PILOT TWO OF THE TNFD FRAMEWORK

LEAP methodology

Application of a Socio-ecological Resilience assessment tool

Ecopetrol’ s core area-Middle Magdalena Valley

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This document presents some of the findings of the Fibras project, specifically focusing on the resilience component, as well as the analysis conducted by Ecopetrol' s Biodiversity and Ecosystem Services team within the Sustainability and Decarbonization Management.

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PRESENTATION

Ecopetrol (ECP) has positioned itself at the forefront of new environmental management frameworks to become a pioneer in the oil & gas sector in Colombia. As part of this commitment, the company is actively aligning with international commitments such as the Global Biodiversity Framework Kunming-Montreal. In order to achieve this, it is crucial for Ecopetrol to strengthen the management of risks and opportunities associated with natural capital, which will enable the company to define and implement positive nature guidelines. These efforts are particularly significant considering Colombia's status as a megadiverse country. Additionally, it is essential to establish synergies between the Task Force on Nature-related Financial Disclosures (TNFD) and the Task Force on Climate-related Financial Disclosures (TCFD) reports.

In 2021, Ecopetrol published its first TCFD report, which helped identify gaps in its environmental reporting practices. Building upon this experience, the company launched its second TCFD report in 2022. Furthermore, Ecopetrol became a member of TNFD in 2021 and was entrusted with leading group No. 6 for the Energy sector in 2022. As part of its commitment to TNFD, Ecopetrol initiated the design of the first pilot of the LEAP methodology proposed by TNFD in 2022. The company has also actively provided feedback on all versions of the beta framework during public consultations.

To implement the TNFD framework effectively, Ecopetrol SA conducted two LEAP pilots. The pilot one focused on a specific production area, while the pilot two concentrated on applying the socio-ecological resilience tool in the core area of the Magdalena Medio valley. This document provides the results of Pilot Two related to the case of study for the socio-ecological resilience tool associated with the implementation of the LEAP methodology from the "Taskforce on Nature-related Financial Disclosures" (TNFD) under the "Fibras: Essence and Territory" project carried out by the Alexander von Humboldt Institute and Ecopetrol.

The tool is based on a dynamic model that simulates the processes of the socio-ecological system in response to various impacts generated by productive activities. It generates time series and indicators that help to establish intervention limits in the territories without altering their equilibrium. The tool has contributed to the LEAP framework in four geographical core areas of Ecopetrol (see Figure 1). This document focuses on the integration of detailed information related to one of the areas, the Middle Magdalena Valley core, where the Yariguí-Cantagallo field, addressed in Pilot 1, is located.

It is important to mention that the application of the resilience assessment in the TNFD framework covered just some stages of the LEAP phase. The assessment started when the framework was in its second version, and it was completed a few days before submitting version 4.0.

The incorporation of the Resilience assessment tool emphasizes the importance of comprehensive analyses of the operational territory, encompassing both social and environmental metrics. This approach enables an objective evaluation of core areas of work and facilitates the identification of the most effective opportunities for enhancing nature management.

OBJECTIVES OF PILOT TWO

- Contribute to the development of a case study that links the TNFD beta framework with the socio-ecological resilience model designed in the Fibras agreement.
- Generate information for the stages of the TNFD LEAP framework, aimed at characterizing the core area through the Localizing phase, identifying the dependencies, opportunities, and interactions between the company and ecosystems in the evaluation and assessment phase.
- Identify gaps in metrics, indicators, and methodology within the context of identifying dependencies and opportunities (company-nature).
- Provide general recommendations for the implementation of the TNFD beta framework and guide a roadmap for identifying nature-related risks.

General information on the Fibras project, resilience assessment tool and the core areas are detailed below.

1. Context

1.1 Fibras Project[1]:

Since 2019, Ecopetrol has collaborated with the Humboldt Institute on the "Fibras: Essence and Territory" project, aiming to plan and manage biodiversity and its contributions to well-being in some of its core areas such as the Huila, Orinoquia, and Middle Magdalena Valley regions, based on scientifically supported information and sustainable development criteria.
This project consists of seven interconnected components that feed into one another.

I. **Ecoreserves**: defined as "A geographically delimited area, owned by the companies of the Ecopetrol Group, which is voluntarily destined in part or completely to the conservation of biodiversity and the supply of ecosystem services, without limiting its productive and exploratory vocation.
II. **Biomonitores**: These are people from the community who, thanks to their interest in learning about biodiversity and their willingness to observe, record and appreciate nature, carry out work that allows them to inventory and monitor biodiversity in the ecoreserves. This component contributes to "Participatory Science", where all the knowledge of the community contributes to the collection of biological data with the support of undergraduate and master's students and the Institute's researchers.
III. **Resilience:** As part of the project, a tool comprising a conceptual model and web application was developed. This tool will enhance our understanding of socio-ecological resilience in the areas where Ecopetrol operates.

[1] Fibras: Essence and Territory.

IV. **BioModels:** These are maps of species distribution, based on data from remote sensing and camera traps. They make it possible to assess changes in the distribution of species by monitoring trends in loss or gain of distribution areas.

V. **Genomics:** Three expeditions were conducted to analyze genomics in high-value ecological ecosystems within Ecopetrol' s core areas. This information represents the first inventory of microbial biodiversity in the soils of the Casanare foothills (Orinoquia), Middle Magdalena Valley, and the La Tribuna Ecological Reserve (Huila). The inventory includes both conserved areas with low hydrocarbon presence and more intervened areas with natural crude oil occurrences on the surface.

VI. **Bioeconomy:** High-impact initiatives focused on research and development in bioeconomy and biosolutions were promoted. Additionally, capacities were strengthened in the knowledge of sustainable uses of biodiversity within local communities in Huila, Orinoquia, and Middle Magdalena Valley.

As a result of this collaboration, an innovative tool has been developed, comprising a conceptual model and a web application. This tool will assist Ecopetrol in gaining a better understanding of socio-ecological resilience in the areas where the company operates. It utilizes a dynamic model that simulates the functioning of the system in response to various impacts generated by productive activities within the territory. By analyzing trends over time, the tool will enable Ecopetrol to generate indicators and comprehend the limits of intervention in these territories, ensuring the preservation of their delicate balance.

1.2 Ecopetrol ’s Core areas

The Ecopetrol’ s core areas are hubs geographically located within the same hydrographic basin where hydrocarbon exploitation projects have generated negative impacts. The purpose of establishing these core areas is to compensate and restore the affected communities and natural environment, aiming to contribute to the sustainable management of natural ecosystems, ecological restoration, and ecosystem services. Below, we identified the four Core areas where we have been working to develop the resilience assessment tool.

