WORLD RESOURCES INSTITUTE

SUSTAINABILITY INDEX FOR LANDSCAPE RESTORATION

A tool for monitoring the biophysical and socioeconomic impacts of landscape restoration

RENÉ ZAMORA CRISTALES, DORIBEL HERRADOR, NELSON CUÉLLAR, OSCAR DÍAZ, SUSAN KANDEL, JORGE QUEZADA, SILVIA DE LARIOS, GIOVANNI MOLINA, MADELYN RIVERA, WILFREDO MORÁN-RAMÍREZ, ABNER JIMÉNEZ, EMMA FLORES, MARÍA FRANCO CHUAIRE, LUCIANA GALLARDO LOMELI, WALTER VERGARA

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AUTHORS

René Zamora Cristales, Doribel Herrador, Nelson Cuéllar, Oscar Díaz, Susan Kandel, Jorge Quezada, Silvia de Larios, Giovanni Molina, Madelyn Rivera, Wilfredo Morán Ramírez, Abner Jiménez, Emma Flores, María Franco Chuaire, Luciana Gallardo Lomeli and Walter Vergara.

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CCAD
COMISIÓN CENTROAMERICANA DE AMBIENTE Y DESARROLLO

SICA

Editorial design:
Nancy Rojas Corichi
nrojascorichi@gmail.com

Translation and copy editing:
Javier Toscano
tosgue@yahoo.com

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FOREWORD

Restoring degraded land has never been more urgent and important, with wildfires, droughts, floods, and other impacts of climate change ever more apparent. The benefits of restoring land are many, from improving food production to protecting water supplies, providing people with new sources of income, and storing carbon in soil and trees, thereby slowing future heating.

There is good news: land restoration is gathering momentum across Latin America, where 17 countries have committed to restoring 53 million hectares through Initiative 20x20, a region-wide, country-led venture. Several countries have prepared national restoration strategies, and money from public and private sources is starting to flow to specific projects.

How can this progress be accelerated? It is key to measure what matters and to allow practitioners to be able to manage landscape restoration projects effectively. This important report shows how.

Restoration is more complex than just planting trees. It requires that farmers, rural communities, businesses, and government agencies – all of which have different interests – unite behind a shared vision of how the land should be used. Establishing common goals and measuring progress facilitates deeper collaboration among these actors. This in turn can improve strategies and implementation, helping to direct investments into activities that maximize results.

The Sustainability Index for Landscape Restoration introduced in this report is a field-tested tool for measuring the impact of restoration efforts. It offers easy-to-use visual metrics to display biophysical and socioeconomic indicators that measure the health of a landscape. It also describes how these metrics have been used to convene dialogues among diverse stakeholders who must actively collaborate to restore the land.

To test the methodology, the World Resources Institute worked with the Government of El Salvador, the Regional Program for Research on Development and Environment (PRISMA), and the German Corporation for International Co-operation (GIZ), to create a Sustainability Index for Landscape Restoration in a 1200 square kilometer landscape. The area is home to about 300,000 people and includes the subtropical forests in the El Imposible National Park, mangrove areas in Barra de Santiago, and Ilamatepec, a volcanic mountain range with diverse natural and agricultural areas.

This report describes how the creation of the index enabled diverse stakeholders to create a common vision for their shared landscape, based on their own values and priorities; it also supports their plans for using the index to help ensure that various players follow through with their commitments.

I share the authors' hope that the Landscape Restoration Index can act as a roadmap for decision-makers in Latin America and the rest of the world as they design systems to track their progress. We also hope that by showing the benefits that El Salvador is poised to realize will inspire other governments, companies, and communities to apply the guide to galvanize local action to restore land at the pace needed to slow climate change and decarbonize economies.

Andrew Steer
President
World Resources Institute

EXECUTIVE SUMMARY

This publication presents a methodological framework for monitoring the impacts of landscape restoration through the construction of an index. The Sustainability index for Landscape Restoration (SILR) is a measure of the biophysical and socioeconomic impacts of restoration actions. The index provides a score (ranging from 0 to 1) for each landscape, based on the degree of compliance with the goals established in restoration plans or strategies with respect to a baseline, and its calculation can be broken down into different biophysical and socioeconomic components. The index was applied in a priority landscape in El Salvador, El Imposible-Barra de Santiago and Apaneca-Ilamatepec, and was implemented through the Ministry of Environment and Natural Resources (MARN). The results presented here represent an opportunity for the strategic assessment of restoration actions.

HIGHLIGHTS:

- Landscape restoration provides an opportunity to reverse ecosystem degradation and promote development. However, it is necessary to establish monitoring, reporting, and verification systems that allow for the evaluation of changes and establish correlations with the implemented actions.
- For addressing climate change in Latin America, monitoring the impacts of restoration is key to facilitating and improving the promotion and planning of adaptive landscape management.
- The potential impacts of restoration —such as increased carbon stocks, increased forest connectivity, improved water quality and quantity, and improved livelihoods, among others - need to be monitored cost— effectively by governments.
- This report offers a methodology for designing a landscape sustainability index for monitoring restoration progress and demonstrates its application in a specific landscape in El Salvador.
- The index is also a guide for decision-makers to assess progress in the implementation of policy instruments in landscapes.

Challenges in landscape monitoring

Landscape restoration involves the implementation of activities with diverse social, environmental and economic impacts that need to be measured. Through the Initiative 20x20, 17 Latin American countries have expressed their ambition to restore around 53 million hectares of degraded land in order to generate positive impacts on the sustainability of landscapes. These impacts need to be monitored by the governments of the region in order to establish the correlation between the activities implemented and their effects on the landscape and to propose corrective actions if needed. Given the complexity of social, environmental, and economic factors within landscapes, it is necessary to design systems that allow, in a simple way, to evaluate and qualify the factors as a whole and, in turn, to provide individual information for each factor.

This publication presents a methodological framework for monitoring the impacts of landscape restoration through the construction of an index. The Sustainability Index for Landscape Restoration (SILR) is a measure of the biophysical and socioeconomic impacts of restoration actions. The index reports a score (from 0 to 1) for each landscape, which depends on the degree of compliance with the goals established in restoration plans or strategies with respect to a baseline. Within the SILR the rating 0 (zero) indicates the absence of progress while 1 refers to the achievement of the proposed goals. The rating is the entry point for determining the status of the targets and its calculation can be broken down into different biophysical and socioeconomic components. The index was applied in a priority landscape in El Salvador, El Imposible-Barra de Santiago and Apaneca-Ilamatepec, and was implemented through the Ministry of Environment and Natural Resources (MARN). The results presented here represent an opportunity for the strategic evaluation of restoration actions.

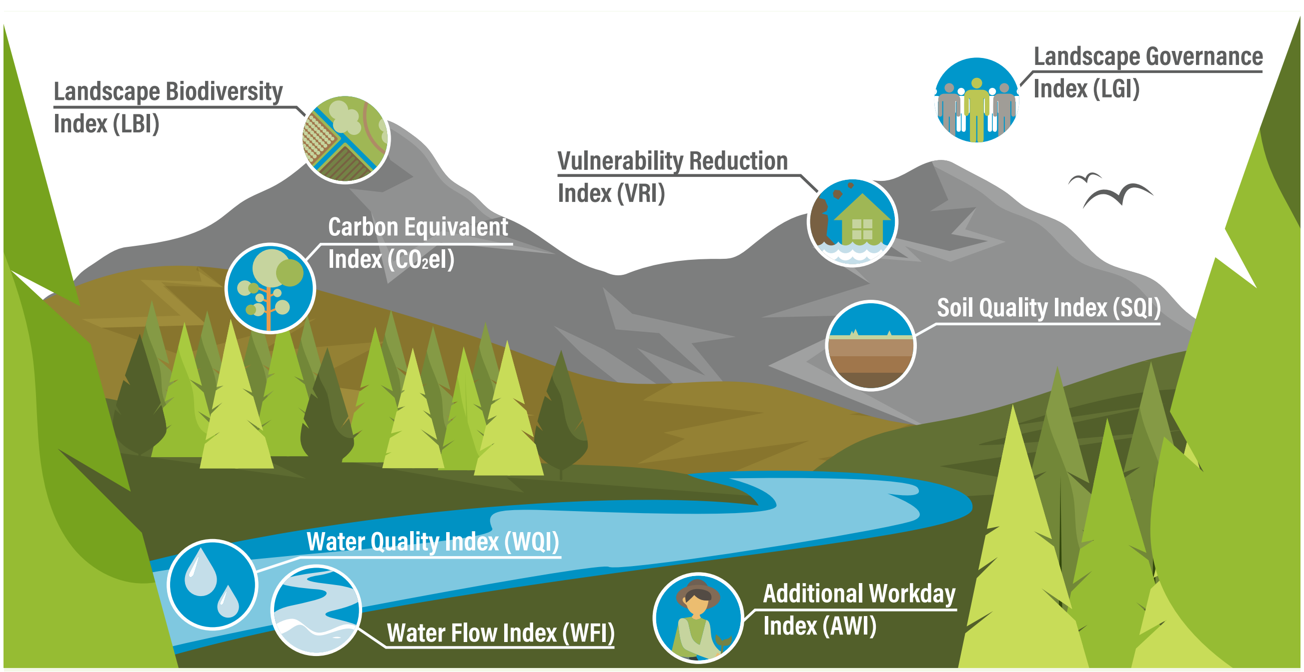
How is the Index assembled?

The SILR is composed of eight indexes that allow monitoring of the impacts of restoration in different dimensions of mitigation and adaptation to climate change: the Water Quality Index (WQI),Water Flow Index (WFI), the Soil Quality Index (SQI), the Landscape Biodiversity Index (LBI), the Carbon Equivalent Index (CO_2eI); the improvement in the livelihoods of rural communities as measured by the Additional Workday Index (AWI); the reduction of vulnerability to environmental risk as measured by the Vulnerability Reduction Index (VRI), and governance for landscape management as measured by the Landscape Governance Index (LGI) (Figure ES 1). The components presented here may vary according to the conditions and information available in each country. The important aspects to emphasize are that the information to be used must be collected periodically, must be made available and must have a reliable source validated by government agencies.

In the case of El Salvador, the Water Flow and Soil Quality Indexes were included, but the information to calculate them was not yet available.

The SILR is composed of thematic indexes, which may or may not be aggregated in a modular manner, according to the information available. In some cases, the information available is directly related to restoration actions. For example, in the case of El Salvador, the Carbon Equivalent and Additional Workdays Indexes give more direct information on the impact of the restoration actions carried out while, for the rest of the components (Water Quality, Water Flow, Biodiversity, Soils, Vulnerability and Governance), the information available regarding impacts also includes the effect of external factors, additional to the restoration actions. It will be shown that the Biodiversity Index not only includes the impact of restoration actions but also that of natural regeneration that has occurred during the analysis period.

