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OPINION

National Soil Strategy for Sustainable Agriculture (ENASAS): A new systemic approach in Mexico

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Abstract

The National Soil Strategy for Sustainable Agriculture (ENASAS) arises in response to the increasing need to organize, coordinate and strengthen the implementation of actions oriented to the sustainable management of Mexico's agricultural soils. The measures recommended in this paper allow the conservation and maintenance of soils' essential functions for agriculture, food security and population well-being. The health and quality of agricultural soils are under constant pressure from several factors, mainly anthropogenic. One of ENASAS's objectives

is to identify and stop the causes involved in land degradation processes using a systemic approach. From this perspective, the participation of various actors in sustainable soil management allows the integration of different systems, practices, techniques and knowledge that promotes awareness among the entire population about the importance of soil resources. On the other hand, given current limitations on the availability of information necessary to support decision-making and evaluate the result of the actions implemented, ENASAS promotes the generation of tools that provide reliable and updated data regarding Mexico's agricultural soils. In the same sense, this strategy encourages the development of scientific and technological research and the transfer of knowledge that meets the needs of farmers, particularly those who carry out their activities on a smaller scale. This perspective describes ENASAS as a multi-institutional initiative that will support sustainable soil management practices across the country's agricultural systems of Mexico and contribute to the adaptation and mitigation of global environmental change.

KEYWORDS

climate regulation, soil governance, soil management, soil restoration, sustainable agriculture, technical and scientific knowledge and innovations

1 | INTRODUCTION

Soils are essential for all life on the planet. They are directly and indirectly related to human survival and ecosystems' structural and functional integrity, particularly terrestrial ones (FAO, 2015). While we perceive climate, water and biodiversity as elements that support life on Earth, soils are generally not appreciated as a living and complex resource. Soils accomplish multiple interactions and essential functions to socio-ecological systems such as soil carbon sequestration, water purification and administration, habitat for biodiversity, and climate regulation. For this reason, this fundamental resource has not been sufficiently valued or protected, so in most cases, anthropogenic decisions negatively modify them, triggering processes of physical, chemical and/or biological degradation.

Soil is related to generating many processes, goods and services essential for ecosystems and human well-being (Lehmann et al., 2020). Moreover, the soil is a resource whose protection and proper management allow us to face global challenges such as food insecurity and malnutrition, water and air pollution, biodiversity loss and climate change. Furthermore, this nonrenewable natural resource of fragile nature has recently become more visible due to constant growing pressure. Therefore, we must stop and reverse the degradation processes by establishing management practices and sustainable soil use with the correct ecological, economic, social and cultural orientation.

Highlights

- A new systemic approach to increase soil governance in Mexico.
- The National Soil Strategy for Sustainable Agriculture to reverse land degradation.
- Support sustainable soil management practices across the agricultural systems of Mexico.
- Multi-institutional effort contributes to adaptation and mitigation of global environmental change.

Mexico's soil diversity includes 25 of 32 main groups recognized by the World Reference Base for Soil Resources (INEGI, 2021; Krasilnikov et al., 2013; Ortiz et al., 2022). Soils in the country are distributed across 1.9 million km^2 of continental territory. Of this surface, approximately 10% is suitable for annual crop agriculture. The remainder has an aptitude for use in perennial cropping, forest resources and grazing. In addition, many unmodified ecosystems serve as biodiversity refuges (Figure 1; Etchevers et al., 2020; Ortiz et al., 2022). The country's current dynamics show that the arable area average per inhabitant decreases as the population increases. At the same time, fertile soil area decreases due to land use change from agricultural to urban land, among other factors. In addition, more than half of national soils exhibits some level of degradation (Figure 2; INEGI, 2019). In the specific case of Irrigation

