at 1 atm. The last distillation column C-102, constitutes the last step to obtain the purified ethanol, which, unlike the two previous ones, used the thermodynamics of Raoult's Law, and 10 atm of pressure to overcome the limiting azeotropic mixture formed by ethanol and water, in a similar way as Kishnani (n.d.) used to purify ethanol using a high pressure column in which he obtained ethanol at 99.8 % v/v.

Use of ethanol as an oxygenating agent

In the process of Figure 4, ethanol was also obtained at 99.8 % v/v, which falls into the category of anhydrous fuel ethanol according to the INTE E5:2017 standard (INTE, 2017), which establishes that it must have a minimum purity of 99.0 % of ethanol, so that in this way, it can be used as an oxygenate in gasoline for internal combustion engines, being able in this case, with the capacity of the biorefinery and the availability of the raw material, to supply 5.16 % of the gasoline in Costa Rica projected by RECOPE (n.d.), to be mixed with ethanol.

By way of comparison, in the city of Catalonia, when it had a population of 7,000,000 inhabitants, taking into account not only forestry waste, but also urban solid waste fractions, agricultural waste and industrial waste, 53,000 tons of (dry) waste could be produced daily, which could produce 23,000,000 liters of ethanol/day, equivalent to 66% of the demand for 34,500,000 liters/day, with a vehicle fleet of 5,500,000 units (Elías, n.d.).

With the above figures, it means that 0.43 liters of ethanol / kg of dry waste can be produced, which shows some similarity with the proposed biorefinery, since it produces 0.31 liters of ethanol / kg of dry waste. Both cases are similar in that they involve the production of second-generation biofuels, but differ in that the biorefinery considered only forestry waste, while in the case of Catalonia, forest, urban, agricultural and industrial waste was considered.

In the Costa Rican market, a project had been proposed for the Costa Rican Petroleum Refinery (RECOPE) to sell ECO95 and ECO91 gasolines, which consisted of blending gasoline with ethanol between 5% and 10% v/v (RECOPE, 2020), and thus have a different alternative to those marketed with MTBE.

To develop this project, the most viable way was to plant 14,800 hectares of sugarcane exclusively to produce ethanol, plus all the ethanol produced from molasses as a by-product of the sugar industry (RECOPE, 2020), to cover the demand until 2039.

The project was not successful, and currently gasoline with MTBE continues to be sold, and differs greatly from the proposed project, since the idea proposed by RECOPE was for a first generation biofuel.

Conclusions

Annually, in the northern zone of Costa Rica, 30 km around Boca Arenal de San Carlos, 40,447 tons of wood residues were obtained.

From the forest residues of the study area, through the simulation performed in DWSIM, and under the thermochemical modality, 16,414.30 kilograms of ethanol were obtained per day (20.84 cubic meters per day), with a purity of 99.8% v/v

The process flow diagram developed is subject to change for optimization. For example, water, being a by-product of the biorefinery, can be used to recover energy and integrated into the plant itself, or it could even be used to produce green hydrogen.

For the proposed biorefinery and taking as an example the consumption for the year 2022 and for the whole Costa Rican territory, 5.16 % of gasoline could be supplied with ethanol.

The availability of raw material is a limiting factor for the success of a project of this type, since there is no certainty of being able to cover the waste market, which constitutes the raw material for the plant, as there are competitors or even competitors that may emerge during the life of the project.

In view of this situation, the idea and opportunity arises to study not only other geographical areas to quantify forest wastes, but also to consider other lignocellulosic urban, agricultural and industrial wastes as raw material, and thus increase the biorefinery's capacity. For example, in the same northern region of Costa Rica, there are many hectares dedicated to pineapple cultivation, the waste from which is an example of raw material.

Taking into account the availability of raw material and the existence of technology to transform biomass into ethanol, we conclude that it is technically feasible to operate a biorefinery in Costa Rica, an aspect that is in line with the National Decarbonization Plan and OECD instruments.

A financial feasibility study must be carried out, for which, among other aspects, the cost of producing ethanol must be lower than purchasing it for the project to be viable.

References

Barrantes, A. y Ugalde, S. (2018). *Precios de la madera en Costa Rica para el primer semestre del 2018 y tendencias de las principales especies comercializadas.* Oficina Nacional Forestal, Costa Rica.

Basu, P. (2010). *Biomass Gasification and Pyrolysis.* Practical Design and Theory. Elsevier.

BEF (2022). *Proximate and ultimate analysis.* Biomass Energy Foundation http://drtlud.com/BEF/proximat.htm.

Brunetti, A., Migliori, M., Cozza, D., Catizzone, E., Giordano, G. y Barbieri, G. (2020). Methanol Conversion to Dimethyl Ether in Catalytic Zeolite Membrane Reactors. *ACS Sustainable Chem. Eng. 2020, 8,* 10471-10479. https://dx.doi.org/10.1021/acssuschemeng.0c02557

Caballero, A., Rojas., M., Villalobos, M., Davis., A., Roldán, C., Moya., R. y Puente, A. (2019). Simulación de gasificación de biomasa enriquecida con hidrocarburos. *Tecnología en Marcha, 32* (4), 60-68.

Castro, M. (2019). *Lluvia ácida: cómo se forma, composición, reacciones y efectos.* Lifeder. https://www.lifeder.com/causas-lluvia-acida/.

Chacón, L. (2012). *Diagnóstico de las existencias de los residuos forestales en la región Huetar Norte de Costa Rica.* Ministerio de Ambiente y Energía, Fondo Nacional de Financiamiento Forestal, Costa Rica.

Chacón, L., Coto, O. y Flores, O. (2018). *Actualización de la encuesta de biomasa como insumo para su incorporación en la matriz energética de Costa Rica.* Energía, Medio Ambiente y Desarrollo, preparado para la Secretaría de Planificación del Sub-Sector Energía (SEPSE) Costa Rica.

Chandraratne, M. y Daful, A. (2021). Recent Perspectives in Pyrolysis Research. En M. Bartoli y Giorcelli, M. (Eds.), *IntechOpen*. https://doi.org/10.5772/intechopen.95170.

Chávez-Sifontes, M. (2019). La biomasa: fuente alternativa de combustibles y compuestos químicos*. Anales de Química - RSEQ, 115 (5)*, 399–407.