Figure ES 1 | Components of the Sustainability Index for Landscape Restoration



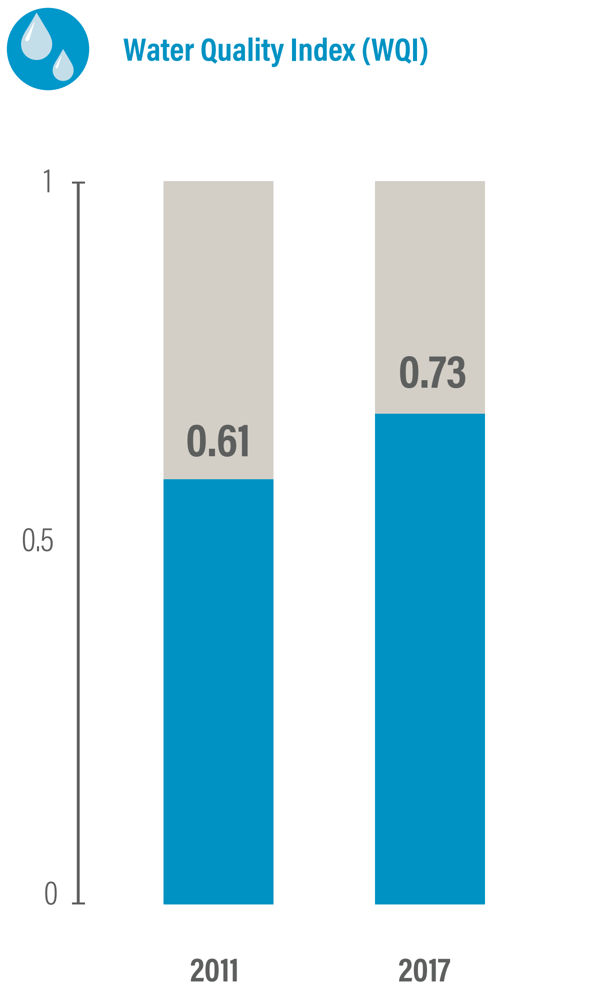
Source: WRI and PRISMA, 2019

What are the results?

Water Quality Index (WQI)

The Water Quality Index provides information on the level of water pollution and its capacity to sustain a high diversity of aquatic life in rivers. In El Salvador's target landscape, information was collected at the MARN measuring stations. The normalized results show a score of 0.73 (on a scale of 0 to 1) for the WQI, compared to 0.61 in 2011 (Figure ES 2).

Figure ES 2 | Water Quality Index Results 2011 and 2017

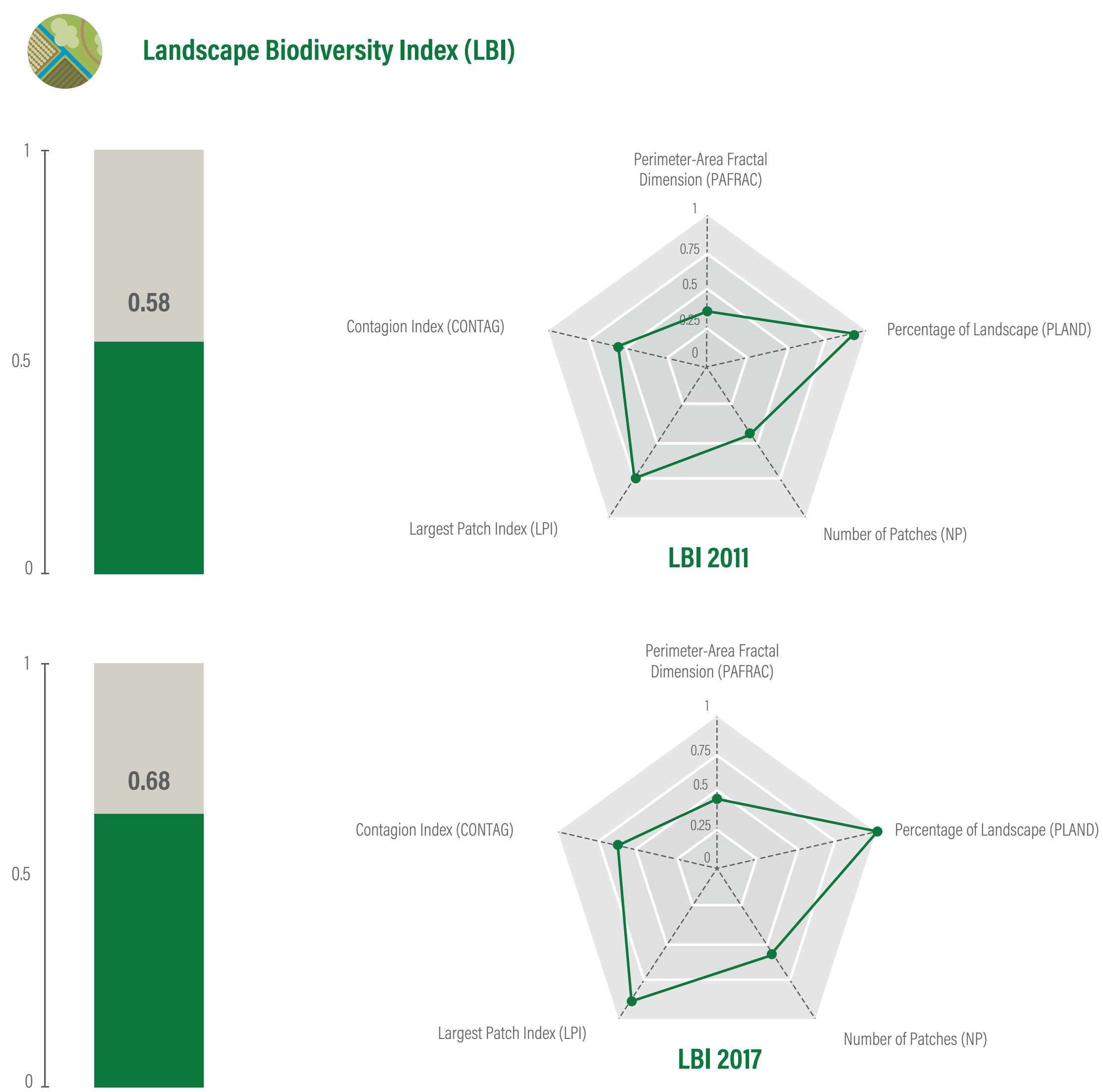


Source: WRI and PRISMA, 2019

Landscape Biodiversity Index (LBI)

The Landscape Biodiversity Index measures the degree of connectivity and fragmentation of the landscape. The index is composed of five parameters that together provide information on the number of existing forest patches, how they are connected, and their level of fragmentation. A maximum LBI of 1 indicates that the landscape has sufficient attributes to protect the biodiversity it harbors, but that number decreases as the degree of degradation of the landscape increases. In El Salvador's landscape, the LBI increased from 0.58 in 2011 to 0.68 in 2017 (Figure ES 3).

Figure ES 3 | Landscape Biodiversity Index



Source: WRI and PRISMA, 2019

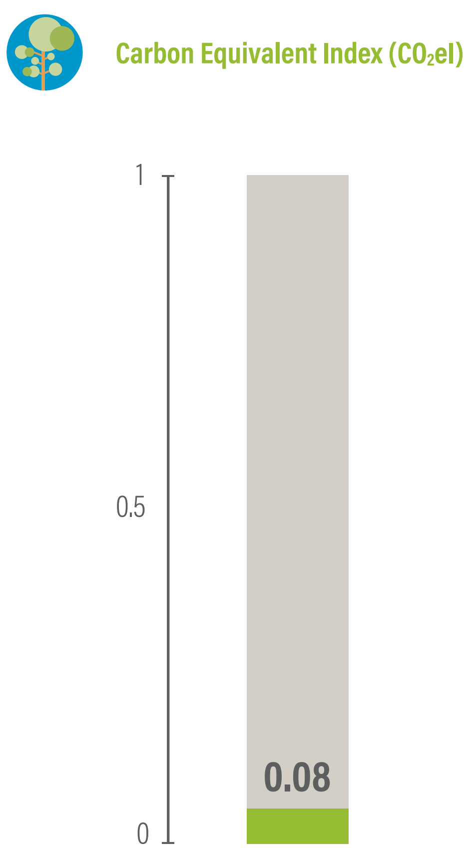
Carbon Equivalent Index (CO_2eI)

The Carbon Equivalent Index (CO_2eI)) measures the additional carbon captured through restoration actions within the landscape. The index is obtained by adding the areas by type of restoration during the study period. In El Salvador, for each type of restoration, its annual carbon contribution and its total contribution up until 2030 were determined. Based on the available information, a carbon gain of 221,623 t of CO_2e was estimated for 2016, which contrasts with the maximum potential of 2,707,195 t of CO_2e that is expected to be obtained if all the restoration activities estimated in the Action Plan for the Restoration of Ecosystems and Landscapes of El Salvador in 2030 are implemented (Figure ES 4).

Additional Workday Index (AWI)

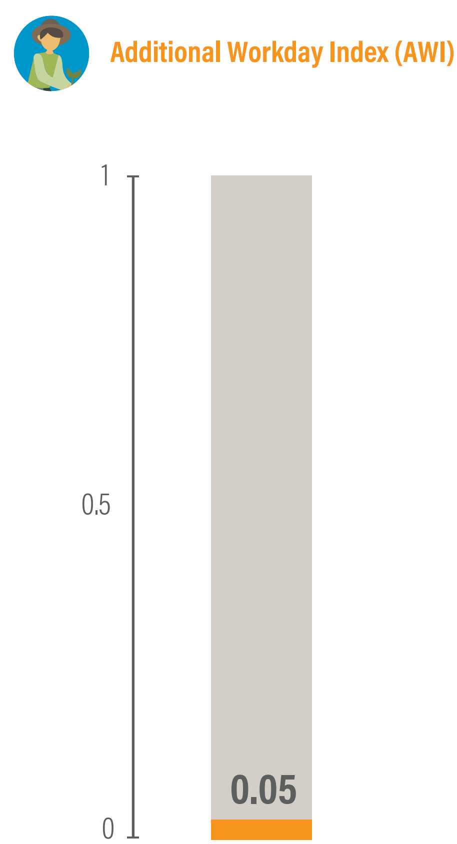
The Additional Workday Index is a measure that estimates the additional working days generated in restoration activities, both in their establishment and in their maintenance. A workday is equivalent to an effective full day of work. For the landscape under study it was determined that a total of 2.6 million additional workdays have been generated in the period between 2016 and 2018. The maximum potential number of additional workdays is 47.3 million if all restoration activities presented in the Action Plan for the Restoration of Ecosystems and Landscapes of El Salvador for the year 2030 were to be fulfilled. The index reported a value of 0.05 (Figure ES 5).