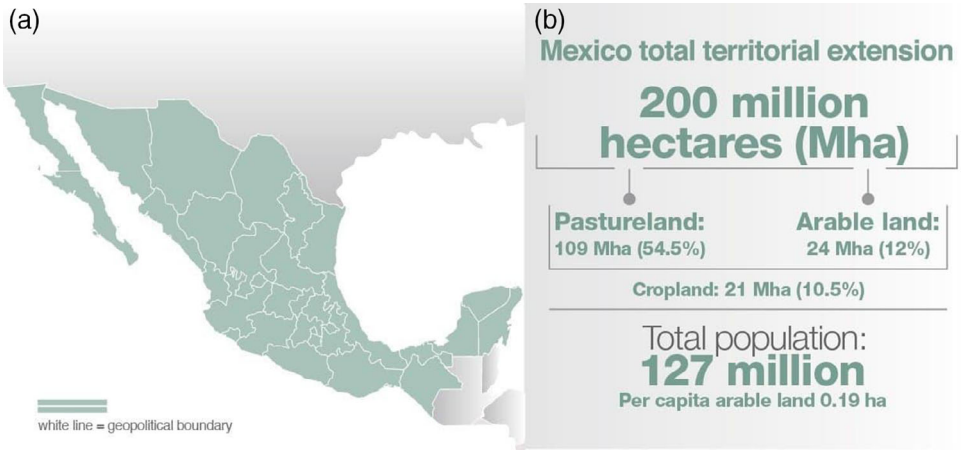

FIGURE 1 Territorial extension with fertile soils for crops in Mexico. Where A = Mexico and its geopolitical boundaries; B = Extension of fertile pastureland and arable soils.

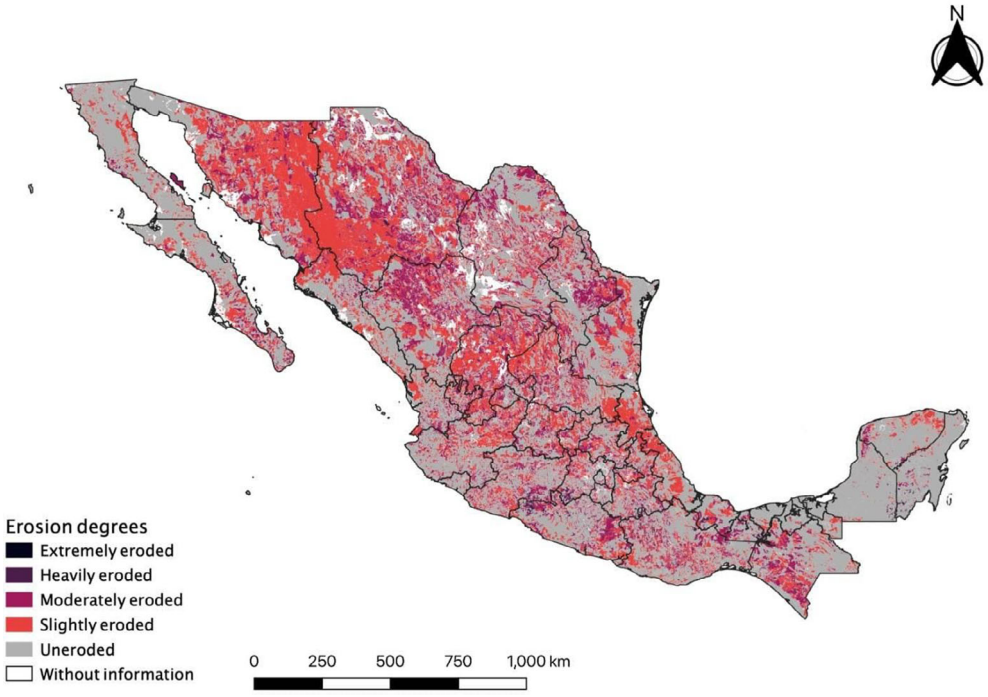

FIGURE 2 Soil erosion in Mexico (data from INEGI), showing that more than half of national soils exhibits some level of degradation.

Districts (irrigation projects developed by the Federal Government since 1926, which includes various works, such as storage vessels, water direct diversions, pumping plants, wells, canals and roads, among others.), 20% of the surface presents salinity problems, processes that increase in climate change contexts (Pulido et al., 2009; Pulido, 2016, 2018). Consequently, there is a severe risk that both the arable area and soil quality currently used for agriculture will be insufficient to meet the needs of current and future generations.

There are enormous inequalities across Mexico between large and small producers, both in surface area and in access to irrigation. About 70.5% of the land is farmed by small producers with less than 5 ha, is seasonal and produces basic foods. Around 0.2% agricultural land corresponds to large producers where the land is irrigated and use to produce mainly for export (Cotler et al., 2019). These differences made the design of a strategy for sustainable agriculture more complex (when considering such dissimilar producers) and so goes for its implementation.