Dahiya, A. (2020). *Bioenergy. Biomass to Biofuels and Waste to Energy.* Segunda Edición. Elsevier.

Demichelis, F., Laghezza, M., Chiappero, M. y Fiore, S. (2020). Technical, economic and environmental assessment of bioethanol biorefinery from waste biomass. *Journal of Cleaner Production, 277 (20).* https://doi.org/10.1016/j.jclepro.2020.124111.

Dionísio, S., Santoro, D., Bonan, C., Soares, L., Biazi, L., Rabelo, S. y Lenczak, J. (2021). Second-generation ethanol process for integral use of hemicellulosic hydrolysates from diluted sulfuric acid pretreatment of sugarcane bagasse. *Fuel, 304 (15).* https://doi.org/10.1016/j.fuel.2021.121290.

E-education (2022). *Products of Combustion*. https://www.e-education.psu.edu/egee102/node/1951.

Elías, X. (s.f.). *Residuos sólidos urbanos* [videoclase]. Programa de Máster en Ingeniería Ambiental. Universidad Europea del Atlántico. España.

Gao, F., Wang, S., Wang, W., Duan, J., Dong, J., y Chen, G. (2018). Adsorption separation of CO from syngas with CuCl@AC adsorbent by a VPSA process. *RSC Adv., 2018, 8, 39362-39370*. DOI: 10.1039/c8ra08578a

Genia Bioenergy (2022). *Syngas: el gas de síntesis o sintegás. https://geniabioenergy.com/que-es-el-syngas/*

Gobierno de Costa Rica (2019). *Plan Nacional de Descarbonización, 2018 – 2050.*

Hingsamer, M. y Jungmeier, G. Biorefineries. (2019). In C. Lago, N. Caldés y Y. Lechón (Eds.), The Role of Bioenergy in the Bioeconomy (pp. 179-222). https://doi.org/10.1016/B978-0-12-813056-8.00005-4.

INTE (2017). Norma INTE E5:2017. Combustibles - Etanol carburante anhidro (especificaciones). *Instituto de Normas Técnicas de Costa Rica.*

IRENA (2018). Solid biomass supply for heat and power: Technology brief, *International Renewable Energy Agency, Abu Dhabi.*

Kishnani, D. (s.f.). *Pressure swing distillation column for separation of Ethanol-water mixture.* [Simulación de una columna de destilación para la separación de etanol agua en DWSIM versión 7.5.5]. University of Petroleum and Energy Studies. India.

Li, X., San, X., Zhang, Y., Ichii, T., Meng, M., Tan, Y. y Tsubaki, N. (2010). Direct Synthesis of Ethanol from Dimethyl Ether and Syngas over Combined H-Mordenite and Cu/ZnO Catalysts. *ChemSus 2010,* 3, 1192-1199. DOI: 10.1002/cssc.201000109

López, I. (2019). *Análisis de las propiedades fisicoquímicas y a tolerancia al agua, de mezclas con etanol de las gasolinas utilizadas en Costa Rica.* [Tesis para obtener el grado de Licenciatura en Ingeniería Química, Universidad de Costa Rica]. http://repositorio.sibdi.ucr.ac.cr:8080/jspui/handle/123456789/16079

Lüking, L. (2017). *Methanol Production from Syngas. Process modelling and design utilising biomass gasification and integrating hydrogen supply.* [Tesis para obtener el grado de Máster en Tecnología en Energía Sostenible, Universidad Tecnológica de Delft]

Methanol Institute (2022). *Essential Methanol*. https://www.methanol.org/wp-content/uploads/2020/04/Essential-Methanol-Methanol-Institute-Infographic.pdf

National Geographic (2022). *El aumento del nivel del mar.* https://www.nationalgeographic.es/medio-ambiente/el-aumento-del-nivel-del-mar.

Nwani, A. (s.f.). *Optimization of the Methanol Synthesis by CO_2 Hydrogenation*. [Simulación para la producción de metanol a partir de syngas en DWSIM versión 7.5.5]. University of Laos. Nigeria.

OECD (2020). *Examen del proceso de adhesión de Costa Rica a la OCDE en las áreas de medio ambiente y residuos.* Informe resumido. Dirección de Medio Ambiente. Comité de Política Ambiental.

Ray, L., Pattnaik, R., Singh, P., Mishra, S., y Adhya, T. (2021). Environmental impact assessment of wastewater based biorefinery for the recovery of energy and valuable bio-based chemicals in a circular bioeconomy. In T. Bhaskar, S. Varjani, A. Pandey y E. Rene. (Eds.), *Waste Biorefinery, Elsevier,* (pp. 67-101). https://doi.org/10.1016/B978-0-12-821879-2.00003-X.

RECOPE (s.f.). *Estimaciones de demanda de gasolinas.* Departamento Investigación. Refinadora Costarricense de Petróleo.

RECOPE (2020). *Estudio de factibilidad del proyecto de mezcla de gasolina con etanol a nivel nacional.* Dirección de Planificación, Refinadora Costarricense de Petróleo.

Rodríguez, D., Zaleta, A., Olivares, A., y Torres, F. (2010). *Análisis y Diseño de un Sistema de Gasificación de Biomasa.* Memorias del XVI Congreso Internacional Anual de la SOMIM. México.

Singh, C. (s.f.). *Production of Dimethyl Ether* [Simulación para la producción de dimetil éter DWSIM versión 7.5.5], Rajasthan Technical University, Kota.

Van-Dal, E. y Bouallou, C. (2013). Design and simulation of a methanol production plant from CO_2 hydrogenation. *Journal of Cleaner Production, 57,* 2013, 38-45.

Vanden Bussche, K.M. y Froment, G.F. (1996). A Steady-State Kinetic Model for Methanol Synthesis and the Water Gas Shift Reaction on a Commercial Cu / ZnO / Al_2O_3 Catalyst, *Journal of Catalysis 161,* 1-10.

ENVIRONMENTAL SCIENCES & PRACTICES
http://mlsjournals.com/Environmental-Science-Practices

(2024) Environmental Sciences & Practices, 2(1), 91-108.