Figure ES 4 | Carbon Equivalent Index Results



Source: WRI and PRISMA, 2019

Figure ES 5 | Results of the Additional Workday Index

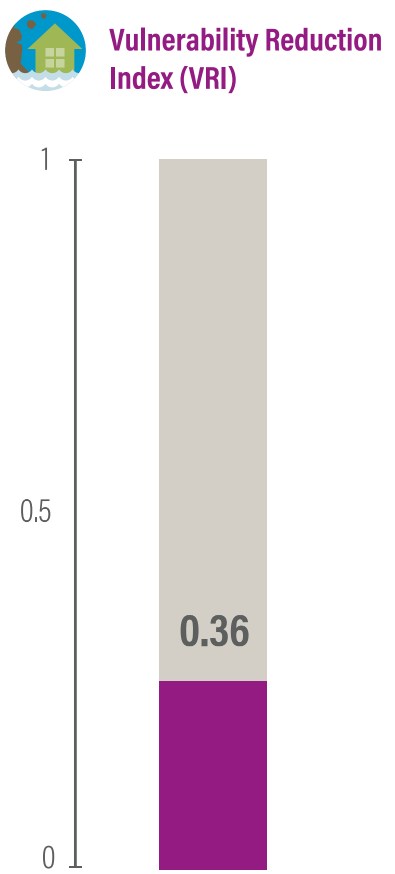


Source: WRI and PRISMA, 2019

Vulnerability Reduction Index (VRI)

The VRI is an indirect metric to estimate the reduction of vulnerability to natural factors. It is calculated from the data of a more complex index, the Risk Management Index (INFORM), which is calculated by MARN and responds to a global collaborative initiative of the Inter-Agency Standing Committee (IASC) and the European Commission. For the calculation of the VRI, only the hazard and exposure component in the natural hazard category was taken into account, from which the values corresponding to flood, landslide, and drought indexes are taken, as these are the factors that would potentially suffer impacts as a result of the restoration actions being carried out. The index value for this landscape is 0.36 (Figure ES 6).

Figure ES 6 | Results of the Vulnerability Reduction Index

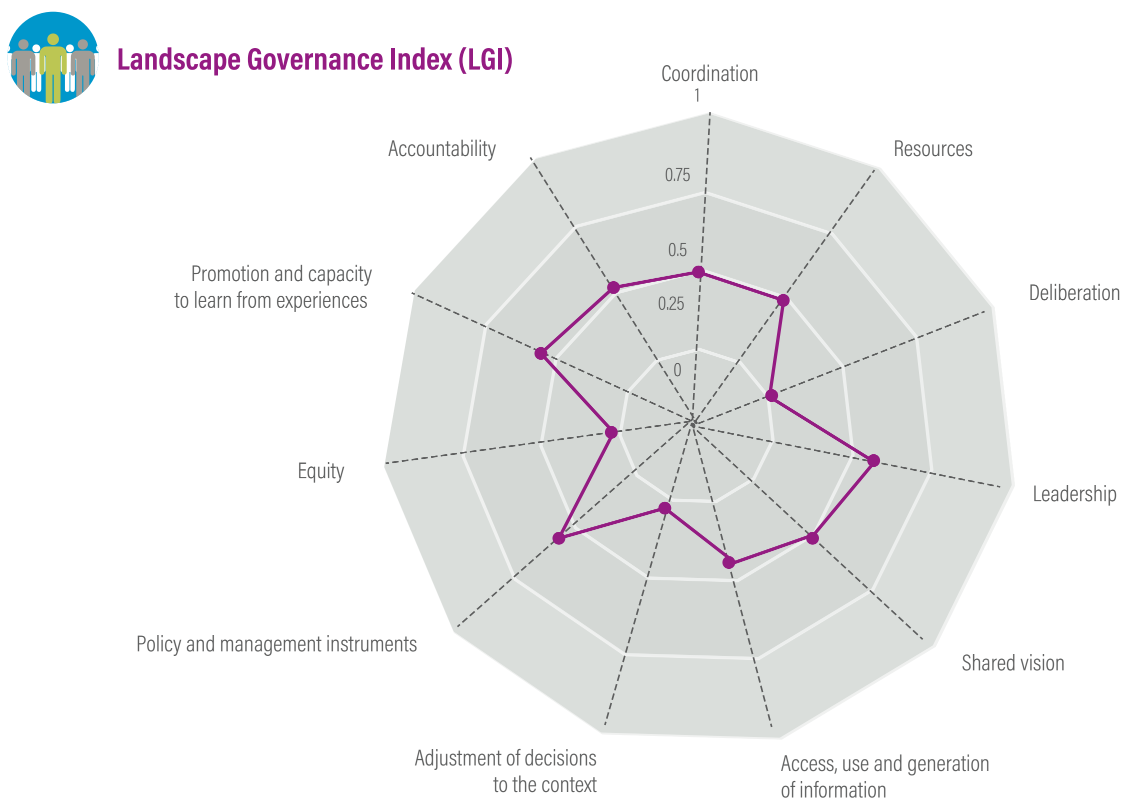


Source: WRI and PRISMA, 2019

Landscape Governance Index (LGI)

The LGI measures the governance situation for the management of a given landscape. This index measures different aspects of governance such as equity, leadership or, shared vision, among others. The index was calculated through surveys with focus groups on the landscape of interest. By applying the methodology described in this report, an LGI of 0.44 was obtained (Figure ES 7).

Figure ES 7 | Landscape Governance Index Results



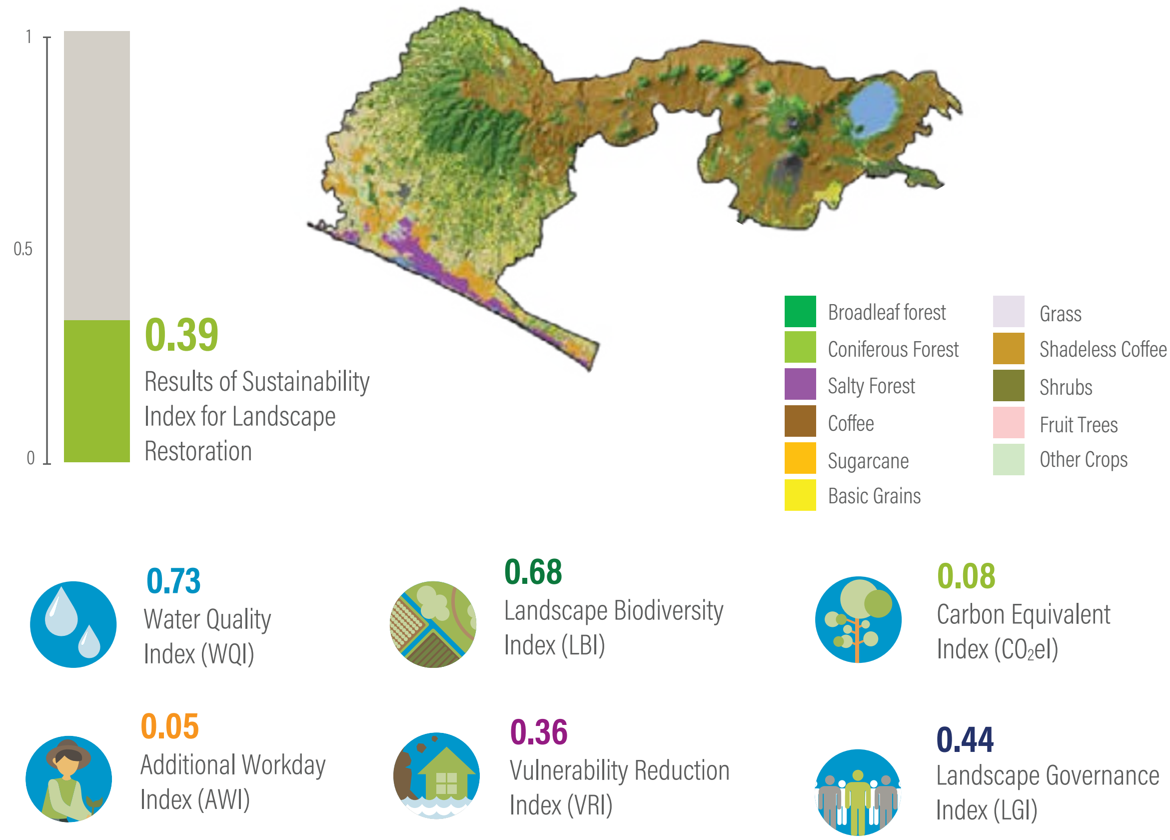
Source: WRI and PRISMA, 2019

Sustainability Index for the Restoration of El Imposible-Barra de Santiago and Apaneca-Ilamatepec

The SILR for the landscape of Imposible-Barra de Santiago and Apaneca-Ilamatepec in El Salvador reported a value of 0.39 by 2018 (Figure ES 8). The LBI and the WQI present the best ratings. In the case of the LBI, the result is related to the presence of three important forest masses: the country's most important natural protected area, the largest shaded coffee area, and an important mangrove. For its part, the WQI reports improvements in almost all of the country's rivers, of which 27% have increased their quality.

CO_2eI and AWI more clearly reflect the impact of restoration actions because the values included in their calculation come directly from the list of restoration actions reported by MARN. Due to the fact that these actions have been initiated recently, these indexes report the lowest values. The SILR is a broader monitoring, reporting, and verification system that reports on the country's progress in terms of local and national level adaptation-based mitigation.

Figure ES 8 | Sustainability Index Results for Landscape Restoration



Source: WRI and PRISMA, 2019

Regional Implications

The SILR has the potential to contribute to strengthening Latin American ecosystem and landscape restoration and management efforts. It is a useful tool to guide the delimitation of restoration actions based on more appropriate criteria of the landscapes' socio-environmental characteristics and dynamics, while promoting efforts that strengthen social capital and landscape governance.

The index can be easily applied as well as integrated into broader national level monitoring systems. Its application will help to improve the criteria for selecting and locating restoration actions from which to define calls for project proposals and priorities for directing international cooperation resources, in addition to promoting productive reconversion processes with private investments.

INTRODUCTION

Landscape restoration is a priority in many Latin American countries, both to reverse the degradation of natural resources in recent decades and to improve the quality of life of people in their territories. Many countries in the region have expressed their interest in restoring land through the Bonn Challenge[1] and the Initiative 20x20[2]. This interest can be seen through the collective setting of a restoration goal by 17 countries in the region that amounts to 53 million hectares of degraded landscapes. In these national targets, the objectives and expected impacts of restoration go beyond biophysical aspects such as forest recovery, improvement in water quality and quantity, improvement of soil quality or increase in carbon stocks. The goals also focus on improving the quality of life of rural populations that depend on the land, on agricultural production, on employment or on the conservation of biodiversity, among others.

In this sense, the countries implied have identified a set of restoration interventions such as agroforestry, silvopastoral systems, agroecology, reforestation and other activities that have the potential to recover the sustainability (health) of the landscape as a system.

Within the framework of this study, the landscape is considered as a geographical space formed by diverse land uses (patches of forest, agriculture and pastures, urban areas, etc.), which are interrelated and provide different ecosystem services, and in which diverse groups, companies, organizations or networks with different interests, capacities and power for decision-making also coexist. For practical and explanatory purposes, an example of a system is the human body. And just like the human body, a landscape can show a sign of degradation (disease) that can affect the production or quality of a resource or ecosystem service such as water or soil. In order to rehabilitate that function (healing) it is necessary to understand which are the priority landscape components (body organs) responsible for providing the services that have been affected by degradation and where are they distributed. Finally, restoration (seen as rehabilitation from disease) should be implemented in the priority areas, where it is expected to have an effect on the health of the landscape as a whole.