Based on this fact, national needs and the importance of soil for agriculture and the well-being of the Mexican population, the Ministry of Agriculture and Rural Development in collaboration with the federal government, international organizations and with experts in soil and agricultural sciences from academic and research institutions, prepared, created and presented a new approach to sustainable soil management: the National Soil Strategy for Sustainable Agriculture (ENASAS).

ENASAS' purpose is to promote the conservation and rehabilitation of Mexico's soils with multiple functions to

TABLE 1 Strategic axes (SAs) of ENASAS, objectives (left), action lines (centre) and specific objectives of action lines on each SA (right).

SA 1 SUSTAINABLE SOIL MANAGEMENT **Objective**: Preserve fundamental soil functions **Goal**: Maintain the provision of ecosystem services for agriculture, food and well-being		
Promote, facilitate and implement actions aimed at preserving the fundamental functions of the soil, by caring for it, improving it, increasing its quality and conserving its health and biodiversity, in order to maintain the provision of ecosystem services for agriculture, the nutrition and well-being of the society.	**Action line 1.1**	Secure the functioning of the essential edaphic processes of the soil through the conservation of the balance and flow of nutrients, fertility, physical and chemical properties and soil biodiversity, as well as reducing degradation processes to the minimum possible.
	Action line 1.2	Reduce greenhouse gas (GHG) emissions based on agronomic management, technological tools and nature-based solutions.
	Action line 1.3	Carry out actions for the re-carbonization of agricultural and livestock soils.
	Action line 1.4	Promote water retention in the soil and sustainable water management for agriculture.
SA 2 RESTORATION OF DEGRADED SOILS **Objective:** systemically identify the factors of soil degradation **Goal:** restore soil ecosystem services		
To systematically identify the factors associated with soil degradation in order to promote, encourage and implement actions aimed at the recovery of the health and quality of the soil, through the integral rehabilitation of its physical, chemical and biological properties, in order to maintain all ecosystem goods and services for agriculture and the well-being of society, considering the specific conditions of each territory.	**Action line 2.1**	Understand and address the socio-environmental causes of soil degradation.
	Action line 2.2	Implement actions aimed at stopping and reversing soil physical, chemical and biological degradation processes.
	Action line 2.3	Establish actions to recover the sustainability of degraded soils.
SA 3 INFORMATION AND MONITORING **Objective:** generate information for analysis and monitoring of soils **Goal:** develop systems and networks for sustainable soil management		
Generate and use relevant information and tools to develop useful indicators to monitor management and restoration practices of degraded soils, as well as to harmonize methods of analysis in laboratories, through the participation with a gender perspective of farmers, technicians and the private sector, in order to establish systems and networks for sustainable soil management and rehabilitation of degraded soils.	**Action line 3.1**	Develop the geographic soil information system for agriculture with high spatial and temporal resolution.
	Action line 3.2	Collect, systematize and disseminate information for sustainable soil management and restoration of degraded soils.
	Action line 3.3	Develop the soil monitoring system for agriculture and promote its use by various stakeholders.
	Action line 3.4	Structure and operate the Mexican Soil Laboratories Network (MEXSOLAN).
SA 4 EDUCATION, AWARENESS AND PARTICIPATION **Objective:** implement participatory actions aimed at educating, raising awareness **Goal:** develop the cultural appropriation of the soil concept as a resource essential for life		
Encourage, promote and implement actions aimed at educating, raising awareness and developing citizen cultural appropriation of the soil concept as a nonrenewable natural resource, essential for the existence of life on the planet and, therefore, a common good to be preserved among farmers, academics, researchers,	**Action line 4.1**	Strengthen education and encourage the participation of all citizens in relation to soil resources, with an emphasis on local actors, farmers and authorities.
	Action line 4.2	Encourage the integration and participation of researchers and students of all educational levels with study programs related to soil, in educational and awareness activities.

