LANCTIGESSR - provider of Geospatial Solutions for Emerging Societal Challenges

LANCTIGESSR - fournisseur de Solutions Géospatiales pour les Défis Sociétaux Émergents

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ABSTRACT: The laboratory focuses on monitoring socio-environmental indicators related to the degradation and environmental impact generated by anthropic activities on forest areas and any other activities associated with environmental sites. In this regard, it is worth highlighting that the country's forests provide a wide range of ecosystem services (ES), which are understood as benefits that ecosystems offer to people and that directly or indirectly influence their well-being. Urban peripheries offer ES at multiple temporal and spatial scales, and their sustainability is crucial for the survival of cities. Geospatial Information Technologies (GITs) enable the development, application, and dissemination of knowledge aimed at solving problems in socio-ecological systems (SES). The project provides society with a practical geospatial tool (Dashboard) that monitors resilience and adaptation indicators in SES. The development and enhancement of Earth Observation through the construction of GIS (Geographic Information Systems) will enable the capture, storage, analysis, and visualization of geographic data. Understanding temporal and spatial socio-ecological changes is necessary to identify historical trends and project future changes, thus allowing for the proposal of guidelines for informed decision-making and integrated land-use planning, with a focus on sustainability and resilience in societies.

KEY WORDS: laboratory, environmental impact, sustainability, resilience.

RÉSUMÉ: Le laboratoire se concentre sur la surveillance des indicateurs socio-environnementaux liés à la dégradation et à l'impact environnemental générés par les activités anthropiques sur les zones forestières et toute autre zone associée aux sites environnementaux. À cet égard, il convient de souligner que les forêts du pays offrent une large gamme de services écosystémiques (SE), qui sont compris comme des avantages que les écosystèmes procurent aux individus et qui influencent directement ou indirectement leur bien-être. Les périphéries urbaines offrent des SE à des échelles temporelles et spatiales multiples, et leur subsistance dépend du bon fonctionnement de ces services. Le développement et la consolidation de l'Observation de la Terre à travers la construction de SIG (Systèmes d'Information Géographique) permettront la capture, le stockage, l'analyse et la visualisation des données géographiques. Comprendre les changements socio-écologiques temporels et spatiaux est nécessaire pour identifier les tendances historiques et projeter les changements futurs, afin de proposer des lignes directrices pour une prise de décision éclairée et une planification territoriale intégrée, en vue de la durabilité et de la résilience des sociétés.

MOTS CLÉS: Laboratoire, impact environnemental, durabilité résilience.

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1. Introduction

Socio-ecological systems are complex systems due to the large number of social and natural subsystems that are part of them, as well as the interactions among them, resilience being their most important characteristic. Resilience refers to patterns of positive adaptation in contexts of significant risk or adversity (Masten & Powell, 2003). Resilience allows the creation of competencies in individuals who have experienced adversity and thus may be less affected in a vulnerable situation.

The emergence of socio-ecological systems at the scientific level introduces a paradigm based on the establishment of a complex interrelation between the social and ecological spheres, integrating and harmonizing each of its elements, which interact under different spatio-temporal circumstances (Balvanera, Astier, Gurrí, & Zermeño, 2017).

The LANCTIGESSR (National Conahcyt Laboratory of Geospatial Information Technologies for Resilient Socio-Ecological Systems) aims to develop and apply geospatial information technologies to address current and emerging problems through geotechnological studies and processes. This will enable the Laboratory to promote strategies and decision-making aimed at building resilience in societies by integrating geospatial and statistical data with community engagement, thereby strengthening the capacity for adaptation and recovery in the face of socio-environmental challenges.

This laboratory is proposed as an action to consolidate these compatriot experiences among the promoting institutions, to contribute to the study and contextualization of new global and local problems. The Autonomous University of the State of Mexico as the host institution and the associated institutions, combine capacities and expertise in human resources training, in the design and implementation of mechanisms for the dissemination of territorial information, and in training actions and citizen participation. In addition to this, the development and enhancement of Earth Observation through the construction of GITs will allow the capture, storage, analysis and visualization of geographic data, besides the capacity for the design and construction of Geospatial tools. As a result, the research topics that have been addressed are: risk analysis, resilience, socioeconomic phenomena, geomatics, spatial conservation planning, climate change, resilient societies, integrated water management, agroforestry management, remote sensing, sustainability, production chains, landscape and geoecological degradation; to name a few of them. For 20 years the group has been a reference in teaching of GIT.