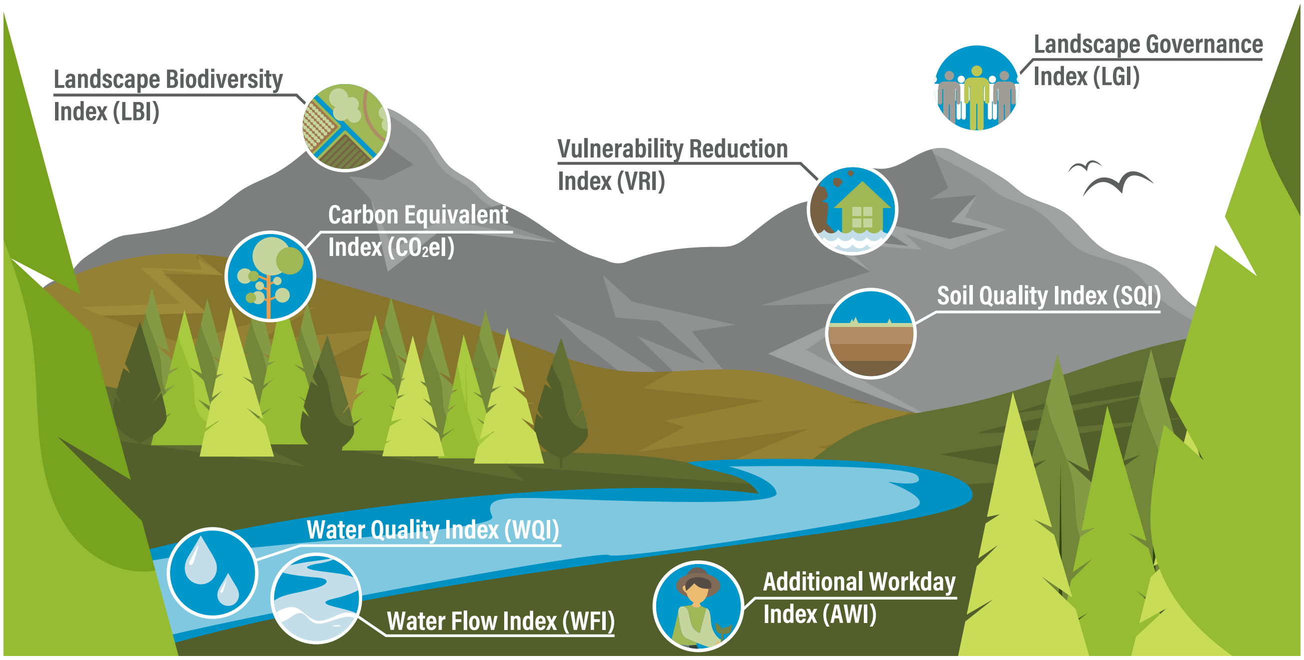
Starting from the definition of landscape as a system, and as restoration begins to be implemented, it is necessary to establish monitoring systems that allow decision makers in the public and private sectors to measure positive or negative changes in order to be able to locate correlations between restoration activities and the impacts achieved in the landscape of interest. For the monitoring system to be effective, a baseline should be established that allows for comparisons on the landscape from an initial scenario. Additionally, the input must be information that is available and cost-effective, in order to allow for a periodic, functional and traceable monitoring that lasts over time. Monitoring should facilitate the reporting of impacts to allow the transfer of information from the system to decision makers and those carrying out the restoration. Finally, the monitoring process must consider the validation of the information and its parameters.

This report presents the Sustainability Index for Landscape Restoration (SILR), which was designed in El Salvador, with the aim of being replicated in other countries in the region. The SILR has the potential to serve as a decision-making tool for governments and organizations that are carrying out restoration actions, including cooperation agencies and the private sector, so that these actions can be redirected in a timely manner to meet the objectives. This index has been applied to a pilot landscape in the country, comprised of two conservation areas: El Imposible-Barra de Santiago and Apaneca-Ilamatepec. This pilot application of the index serves as an entry point for determining the health of the landscape as a whole and for monitoring the relationship between restoration actions and the desired impacts.

The SILR constitutes a contribution to the transparency of restoration processes and to the consolidation of impact monitoring systems at a strategic level. The index is composed of a matrix of different indexes that provide specific information about key impacts established in the local development plans of the pilot landscapes and in the Ecosystem and Landscape Restoration Program (PREP). It consists of eight components: (1) the Water Quality Index (WQI), (2) the Water Flow Index (WFI), (3) the Landscape Biodiversity Index (LBI), (4) the Carbon Equivalent Index (CO_2eI), (5) the Soil Quality Index (SQI), (6) the Additional Workday Index (AWI), (7) the Vulnerability Reduction Index (VRI) and (8) the Landscape Governance Index (LGI). The methodology for the construction of the index can be implemented in various countries within and outside the Latin American region and has the flexibility to monitor and evaluate other components of interest (see Figure 1).

The components of the SILR may or may not be added in a modular form, according to the information available. In some cases, the information available is directly related to the restorative actions. For example, in the case of El Salvador, the Additional Carbon and Additional Workday Indexes give more direct information on the impact of the restoration actions carried out, while for the rest of the Indexes -Water Quality, Water Flow, Biodiversity, Soils, Vulnerability and Governance- the available information regarding impacts also includes the effect of factors external to the restoration actions. Later on, it will be seen that the Biodiversity Index includes the impact of restoration actions, but also

Figure 1 | Biophysical and socioeconomic components



Source: WRI and PRISMA, 2019

that of the natural regeneration that has taken place during the period of analysis.

Landscape monitoring approach

As mentioned earlier, a landscape is a system of different land uses that provides multiple services that affect (positively or negatively) human well-being. In landscape ecology, there are four laws or rules developed by Commoner (1971) that clearly exemplify the nature of landscapes. The first law states that **"everything is connected to everything"**, which has an important connotation for those landscapes whose intervention may affect surrounding or non-neighboring areas. The clearest example is at the basin level, where interventions at the top - such as forest cover removal - can have an effect at the bottom, sometimes by increasing drippings or generating floods. The second law refers to the fact that **"everything goes somewhere"**, which implies that any intervention within the landscape involves the transfer of an element within the system, be it nutrients, water, soil, etc. This movement can affect the availability of that element in one place and saturate its presence in other areas. Such is the case with erosion and nutrient loss, which can affect water quality in surrounding rivers, as well as soil fertility. The third law has to do with human impact on landscapes and states that **"nature does it better, but people decide".** This law is based on the fact that nature has a high capacity for resilience and adaptation to change. However, when there is human intervention, the capacity to regulate different biological and chemical cycles can be affected. Finally, the last law states that **"nothing comes from nothing"**. This law indicates that any event that occurs in the landscape has an underlying cause. Some examples are fires or floods, which may in turn be caused by loss of cover, land degradation or the effects of climate change.

Generally speaking, restoration is sought in priority areas within the landscape, in order to improve its condition as a whole. The improvement can be defined in terms of the impacts to be achieved in each landscape. In the case of landscape restoration there may be many desired impacts, including increased carbon stocks, better water quality and soil, improved biodiversity and improved living conditions for rural populations, among others. Monitoring these impacts at a landscape scale is key to determining if there is any progress towards the accomplishment of established goals and if there is a correlation between these and the actions being implemented.

From the above, the need arises to establish criteria to measure the changes in the system and to be able to establish the correlation of the changes with the implemented actions at a strategic level. This can lead to the spatial identification of areas that require tactical or operational monitoring to determine the causality of specific actions within the landscape.

Monitoring at a landscape scale is done strategically, so that changes in priority landscapes for restoration can be assessed. This need for monitoring can come from governments, which have an interest in estimating changes, guiding thus policies that facilitate the implementation of restoration in landscapes. These policies might in their turn allow for transparent reporting of changes and impacts achieved at different stages of the restoration process. Monitoring can also enable concerned individuals or communities to have a true and transparent estimate of changes in their landscape, and then to locate the most successful restoration activities and compare them with the objectives initially set. In addition, monitoring at this scale provides a framework for prioritizing monitoring actions at smaller scales (e.g., farm/land and parcel) and enablean adaptive management of landscape interventions.

El Salvador's Ecosystem and Landscape Restoration Program and the Sustainability Index for Landscape Restoration

The impacts associated with climate variability and change have been accentuated in the Central American and Caribbean regions and constitute another barrier to the countries' development processes (ECLAC 2015). According to the latest report of the Intergovernmental Panel on Climate Change (IPCC), future scenarios are worrying for the Central American region, as they point to droughts, more intense midsummer heat and historically unprecedented heat waves. Likewise, there is a high probability that the El Niño Southern Oscillation (ENSO) phenomena will intensify rainfall, increasing the probability of floods and landslides (IPCC 2013, quoted in MARN 2017).

The region has been recognized for its high vulnerability to climate variability and change in global negotiation spaces (PRISMA 2013). Faced with this reality, countries are promoting strategies and programs aimed at reducing vulnerability and strengthening adaptation capacities.

As an example, El Salvador formulated the National Environmental Policy (GOES 2012) in 2012. One of the components of this policy is the restoration and conservation of ecosystems to reduce risks, sustain productive activities and advance on the adaptation to climate change (MARN 2013). The National Ecosystem and Landscape Restoration Program (PREP, in Spanish) was created within this framework to establish synergies with the other components of the policy: biodiversity, environmental sanitation, water resources and the National Climate Change Plan (PRISMA 2015).

The PREP was designed under a novel approach and adjusted to the context of climate change that the country is facing: the Adaptation-based Mitigation (AbM) approach that seeks to take advantage of the co-benefits for mitigation that can be generated through adaptative actions (GOES 2013; PRISMA 2013). Specifically, the approach implies that adaptation and mitigation objectives must be explicitly formulated in the planning of the different restoration actions to ensure the strengthening of community resources of the populations involved, besides increasing carbon capture and storage in vegetation and soil (Kongsager and Corbera 2015). The PREP is also the framework under which El Salvador made a commitment in 2012 to restore one million hectares by 2030, as a country's response to the Bonn Challenge and the Initiative 20x20.

Through the PREP, it is hoped that the most vulnerable practices around variability and change will be transformed. The Ministry of Environment and Natural Resources of El Salvador (MARN, in Spanish), with the support of the International Union for the Conservation of Nature (IUCN), has generated tools and instruments to help prioritize and cover PREP actions. From this effort, a set of 49 measures was specified, including agroforestry and silvopastoral practices, changes of harvesting practices in some crops, and restorative actions through native forest reforestation and ecological restoration of mangroves (ERM). Additionally, priority was given to degraded areas requiring urgent intervention within the PREP, and this was consolidated in El Salvador's Action Plan for Ecosystem and Landscape Restoration (MARN 2017).