Analysis of Guatemala city applying the european smart cities model

Análisis de la ciudad de Guatemala aplicando el modelo europeo de ciudades inteligentes

María Balsa Núñez
Psychologist, Spain
(maria.balsa.n@gmail.com) (https://orcid.org/0000-0001-7844-9148)
Johan Chris Haeussler Vesco
European University of the Atlantic, Spain
(johan.haeussler@alumnos.uneatlantico.es) (https://orcid.org/0000-0002-6017-4972)

Manuscript information:

Received/Recibido: 31/08/22
Reviewed/Revisado: 07/09/22
Accepted/7Aceptado: 27 /09/22

Keywords:
Guatemala city, parameters of a smart city, adaptation to the performance model, urban development.

ABSTRACT

This paper presents an analysis of five parameters that make up a smart city adapted to Guatemala City. These parameters were extracted from the European Model of Smart Cities found in the report "Smart Cities: Classification of large European cities". Due to the uncertainty surrounding the global meaning of a smart city, the parameters proposed to encompass the topic at all consist of: Economy, Population, Governance, Mobility and Environment. Each of these will be evaluated with three selected indicators based on the availability of the data required for the analysis, which are currently available for Guatemala City. Next, the state of each parameter is based on an analysis and development based on official qualitative and quantitative data extracted from the corresponding ministries, public entities and reports from non-profit organizations. Given that the collection of information has concluded and the final status of each of the five parameters in the body of work has been determined, the conclusions chapter summarizes the gaps and limitations for adapting the Model to this particular city. Finally, recommendations are included for the dissemination of this study and its possible adaptation for other cities with characteristics similar to those of Guatemala City.

Palabras clave:
ciudad de Guatemala, parámetros de una ciudad inteligente, adaptación al modelo de desempeño, desarrollo urbano.

RESUMEN

Este trabajo presenta un análisis de cinco parámetros que conforman a una ciudad inteligente adaptados a la Ciudad de Guatemala. Dichos parámetros fueron extraídos del Modelo Europeo de Ciudades Inteligentes encontrado en el reporte "Ciudades Inteligentes: Clasificación de las ciudades europeas de gran tamaño". Debido a la incertidumbre que rodea al significado global de una ciudad inteligente, los parámetros propuestos para abarcar el tema en absoluto consisten en: Economía, Población, Gobernación, Movilidad y Ambiente. Cada uno de estos será evaluado con tres indicadores seleccionados con base en la disponibilidad de los datos requeridos para el análisis, con los que actualmente se cuentan para la Ciudad de Guatemala. Seguidamente, se

	fundamenta el estado de cada parámetro con un análisis y desarrollo con base a datos cualitativos y cuantitativos oficiales extraídos de los correspondientes ministerios, entidades públicas e informes de organizaciones sin lucro. Dada por concluida la recopilación de información y determinado el estado final de cada uno de los cinco parámetros en el cuerpo del trabajo, el capítulo de conclusiones sintetiza las brechas y limitaciones para la adaptación del Modelo a esta ciudad en particular. Por último, se incluyen recomendaciones para la difusión del presente estudio y la posible adaptación de éste para otras ciudades con características similares a las de la Ciudad de Guatemala.

Introduction

Cities, generally speaking have a vital role in the social and economic spheres worldwide, as well as a great impact on the environment (Mori & Christodoulou, 2012). Therefore, the proper and controlled management of all the elements that make them up plays an important role in their development. Globally, cities have begun to look for solutions that enable transportation linkages, varied land uses, and high-quality urban services with positive long-term effects on the economy (Albino et. al., 2015).

According to data identified by the United Nations, by 2050 there will be approximately 9.7 billion inhabitants worldwide. Of these, more than 50% live in cities (UN, 2011-2019) which means that city governments continuously face an extensive range of challenges: they have the need to produce wealth and innovation, but also health and sustainability (Meijer & Bolivar, 2016). The socio-spatial segregation of the population and voluminous sprawl has produced several pressures on the quality of life and environment of all citizens (Morataya, 2011). Due to the intemperance caused by former governments, the problem continues to persist and increase, and these events complicate the implementation of new methodologies for improvement in all areas of development.

At the beginning of 2013, there were approximately 143 smart city projects underway or completed. Among these initiatives, North America had 35 projects; Europe, 47; Asia 50; South America 10; and the Middle East and Africa 10 (Lee at al., 2014). Based on the fact that the analysis in this article focuses on adapting a project of this type to Guatemala City, which is developing; it is worth mentioning that 20 of the total number of these projects conducted in 2013 were located in countries that are also developing countries today. However, it is not possible to make use of existing information on these projects or their methodology, given that they were planned from the outset around the concept of sustainable development. On the contrary, Guatemala City was by no means designed for sustainable technological purposes.

Smart Cities

From the constant need to create solutions to the variety of existing problems arises the term "smart city". There is no single template to frame or define it, nor is there a "one-size-fits-all" template that fits all the issues it can encompass (O'Grady and O'Hare, 2012). However, there are two perspectives to define this term. First, those such as Glaeser & Berry (2006) who expose how smart cities are categorized by numbers and literal intelligence, such as the percentage of the population who have a bachelor's degree, college degree, PhD or those who know 2 or more languages. On the other hand, as a second perspective, Whashburn & Sindhu (2010) focus more on problem solving by adapting new methodologies. These types of authors demonstrate how a smart city should be oriented towards reducing challenges that may include resource scarcity such as energy, health, housing, deteriorating or inadequate infrastructure (such as potable water, renewable energy, roads, education and transportation), price instability, climate change, and most of all the demand for better economic opportunities and social benefits.

In terms of academic literature, the meaning of "smart" covers a range of technological features, such as self-configuration, self-protection and self-optimization. Then, in industrial literature with a tendency in business and industrial instruments, "smart" refers to the astute performance of products and services, artificial intelligence and independent machines (Nam & Pardo, 2011).

In this way, we can proceed to define a smart city as one that focuses or dedicates its resources towards the constant implementation (through research and development studies) of improvements in all areas that have an impact on the economic and social development of the city. This, with the sole purpose of offering an improvement in the quality of life to its inhabitants that is evidenced by a favorable increase in the economy, education, access to services, mobility such as logistics and infrastructure, efficiency and sustainability in the environment and most importantly, safety and high quality of life.

Figure 1

Indicators of a smart city

Parameters

The first "Economy" parameter is used to describe a city with "smart" industry. This especially involves industries in the areas of information and communication technologies (ICTs) as well as the application of ICTs in the production process. Therefore, the first parameter to be studied is public spending on research and development as well as on education.