TABLE 1 (Continued)

authorities, students and citizens in general, inclusive and with a gender perspective.	**Action line 4.3**	Link and promote the strengthening of soil issues in educational programs at all levels.
	Action line 4.4	Development of educational and awareness-raising materials for dissemination through all media communication.
	Action line 4.5	Promote and carry out activities that socialize and disseminate the importance of the soil resource and its ecosystem services as essential elements for carrying out any activity and for the existence of life on the planet.
	Action line 4.6	Promote the implementation of the Soil Doctors Program.
SA 5 KNOWLEDGE, RESEARCH, INNOVATION, DEVELOPMENT AND TECHNOLOGY TRANSFER **Objective:** promote scientific research and link it with traditional knowledge **Goal:** promote technological innovations adapted to different socio-ecological contexts		
Promote scientific research, technological development and innovation and promote actions to link with producers' experience (ancestral, traditional and local knowledge), incorporating them into scientific research work, particularly those carried out at the plot ejidos level, with the purpose of submitting them to validation tests for later transfer.	**Action line 5.1**	Define the topics of national interest for scientific and technological research for sustainable soil management and its link with research institutions.
	Action line 5.2	Coordinate and link scientific and technological research aimed at sustainable soil management for its conservation and restoration of degraded soils, with the purpose of making the best possible use of human, material and economic available in the country.
	Action line 5.3	Coordinate and link innovation and technological development aimed at sustainable soil management and the restoration of degraded soils.
	Action line 5.4	Recover, validate and promote the application of local, traditional and ancestral knowledge and knowledge, as well as the lessons learned for sustainable soil management and its subsequent conservation.
	Action line 5.5	Develop permanent programs of technology transfer and duly proven local and traditional knowledge, related to the restoration, sustainable management and conservation of the soil.
SA 6: COORDINATION AND COOPERATION **Objective:** articulate the strategy with different actors **Goal:** Achieve coordination of actions for sustainable soil management		
Implement actions aimed at the strategy articulation of producers, academia and research centres, civil society, private sector and international organizations through of both administrative and financial as well as technical and regulatory instruments.	**Action line 6.1**	Establish and coordinate the Sectoral Committee on Soil for Sustainable Agriculture.
	Action line 6.2	Promote before competent authorities of the three orders of government the implementation of knowledge, practices and technological alternatives for the restoration and sustainable management of the soil.
	Action line 6.3	Boost the cooperation international in area of restoration and sustainable soil management with emphasis on the regional level.
	Action line 6.4	Promote and strengthen the Secretariat's links with research centres and institutions of secondary and higher education in order to promote the research and education on soil science.

(Continues)

TABLE 1 (Continued)

	Action line 6.5	Boost the collaboration and coordination with government authorities for the implementation of ENASAS.
SA 7: Harmonization and regulatory update **Objective:** harmonize legal instruments related to soil **Goal:** strengthen through legal certainty the objectives of sustainable management		
Implement actions aimed at harmonizing the provisions established in legal instruments related to soil and promoting the updating of current regulations, in order to strengthen management objectives sustainable and soil restoration.	**Action line 7.1**	Promote actions in the field of standardization that improve the fertility, conservation and restoration of agricultural soils.
	Action line 7.2	Promote the development of the General Land Law.
	Action line 7.3	Promote the development of the National Land Commission.