An important element of the PREP is the monitoring of restoration actions taking place and the impacts of these actions. Currently, many initiatives on restoration monitoring focus on mitigation, which leaves adaptation in the background. However, in El Salvador, monitoring and evaluation must respond to the AbM approach to restoration and must therefore be framed in terms of both measuring progress in mitigation and measuring progress in adaptation (Ndamani and Watanabe 2017). Acknowledging the need for this approach, the SIRL to be generated must describe quantitatively and qualitatively the impact of restoration actions on various aspects related to climate change and adaptation.

As already mentioned, the SIRL is a measure of the biophysical and socioeconomic impacts of restoration actions on a landscape and it is composed of eight indexes. These components capture the relevance of the different dimensions of climate change mitigation and adaptation (Table 1).

Table 1 | Summary of Index components and targets

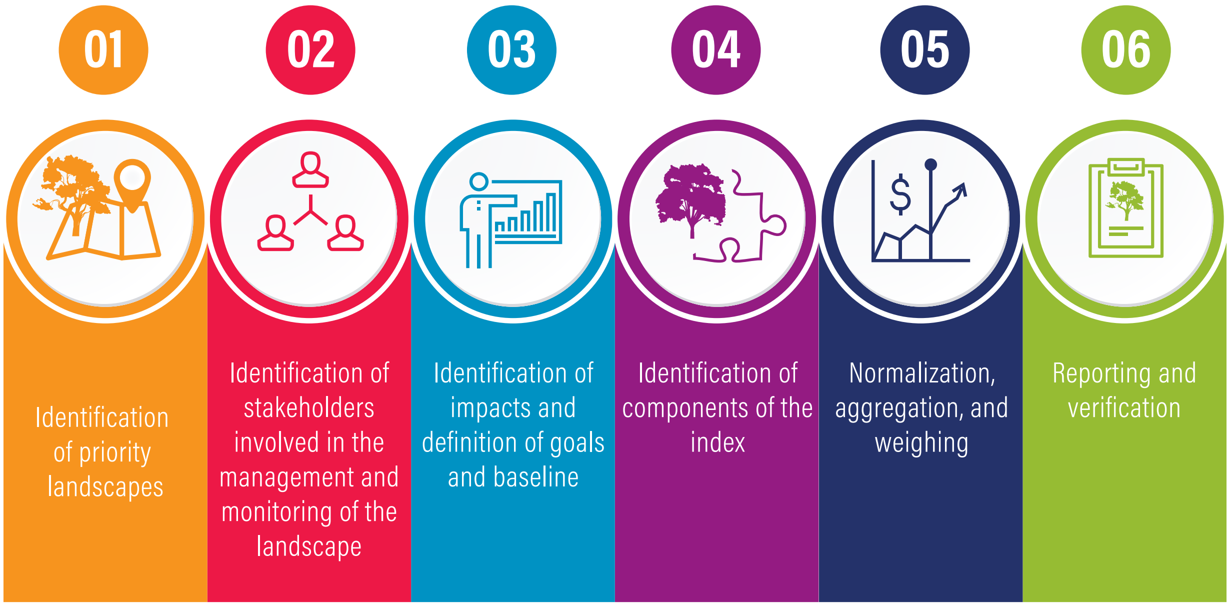
INDEX	GOAL
Water Quality Index (WQI) and Water Flow Index (WFI)	To improve water regulation and water quality
Landscape Biodiversity Index (LBI)	To protect biodiversity
Soil Quality Index (SQI)	To reduce erosion and to improve soil quality
Vulnerability Reduction Index (VRI)	To reduce vulnerability to environmental risk
Additional Workday Index (AWI); Landscape Governance Index (LGI)	To improve community resources and governance of landscape management
Carbon Equivalent Index (CO_2eI)	To increase carbon stocks (mitigation)

METHODOLOGY FOR THE SUSTAINABILITY INDEX FOR LANDSCAPE RESTORATION

The SILR arises from the need to establish a measure that can estimate changes in the landscape in relation to the impacts of the restoration actions carried out.

The following steps were taken to develop the index: (1) identification of priority landscapes; (2) identification of stakeholders involved in the management and monitoring of the landscape; (3) identification of impacts and definition of goals and baseline; (4) identification of components of the index; (5) normalization, aggregation and weighing, and (6) reporting and verification (Figure 2).

Figure 2 | Steps for the generation of the SILR



Source: WRI and PRISMA, 2019.

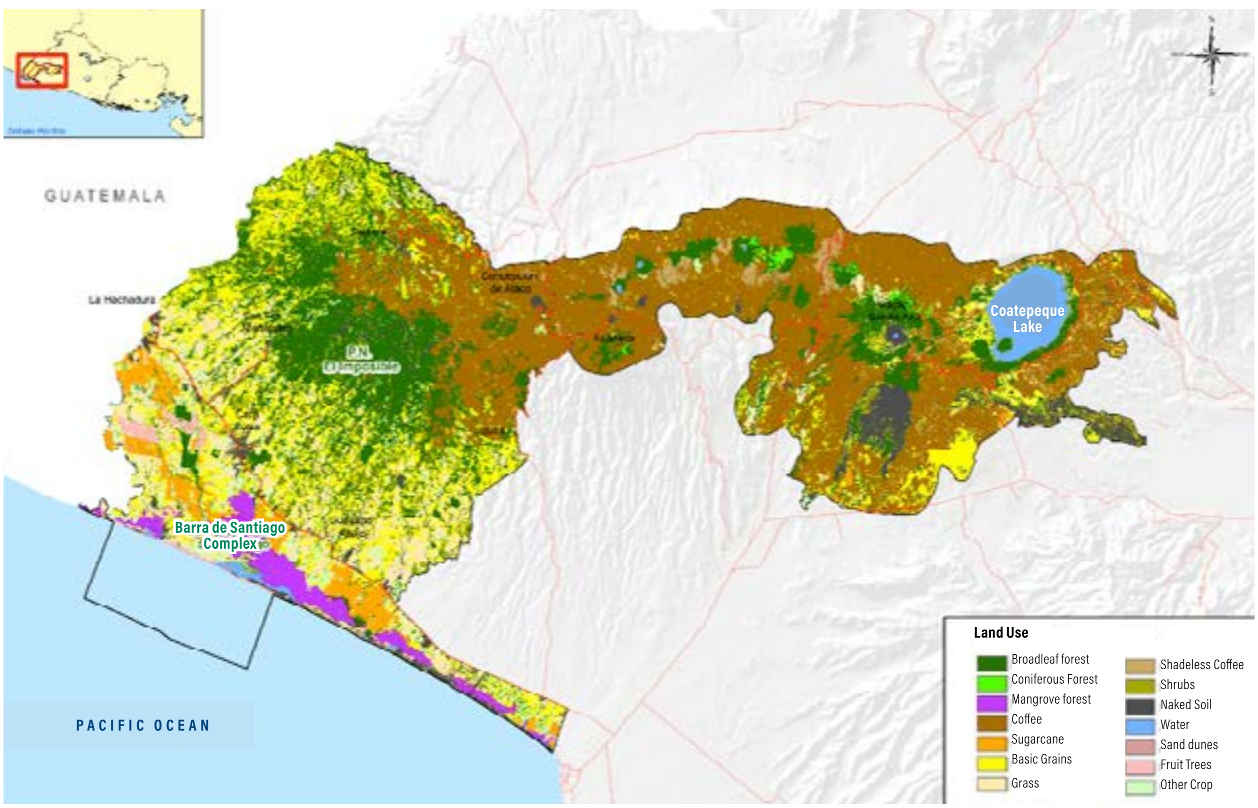
Identification of priority landscapes

One of the first steps in the landscape monitoring process is to define the priority landscapes in which restoration impacts will be monitored. These areas should be prioritized according to the objectives for reversing degradation in a given region.

In the case of El Salvador, the index was applied to a pilot landscape, made up of two conservation areas: El Imposible-Barra de Santiago and Apaneca-Ilamatepec. The landscape reaches approximately 120,000 hectares and is located in the southwestern part of the country, where restoration actions in several areas are already taking place.

This landscape contains the largest protected area in the country (El Imposible National Park) a RAMSAR site (Barra de Santiago) and a biosphere reserve (Apaneca-Ilamatepec). Additionally, the country's most important shaded coffee plantations and a productive mosaic that includes sugarcane, basic grains and cattle ranching, among others, are located here, generating one of the most diverse landscapes in El Salvador (Figure 3).

Figure 3 | Landscape El Imposible - Barra de Santiago – Apaneca-Ilamatepec



Source: WRI and PRISMA, 2019

Identification of stakeholders involved in landscape management and monitoring

An important aspect in the construction of the index is the identification of key stakeholders that are managing the landscape, such as local communities that will benefit from restoration actions or actors that carry out monitoring actions at different levels and that are able to produce relevant information for the monitoring system. This process allows the collection of the most suitable information for monitoring and the identification of synergies between relevant stakeholders. It is also important to identify the end users of the information that is being generated and that which is expected with the monitoring at a landscape scale, such as the local and national governments that are reporting the progress of their restoration goals.

In the case of El Salvador, it was identified that monitoring is of great interest to several organizations and projects linked to restoration, as well as to cooperation agencies in El Salvador (PRISMA 2017). In order to identify the stakeholders, the Social Landscape Methodology developed by Buckingham et al. (2018) was implemented; this allows for the mapping of key actors, the links between them, and their levels of influence.

The set of organizations and projects that are addressing the issue of monitoring in the country are interested in different aspects of restoration and use different methodologies, mostly focused on monitoring issues of interest such as tree coverage and carbon stocks, but also on biodiversity in natural protected areas. Soil is another topic of interest, and so is hydrological monitoring. This approach from the organizations and projects is favorable to the country, since it represents a demand for much needed information for the adequate formulation of policies and plans. This demand contributes to making information increasingly accessible; it also opens up opportunities for the establishment of protocols and agreements between institutions, both public and private, to share information.

Given the number of stakeholders focused on the issue of monitoring restoration, good communication among them is very important. This helps establish synergies and prevents the duplication of efforts. To promote it, MARN has organized several meetings and workshops so that all agents can learn about other efforts in the field. This type of dynamics in which stakeholders get to know each other and exchange efforts is key to achieving synergies and increasing knowledge about monitoring techniques and functions.

As a result of this effort, a support group was formed in order to formulate the SILR. This group has included most of the agents working on monitoring issues and, during four months, met periodically to discuss and validate the methodologies for each one of the indexes that would make up the SILR. Table 2 shows, arranged by topic, the stakeholders involved in monitoring activities in the country, the methodologies used and the information currently being generated, as well as the scale for monitoring.