The second "Population" parameter. It investigates the educational level of the total percentage of citizens, their skills and opportunities for growth. The foundation of a smart city is formed by the individuals who inhabit it, placing in a high position their capacities of understanding because they are the ones responsible under the command of their superiors to engineer and implement the improvements.

Next, the third "Governance" parameter refers to the relationship between government representatives and the population. Good governance as a fundamental aspect of intelligent administration also refers to the use of new methods of communication for its citizens. Likewise, smart cities are used to discuss the use of modern technology in everyday urban life (Giffinger, et al., 2007).

In the penultimate parameter of "Mobility" we focus on modern transportation technologies. New "intelligent" transportation systems are therefore emerging in order to improve urban traffic and population mobility. To know how to conduct the "Mobility" study, it is necessary to analyze the current structure in order to know how the implementation of these new technologies can solve them.

The last parameter is "Environment". It is intended to analyze natural conditions, pollution, resource management and also efforts towards environmental protection (Giffinger, et al., 2007).

Guatemala City

Proceeding to the present day Guatemala City extends over 228 km2, making it the largest city in Central America. According to the National Institute of Statistics and the Judicial Organism of Guatemala, in the last census carried out this year, the approximate population has a total of 995,393 inhabitants. It is home to 20% of the country's population, as well as the main political, economic, social and social headquarters and most economic activities (Morataya, 2011). However, it is important to consider the metropolitan area that extends outside the city; as it reaches an estimated 3.5 million inhabitants (INE, 2018). They have an impact on all the activities in the area of this study because they circulate, consume and are part of the movements that take place on a daily basis.

Method

Following the classification proposed by Hernández et al. (2014) the present work has a mixed descriptive approach and employs content analysis. The inclusion of quantitative data complements the content analysis, giving an idea of the magnitude of impact on the five parameters. These data are taken from various studies with the same purpose, although focused on cities with varied backgrounds and needs.

An analysis of five of the parameters proposed by the European Model of Smart Cities to Guatemala City is developed. Within each one, three indicators are included, selected for the reason that they have the most information available as well as their ease of adaptation to a city of this type. Finally, it is necessary to mention that the following analysis develops five of the six parameters, excluding the last one "Life". This is due to the fact that this parameter is continuously mentioned in the development of all the previous ones, making a section dedicated only to this one unnecessary.

Results

Economy

Presented as the first indicator, public spending on R&D and education are characterized as the "innovative spirit" factor of a smart city according to Dr. Giffinger (2007). In Guatemala City, this indicator is monitored by two different public entities: the National Science and Technology System and the Ministry of Education.

Starting with R&D, in Guatemala City all activities related to scientific and technological research are coordinated by the National Secretariat of Science and Technology (SENACYT) and directed by the National Council of Science and Technology (CONCYT) (SENACYT, 2018).

The funds and budget are allocated by need or by activity development, causing the figures to vary from year to year. In order to provide an overview of the resources available to these entities, Table 1 is presented below.

Table 1

Relevant figures of Guatemala's R&D budget

Budget	Amount (€)
Total R&D budget of the country	3.368.790
Total budget executed	2.986.752
Approximate budget to Guatemala City	153.127
Percentage	%
Percentage of total executed	88,66
Total percentage of GDP	0,0048

Note: Source: SENACYT, 2018

Education is an indispensable instrument for human development, since it enables the acquisition of new knowledge, skills and competencies that allow the population to have access to a greater number of opportunities. This is why it is called a key factor towards the implementation of a smart city. The figures for the Education budget are shown in Table 2.

Table 2

Relevant figures of Guatemala City's education budget

Students	Figures
Total school-age population (4 to 21 years)	264.725
Total students withdrawn	19.897 (7.5%)
Budgets	Figures
Approximate total education budget	€89.008.486
Total GDP spent on education	0.13%
Approximate annual amount per student	€336.2

Note: Source: Own elaboration based on MFP, 2019 and MINEDUC, 2001.19

Regarding the state of employment, it should be noted that by the beginning of 2010, they generated approximately 53% of national jobs, 79% of industry, 61% of the services branch offered and finally 86% of jobs in commerce (Morataya, 2011). Table 3 shows the data collected:

Table 3

Relevant figures of the labor force and unemployment in Guatemala City

Population	Figures
Population 15 years and older	706.702 (71%)
Economically active population	437.313 (44%)
Population working outside the city	6.036 (1.38%)
Unemployment rate	Figures (%)
Unemployment rate in the city for 2010	69.678 (7%)
Unemployment rate in the city for 2015	28.867(2.9%)

Note: Own elaboration based on INE, 2018; América Economía, 2016; MGI, 2016 and Morataya, 2011.

After analyzing the economic indicators, an overview of the general state of the economic parameter can be made.

As for the indicator dedicated to R&D, it is evident that the insufficient funds dedicated to these areas bring a variety of chain problems, thus impeding the main goal of human development. Based on the data presented in the indicator, according to the funds dedicated to education, each student in Guatemala City is allocated approximately €34 per month for the ten months of the course. Clearly, this is a figure that is not evenly distributed, with the majority going to official or municipal education. The aforementioned then argues that the educational quality offered to them is not sufficient or effective, starting from pre-primary and primary to basic and diversified (INE, 2018). Creating a mentality in which education is not seen as necessary.