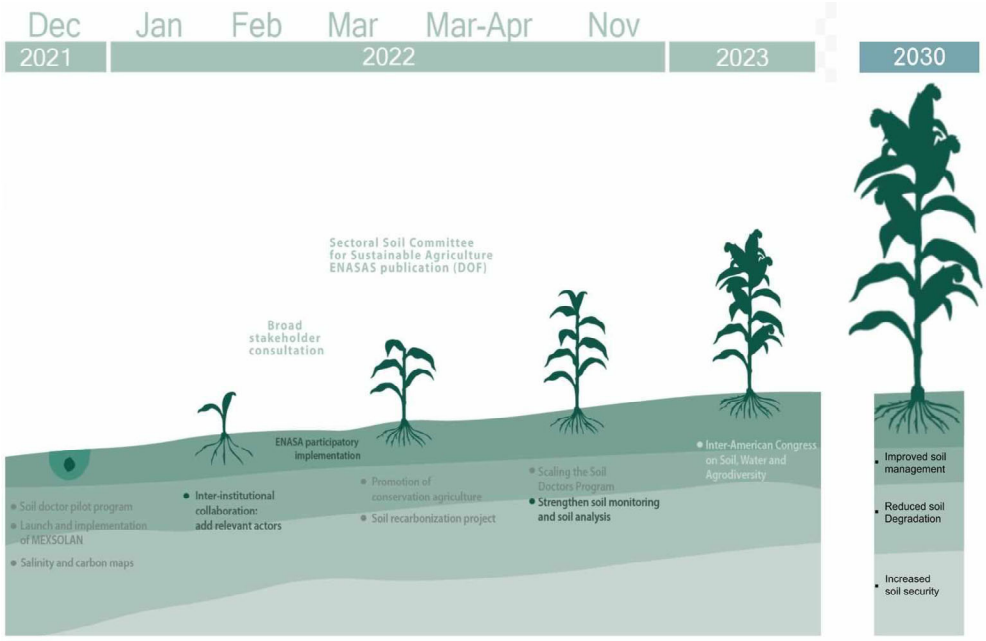

FIGURE 3 ENASAS planning process and strategy development through time and vision of ENASAS towards the year 2030.

contribute to food security and population well-being. Strategic axes structure the proposal (Table 1). The aim of these axes is: to manage the soil sustainably; restore the degraded soils; monitor changes and generate helpful information for decision-making, strengthen education, awareness and participation of several actors; promote the development of scientific and technological research and rescue ancestral, traditional and local knowledge; and coordination and cooperation and updating regulations on the matter, all based on land governance. The Ministry of Agriculture and Rural Development integrates into ENASAS a systemic and inclusive vision that starts by recognizing the multiple ecosystem services of agricultural soils, referred to in its broadest sense (agriculture, livestock and agroforestry). Consequently, stopping and reversing degradation processes that affect the country's agricultural soils through comprehensive and participatory actions that improve and restore soil health and quality represents a priority attention objective of ENASAS. In this vision, the conservation of health, quality, improvement of soil fertility, strengthening its role in mitigating climate change, and its potential to increase resilience and well-being of the Mexico's population, particularly the rural population, form part of the goals to be specified in the short term (2022), medium term (2024) and long term (2030), with a view to ENASAS constituting the initial roadmap of actions and instruments for implementation beyond the 2030 Agenda

and the Sustainable Development Goals (Figure 3). Considering that soil sustainable management conservation involves the participation of multiple actors, the construction of ENASAS draws contributions from different sectors and levels, including government representatives and agricultural producers, academic and research institutions, and civil society organizations, which participate at different scales.

ENASAS seeks to establish itself as a fundamental and integrating factor for the construction and consolidation of land governance in Mexico. The emphasis is placed on equitable and effective local governance, recognizing the vast socio-ecological diversity present in the country's various regions, which gives rise to a broad mosaic of agroecological conditions. In this approach, soil governance which in part involves integrating ancestral, traditional and local knowledge with technical and scientific knowledge and innovations, with government support, will contribute to meeting the needs of farmers and technicians in their field goal of sustainable management and soil restoration.

The objective of ENASAS is to support, strengthen and coordinate actions to promote and increase sustainable management of agricultural soils in Mexico's national territory, which contributes to food security and the well-being of the population through the conservation of its multiple functions, and the restoration of degraded agricultural soils. ENASAS also looks to promote education and social awareness about the importance of soils to terrestrial life, with the participation of various actors, particularly local actors. Likewise, it fosters the generation and integration of traditional and scientific knowledge to promote technological innovations adapted to different socio-ecological contexts, which meet the specific needs of the territories and populations in the country.

2 | MULTILEVEL GOVERNANCE OF MEXICO'S SOIL RESOURCE

The practical and equitable governance of agricultural soils in Mexico presents severe challenges for its implementation. The latter is particularly true in socio-environmental contexts with degraded soils, as well as various other problems: phytosanitary, poverty, socio-economic asymmetries (e.g., rights, gender and access to training, financing and technologies), food insecurity, marginalization, urban expansion and high vulnerability to climate change. In addition, complexity increases considering the multi-scale conditions related to land management and governance's multilevel and multi-actor nature (Juerges & Hansjürgens, 2018; Weigelt et al., 2015).

FIGURE 4 Soil governance and ENASAS axes. Where: EE, essential axes.