The Juárez University of the State of Durango uses cutting-edge geospatial technologies to generate solutions to forest and environmental resource problems through projects applied to their management and conservation, for the benefit of the natural, social and productive environment.

The Mexican Space Agency collaborates with scientific activities and space technology development to meet the needs of society, which positions Mexico as a leading nation, improving the quality of life and the economy of the country. On the other hand, the Autonomous University of Sinaloa produces geospatial information and drone management.

Finally, the State University of Quintana Roo provides research and information on resilience as well as mitigation and recovery actions before, during and after a natural disaster.

These academic collaborations and synergies create the foundations for developing more precise and timely technologies and tools, allowing the laboratory to offer innovative and effective solutions to society's challenges. The Laboratory seeks to be a bridge between science, technology, and society, generating knowledge and promoting the use of geospatial information technologies

that support the resolution of the country's socio-environmental problems. It also provides reliable tools to support decision-making, thus contributing to sustainable development, efficient resource management, and strengthening social and environmental resilience.

2. Study area

The laboratory is part of the PRONACES of socio-ecological systems, specifically in the construction of resilient societies facing climate change, through the generation of capacities based on social organization, assisted by information and geotechnological tools. It will also contribute to PRONACES: water, education, health, food security and energy and climate change through academic research projects, involving various sectors with a multidimensional and interdisciplinary approach.

This initiative is part of the pentahelic, promoting synergy between academy, government, business, society and the environment (Mateos, & Estrada, 2024). With this strategic collaboration, research, technological development and innovation are fostered to address common challenges and generate a positive impact on society.

Society is a key factor in this project, whose active participation is essential to address the challenges in a more effective and realistic way. Its direct involvement ensures that the solutions developed are relevant and respond to the real needs of the community.

The laboratory enables the application of space sciences and computational systems with cutting-edge technological development and innovation, aimed at diagnosis to create actions that allow promoting the generation of new knowledge in socio-environmental systems to promote resilience and sustainability The development of a national territorial information base specializing in risks and vulnerability to climate change is one of the most importnat specific actions, which will enable the distribution of quality and timely information to the different sectors and entities involved in comprehensive risk management (Bello, Bustamante, & Pizarro, 2020).

3. Methods

Geographic information allows us to understand the behavior of a phenomenon from a holistic perspective, thanks to the ability to analyze data in a structured manner and apply formulas to obtain specific information that facilitates understanding its dynamics.

According to Hernández and Rodríguez (2016), applying geography improves the decision-making process by addressing problems and implementing proposed solutions in a holistic, comprehensive, systematic, analytical, and visual manner. Geotechnologies provide digital tools to abstract and organize data, model geographic processes, and visualize information, allowing organizational leaders to make effective and meaningful decisions. This enables a deeper analysis of problems as more layers of physical and sociocultural information can be integrated.

Some of the technologies included are:

1. **Geographic Information Systems (GIS):** Tools that allow the storage, analysis, and visualization of geographic data. GIS are used to create maps and perform spatial analysis.
2. **Remote Sensing:** Technologies that allow the capture of information from a distance, such as satellite images and aerial photographs. These images are used to monitor changes on the Earth's surface.

3. **Global Positioning Systems (GPS):** Technology that allows the exact position of an object on Earth to be determined using satellite signals.
4. **Digital Cartography:** The creation and manipulation of maps using digital tools, allowing for greater accuracy and ease of updating.
5. **Digital Elevation Modeling (DEM):** A digital representation of a terrain's topography, used for relief analysis and scenario modeling.

These technologies are essential for land management and planning, as they provide accurate and up-to-date information that is crucial for decision-making across various sectors.

Geospatial Information Technologies (GITs) allow the development, application and transmission of knowledge aimed at solving problems of Socio-Ecological Systems (SES).

According to Córdova, Martínez, and Córdova (2021), dashboards are tools that allow an organization to share, group, centralize, and provide a graphical display of relevant information, thereby facilitating decision-making. Using an appropriate dashboard enables those responsible for monitoring key indicators to have a clear perspective on an organization's current situation, as the indicators to be monitored are specific and can be decisive in achieving the organization's objectives.

In the project, it is based on the Integration of Geospatial databases and participatory techniques for the construction of indicators. An exhaustive collection of data from various official sources is carried out; from this information, key variables and indicators for monitoring are defined. The geographic data is then processed using ArcGIS Pro, integrating the results into a dashboard. This integrated visualization of statistical and cartographic data facilitates understanding of the phenomena studied and supports more informed decision-making. The design of a geoenvironmental calculator for monitoring and tracking the current and prospective state of forests, presenting as a result a control panel with a simple, practical and useful interface as an environmental management tool for decision-making in the construction, application and measurement of the effectiveness of public policies, which mainly benefit local actors and conserve ecosystems.