1.3 Socio-ecological resilience assessment tool

Resilience has been defined as the capacity of a system to absorb disturbances and reorganize itself while undergoing different changes, to maintain the same ecological functions, it initially exhibited.
This capacity depends on the system properties, which include (Based on Biggs, 2014):

- Diversity and redundancy
- Connectivity
- Learning and experimentation
- Participation for equity
- Polycentric governance

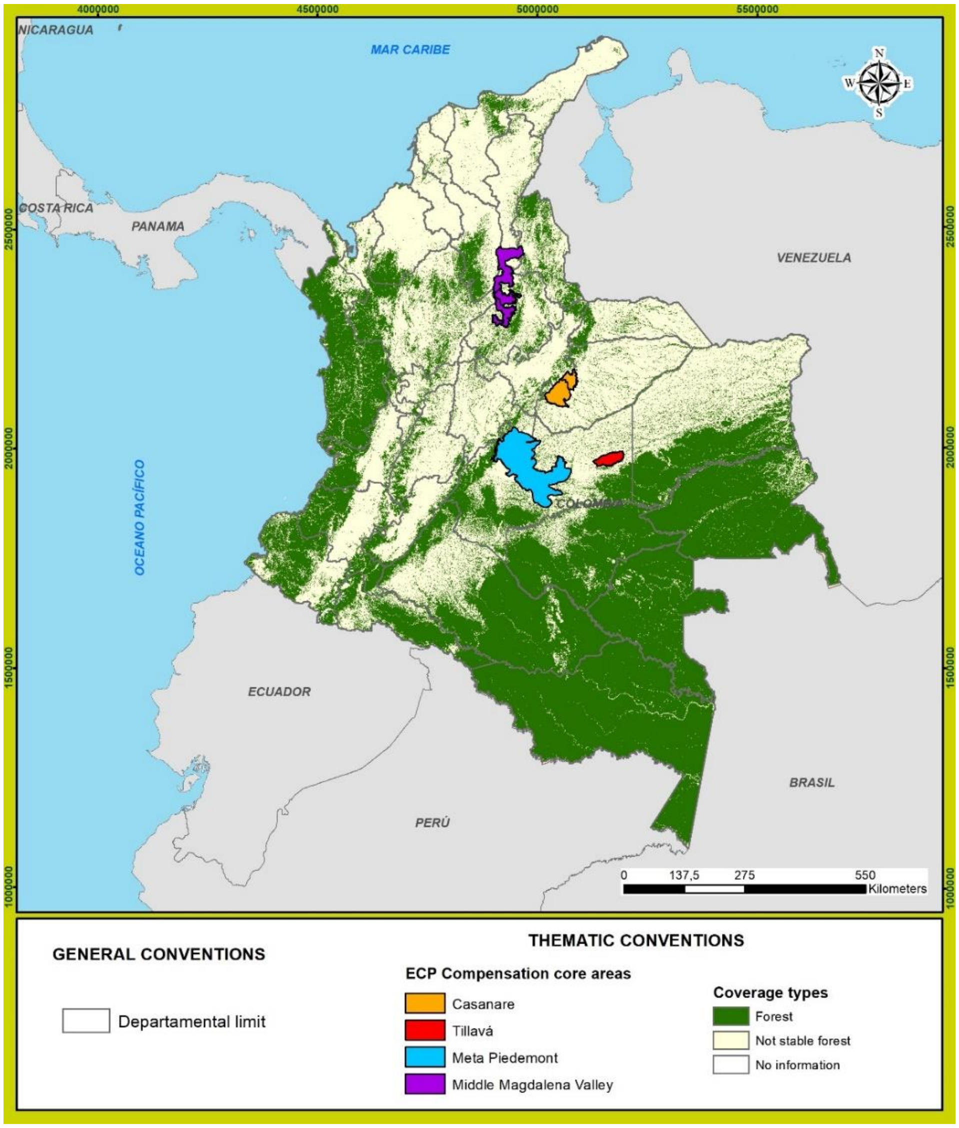


Figure 1.Ubication of Ecopetrol' s core areas. In purple we mark the location of this TNFD pilot.

A system property is an emergent characteristic that arises from the interactions among the elements of the socio-ecological system and cannot be predicted by analyzing each component of the system in isolation (Biggs, 2015).

The objective of this tool is to simulate the behavior of both ecological and social variables that contribute to resilience in a socio-ecological system. By analyzing the trends in these variables, the tool generates a resilience index, which serves as an indicator of the system's capacity to adapt and respond to changes over time.

The tool enables:

- Understanding socio-ecological resilience in the operational areas of the Ecopetrol' s Group.

- Simulating the system's response to impacts resulting from productive activities, allowing for analysis over time.
- Generating time series data within a specified time window (e.g., between 2018 and 2040) for the variables associated with resilience properties.
- Generating an aggregate resilience index that encompasses the system's resilience. This index can be interpreted alongside the behavior of the variables, enabling the identification of aspects that require greater attention.
- Integrating data from both the company and national sources for regional analysis.
- Conducting scenario modeling using time series data of system variables to reveal trends in changing environments.

Modules

The tool integrates eight (8) modules that encompass the socio-environmental components present in the environment: land cover, water, abiotic variables, habitat availability, diversity and redundancy, socio-environmental conflicts, diversity of productive activities, and health. Each module, is represented by differential equations (mathematical model), allowing for the simulation of the system's functioning, and modeling the trend of resilience-generating properties in response to potential impacts over time.

Each module is fed with varied information derived from Environmental Impact Assessments (EIA), Environmental Compliance Reports (ICA), monitoring reports, and other variables for which information is available and that can complement each module based on discussions between the teams from Humboldt and Ecopetrol.

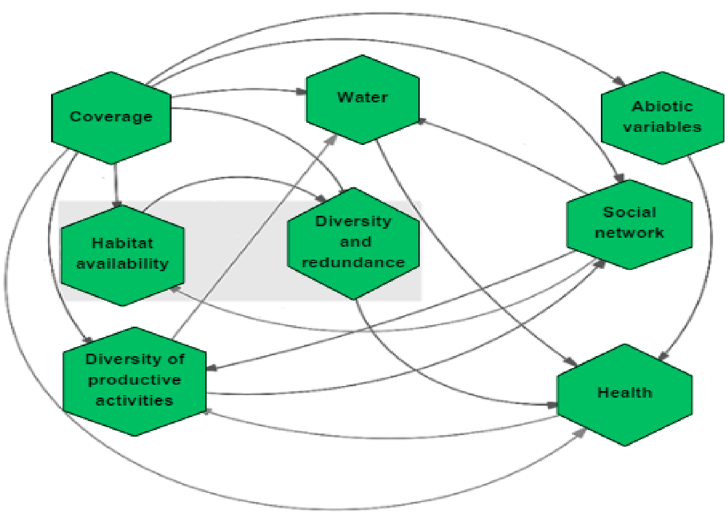


Figure 2: Modules of Socio-ecological Resilience assessment tool

1.4 Illustrative Results of the Socio-ecological Resilience Tool's Analysis

The tool encompasses specific properties and variables, and through the analyses, it reveals the varying trends of each individual variable, as well as an overall trend of the property. When combined, these trends provide insight into the general resilience of the system, as indicated by the resilience index. These trends can display positive, negative, or consistent patterns over time, highlighting the relationships among multiple variables. This understanding enables the generation of integrated management actions (Table 1).

Table 1. Illustrative Results: Trend of the socio-ecological system (negative, positive, or stable).

Property	Variable	Trend of the variable	Property Index	Resilience index
Conectivity	Polinization	+	+	−
	Seed dispersión	+		
	Presence of wildlife corridors and wildlife	+		
	Water regulation	−		
	Strong social network and communication	→		
	Mobility	→		
Diversity and redundance	Landscape diversity	−	−	
	Diversity of the local food system	−		
	Diversity in knowledge systems	−		
	diversity in ways of life	−		
	Diversity of actors involved in decision-making	→		

Additionally, it should be considered that the results assume that the initial conditions of the model will remain unchanged over time. This means that the scenarios allow for the evaluation of potential changes that would occur in the socio-ecological system under predetermined conditions at the beginning of the model.