Mexico has complex needs related to land governance. An example is the productive dynamics systems that deplete finite resources, such as soils, widely implemented in the country's agriculture. These dynamics are present in contexts with different land tenure regimes, diffuse agricultural frontiers and rent of farmlands under unfavourable agreements for the owners. In scenarios where the common factor is the reduction of soil health and farm quality and its functional capacity for services provision, it is relevant to implement specific actions aimed at reversing the degradation processes and promoting the sustainable management of the resource starting from governance (Ortiz et al., 2022; Weigelt et al., 2015).

Legislation on agricultural land is broad and fragmented into multiple instruments with objectives that may be complex to operate together (land tenure, sustainable development, ecological balance and management, climate change, land use and organization of the land and territorial space). Moreover, these legal instruments coexist with the international commitments to which the country is a party, local regulations, commercial agreements, verbal arrangements, collective and individual perceptions and attitudes on land. In this framework, it is necessary to develop instruments that effectively and fairly link the formal and informal institutions associated with decision-making on land, particularly regarding its sustainable management between different actors at different levels and scales (Ortiz et al., 2022).

Soil governance requires shaping social relationships, and promoting the effective participation of all stakeholders, particularly local ones (Ortiz et al., 2022; Weigelt et al., 2015). The latter aspects are relevant, particularly

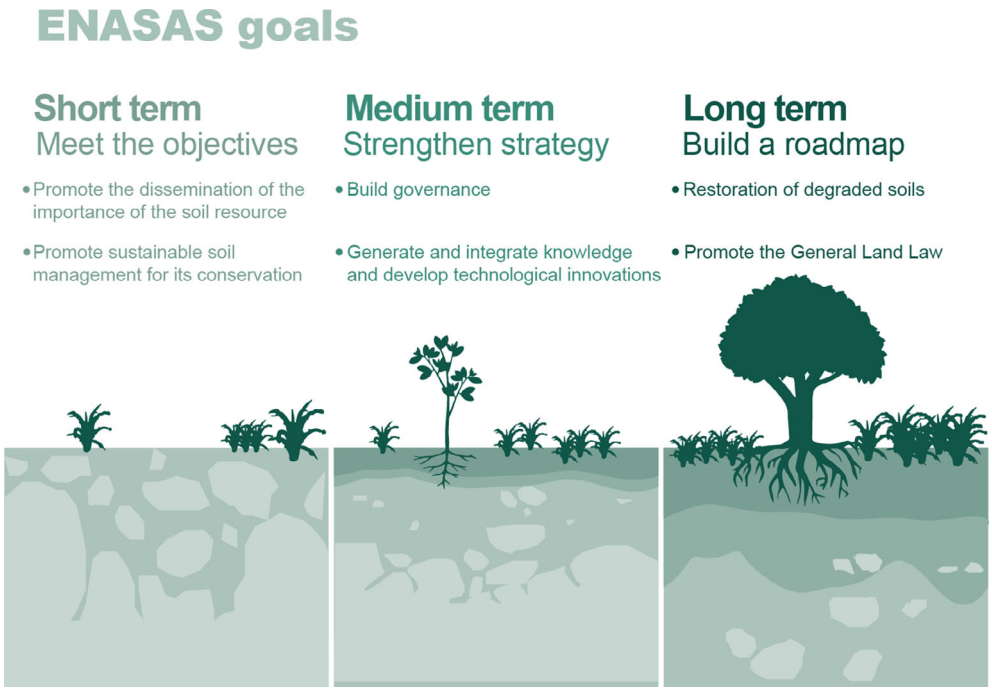

FIGURE 5 ENASAS goals through short, medium and long term.

in territories under a collective regime. Such as the case of 'ejidos' (a society of social interest comprised of lands, forests and waters that the State grants free to Mexican peasants) and communities in Mexico, where there are essential experiences that contribute to the local governance, like the case of the National REDD + Strategy (Trench et al., 2017). In this regard, 51% of the territory of Mexico corresponds to social property (CEDRSSA, 2015). Therefore, any national strategy that seeks to combat soil degradation and its productive recovery must consider this aspect. In this sense, ENASAS seeks to promote and strengthen, through the operation of the different strategic axes (Table 1), decision-making by local actors that contribute to the sustainable management of soils based on the development of effective multilevel governance (Figure 4).