Table 2 | Monitoring of restoration in El Salvador: issues of interest and stakeholders involved

TOPICS INVOLVED ON THE MONITORING	ACCOUNTABLE ORGANIZATION	INFORMATION GENERATED	METHODOLOGY USED	SCALE
Forests: cover, biomass, carbon stock	- MARN, GIZ Natural History - REDD+ MBA, CATIE - UICN	Forest inventory, phytosanitary state Forest cover and benefits, forest and non-forest maps, land use map Restoration barometer	Teledetection, establishment of plots in the field	National
Soil: carbon stock in soil, quality of soil	- Facultad de Ciencias Agronómicas-UES - CRS, CENTA, CENTA-CAFÉ - MARN La Montañona	Carbon stock in soil Database of physic-chemical properties Digital mapping of soil Fertility analysis	Experimental plots Plot sampling, lab analysis	National Local: La Montañona
Biodiversity	- GIZ - GEF-Humedales - MARN La Montañona	Fragmentation Indexes and landscape connectivity Indexes and biodiversity markers Soil macro-fauna	Patch or fragment matrix analysis Trans-sections, counting points, lab tests, modeling Land Degradation Surveillance Framework (LDSF)	Local: Barra de Santiago, El Imposible Local: Jaltepeque, Jiquilisco and laguna El Jocotal Local: La Montañona
Restoration actions	- Dirección de Ecosistemas y Vida Silvestre (MARN) (Direction of Ecosystems and Wildlife, MARN) - FIAES	Transitional use of soil (techniques), number of hectares, number of trees Agro-productive systems, mangroves, green employment, sea turtles, forest	Information input on official forms Index elaboration based on primary information	National Municipal

Source: WRI and PRISMA, 2019

Identification of impacts and definition of targets and baseline

Once a group of stakeholders has been formed to inform and support the restoration monitoring process, a consensus must be reached on the focus of the impacts to be monitored. Degradation processes are the result of different types of pressures and, therefore, the remediation processes are far from their objectives according to the new potential of the landscape and the presence of pressure factors. Additionally, each restoration process is likely to start from a different situation. For these reasons, it is important to define the impacts of interest, the initial situation from which changes will be reviewed, and the goals pursued in a given period by the remediation activities.

In the case of El Salvador, officials from MARN, the Ministry of Agriculture and the Cabinet of Environmental Sustainability and Vulnerability have identified positive impacts that need to be promoted in the target landscape. For each impact established within the Ecosystem and Landscape Restoration Program, goals to be achieved were defined within certain timeframes. The priorities of the local stakeholders, expressed in the Local Development Plans (Cobar 2016), were also considered. The ideal scenario for restoration interventions resulting from the application of the Restoration Opportunities Methodology (ROAM) (IUCN and WRI 2014) was taken as the basis for some indexes. **These goals have been framed in the following objectives:**

a) To achieve a Water Quality Index in major rivers within the landscape with an excellent level, capable of sustaining a diversity of aquatic life and having a suitable environment for all forms of life in contact with it.

b) To maintain the current water flow in major rivers in the landscape during the dry season.

c) To increase the current connectivity of forests within the landscape.

d) To increase carbon stocks by implementing the restoration activities expressed in the Action Plan for Ecosystem and Landscape Restoration of El Salvador.

e) To increase the percentage of organic matter in the soil at landscape level.

f) To increase the number of direct workdays used in the implementation of restoration activities expressed in the Action Plan for Ecosystem and Landscape Restoration of El Salvador.

g) To reduce the vulnerability of populations within the landscape to droughts, floods and landslides.

h) To improve governance in the landscape to a level that allows coordination, equity and the development of positive leadership that contributes to landscape restoration.

A baseline is required as a reference in order to be able to compare the changes that have occurred during the time that restoration actions are being carried out. In the case of El Salvador, 2011 was defined as the baseline year, which corresponds to the year the Bonn Challenge was launched. However, for that year, much of the information needed to establish the baseline could not be found. For this reason, different baselines were selected according to the information available. In order to make visible the impacts associated with the implementation of restoration practices, a minimum periodicity of three years was established for the calculation of the Index.

Identification of the components of the Index and process of construction with stakeholders

The Sustainability Index for Landscape Restoration (SILR) is a tool designed to report the impacts of restoration on various aspects related to mitigation and adaptation to climate change and restoration actions, which allows a correlation between these to be estimated. Its elements or indexes give a measurement on the sustainability of the landscape. Each of them has been calculated with different methodologies and their results have been normalized to be part of the Index.

The criteria for the selection of each of the elements of the Index were three: (1) the correlation with the restoration actions, (2) the feasibility of obtaining the information required for its calculation and (3) its applicability, that is, that the methodology for calculating it was simple and easy to apply. The SILR is then obtained by averaging the indexes that build it up.

The information for the calculation of the SILR comes mostly from different MARN agencies, including the Dirección de Ecosistemas y Vida Silvestre (Direction of Ecosystems and Wildlife), the Gerencia de Información Geoambiental (Office of Geoenvironmental Information) and the Observatorio Ambiental (Environmental Observatory). Information was also requested from the Centro Nacional de Tecnología Agropecuaria y Forestal (CENTA, for National Center for Agricultural and Forestry Technology) on the topic of soils.

The country has made progress in setting up a National Integrated Monitoring System on REDD+ and AbM –an information management system that will make it possible in the short term to connect the different computer platforms that generate environmental data– to carry out consultations and integrated analysis, and thus provide answers to the different information requirements at the national and international levels. The SILR will be one of the outputs provided by this system. However, it is deemed necessary that another unit, directly linked to the issue of restoration, be in charge of the analysis of the information required for the calculation of the Index and the subsequent analysis of its results.

In the case of El Salvador, the MARN will be in charge of calculating the Index through the Office of Geoenvironmental Information, which is part of the MARN Environmental Observatory.

$$ISP = \frac{(WQI + LBI + SQI + CO_2el + LGI + WFI + VRI + AWI)}{8}$$

Where:

SILR - Sustainability Index for Landscape Restoration

WQI - Water Quality Index

LBI= Landscape Biodiversity Index

CO_2el = Carbon Equivalent Index

SQI= Soil Quality Index

LGI= Landscape Governance Index

WFI= Water Flow Index

VRI= Vulnerability Reduction Index

AWI= Additional Workday Index

Normalization, aggregation and weighing

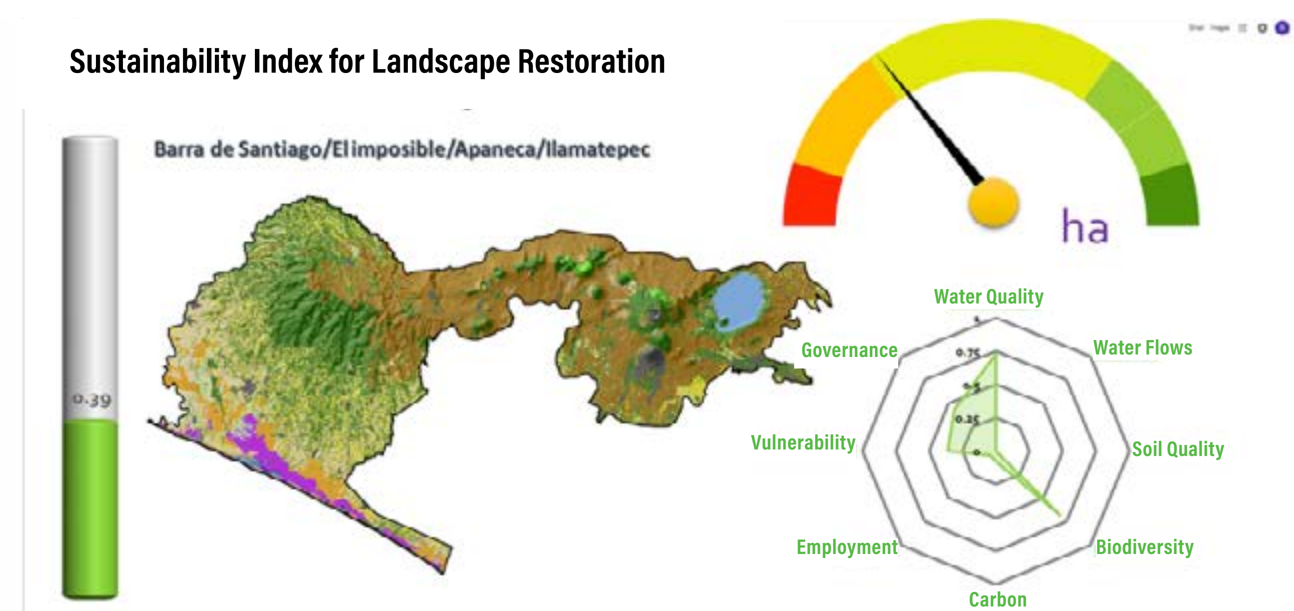
Normalization is intended to provide a value within a common scale to the rating of each component of the index. The index's technical coordination team defined a scale of 0 (zero) to 1, where zero represents a degraded state and 1 is the maximum value once the targets have been achieved, as it indicates a sustainable landscape. It is expected that the index values will increase as the landscape is restored. With a value of 1, all the indexes that make up the SILR would be at their maximum value and the desired progress in Adaptation-based Mitigation would have been achieved.

Weighing is an option if certain components are given a greater importance than others. It is crucial to mention that, in El Salvador, it was decided not to assign different weights to each of the components of the SILR, since this would acknowledge an equal significance to each of them. This is also because the approach that guides the PREP –Adaptation-based Mitigation– seeks to meet mitigation goals through restoration actions that are focused on adaptation. This results in a "mitigation-adaptation" duet, in which both have the same degree of importance. However, the design of the Index allows for changes in the weighing of the components, or even the removal or addition of new ones, according to the context in which it is applied.

Reporting and verification

As mentioned above, the SILR is produced in order to provide information for decision-making processes, especially if goals are not being achieved at the necessary speed or if there is a setback from the baseline. Figure 4 shows an online reporting and verification system in which the value of the Index and its components, as well as a map of the landscape with the different land uses, can be seen. At a strategic level, the Index represents the point of departure towards tactical and operational analysis that would lead to concrete actions. The report should include, as a minimum, the number

Figure 4 | Vision of an online reporting and verification system



Source: WRI and PRISMA, 2019

of hectares on which intervention is made to restore the landscape, the index that adds up sustainability in relation to the stated goals and, finally, each of the components.

Range and limitations

The SILR was developed with a focus on a landscape scale in which the impacts of interest and their correlation with restoration activities are measured. The index is a strategic decision-making supporting tool that determines different relationships between interventions and actual impacts on the landscape. This approach can also help determine the spatial effect of actions for those spatially explicit indexes and allow for a better understanding of socio-economic factors such as governance. It is important to note that the Index is intended to estimate the correlation, not the causality, between restoration actions and their associated impacts. To determine causality, it is necessary to lower the level of monitoring to a smaller scale (e.g. project, farm or estate); to recollect evidence of how different landscape components and their uses are connected and affect each other, and to identify mediating or confusing variables that, when not taken into account, can lead to false correlations between interventions and impacts.

Currently, different countries present the number of hectares in projects that have been implemented in the territory as a measurement for restoration. If we return to the example of the human body presented in the introduction to this report, the Index allows us, as a point of departure, to assess whether the patient is sick or healthy. However, in order to determine the cause of their health status, it is necessary to make more exhaustive evaluations that require a greater volume of resources that can then be allocated to support local stakeholders or private owners (communities and individuals) to carry out these measurements.