Furthermore, this analysis is based on the conditions observed for the socio-ecological systems during the period of 2015-2020. The modeled trends are derived from this baseline and do not refer to states of the system prior to these dates. In other words, the condition of a variable either remains, improves, or deteriorates compared to its state in the 2015-2020 period.

The tool should be used at least twice, once with the input data representing the BAU (Business-as-Usual) scenario, and again with the input data representing each alternative scenario. This approach allows the tool to simulate multiple scenarios, and the user can compare the results obtained from each usage. By contrasting the outcomes, the user can gain insights into the different scenarios and make informed decisions.

2. Scope of the LEAP Pilot

Within the context of the use case of the resilience tool, the following stages of LEAP were tested, along with the inclusion of scenario design and implementation for the evaluation of nature-related opportunities (Figure 3).

Figure 3. Stages included in Pilot Two with the Socio-ecological Resilience Assessment Tool.

3. Results for each stage of LEAP

3.1 Locate (Nature interface)

Based on the information generated in the tool for the Middle Magdalena Valley core, the opportunities are related to the location and integrity of the biomes and ecosystems with which the activities interact.

- **L2: Nature Interface**

The results generated at the Fibras project were used to answer the following questions:

- *Which biomes and ecosystems do these activities interact with?*
- *What is the current integrity and importance of the ecosystems in each location?*
- *Which biomes and ecosystems do these activities interact with?*

The core area in Middle Magdalena Valley is in the departments of Norte de Santander, Santander, and Cesar, covering an area of 575,150.80 hectares. It falls mainly within the jurisdictions of the Corporación Autónoma Regional del Cesar (CORPOCESAR) and the Corporación Autónoma Regional de Santander (CAS), in the Middle Magdalena and Sogamoso River watersheds (IDEAM, 2013).

What is the current integrity and importance of the ecosystems in each location?

For this core, most of its area (95,714 ha) consists of ecosystems categorized as "Vulnerable" (VU), followed by ecosystems classified as "Endangered" (38,589 ha). Additionally, most of the core area (442,172 ha) falls under the "High" category of the Human Spatial Footprint Index, indicating the highest impact from human activities. The strategic ecosystems present are wetlands and tropical dry forests, with temporary wetlands covering the largest area (98,939 ha). Furthermore, the tropical dry forest occupies 111 ha, located in the center of the core towards the western boundary (Figure 4).

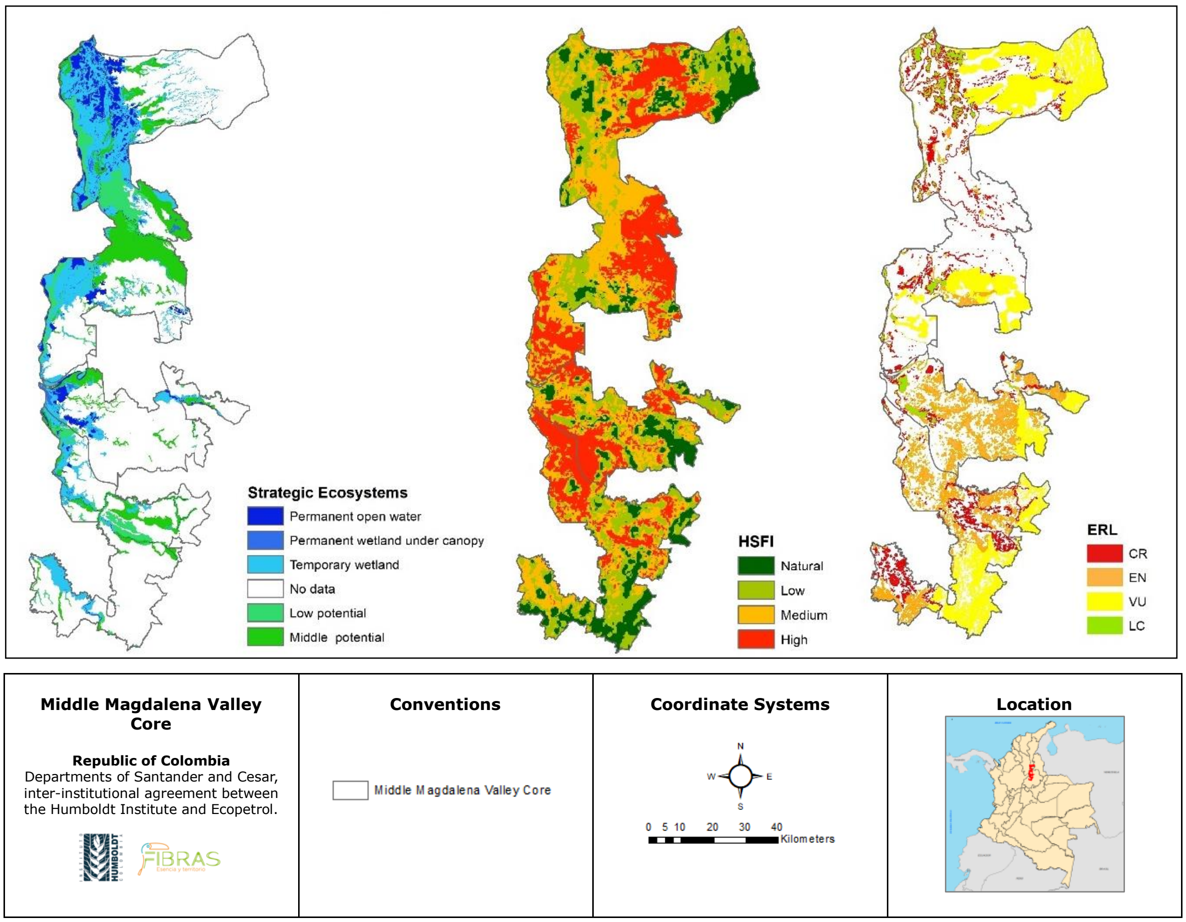


*Figure 4. Characterization of the Middle Magdalena Valley core based on the presence of strategic ecosystems (Instituto Humboldt, IDEAM 2015; Instituto Humboldt, 2018), categories of the Human Spatial Footprint Index (HSFI) (Correa Ayram et al., 2018), and categories (EN: Endangered; VU: Vulnerable; LC: Least Concern) from the Red List of Ecosystems (RLE) (Etter et al., 2017) *Source: Humboldt-Fibras project. Information base: IGAC's base cartography (2022).*

In view of the importance of ecosystems, there are prioritization portfolios produced at national level where priority areas for conservation intercept with the core area, these areas contribute to biodiversity conservation and complements the integrity analysis, as follows:

A. WePlan: Prioritizes areas based on their potential for forest restoration planning using a cost-effective criterion, where the restoration cost is minimized while maximizing the biodiversity and climate change mitigation benefits (International Institute for Sustainability Australia and Instituto Humboldt, 2021).

B. ELSA: Refers to "Essential Areas for Life Support in Colombia." The results of the systematic prioritization conducted in this project contribute to the discussions of the 2030 Agenda and the Post-2020 Global Biodiversity Framework, resulting in potential areas for protection, restoration, or sustainable use (Corzo et al., 2020).

C. ACC: This portfolio is based on "Key Areas for the Conservation of Aquatic Biodiversity." It considers threatened freshwater species, including mollusks, crabs, fish, turtles, crocodiles, birds, or aquatic mammals (Lasso et al., 2017).