3 | ENASAS DEVELOPMENT PROCESS

The strategy idea was manifested in December 2020 during the commemoration of World Soil Day, as a result of the evident need to conserve and rehabilitate Mexico's agricultural soils, an urgent aspect indicated by experts in soil science and representatives of the Sector that participated in said commemoration. Agriculture, as National Focal Point before the FAO Global Soil Partnership (GSP), took the commitment to develop an instrument aimed at promoting the sustainable management of this resource and restoring degraded soils, which promotes the participation of all stakeholders, interested parties, in order to join efforts to achieve the objective of conserving the country's agricultural soils.

With the support of the German Cooperation for Sustainable Development (GIZ) and the Ministry of Agriculture and Rural Development convened experts in soil science from academic institutions, research, government and representatives of civil society, to form the Group of Advisors for the development of a soil and water strategy for increasing governance of agricultural systems of Mexico, increasing sustainable food production, and overall soil security. In the development process, the works focused on the soil resource, leading to the emergence of ENASAS. Among the experts that made up the Advisory Group for the construction of ENASAS, there was the collaboration of the AMS Pillars, members of the Intergovernmental Technical Panel on Soils (ITPS) and the International Union of Soil Sciences (IUSS). The national institutions represented in this process were the National Autonomous University of Mexico (UNAM), through the Interdisciplinary Soil Studies Program (PUEIS), the Geosciences Center and the Cuautitlán Faculty of Higher Studies, the Center for Research and Advanced Studies of the National Polytechnic Institute (IPN), the Antonio Narro Autonomous Agrarian University (UAAAN), the Center for Research in Geospatial Information Sciences (Centro Geo), the Postgraduate College (COLPOS), the National Institute for Agricultural, Forestry and Livestock Research (INIFAP); the Mexican Institute of Water Technology (IMTA), the Mexican Society of Soil Science (SMCS), the International Center for Demonstration and

Training in the Use of Rainwater (CIDECALLI A.C.) and independent consultants. In total, nine meetings of the Advisory Group were held, during the months of March to October 2021. To define the strategic axes, lines of action and actions, specific advisory groups were formed, whose work was carried out at the same time, couple of the meetings of the Advisory Group, which made it possible to advance in a timely manner and establish consensus in the general meetings.

Parallel to the construction of ENASAS, with the support of GIZ, the 'Diagnosis of the knowledge and current situation of soils for agriculture in Mexico' was carried out, prepared by Gestión Integral de Cuencas SA de CV, with the aim of have reference information on the information available regarding the condition of the country's agricultural soils.

Therefore, ENASAS represents the first and multidisciplinary effort to organize, coordinate and strengthen actions for sustainable management of Mexico's agricultural soils, that will derive to conservation and maintenance of soils', food security and population well-being.

ENASAS will be able to identify land degradation with the participation of different actors and different approaches, practices, techniques, education and knowledge that will contribute to promote awareness among the entire population. It will develop scientific and technological research, transfer of knowledge, the restoration of degraded soils, monitoring and generation of useful information for decision-making and strengthening education awareness all based on land governance (Figure 5).

4 | CONCLUSIONS

ENASAS is the result of the need to identify and stop the causes involved in land degradation (e.g., contamination, salinity and soil erosion) in Mexico using a new systemic approach and therefore to maintain the health and quality of agricultural soils which are under constant pressure, mainly from anthropogenic factors including the eliminating use of glyphosate, and prohibiting transgenic corn.

ENASAS will allow the conservation and maintenance of soils' essential functions for agriculture, food security, food sovereignty and population well-being by organizing, coordinating and strengthening the participation of various actors in sustainable soil management and therefore the integration of different systems, practices, techniques and knowledge that will promote awareness among the entire population about the importance of soil resources.

ENASAS is Mexico's first multi-institutional initiative that will support sustainable soil management practices across the country's agricultural systems and contribute to the adaptation and mitigation of global environmental change.

AUTHOR CONTRIBUTIONS

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investigation; writing – original draft; methodology; writing – review and editing; supervision. **Mario Guevara:** Conceptualization; investigation; funding acquisition; writing – original draft; methodology; writing – review and editing; supervision.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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