In this dashboard, a study was conducted at the state level over a period of 10 years (2010-2020), with the main objective being to analyze the changes in land cover during these two time periods, along with other indicators selected for this study.

This control Dashboard allows:

- Visualize changes in land cover: Observe how the territory of the State of Mexico has evolved in a decade.
- Identify the main trends: Determine whether there has been a loss or gain of forest, agricultural and urban areas.
- Detect areas of greatest transformation: Identify the areas where the most significant changes in land cover have occurred.
- Evaluate the impact on the environment: Analyze the consequences of these changes on biodiversity, natural resources and climate.

Figure 1 Dashboard (Source: Prepared by the authors. Cartographic information obtained from CONABIO and CONAFOR. http://www.conabio.gob.mx/informacion/gis/).

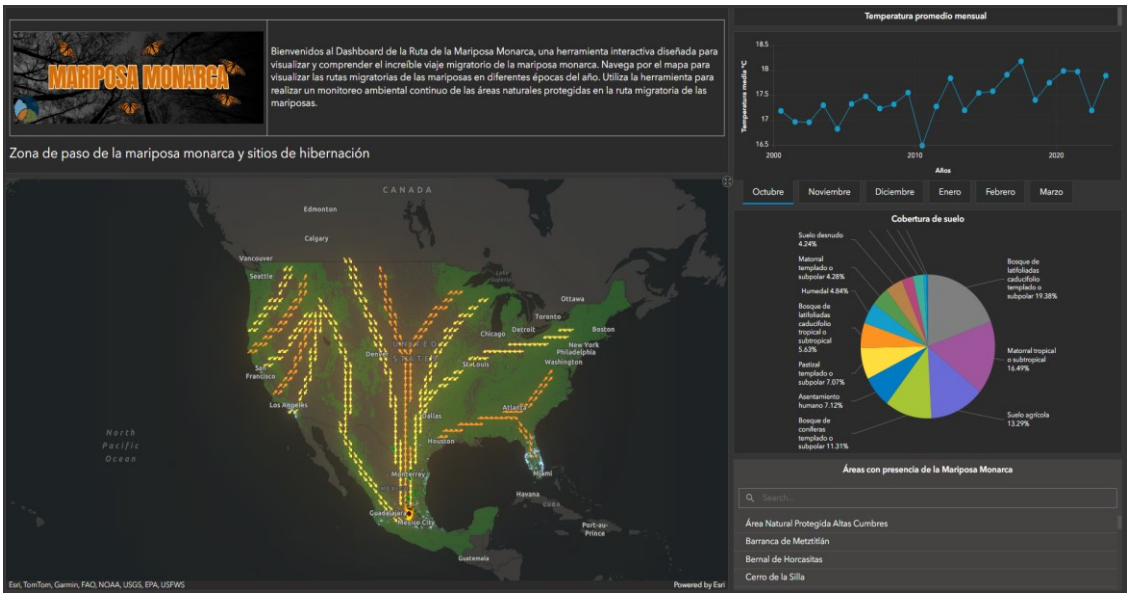

Figure 2 Dashboard monarch butterfly route (Source: Prepared by the authors. Cartographic information obtained from INEGI, Series VII, and the CONABIO Geoportal. http://www.conabio.gob.mx/informacion/gis/)

Using ArcGIS Pro, data on the migratory route of the monarch butterfly was processed, considering variables such as land use, hibernation sites, and vegetation. The resulting information was integrated into a control dashboard that allows dynamic visualization of the distribution and factors that influence the migration of this species, thus facilitating its monitoring and conservation.

The dashboard presents an interactive visual tool designed to understand and explore the incredible migratory journey of the monarch butterfly. Through its different sections, it offers an overview of this natural phenomenon and allows environmental monitoring of the protected areas that form part of the migratory route.

This dashboard allows you to visualize the migratory route by observing the movement patterns of butterflies throughout the year.

• Analyze environmental factors: Study how temperature and land cover influence migration.

• Identify key areas: Know the most important areas for the conservation of the monarch butterfly.

• Conduct environmental monitoring: Monitor the status of protected areas and detect possible threats.

4. Results and discussion

This tool is expected to become an invaluable resource for the public and private sectors, as well as for the academia. By providing reliable data and solid analysis, it will facilitate more informed and strategic decision-making, optimizing resources and maximizing the positive impact on society.