D. Deforestation 2030: This portfolio can be used to prioritize areas that, according to modeled scenarios, are more likely to be deforested if left untouched, following the trend of IDEAM's analyses, considering principal socio-economic and socio-political deforestation drivers (Rosa et al., 2013).

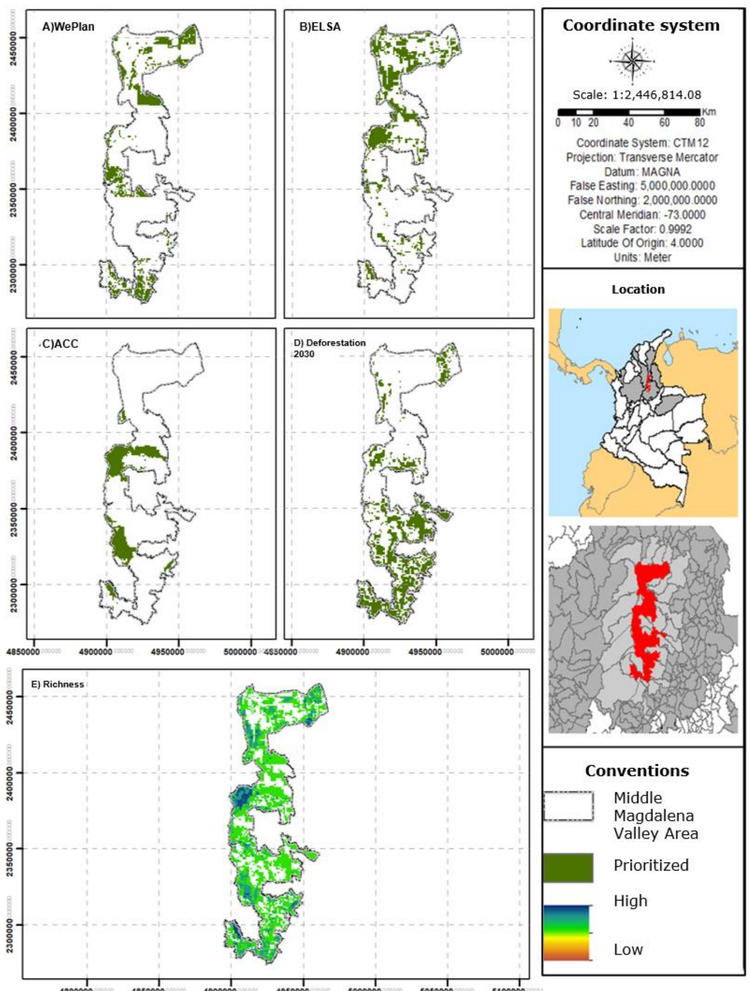


*Figure 5. Portfolio maps in the Middle Magdalena Valley core. *Source: Humboldt-Fibras project. Information base: IGAC's base cartography de (2019).*

3.2 Evaluate (Dependencies and impact)

- **E1:** Identification of environmental assets and ecosystem services

What are our processes and business activities in each prioritized location?

This information included here is derived from the reading and interpretation of Environmental Impact Assessments, Compliance Reports, and Environmental Management Plans. It is recommended to generate periodic updates of the impact sources as well as their repercussions on the territory.

As a basis for building the resilience assessment tool, a matrix of relationships was constructed between Impact Sources and Impacts, which allowed us to identify the activities from the hydrocarbon sector that generated the highest number of impacts , these where: land clearing and stripping for the construction or expansion of infrastructure such as access roads, locations, and production and injection facilities. They are followed by the mobilization of personnel, vehicles, equipment, and machinery. It is evident that excavation, cutting, and filling activities, as well as the generation and disposal of solid and liquid waste, also have significant importance. The numbers identified the variables with most relevant impacts for the study site.

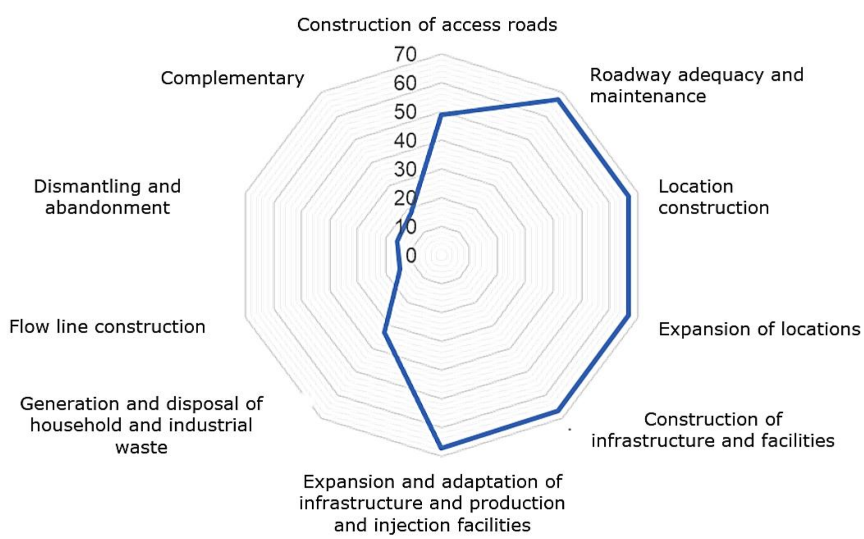


Figure 6. Impact Sources in the Middle Magdalena Valley core.

Impact are related to the alteration of terrestrial fauna communities, their composition and distribution. This is primarily attributed to the construction of new infrastructure such as roads and the loss of vegetation cover. Consequently, it affects landscape quality, as well as terrestrial ecosystems and the physicochemical properties of the soil.

Additionally, in relation to the overall analysis of the core area, the presence of other exploration and drilling blocks is reported, with a significant concentration throughout the area. These aspects entail implications for the different components: abiotic, biotic, and socioeconomic, identifying the most significant impacts, as follow:

Table 2. Component and main impact in the Middle Magdalena Valley.

Component	Impact
Abiotic	Change in landscape quality
Abiotic	Soil quality alteration
Abiotic	Alteration in noise levels
Biotic	Modification of fauna composition and distribution
Biotic	Alteration to terrestrial ecosystems
Biotic	Disruption of trophic relationships, terrestrial habitats, and corridors
Socioeconomic	Alteration in visual perception of the landscape
Socioeconomic	Generation and/or exacerbation of social conflicts
Socioeconomic	Modification of local economic activities

- **E2: Identification of dependencies and impacts by priority location.**

What is our nature-related dependencies and impacts across our business at each priority location?

In accordance with the modeling results and information from ENCORE (Exploring Natural Capital Opportunities, Risks, and Exposure) of the NCFA (Natural Capital Finance Alliance), the sub-industry dependencies of the Oil & Gas drilling sector, concerning ecosystem services or contributions from nature, are primarily related to water resources in the form of surface and groundwater.