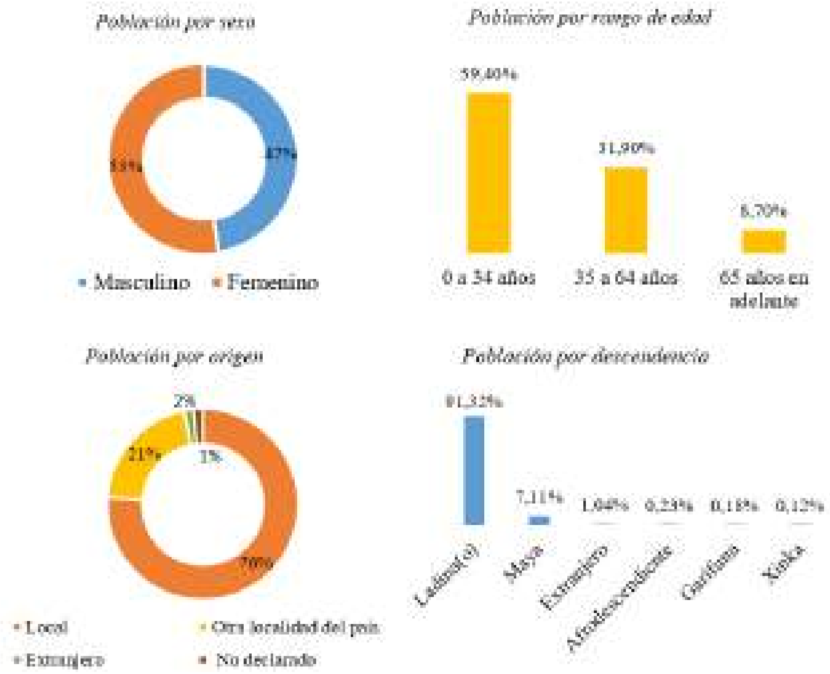
Finally, with respect to the GDP per capita and unemployment rate indicators, there is no doubt that their figures are largely the result of the first indicator. Guatemala as a country has one of the lowest levels of investment in the world. The total investment rate stands at around 14 percent of GDP, which is well below the average of 21 percent for Latin America. The limited investment in the economic sector has a knock-on effect on the positive growth of the indicators analyzed. Thus, it can be said that continuous improvement methods dedicated to the life of the population are not promoted; only enough to keep it stable.

Population

Guatemala City, having moved on four different occasions and also being the capital of the country, hosts a great diversity of population. This may come from different parts of the country or from abroad and may be manifested as cultural, ethnic and linguistic diversity. Therefore, the following data extracted from the Census are presented to support this argument:

Figure 2

Demographics of the population of Guatemala



Note: Source: INE, 2018

Initially, the following population indicators are directly related to the concept of human development. It describes the achievements of a city in relation to different dimensions, one of them being access to knowledge and a decent standard of living. Without further ado, the most relevant approximate data for the following indicator are presented in Table 4 below:

Table 4

Relevant figures for the population with higher education in Guatemala City

Population	Figure
Population over 25 years old	530.132 (53.26%)
Total population with advanced education	36.049 (3.62%)
Graduates	Figure
Graduates over 25 years of age	34.459 (6.5%)
Master's degree graduates over 25 years of age	1.590 (0.3%)

Note: Source: Lemarchand, 2017; MINEDUC, 2018

For the next indicator, different digital skills were taken into account within a high percentage of the population. These include not only economically active individuals with advanced knowledge of basic coding or Microsoft Office-type software. The main reason for the inclusion of all stakeholders is due to the impact they have or will have on all areas of the city. The following data include individuals aged 7 years and older as well as executives and workers from different companies in Guatemala City.

Table 5

Figures relevant to the digital literacy of the population of Guatemala City

Population	Figure
Population 7 years and older	823.541 (82.73%)
Population using cell phones	686.460 (83.35%)
Population using computers	437.433 (53.11%)
Population using the Internet	512.366 (62.21%)
Population using the 3	413.195 (50.17%)
Population using cell phones and computers	418.986 (50.87%)
Population using cell phones and internet	498.236 (60.49%)
Population using computers and internet	427.192 (51.87%)

Note: Source: MINEDUC, 2018

Finally, in this last population indicator, the level of knowledge of foreign languages in the population of Guatemala City is developed. In general, the knowledge of languages by maternity or apprenticeship within the city is divided as follows:

Figure 3

Percentage of languages by mother tongue

Note: Source: INE, 2018

Table 6

Knowledge of foreign languages as a second language by population at the country level and its approximation to the city

Language	Country	City
English (52.8%)	8.236.800	525.568
Other foreign language (3.2%)	499.200	31.853
English proficiency level	52.50% (moderate)	53.51% (moderate)

Note: Source: INE, 2014; EF, 2019

From the data presented, it can be determined that, of the total population evaluated in Guatemala City, only 0.43% have English or another foreign language as their mother tongue. On the other hand, although the main intention of this indicator focuses only on foreign languages, it is of utmost importance to mention the variety of native communities in the country with unique dialects that make it multilingual.

After completing the development of the main population indicators, it is possible to infer both the reason for their status and the variables that affect them. First, with respect to the percentage of the population with advanced education, there is no doubt that the number of graduates has increased over the years. However, its improvement is directly linked to public investment in education, which significantly limits its development. The scope of advanced education in Guatemala City remains limited due to the scarcity of regulations and investment in student, teaching and academic offerings.

Continuing, the status of the digital literacy and foreign language indicators is similar. The skills are not fully developed. Regarding digital literacy, there is no doubt that a high percentage of the population has the necessary knowledge for the average use of devices. Regarding the last indicator, it can be said that the knowledge of foreign languages is not diverse in a high percentage. In any case, the figures of the three indicators present a clear potential in social and human capital; which currently at the country level has a value of 52.2 out of 100 (Schwab, 2019). For this reason, it can be inferred that, when correctly oriented, it can have a high impact on the development of the population and the different associated parameters.

Government

This third parameter focuses on the type of relationship that exists between the actors of the main governmental entities and the population. This relationship includes all institutions of higher education and research centers as well as every individual in the population who is active in the development of the city. Essentially, in order to obtain effective results; fields of action have to be identified according to their strengths and weaknesses as well as to advise which governance approach is more effective to achieve the cooperation of all stakeholders (Lombardi, et al., 2012).

The three indicators chosen to be developed have as their main focus to express the potential for participation in decision making, the availability of public and social services and government transparency in all areas.

Through Table 7, it can be noted that the only public center is the University of San Carlos and therefore this evidences that approximately 68% of all higher studies and advanced education centers are run by the private sector (Lemarchand, 2017). On the other hand, based on more subjective indexes, Table 8 shows the general results obtained based on the offer of these academic studies.

Table 7

Universities and research centers in Guatemala City by type and academic offerings in 2011

University	Faculties	Degrees	Masters	Doctorates	Research Centers
Universidad de San Carlos	10	109	113	8	33
Universidad del Occidente	4	14	-	-	-
Universidad del Istmo	6	15	6	-	1
Universidad del Valle	4	29	9	-	11
Universidad Francisco Marroquín	5	19	12	1	5
Universidad Galileo	9	49	44	-	6
Universidad InterNaciones	3	9	1	-	-
Universidad Mariano Gálvez	12	34	51	12	3
Universidad Mesoamericana	2	9	3	3	1
Universidad Panamericana	7	12	14	-	-
Universidad Rafael Landívar	9	110	34	-	11
Universidad Rural	7	9	7	1	-

Universidad San Pablo	7	5	7	-	-
Total	**85**	**423**	**301**	**25**	**71**

Note: Source: CONADUR/SEGEPLAN, 2014; Rosado, 2011

Table 8

Quality indexes based on the supply of academic studies and research centers

Index	Rating (1-7)
Quality of research institutions	3.5
University-industry collaboration in R&D	3.5
Availability of scientists and engineers	4

Note: Source: Schwab, 2016.