In the academic field, students will be provided with solid tools for developing research projects, including theses, scientific articles, and other academic works. Furthermore, the training of a highly qualified workforce specialized in the use and development of geotechnologies will be encouraged.

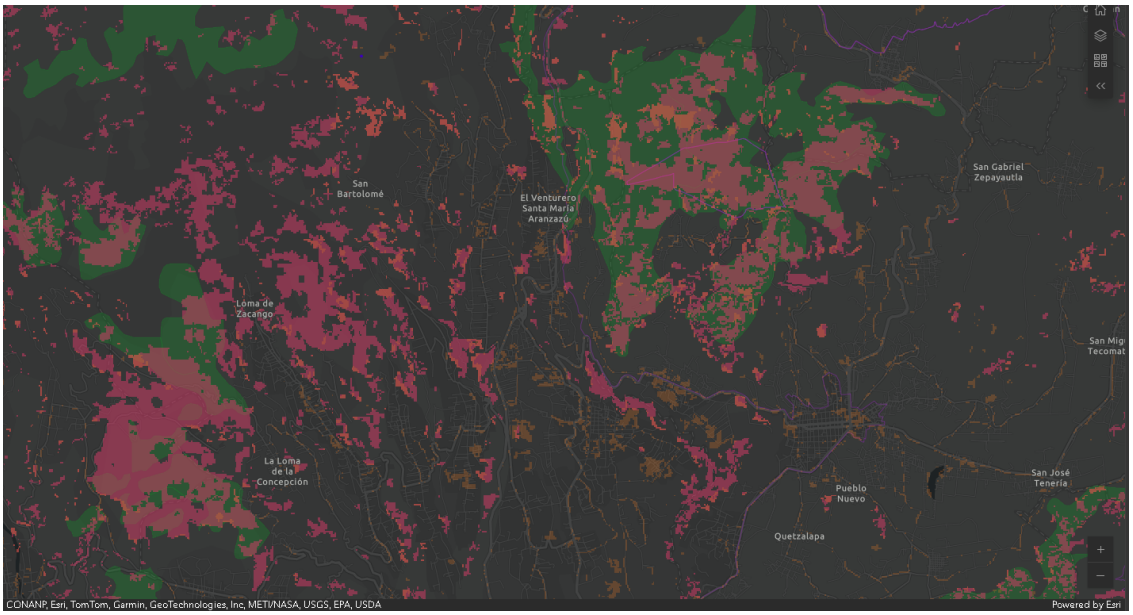

Figure 3 Displaying variables on specific sites (Source: Prepared by the authors. Dashboard https://uaemex-geo.maps.arcgis.com/apps/dashboards/2565ebea61cc405cb83a55251c302803)

Both examples presented in this document show the results obtained from the impact of data processing, geospatial analysis, and information structuring for distribution and consultation. Figure 3 illustrates the comparison of land use between 2010 and 2020, interacting with forest

cover loss (red polygons) due to the growth of urban areas (yellow polygons) and agricultural areas (orange polygons). The area represented corresponds to the municipalities of Villa Guerrero and Tenancingo, where floriculture is the main activity. This activity has generated significant impacts such as biodiversity loss, landscape loss, and soil and water pollution. Interaction with the information allows for in-depth and specific analysis tailored to the interests of each user.