Beyond the discussion of correlation and causality, each calculated index has a margin of error associated both with its calculation and with the base information used for it. The limitations of each component are shown in the annexes.

METHOD OF CALCULATION OF THE COMPONENTS

For each component of the Sustainability Index, the necessary elements were defined for the compilation of information, its calculation and the analysis of the results it provides. The proposed methods were selected based on the restoration objectives, the available information, the cost-effectiveness of collecting and processing it, and the frequency of collection, among other aspects. For each component, a range of values and some keys for their interpretation are considered, as well as a normalization for the calculation of the total SILR value for the landscape of interest.

Water Quality Index (WQI)

The Water Quality Index (WQI) is a measure that shows the quality of the water present in the country's surface water bodies, according to the parameters and guide values used by MARN, which has been permanently monitoring water quality since 2006 through a monitoring network covering 55 of the country's rivers and 115 stations (MARN 2017). The WQI classifies the water quality of the rivers analyzed in relation to their general condition to enable the development of aquatic life and their suitability for various uses. The index adopts the maximum value of 100 for optimal conditions and decreases when pollution increases, until it reaches the minimum value of 0, as shown in Annex 1.

MARN calculates the WQI each year taking into account nine parameters, based on the Brown Index formula (Brown et al. 1971) as shown below:

$$WQI_a = \sum_{i=1}^{9} (Sub_i * w_i)$$

To determine the value of the WQI it is necessary to substitute the data in the above equation by obtaining the sub-indexes (Sub_i) from default graphs (see Annex 1). The resulting values are multiplied by their respective w_i , which are constant values, equivalent to the weighing assigned to each of the parameters (Table 3)

The results obtained will fall in a range of between 0 and 100, so they should be normalized to fit in a range between 0 and 1 within the SILR.

Water Flow Index

The water flow is the amount of water per unit of time in the rivers. MARN monitors the flow of the main rivers through 28 stations; however, this information is not adequate to measure the expected impacts of restoration practices. Changes in water flows related to restoration would not be easily perceived in the country's main rivers as they have higher flows and come from multiple sites. This rules out the possibility of using information from such monitoring.

However, the importance of water provision makes it necessary to include a water flow index in the SILR. Therefore, the implementation of a water flow monitoring system on a micro-basin scale is suggested. Under this scheme, an ideal water flow value can be established (determined according to the demand of the region and the biophysical limits) and a rating from 0 to 1 can be set, where 1 represents the ideal water flow. In this local monitoring system, the Red de Observadores Locales Ambientales (Network of Local Environmental Observers, ROLAS in Spanish) would play a leading role. They would be trained in the proper monitoring of water flows, either with limnimeters or in the use of other more rudimentary methods, such as a float. In this way, a series of valuable information on flow fluctuations in small rivers would be available, and this could be compared with the

Table 3 | Parameters and their weighing for the WQI

i	Sub_i	w_i
1	Fecal coliforms	0.15
2	pH	0.12
3	DBO_5	0.10
4	Nitrates	0.10
5	Phosphates	0.10
6	Temperature change	0.10
7	Turbidity	0.08
8	Total dissolved solids	0.08
9	Dissolved oxygen saturation	0.17

dynamics of rainfall in previous months and then correlated with restoration practices carried out. The information collected through the ROLAS can be transferred to the Environmental Observatory to be processed by MARN.

Landscape Biodiversity Index (LBI)

The Landscape Biodiversity Index (LBI) is an index composed of five landscape indexes, which are numerical measures used in landscape ecology to report on the composition and configuration of landscapes, the proportion of each soil's cover, the morphology of landscape elements, the fragmentation of the landscape and the connectivity that exists between its components (Vila 2006). These indexes allow for the comparison between different landscapes or changes in the same landscape over time. They also have the potential to establish future scenarios in a given landscape (Salazar et al. 2016). The analysis can be done on three levels: fragment or patch level, class level (land use types) and the general landscape level. With increased connectivity, it is expected that the habitat for certain species and the ability of wildlife species to move would improve.

Five landscape indexes were selected to form the LBI. First, the Perimeter-Area Fractal Dimension (PAFRAC) explains the complexity in the shape of each of the patches of the same type of land use (class), which can range from very simple ones –squares or rectangles (in the case of crops)– to more complex shapes, typical of a forest. Secondly, the Percentage of Landscape (PLAND) shows the percentage of the area that each class occupies in the landscape. As a third point, the Number of Patches (NP) expresses the fragmentation of a certain class or of the landscape in general. As a fourth aggregate, the Largest Patch Index (LPI) is an index of dominance showing the area of the largest fragment for each of the classes. Finally, the Contagion Index (CONTAG) indicates the potential for connectivity in the landscape. A land use map is needed as a point of departure for its calculation. In case updates are lacking, open access mapping techniques, such as Collect Earth (Bey et al. 2016), can be used to produce updates based on current information.

To calculate the landscape indexes, there are several programs such as Grass, Patch Analyst, V-late and Fragstats, among others. In the case of El Salvador, Fragstats version 4.2 has been used because it has the scientific backing of Oregon State University in terms of diversity and capacity to develop metric calculations[3].

It is important to take into account that the analysis of the results of these landscape indexes must be carried out jointly, since they complement each other and are calculated from an average between all of them. Table 4 contains the keys to the interpretation of the five indexes. Each of them is analyzed with different ranges, therefore, it has been necessary to normalize them so that they can be entered first into the LBI and then into the SILR.

Table 4 | Interpretation, classification and normalization of the indexes that make up the LBI

Perimeter-Area Fractal Dimension (PAFRAC)[4]
Range: 1≤ PAFRAC ≤ 2
A PAFRAC greater than 1 for a two-dimensional landscape mosaic indicates an increase in the complexity of the patch shape. PAFRAC approaches 1 for shapes with very simple perimeters—such as squares involving crop areas, for example—and it approaches 2 for shapes with highly complicated plane filling perimeter.

Classification	1.0 to 1.2	1.21 to 1.4	1.41 to 1.6	1.61 to 1.8	1.81 to 2
Rating	Poor	Regular	Good	Very Good	Excellent
Normalization for LBI	0 to 0.2	0.21 to 0.4	0.41 to 0.6	0.61 to 0.8	0.81 to 1.0

Total class area (CA)[5]
CA≥ 0, unbounded
CA approaches 0 (zero) as the type of patch becomes increasingly rare in the landscape. CA = TA (total area of the landscape) when the entire landscape consists of a single type of patch; i.e., when the entire image consists of a single patch.

Percentage of Landscape (PLAND)[6]
0 ≤ PLAND ≤ 100

The Percentage of Landscape quantifies the proportional abundance of each type of landscape fragment. It is a measure of landscape composition, important in many ecological applications.

PLAND approaches 0 (zero) when the corresponding patch type (class) in the landscape progressively becomes rare in the landscape. PLAND=100 when the landscape is composed entirely of a single patch type; i.e., when the entire image on the map is represented by a single type or class of land use.

Classification	0 to 15	16 to 25	26 to 35	36 to 45	46 to 70
Rating	Poor	Regular	Good	Very Good	Excellent
Normalization for LBI	0 to 0.2	0.21 to 0.4	0.41 to 0.6	0.61 to 0.8	0.81 to 1.0

Number of Patches (NP)
NP ≥ 1, unbounded
NP = 1 when the landscape contains only one patch of the corresponding type patch; i.e., when the class consists of only one patch.

Classification for LBI

0 to 0.2 **Poor**	0.21 to 0.35 **Regular**	0.36 to 0.55 **Good**	0.56 to 0.7 **Very good**	0.71 to 1 **Excellent**
The classes corresponding to forest and coffee are atomized (with many patches) and do not occupy 25% of the landscape.	The classes corresponding to forest and coffee are atomized (with many patches) and do not occupy 25% of the landscape.	The classes corresponding to forest and coffee are not so fragmented but reach only between 26 and 45% of the landscape.	The classes corresponding to forest and coffee are not so fragmented and cover more than 46% of the landscape.	The classes corresponding to forest and coffee have very little fragmentation and cover more than 45% of the landscape.

Largest Patch Index (LPI)

LPI equals the area (m^2) of the largest patch in the landscape divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage). In other words, LPI is equal to the percentage of the landscape comprising the largest patch.

$0 \leq LPI \leq 100$

LPI approaches 0 (zero) as the largest patch in the landscape gets smaller. LPI = 100 when the entire landscape consists of a single patch; that is, when the largest patch comprises 100% of the landscape.

The Largest Patch Index quantifies the percentage of the total landscape area covered by the largest patch. As such, it is a simple measure of extension.

Classification for LBI

0 to 0.2 **Poor**	0.21 to 0.35 **Regular**	0.36 to 0.55 **Good**	0.56 to 0.7 **Very good**	0.71 to 1 **Excellent**
All highest LPI values are for basic grains, grasses, and other land uses.	The highest LPI values are distributed between basic grains and grass, forests, and shaded coffee.	The highest LPI values for forest and coffee with leftovers are slightly higher than the values for basic grains and grasses.	Most LPI values are for forest and shaded coffee.	All the highest LPI values are for forest and shaded coffee.

Contagion Index (CONTAG)

Contagion explains the extent to which patch types are aggregated or grouped (i.e., dispersed). Higher values of contagion may result from landscapes with some large, contiguous patches, while lower values generally characterize landscapes with many small, scattered patches.

$0 < CONTAG < 100$

CONTAG approaches 0 (zero) when patch types are fully disaggregated and intermixed.

CONTAG = 100 when all patch types are aggregated to the maximum.

Classification	0 to 20	21 to 35	36 to 55	56 to 75	71 to 100
Rating	Poor	Regular	Good	Very Good	Excellent
Normalization for LBI	0 to 0.2	0.21 to 0.35	0.36 to 0.55	0.56 to 0.70	0.71 to 1.0

Once the five indexes have been calculated and normalized, the LBI can be calculated by averaging the five values:

$$LBI = \frac{(PAFRAC + PLAND + NP + LPI + CONTAG)}{5}$$

The LBI ranges between 0 and 1. When the value is equal to 1, it indicates that the landscape has sufficient attributes to protect the biodiversity it holds. The index decreases as the degree of degradation of the landscape increases.