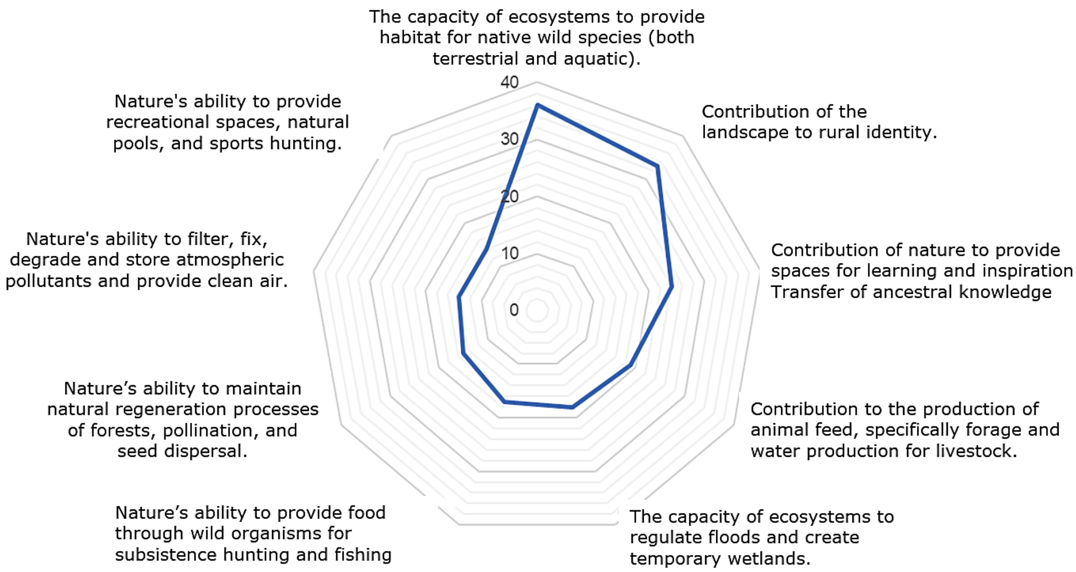
Mitigation of direct impacts is mainly associated with the capacities of species, ecosystems, and the socio-ecological system for bioremediation and filtration.

The ecosystem services that facilitate the provision of water resources for the sector's activities include climate regulation, flood and storm control, erosion control, and soil stability.

For the Oil & Gas Equipment & Services sub-industry, which includes processes related to the manufacturing of machinery and equipment, and service areas for hydrocarbon production, there is also a direct dependence on water resources, making it the most important asset. Regarding the services that enable these productive processes in the socio-ecological system, they include maintaining air quality, water regulation, and water quality.

Regarding the relationship with stakeholders, one of the main aspects is ensuring a healthy environment that offers well-being to the communities within the Company's area of influence. The value of biodiversity conservation actions and ecosystem services can become the seed for economic exploitation (e.g., green businesses) that, in the long term, facilitate the diversification of local economies within the framework of the energy transition process. This can be achieved through investment in strengthening entrepreneurial skills by the Company, which can favor conditions for conservation or restoration businesses (Arce & Amaya, 2023).

To identify the aspects that offers well-being to the communities we used nature contributions to people (NCP) as proxies, identifying for the Middle Magdalena



Valley region those NCP that could be affected by the different impacts previously identified on Figure 6 and Table 2 (Figure 7). The numbers indicate the contributions of nature with the highest importance for the study site.

Figure 7. Nature's Contributions with the Highest Degree of Relationship - Degrees of Importance to the Socio-Ecological System.

3.3 Assess (Material risk and opportunities)

- **A1: Risk and opportunity ID**

What are the corresponding opportunities for our organization?

For the assessment of opportunities, based on the proposed modeling, four prospective scenarios of variables and principles associated with the socio-ecological system resilience were formulated. These scenarios are narratives that describe possible present or future contexts. They allow for visualizing changes in the behavior of variables through the introduction of actions that would modulate their trajectory.

Recognizing the potentiality of possible actions in influencing the dynamics of the socio-ecological system, the scenarios are focused on changes in land cover through the implementation of preservation measures and changes in the implementation of programs involving actors within the socio-ecological system.

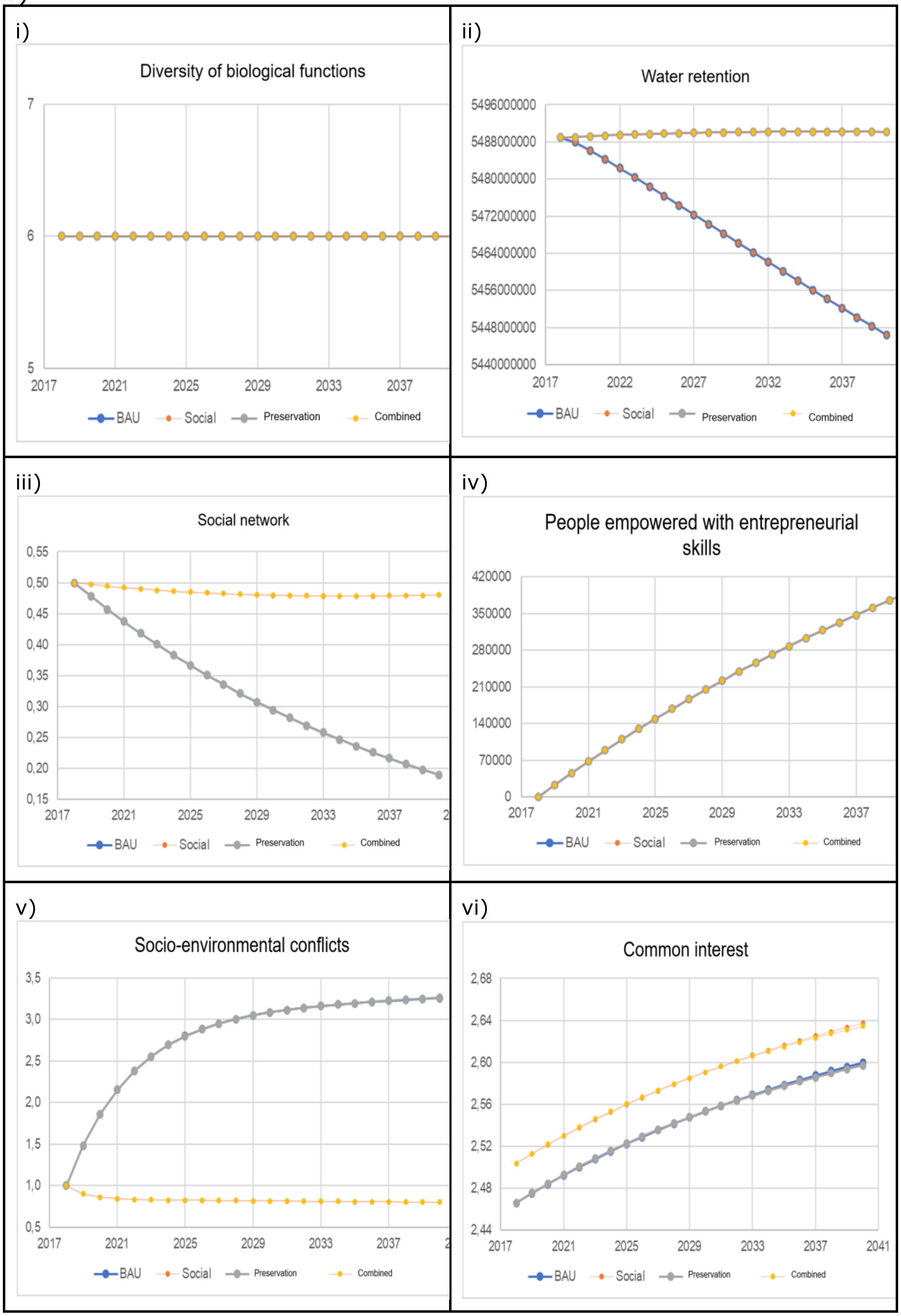
Table 3. Scenario description and metrics used to build it.