As for the second indicator, an online e-government refers to Internet technologies that act as a platform for the exchange of information, provision of services and conducting transactions with citizens, businesses and other branches of government.

In more specific terms, the most recent national action plan includes 5 axes with different commitments to reach the goal. These are divided into the following:

- Access to public information and institutional archives.
- Technological innovation (Creation of an open data portal, a technical roundtable to address issues of technological innovation, online public services, municipal services and public information requests).
- Citizen Participation (Creation of programs and mechanisms for opinion, collaboration and participation).
- Accountability (Transparency of actions in integrated management for disaster risk reduction).
- Fiscal Transparency (Creation of an open and participatory budget process in public finance, tax administration, public health and social assistance, and education).

In order to analyze them, it was necessary to access the official platform of the Municipality of Guatemala City. In it, there are three tabs containing external links depending on the topic to be covered. As can be seen in Figure 4, the required information from the 5 axes was accessed without any problem. However, according to the existing reports of the three action plans carried out to date, the monthly monitoring and review of these plans was not carried out correctly. This is evidenced by the fact that the rating of timeliness and level of compliance with each commitment only exists for the first two plans, with 14% for the first and 63% respectively. Regarding the third plan, being this the most recent of the years 2016-2018; there is no information about the follow-up that has been carried out. On the other hand, there is also no action plan formulated for the years 2019-2021.

Figure 4. Online platform of the Municipality of Guatemala.

For the last population parameter, the number of households within Guatemala City that have access to internet at home is developed. To present the data in greater detail, the typology of each household is also included.

Table 9

Households by typology in Guatemala City

Typology	Figure
Unipersonal	23.894 (9.8%)
Nuclear	137.478 (56.6%)
Extensive	68.536 (28.2%)
Composed	10.525 (4.3%)
Co-chairs	2.581 (1.1%)
Total	243.014 (100%)

Note: Source: INE, 2018.

Figure 5

Percentage of households with Internet access at home

Note: Source: INE, 2018

After obtaining accurate data on the three main governance indicators, the task of determining their overall status is expedited. Proceeding with the case of universities and research centers in the city; it can be noted that 12 out of 13 institutions are private. The fact that they are means limitations for a large percentage of citizens due to the inability to cover the costs of assistance. In addition, the absence of post-graduate programs such as master's and doctoral programs imposes another important barrier to development on the city, directly related to the preparation of teachers to transmit knowledge.

Next, for the second indicator of online e-government, it should be noted how complete the official platform of Guatemala City is based on the 5 axes of the Open Government Partnership. Therefore, it is evident that existing governance norms and standards support and guide the city's population towards a high quality of life (Lombardi, et al., 2012). However, it is worth mentioning that there is a failure to update the data, which was proposed for every two years. Unfortunately, this affects the accuracy and transparency of information such as the timeliness rating of commitments. Finally, with respect to the indicator of households with Internet access at home, it can be noted that there is only 50.83% coverage of the population in the city. This indicates that connectivity among all stakeholders and leveraging of public platforms is limited.

Mobility

As the penultimate parameter of analysis, the issue of mobility is introduced. The first indicator is "local and international accessibility". This means the coverage of the same within the city, the satisfaction of the inhabitants for such access and its quality.

First, with respect to local accessibility, the three existing public media are included: Traditional, Transurban and Transmetro. Table 10 shows the use of different modes of transportation in the city.

Table 10

Households in Guatemala City by means of transport

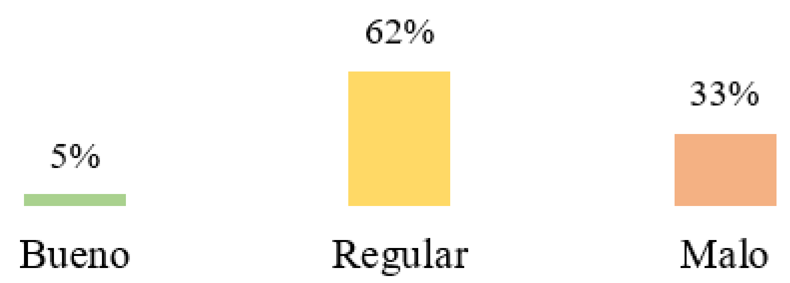
Means of transportation	Number of households
Automobile	115.763 (47.64%)
Motorcycle	52.588 (21.64%)
Public transportation or on foot	74.663 (30.72%)
Total	243.014 (100%)

Note: Source: INE, 2018

It is worth mentioning that, due to the percentage of coverage, reliability of use and safety, a high percentage of households opt for other means of transportation such as motorcycles or automobiles. In relation to this, Figures 6 and 7 illustrate the quality perceived by users of public transport in the city.

Figure 6

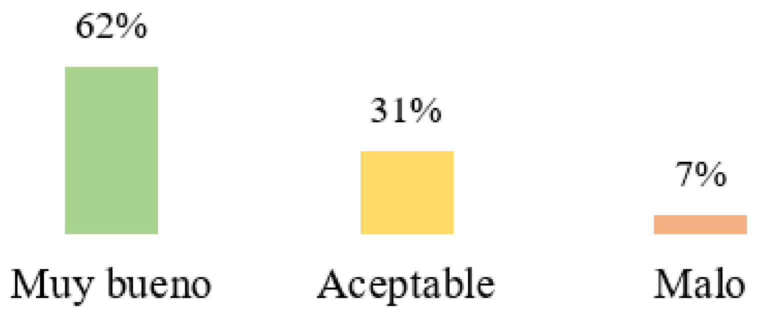
Quality of the traditional transport service



Note: Source: Morán et al., 2001

Figure 7

Quality of Transmetro transportation service



Note: Source: Lossau, 2012

With the main methods of public mobility in mind, we then evaluate the sustainability and safety offered by these systems at present and their consequent effect on Guatemala City.