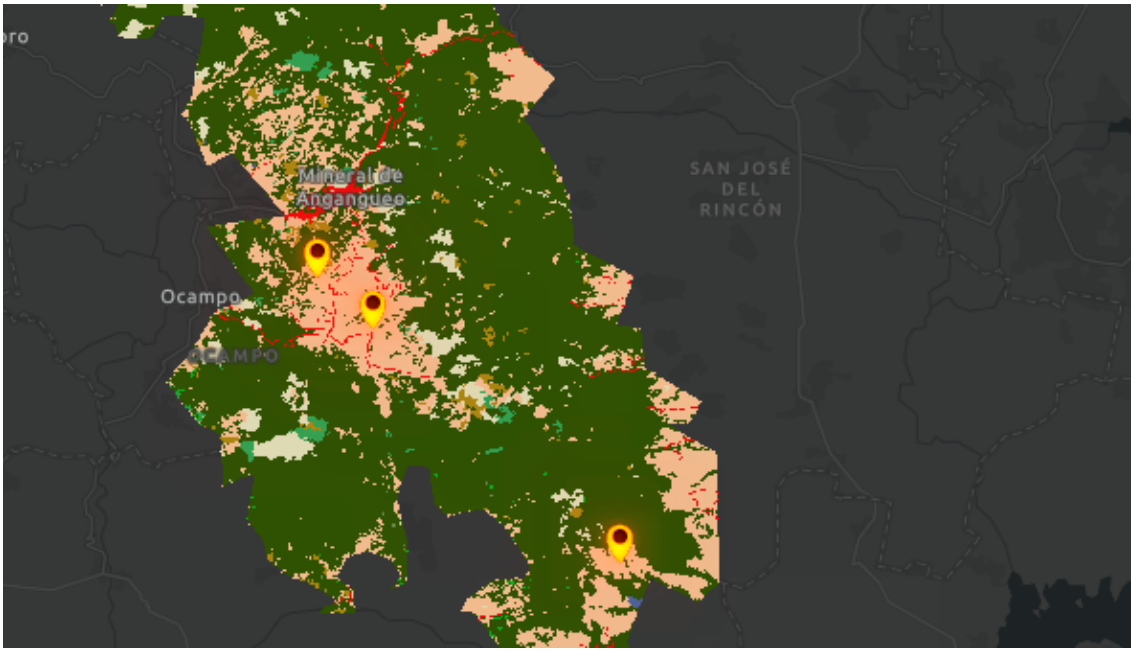

Figure 4 Monarch Butterfly Biosphere Reserve Site (Source: Prepared by the authors. Dashboard https://uaemex-geo.maps.arcgis.com/apps/dashboards/2565ebea61cc405cb83a55251c302803)

On the other hand, Figure 4, Monarch Butterfly Biosphere Reserve Site, shows one of the most important sites for monarch butterfly conservation. Three points are displayed, representing overwintering areas. This area is dominated by coniferous forests, which generate ideal microclimates for the butterflies to congregate during the winter. However, the map shows that the land cover in these sites is not forest, but rather agricultural areas.

This suggests that these areas have been altered by anthropogenic activities, with negative impacts on the ecosystem. For decision-makers, this type of information and analysis allows them to understand the current situation and design immediate, evidence-based response strategies.

These examples demonstrate geospatial analysis, integrating different data sources and interactive visualization tools that allow a specific understanding of territorial dynamics and socio-environmental implications, promoting sustainable territorial planning.

Contribute to the development of strategies, actions and implementation of eco-techniques to increase resilience to strengthen socio-ecosystemic services in the population. Below are the laboratory´s prospects and challenges.

- Disseminate the activities carried out.
- Prioritise and rank the services offered in the short term.
- Implement the necessary adjustments to the service offering.

- Carry out dissemination campaigns offering the laboratory services.
- Disseminate to postgraduate and undergraduate degrees candidates the opportunity to work on the laboratory's projects and the postgraduate courses.
- Review, prioritise and select the problems of the country's socio-ecological systems in which the laboratory can have an impact.
- Develop collaborative work between the different laboratory locations.
- Participate in calls for academic, governmental and business funding.
- The strategy will be developed with other government entities to present the information and its effects. In addition to this, the ways to access to that information as well as the benefits they will obtain in the decision-making processes, preparation of the public agenda, public policy, programs, etc.
- Design and implement training workshops.

5. Conclusion

The conjunction of environmental challenges, such as water scarcity and natural disasters, with the advancement of technologies has opened new possibilities for risk management. The advantage of this approach is the integration of societal knowledge at different scales, enabling a more appropriate use of ecosystem services and generating real, sustainable strategies that would reduce the rapid overexploitation of ecosystems. (Cerón, Fernández, Figueroa, & Restrepo, 2019).

Geotechnologies offer a set of powerful tools to monitor the environment, predict extreme events and make informed decisions, thus contributing to disaster prevention and building more resilient communities.

The importance of knowledge and management of geospatial information today is a very important topic within the sociological and political systems of a region. Understanding and comprehending the organizational and coexistence structure of the systems makes it easier the decision-making focused on improving the various variables that converge in a spatial set.

To better understand and manage the geospatial informatdecision-making easierecessary to know what is happening in the environment through spatiotemporal monitoring of each of the actors involved; and with this, to know the level of resilience that we have as a society and ecosystem with the diverse changes that occur.

Having said that, to understand the behavior of the factors and establish better spatio-temporal management of the several variables and indicators that interact in a geographic environment, it is necessary to have geospatial control panels, which are an effective and supportive tool that allows continuous and updated monitoring of spatial information.

Nowadays, the use of geotechnological tools has enabled the activities carried out within this research and the public and private sectors to facilitate decision-making and strengthen the study and knowledge of the territory, as well as the problems that impact the geographic environment.

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