Narrative	Metrics*
Social Scenario	
Reduction in the number of petitions, complaints, claims, and/or requests, to diminish the value of the factor contributing to increased socio-environmental conflicts. Regarding the weights assigned to water, fauna, and forest-ecosystem care practices, they were increased to favor the variable of diversity in care programs and practices. As for participation programs, their participation percentage per program was increased, resulting in a direct positive effect on common interest	1. Multidimensional poverty index 2. Number of water care practices per municipality 3. Number of fauna care practices per municipality 4. Number of forest-ecosystem care practices per municipality. 5. Number of requests, complaints, claims (PQRs) 6. Average number of individuals per community participation program. 7. Percentage of individuals belonging to a community participation program 8. Percentage of individuals belonging to two or more community participation programs 9. Weight of water care 10. Weight of fauna care 11. Weight of forest-ecosystem care 12. Diversity of knowledge systems
Preservation Scenario	
The forest cover is maintained and protected, promoting the stabilization and recovery of local wildlife populations present in these areas. There is stricter control over the expansion of populated areas, eliminating the impacts on surrounding natural covers. The function of wetlands is maintained and strengthened, allowing for the natural cycles of flooding and drought typical of the region. Food cultivation is diversified, and techniques are improved to increase productivity, avoiding agricultural expansion into other natural areas. Secondary vegetation areas in succession processes are preserved, allowing for their natural regeneration.	1. Rate of Forest transformation to Heterogeneous Agro-Pastoral 2. Rate of Forest transformation to Homogeneous Agriculture 3. Rate of Forest transformation to Homogeneous Pastures 4. Rate of Forest transformation to Urban – Urbanized 5. Rate of Forest transformation to Extractive Uses 6. Rate of Forest transformation to Degraded Areas 7. Rate of Grasslands and Shrublands transformation to Heterogeneous Agro-Pastoral 8. Rate of Grasslands and Shrublands transformation to Homogeneous Agriculture 9. Rate of Grasslands and Shrublands transformation to Homogeneous Pastures 10. Rate of Grasslands and Shrublands transformation to Urban - Urbanized Rate of Grasslands and Shrublands transformation to Extractive Uses 11. Rate of Grasslands and Shrublands transformation to Degraded Areas 12. Rate of Wetlands transformation to Heterogeneous Agro-Pastoral 13. Rate of Wetlands transformation to Homogeneous Agriculture 14. Rate of Wetlands transformation to Homogeneous Pastures 15. Rate of Secondary or Seminatural Vegetation transformation to heterogeneous Agro-Pastoral

Narrative	Metrics*
Social Scenario	
	16. Rate of Secondary or Seminatural Vegetation transformation to Homogeneous Pastures 17. Rate of Secondary or Seminatural Vegetation transformation to Vegetation-free Soils (Natural) 18. Rate of Secondary or Seminatural Vegetation transformation to Urban - Urbanized 19. Rate of Secondary or Seminatural Vegetation transformation to Extractive Uses 20. Rate of Secondary or Seminatural Vegetation transformation to Secondary or Seminatural Vegetation
Combination of the two scenarios, adding social and ecological variations.	12 social metrics 20 ecological metrics

* Modified parameters for constructing the scenario that prioritizes the ecological aspect of preserving the Middle Magdalena Valley.

Combined Scenario narrative could explain with the following variables (Figure 8):



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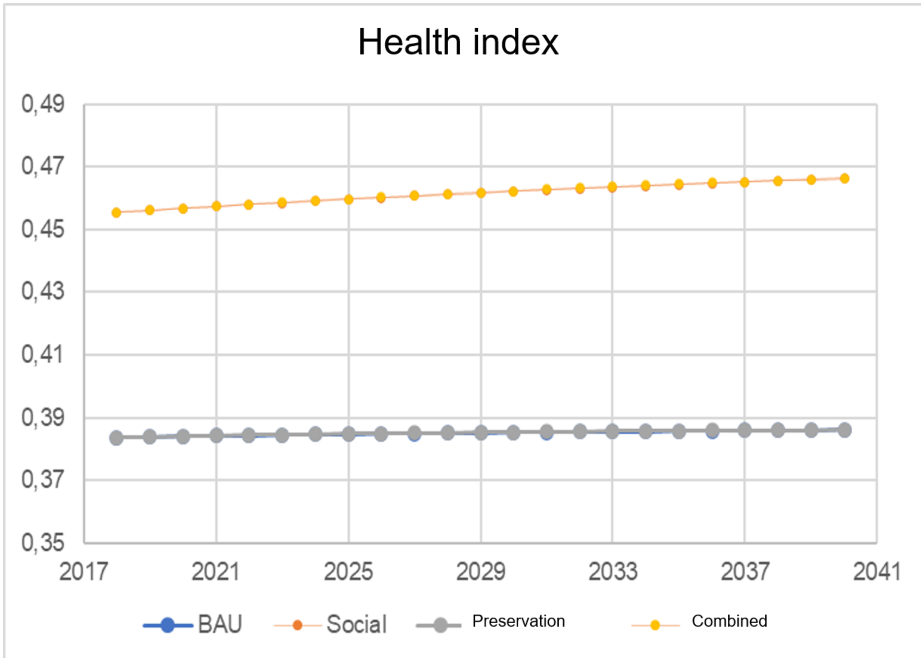

Figure 8. Variations in variables associated with BAU, Social, Preservation and Combined scenario changes: i) Diversity of ecological functions, ii) Water retention, iii) Social fabric, iv) People empowered with entrepreneurial skills, v) Socio-environmental conflicts, vi) Common interest, vii) Health index.

The variable "diversity of ecological functions" refers to the average persistence of all ecological species. If we have sufficient forest cover, above 30%, and take care of wildlife and the forest, the resilience of the socio-ecological system increases.

The difference in water retention trends in the proposed scenarios (Figure 9) is exclusively due to the water demand of vegetation cover, as changes in sector demands, percolation rates, and oversaturation have not been considered in any of the scenario. Although the amount of water retained in the soil is relatively stable for all scenarios (considering the range of values in the time series), it is much more stable in scenarios aiming to conserve natural areas (preservation and combined) compared to those that do not (BAU and social). These changes demonstrate the vulnerability of the system in regulating the hydrological cycle when land covers change. Efforts to preserve or even increase current land covers, as seen in the preservation scenario, allow the soil to retain sufficient water for system balance, avoiding oversaturation that can lead to floods, sudden increases in water flow, and landslides.

In the preservation scenario, where social and ecological variables are combined to promote preservation; the social networks decrease to a greater extent than in the social and combined scenarios. The decrease in the preservation scenario is due to restrictions on the use of productive land covers, which do not promote decision-making by different stakeholders regarding land use or the implementation of good practices, for example. The BAU scenario also does not provide opportunities for land cover use.

Empowered individuals with entrepreneurial skills usually increase in number, which favors the diversity index of productive activities. Socio-environmental conflicts vary across all scenarios, with the social and combined scenarios showing the fewest conflicts. The least favorable scenario is BAU and preservation, and only scenarios that consider improvements in social aspects have the potential to transform conflicts.

The positive trend of common interest is related to increased connectivity, self-consumption reports, a high proportion of protected areas, positive average habitat for all species, good agricultural practices obtained in the CNA (National Agricultural Census) at 50.97%, and governance practices for forest-ecosystem care. The graph shows that although the BAU scenario is positive, it is further strengthened in the combined and social scenarios.