When U.S. cars, motorcycles or buses fail emissions tests, they are auctioned and bought by dealers in Central American countries such as Guatemala and Honduras. Therefore, due to lack of law enforcement, they continue to operate in Guatemala City. Table 11 shows the pollution data for the city.

Table 11

Comparison of the WHO standard level of particulate matter pollution (PM2, %) and the current level in Guatemala City.

Note: Source: USCG & Ecoquimsa, 2017

Recommended annual average level	Actual annual average level
10 milligrams per m^3	65 milligrams per m^3

Thus, the highest annual average exceeded the proposed recommendations by 5.5 times. This data makes it the sixth most polluted city in the Americas, with approximately 70% of the total coming from emissions from these vehicles. (Pskowski, 2019).

Finally, international accessibility within Guatemala City is made up of two distinct means of mobility; La Aurora International Airport and private long distance bus companies. The airport is the country's main air embarkation and disembarkation port. For 2019, it reported an inbound and outbound movement of 2,983,042 passengers among 18 airlines; placing it among the four most trafficked airports in Central America (DGAC, 2019).

In terms of initiatives towards an advanced ICT infrastructure, the aerometer and the metrometer stand out. The Aerometro is a cable car type public transportation project designed to connect the neighboring city of Mixco to Guatemala City in a 100% electric way. It is designed to connect the existing Transmetro and bicycle systems to mobilize citizens in a more fluid manner. On the other hand, the Metrorail is introduced as a type of light rail also 100% electric.

In concluding the development of mobility in Guatemala City, it can be deduced that its current state is not adequate for its inhabitants and is far from optimal. Despite the partial effectiveness achieved by some existing systems, this is not sufficient in terms of coverage, safety and sustainability to meet the required demand. The continuous expansion of the city forces the increase of accessibility methods to its inhabitants. Therefore, the expansion of an effective mobility system is necessary to achieve urban planning (Morán et al., 2001).

Environment

This parameter briefly covers natural conditions, pollution, resource use and resource protection (Giffinger, et al., 2007).

Guatemala as a country is particularly vulnerable to the effects of climate change and this creates the need to carry out all responsibilities in relation to the environment. Therefore, and in response to the urgent need for action, Guatemala accepts the decisions taken at the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) by submitting its Intended Nationally Determined Contribution (INDC).

With regard to CO_2 emissions reduction, the following priorities are covered (CONADUR/SEGEPLAN, 2014):

- Conservation and sustainable use of forests and biodiversity.
- Sustainable management of water resources to achieve social, economic and environmental objectives.
- Agricultural technification and family farming for food security.

Guatemala is not a country with relevant emissions of this type. Therefore, despite being linked to the efforts of the United Nations and applying several regulations, it is excluded from the commitments to reduce these gases by the Kyoto Protocol (Kosch, 2013).

Due to the geographical position and topography of the country, the potential of the electricity sector is favored with respect to the diversification of the electricity matrix. Currently, this includes hydropower productions, geothermal, solar, wind, biomass and more (Lemarchand, 2017). In more specific terms regarding potential and origin, Table 12 shows power generation.

Table 12

Different power generation components for 2015.

Type	GWh	Percentage with respect to annual total
Hydroelectric	3,851.8	37.4%
Geothermal	251.5	2.4%
Wind	107.3	1.0%
Cogeneration	2,685.1	26.1%
Solar	149.3	1.4%
Biomass	1.1	0.01%
Biogas	4.0	0.04%
Thermal	3,251.8	31.6%
Total	10,301.9	100%

Note: Source: Lemarchand, 2017

With respect to efficient water use, Guatemala has three hydrographic basins: the Gulf of Mexico, the Atlantic and the Pacific, 38 watersheds and 194 bodies of water. Despite this, it is one of the countries with the lowest water supply per person in Central America.

The last indicator is waste control, focusing on the proportion and management of recyclable and non-recyclable solid waste from any source. First, with respect to waste produced in households in Guatemala City.

Figure 8

Composition of household solid waste

Note: Source: INE, 2015

When 93.5% of household waste is collected, whether by private or municipal service, it is taken to one of the 17 open dumps around the city. Of all of them, none has an environmental impact study from MARN.

With the environment parameter completed and with the essential data presented in each of them, the general state of the environment is quite clear. Since MARN is the entity responsible for all environmental and natural resource issues in Guatemala City and the entire country, it is appropriate to indicate that the poor control and the social, economic, environmental and sanitary impact falls on them. However, they are funded by the government, which means that their actions are directly linked to the budget allocated to them.

Regarding the first indicator, there is no doubt that there is a variety of regulations in force that cover a high percentage of the problems facing the city today. However, these are not adequately exercised or monitored. The lack of coordination between entities, complete allocation of resources and compliance with already stipulated rules are some of the factors that most affect the achievement of the proposed goals against CO_2 emissions.

Next, the second indicator regarding the efficient use of water and electricity is favored by Guatemala's geographic location. The wide variety of natural resources available around the country and the high coverage of them within the city mean that the issue of scarcity is not often mentioned. However, the best quality can also become the least favorable if not properly controlled.

Finally, the information presented with respect to the waste control indicator clearly shows the almost nonexistent infrastructure for waste collection services, as well as in most of the city's landfills, which are only places for final disposal, where there is no adequate management or logistics for the waste that arrives daily.

Discussion and conclusions

With the states of each parameter in mind, both the results obtained and the gaps and limitations of the study are analyzed.

The insufficient funds dedicated to the development of each parameter, the incorrect administration and management carried out by the responsible actors in their areas, as well as the scarce interconnection among them, prevent the transmission of key information among them. Consequently, the ability to use such information to create behavioral patterns and establish improvement actions towards a smart city becomes impossible to carry out in a seamless manner.

Despite the extensive availability of laws, regulations and articles to promote the functioning of the parameters and quality of life of citizens, as well as to avoid risks; these are affected by the failure to exercise or enforce the respect and authority of the same causing the problems presented to continue to occur and increase in fatality.

The variety of more severe problems throughout the country that the Government of Guatemala has to address, as well as the fact that Guatemala City is in the best state compared to the other cities within its territory, limit the scope of a smart city initiative. For this reason, the work of implementation falls to non-governmental organizations, which, although they manage to implement such initiatives, have limited scope due to the lack of support from the main entities.