The health index summarizes several aspects. From the social perspective, only the Multidimensional Poverty Index (MPI) was considered, and the combined scenario introduces changes in the persistence of ecological functions and the food provision indicator that affects the diversity of the food system. There is also a change due to noise mitigation. The combined and social scenarios are the ones that favor the health index.

From the behavior of the weighted average and resilience index in the four proposed scenarios represented in Figure 9, the following can be observed:

- All scenarios show a positive trend, indicating that the system has the capacity to assimilate changes and maintain its state over time (remember the reference period is 2015-2020).
- The preservation scenario does not show significant changes compared to the BAU scenario. This suggests that the preservation of natural areas, from a socio-ecological perspective, may generate a response that is not sufficient to improve the resilience of the system.
- Actions focused solely on social aspects significantly improve the weighted average of variables while maintaining an increasing trend. This indicates that the system can assimilate the proposed changes in the scenario, improving them in the medium and long term.
- Preservation, when combined with social changes (combined scenario), provides the best response from the system. This means that the weighted average of variables increases, and the resilience index is higher than in the other scenarios.
- In socio-ecological system resilience, preservation actions must be accompanied by social strategies.

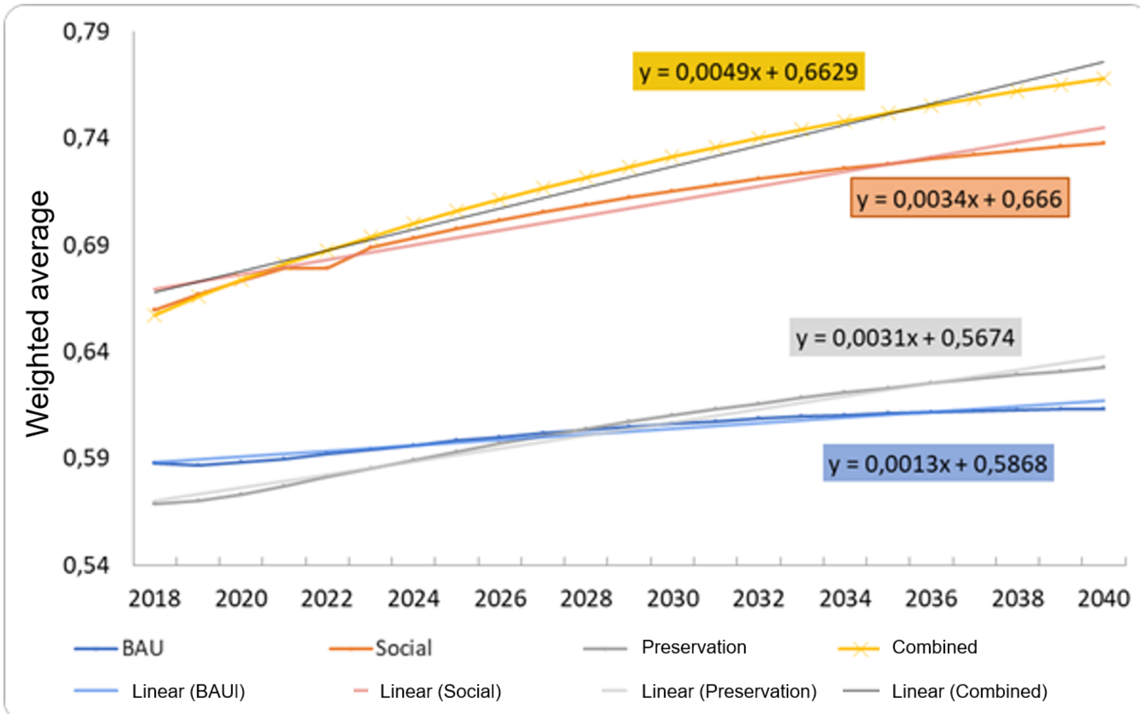

Figure 9. Resilience Index to scenario evaluated.

Starting from the BAU scenario, actions focused solely on preservation could have a negative impact on the resilience of the socio-ecological system. What is particularly interesting is that actions driven by social considerations lead to substantial improvements in both the weighted average and the resilience index. Preservation, in conjunction with social approaches, is what strengthens resilience. Therefore, the implementation of preservation measures requires complementary strategies that enhance common interest.

In this regard, the scenario results provide insights into sources of opportunities for the socio-ecological system related to biodiversity and stakeholders. Specifically, they highlight potential opportunities related to biodiversity that can offer financial benefits to the company, such as increased stability, continuity, risk mitigation, resilience to natural disasters, and improved adaptability to regulatory changes (CBDB, 2021).

4. Conclusions and recommendations for enhancement the TNFD framework

Issues that may be important to enhance the TNFD framework are considered below. Those are based on the experience of applying resilience assessment in some stages of the LEAP phase and the maturation process from version 2.0 to version 4.0.

Understanding the dynamics of the socio-ecological system being assessed

- In version 4.0, the locate and assess phases introduce a set of metrics within the TNFD framework to characterize the evaluated area and its impact. However, there is a lack of a reference framework to relate the metrics used in different stages of LEAP. The metrics are presented independently for impacts and dependencies.
- Frameworks such as Pressure-State-Response-Benefits (Sparks et al., 2011) or methodologies that help understand aspects of the evaluated socio-ecological system's dynamics are crucial. They enable the utilization of metrics in specific contexts and transform them into indicators that provide information beyond mere numbers.
- The metrics included in the resilience index are used in contexts and narratives that explain their significance for the resilience of socio-ecological systems. However, when applying the TNFD framework according to the proposed steps in version 4.0, there appears to be a missing step in comprehending the socio-ecosystem context, which is necessary for relating impact and dependency variables.
- Introducing a contextual step in the evaluation phase could be the most suitable approach, as it would allow for a deeper understanding of the social-ecological system under evaluation, rather than solely focusing on the perspective of the business or company's value chain.
- Enhancing the TNFD framework in these aspects would improve the utilization of the proposed metrics, which are currently presented in isolation, making it challenging to interpret them holistically.
- The resilience tool considers theoretically documented interrelationships between variables, which are part of the generated mathematical model. Hence, modifying one of them leads to the transformation of the entire scenario. These interrelationships could be useful for constructing more realistic scenarios regarding the impacts and dependencies on nature. Currently, TNFD does not incorporate this type of relationships.

Incorporation of social dimensions

- It is crucial to consider social aspects in the TNFD framework, as they are closely related to social license to operate, analyzing socio-environmental conflicts, and assessing reputational risk in areas of influence. Additionally, understanding the socio-economic dynamic can contribute to identifying business opportunities in the territories. It is important to incorporate metrics that assess social dynamics and socio-environmental conflicts to complement the existing categories of opportunities and reputational risks.

Temporal dynamics

- The TNFD framework does not explicitly include analysis of the proposed metrics over different time periods. Time series analysis would allow to understand the trend of change in the assessed area and to detect lags in variables caused by impacts, especially in variables related to biodiversity and ecosystem functioning.

Relevance of national data

- It is important to identify the "why" of the use of assessments, in order to use the best available data for each purpose: if the assessment is expected to help the company to implement better actions in the territory, it is possible that only national information may be detailed enough to facilitate decision making in the prioritized areas, otherwise if the use of the assessment is to comply with international requirements, global information sources may be sufficient.
- Although it is unlikely that a new version of the TNFD will specifically mention national information sources, it would be advisable to discuss the scope of the global databases presented and recognize the importance of national data layers. This would increase the usefulness of the TNFD as a decision support tool at the subnational level.

Use of scenarios

- In version 4.0 of the TNFD framework, a section dedicated to scenarios is included. Based on the scenario approach presented in this report, it is suggested that TNFD make explicit its use in the identification of opportunities during stage A (risk and opportunity assessment) of the LEAP, following the example presented in this report.
- It is recommended that social aspects be more explicitly incorporated in the scenarios presented in version 4.0, considering their importance in the analysis of opportunities. In addition, it is suggested that the metrics used in the LEAP localization and evaluation stages can be modeled under different scenarios, which will facilitate the planning of opportunity and risk actions.
- It is crucial to be able to adapt global scenarios to local scenarios, especially in the areas assessed in stages L2 and L3. If global scenarios do not fit local contexts, it will be difficult to use them for decision making in specific areas. Since the TNFD framework prioritizes application areas, it is important that scenarios can be localized without losing their relationship to archetypes that allow comparability between studies at regional or global scales. This need for scalability between global archetypes and regionalized scenarios has been recognized in the IPBES evaluation (Rosa et. al. 2017).

Bibliography

- Arce Castellanos, L. O., Amaya, B., Cubides, A., Montoya, M. & M. Murcia. (2023). Documento con el análisis potencial de negocios verdes y ecoturismo para los tres (3) predios restantes seleccionados. ASA La Guarupaya, Centenario La Pacora y La Doncella - Isla IV. Bogotá: Convenio de cooperación Instituto de Investigación de Recursos Biológicos Alexander von Humboldt y Ecopetrol S.A.
- Biggs, R., Simonsen, S., Schoon, M., Bohensky, E., Cundill, G., Dakos, V., Daw, T., Kotschy, Leitch, A., Quinlan, A., Petterson, G., Moberg, F., Schlüter, M. (2014). Poniendo en práctica el pensamiento resiliente. Siete principios para desarrollar la resiliencia en los sistemas socio-ecológicos. Stockholm Resilience Center. Stockholm University. https://whatisresilience.org/wp-content/uploads/2016/04/Applying_resilience_thinking_SP_aktiv.pdf
- Correa Ayram, C.A., Díaz-Timote, J., Etter, A., Ramírez, W. y G. Corzo. (2018). El cambio en la huella espacial humana como herramienta para la toma de decisiones en la gestión del territorio. En Moreno, L. A, Andrade, G. I. y Gómez, M.F. (Eds.). 2019. Biodiversidad 2018. Estado y tendencias de la biodiversidad continental de Colombia. Instituto de Investigación de Recursos Biológicos Alexander Von Humboldt. Bogotá, D. C., Colombia. http://geonetwork.humboldt.org.co/geonetwork/srv/spa/catalog.search#/metadata/3f37fa6b-5290-4399-9ea3-eaafcd0b2fbe
- Corzo, L., Rodríguez-Buriticá, S., Ochoa, D., Batista, M. F., Fonseca, C., Marigo, M., Virnig, A., Venter, O., Atkinson, S., Ervin, J., & García, H. (2021). Mapeo de áreas esenciales para el soporte de la vida -ELSA- en Colombia. En: Moreno, L. A., Andrade, G. I., Didier, G & Hernández-Manrique, O. L. (Eds.). Biodiversidad 2020. Estado y tendencias de la biodiversidad continental de Colombia. Bogotá, D. C., Colombia: Instituto de Investigación de Recursos Biológicos Alexander Von Humboldt. 112p.
- Ecopetrol S.A. (2018). Reporte Integrado de Gestión Sostenible 2018. Bogotá, Colombia.
- Etter, A., Andrade, A., Saavedra, K., Amaya, P., Arévalo, P. Cortés, J., Pacheco, C. y D. Soler. (2017). Lista Roja de Ecosistemas de Colombia. Pontificia Universidad Javeriana y Conservación Internacional Colombia. http://geonetwork.humboldt.org.co/geonetwork/srv/spa/catalog.search#/metadata/53474f84-b5b8-4965-a1f0-848d302495a6
- Instituto Humboldt. (2018). Cobertura de Bosque Seco Tropical en Colombia, año 2018, escala 1:100.000. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Bogotá, D. C., Colombia. http://geonetwork.humboldt.org.co/geonetwork/srv/spa/catalog.search#/metadata/6ccd867c-5114-489f-9266-3e5cf657a375
- Instituto Humboldt, IDEAM (2015). Clasificación del mapa de humedales continentales de Colombia por tipología, Escala 1:100.000. Proyecto: Insumos para la delimitación de humedales y páramos en cuencas hidrográficas afectadas por el fenómeno de La Niña 2010-2011. Bogotá, D. C., Colombia. http://geonetwork.humboldt.org.co/geonetwork/srv/spa/catalog.search#/m

etadata/7ff0663a-129c-43e9-a024-7718dbe59d60

- IDEAM (2013). Zonificación y codificación de unidades hidrográficas e hidrogeológicas de Colombia, Bogotá, D. C., Colombia. Publicación aprobada por el Comité de Comunicaciones y Publicaciones del IDEAM, noviembre de 2013, Bogotá, D. C., Colombia.
- International Institute for Sustainability Australia & Instituto Humboldt. (2021). WePlan Forests Colombia. http://weplan-colombia.s3-website-us-east-1.amazonaws.com/
- Lasso, C. A., D. Córdoba y M. A. Morales-Betancourt (Eds.). 2017. XVI. Áreas clave para la conservación de la biodiversidad dulceacuícola amenazada en Colombia: moluscos, cangrejos, peces, tortugas, crocodílidos, aves y mamíferos. Serie Editorial Recursos Hidrobiológicos y Pesqueros Continentales de Colombia. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. Bogotá, D. C., Colombia. 353 pp.
- Rosa, I. M., Purves, D. W., Souza, C., & Ewers, R. M. (2013). Predictive Modelling of Contagious Deforestation in the Brazilian Amazon. PLOS ONE, 8(10), e77231. https://doi.org/10.1371/journal.pone.0077231
- Sparks, T. H., Butchart, S. H. M., Balmford, A., Bennun, L., Stanwell-Smith, D., Walpole, M., Bates, N. R., Bomhard, B., Buchanan, G. M., Chenery, A. M., Collen, B., Csirke, J., Diaz, R. J., Dulvy, N. K., Fitzgerald, C. M., Kapos, V., Mayaux, P., Tierney, M., Waycott, M., . . . Green, R. E. (2011). Linked indicator sets for addressing biodiversity loss. Oryx, 45(3), 411-419. https://doi.org/10.1017/s003060531100024x
- TNFD. Taskforce on Nature-related Financial Disclosures Framework. https://tnfd.global/
- Rosa, I. M., Pereira, H. M., Ferrier, S., Alkemade, R., Acosta, L. A., Akcakaya, H. R., & Van Vuuren, D. (2017). Multiscale scenarios for nature futures. Nature Ecology & Evolution, 1(10), 1416-1419.
- Sparks, T. H., Butchart, S. H., Balmford, A., Bennun, L., Stanwell-Smith, D., Walpole, M., & Green, R. E. (2011). Linked indicator sets for addressing biodiversity loss. Oryx, 45(3), 411-419.

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