As a last point, it is vitally important to mention that the lack of updated data or lack of precise information on the parameters in general or indicators specific to Guatemala City, limits the scope of the study with respect to its current status and consequently the equity of information included in all parameters. Therefore, in cases where it was not possible to obtain what was required at the city level, it was necessary to use the country level, thus affecting the accuracy of the results. However, it is evident that the nature of the model applied to analyze Guatemala City is dedicated to European cities only. It is structured by means of indicators for each parameter, which emerge from areas in which researchers in these European cities take for granted that they exist. On the contrary, in the case of Guatemala City, it was necessary to make a selection of indicators based on the information that was possibly available, which meant the exclusion of possibly significant indicators.

References

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of urban technology*, *22*(1), 3-21. https://doi.org/10.1080/10630732.2014.942092

América Economía. (2016). Mejores Ciudades para hacer negocios en América Latina.

Consejo Nacional de Desarrollo Urbano y Rural de Guatemala (CONADUR) y Secretaría de Planificación y Programación de la Presidencia (SEGEPLAN). (2014). Plan Nacional de Desarrollo K'atún: Nuestra Guatemala 2032.

Dirección General de Aeronáutica Civil (DGAC). (2019). Informes: Tráfico de pasajeros desembarcados/embarcados. *Servicio Regular Internacional.*

Education First. (2019). Education First English Proficiency Index: A ranking of 100 Countries and Regions by English Skills. 8-28.

Giffinger, R., Fertner, C., Kramar, H., Meijers, E. (2007). Ciudades Inteligentes: Clasificación de las ciudades europeas de gran tamaño; Centro de Ciencia Regional en la Universidad Tecnológica de Vienna: Vienna, Austria; Universidad Tecnológica de Delft: Delft, Países Bajos. 10–12.

Giffinger, R., Kramar, H., Haindlmaier, G., Strohmayer, F. (2007). Modelo Europeo de Ciudades Inteligentes; Centro de Ciencia Regional en la Universidad Tecnológica de Vienna.

Glaeser, E. L., & Berry, C. R. (2006). Why are smart places getting smarter?. *Rappaport Institute/Taubman Center Policy Brief*, *2*.

Hernández Sampieri, R., Fernández Collado, C., & Baptista Lucio M.P. (2014). *Metodología de la investigación*. (6ª ed.). Distrito Federal, México: McGraw Hill.

Instituto Nacional de Estadística Guatemala (INE). (2014). Perfil estadístico de Pueblos 2014.

Instituto Nacional de Estadística Guatemala (INE). (2014). República de Guatemala: Encuesta Nacional de Condiciones de Vida 2014.

Instituto Nacional de Estadística Guatemala (INE). (2018). Resultados del XII Censo Nacional de Población y VII Censo Nacional de Vivienda.

Kosch, M. (2013). Guía sobre el Cambio Climático y el Riesgo de Desastres en Guatemala. Brot für alle.

Lee, J. H., Hancock, M. G., & Hu, M. C. (2014). Hacia un marco efectivo para la construcción de ciudades inteligentes: Lecciones de Seúl y San Francisco. *Previsión Tecnológica y cambio social*, *89*, 80-99.

Lemarchand, G. (2017). Relevamiento de la Investigación y la Innovación en la República de Guatemala*. Colección GO-SPIN de perfiles nacionales en políticas de ciencia, tecnología e innovación, vol. 6.* UNESCO Publishing.

Lombardi, P., Giordano, S., Caragliu, A., Del Bo, C., Deakin, M., Nijkamp, P., Kourtit, K., & Farouh, H. (2012). An advanced triple-helix network model for smart cities performance. In *Regional Development: Concepts, Methodologies, Tools, and Applications*. 1548-1562. IGI Global. https://doi.org/10.4018/978-1-4666-0882-5.ch808

Lombardi, P., Giordano, S., Farouh, H. and Yousef, W. (2012). Modelando el rendimiento de una ciudad inteligente, *Innovación: Revista Europea de Investigación en Ciencias Sociales,* 25(2), 137-149. https://doi.org/10.1080/13511610.2012.660325

Lossau, A. (2012). Transmetro: Sistema BRT de la Ciudad de Guatemala. 35-38.

Meijer, A., & Bolívar, M. P. R. (2016). Gobernando una ciudad inteligente: Revisión de literatura sobre gobernación urbana inteligente. *Revisión Internacional de ciencias administrativas*, *82*(2), 392-402. https://doi.org/10.1177/0020852314564308

Morán, A., Herrera, A., Urbina, R., & Bethancourth, R. (2001). Informe Final: El transporte colectivo urbano en el área metropolitana: Hacia una solución integral. Universidad de San Carlos de Guatemala. Dirección General de Investigación y Centro de Estudios Urbanos y Regionales.

Morataya, E. (2011). Encuesta CIMES Ciudad de Guatemala. Observatorio del Desarrollo Urbano y Territorial de la Universidad Politécnica de Cataluña. 8-32.

Nam, T., & Pardo, T. A. (2011). Smart city as urban innovation: Focusing on management, policy, and context. In *Proceedings of the 5th international conference on theory and practice of electronic governance*. 185-194. https://doi.org/10.1145/2072069.2072100

O'Grady, M., & O'Hare, G. (2012). How Smart Is Your City?. *Science Magazine* 335(3), 1581–1582.

Organización de las Naciones Unidas (ONU). (2011-2019). Perspectivas de la población mundial: Revisión 2019. Departamento de Asuntos Económicos y Sociales & Departamento de Población.

Pskowski, M. (2019). Medio Ambiente, un problema nocivo II: Así se alarga la vida de los coches mientras se acorta la de los humanos. *El País.*

Rosado, D. (2011). Revista Innovación Educativa, 11(57) ,1.

Schwab, K. (2019). The global competitiveness report: 2019. World Economic Forum. 250-253.

Secretaría Nacional de Ciencia y Tecnología de Guatemala (SENACYT). (2018). Memoria de Labores 2018. 6-11.

Universidad de San Carlos de Guatemala (USCG) & Ecoquimsa. (2017). Calidad de Aire de la Ciudad de Guatemala. *Gráfica PM 2.5.*

Washburn, D., Sindhu, U., Balaouras, S., Dines, R. A., Hayes, N., & Nelson, L. E. (2009). Helping CIOs understand "smart city" initiatives. *Growth*, *17*(2), 1-17.