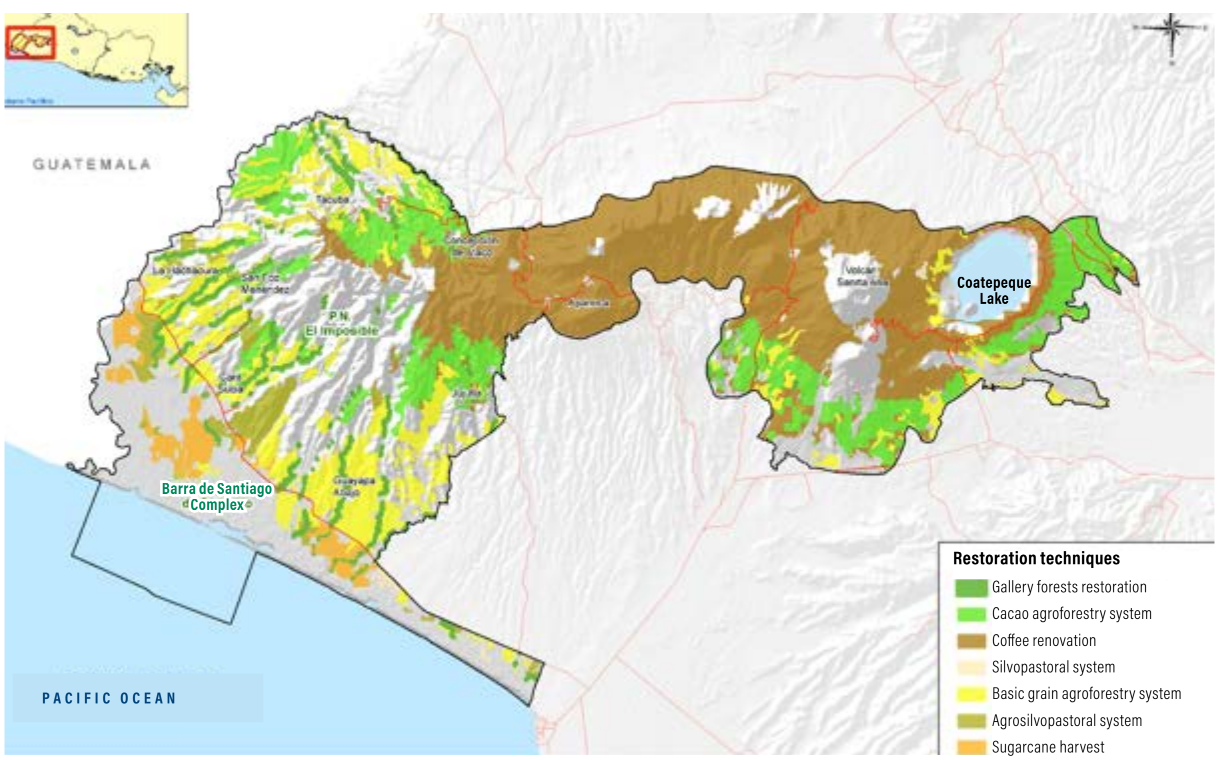
Carbon Equivalent Index (CO_2eI)

The Carbon Equivalent Index (CO_2eI) refers to climate change mitigation. That is, the impact of restoration actions on the carbon equivalent balance that seeks to fix additional carbon to the existing stock[7]. The CO_2eI is given by:

$$CO_2eI = \frac{(\text{Current } CO_2e \text{ gain - Minimum value})}{(\text{Maximum value - Minimum value})}$$

This calculation requires the determination of minimum and maximum values. The maximum value is the maximum amount of carbon equivalent that would be stored if the entire area proposed in El Salvador's Action Plan for Ecosystem and Landscape Restoration (MARN 2017a) were restored. On a national scale, this represents the stock of additional carbon when the target of one million hectares restored is reached. To calculate this maximum expected value in the landscape under study,

Figure 5 | Restoration techniques proposed in the map of restoration priorities



Source: self-elaboration

the Map of Priority Restoration and Opportunities for Transition to Restoration was used, particularly considering the section on the landscape under study from the national scale map contained in the Action Plan (see Figure 5). From this, the number of potential hectares for restoration, and for each of the practices proposed in the Plan was calculated.

By multiplying these hectares by the values of the carbon equivalent balance per hectare, according to the calculations made by Raes et al. (2017), the amount of carbon equivalent stored for each of the proposed practices in the landscape can be obtained. The sum of the values obtained would be the maximum expected value of carbon equivalent stored when implementing all practices.

The minimum value represents the amount of carbon equivalent that would be stored if the restoration actions were not carried out. This would theoretically give a value of 0 (zero), as the carbon that could be stored would not result from restoration practices. This implies that the CO_2eI will range between 0 and 1. The index value will be closer to 1 as it approaches the expected target of maximum carbon equivalent stored as a result of restoration.

The current gain in carbon equivalent is obtained by adding the carbon balance attributed to each of the practices reported by MARN in the period of study and its corresponding areas. Table 5 presents the classification of values for this index.

Table 5 | Rating values for the CO_2eI

Value Range	Rating
0 to 0.1	Poor
0.11 to 0.25	Regular
0.26 to 0.5	Good
0.51 to 0.75	Very Good
0.76 to 1.0	Excellent

Soil Quality Index (SQI)

The Soil Quality Index (SQI) is a measure of soil health or quality, which can be improved by restoration practices. To calculate the SQI, an adaptation of the methodology described by Cantú et. al. (2007)[8] was developed here. For the Sustainability Index, the SQI will be calculated from information already available at the Centro Nacional de Tecnología Agropecuaria y Forestal (National Center for Agricultural and Forestry Technology, CENTA), which is the focal point of the Global Soil Alliance in the country. Within the framework of the Alliance's agenda, soil quality monitoring is carried out in several areas of the country and this provides the relevant information for the calculation of the SQI.

Three components are considered for the index: Organic Matter (OM), pH and Apparent Density[9]. For each of the selected indexes, maximum and minimum values are established, based on theoretical criteria, as will be explained below.

For the OM content, the expected maximum and minimum values were determined based on the assumption that the percentage of organic matter in soils, in general, ranges between 1 and 6% of the surface horizon and decreases as depth increases (Thompson and Troeh 1988; Ghisolfi 2011). Therefore, the maximum value is 6% and the minimum value is 1%.

The minimum pH value is established taking as a reference the average toxicity point for the development of the different crops present in the area of analysis, without reaching this same value (Hans and Bornemisza 1987; Cantú et al. 2007). The maximum value corresponds to the average maximum pH for the optimal development of each crop present in the area of study. These values can be found in the CENTA Technical Guidelines for each crop (CENTA 2015). It is understood that any value outside these ranges will represent a level of toxicity for each crop.

In the case of Apparent Density, the maximum and minimum values were established according to the classification made for the soils of the tropics by Cairo (1995), quoted by Duarte et al. (2011). According to these authors, the maximum value is 1.6 g/cm3 and the minimum is 1.0 g/cm3.

According to Cantú et al. (2007), once these values have been obtained, the indexes can be normalized to a range of between 0 and 1 using the following formula:

$$Vn = \frac{Im - Imin}{Imax - Imin}$$

Where Vn is the normalized value of the index, either of OM, pH or Apparent Density; Im is the index value, obtained through the analysis of the soil samples; Imax represents the maximum value of the index, and finally Imin is the minimum value of the index. The procedure is repeated for each of the three indexes.

Once the three indexes have been standardized, the SQI can be calculated using their average. For its interpretation, a scale of transformation into five soil quality classes is used (see Table 6), as suggested by Cantú et al. (2007).

Table 6 | Rating values for the SQI

Range of values for the SQI	Rating
0.80-1.00	Excellent
0.60-0.79	Very Good
0.40-0.59	Good
0.20-0.39	Regular
0.00-0.19	Poor

Additional Workday Index (AWI)

The Additional Workday Index (AWI) is a proxy of the improvement in the living standards of the populations involved in the restoration actions and measures the additional workdays generated by different restoration actions. It is given by:

$$AWI = \frac{(\text{Current additional days - Minimum value})}{(\text{Maximum value - Minimum value})}$$

To calculate the limits of this index, we will understand as a maximum value the amount of workdays that would be generated if the entire area proposed in El Salvador's Action Plan for Ecosystem and Landscape Restoration were restored.

The maximum number of workdays was obtained from the Map of Priority Restoration and Opportunities for Transition to Restoration in the landscape under study. The map reports the number of potential hectares of restoration for each of the practices proposed in the Action Plan. By multiplying these hectares by the number of days that each restoration activity would generate according to the calculations made by Raes et al. (2017), the number of days for each of the proposed practices in the landscape during their establishment and maintenance is obtained. The sum of the values obtained would be the maximum number of workdays that would be obtained by implementing all the practices in the landscape.

The minimum value represents the number of workdays generated if the restoration actions were not carried out, which is theoretically 0 (zero). It is important to take into account that the maximum value corresponds to the maximum expected in the year 2022, the last year of the Action Plan (Raes et al. 2017). However, the expected goal of restored hectares is for the year 2030, so, for this year, the maximum value of workdays would be higher than for 2022.

MARN's Dirección de Ecosistemas y Vida Silvestre (Direction of Ecosystems and Wildlife) has generated a record of restoration actions that details the type of action, the hectares intervened, the georeferenced location and the organization in charge of the action. From these cards, this office feeds a database from which the restored hectares can be calculated according to the type of practice carried out. In this way, with the help of information on the requirements of workdays per hectare and per practice (Raes et al. 2017), the number of workdays generated by the restoration practices in a given period is obtained.

The AWI ranges between 0 and 1. The value will approach 1 as all restoration practices have been carried out, and more days will be generated until the maximum expected level is reached.

Vulnerability Reduction Index (VRI)

The Vulnerability Reduction Index (VRI) is a proxy for the reduction of vulnerability to natural factors and is calculated from the data of a more complex index, already existing in several countries of the world: the Index for Risk Management (INFORM)[10], which is calculated at MARN as part of a global collaborative initiative from the Inter-Agency Standing Committee (IASC) and the European Commission[11].

The VRI is calculated from several indexes grouped into three major components: hazard and exposure; vulnerability, and lack of capacity. Each of these three components is broken down into two different categories, and each category in turn is made up of several indicators, through which the VRI is calculated.

For the calculation of the VRI, only the hazard and exposure component (Natural Hazard Index) was taken into account in the category of natural risks of the MARN´s Index for Risk Management, from which the values corresponding to the indicators of floods, landslides and droughts are taken, since these are the factors that would potentially be mitigated by the restoration actions carried out. An example is the recovery of tree coverage in unstable or highly sloped soils that allows for the mitigation of landslides and the reduction of surface drippings during extreme rainfall. This index is calculated estimating the number of people exposed to floods, landslides and meteorological droughts each year at the municipal level[12] (see Annex 13).

The Natural Hazard Index ranges between 0 and 10, so it is necessary to normalize the values of the resulting VRI. Table 7 shows the values for the qualification and normalization of the VRI (co-lumns in bold) from the values of the Natural Ha-zard Index (INFORM). The scales in this case have been reversed, as a value of 10 for the case of the Natural Hazard Index means the greatest danger to the affected population. This is equiva-lent to a poor reduction in vulnerability, which on the norma-lized scale is equivalent to 0 (zero) for the VRI. For example, in the first row of Table 7 we observe that a Hazard and Exposure Index value (taken directly from the hazard and exposure component of the INFORM) that is between 6.9 and 10 has the category of "very high", that is, very high hazard and exposure to floods, landslides and droughts. This is equivalent to a poor reduction in vulnerability, which implies a VRI of between 0 and 0.1. This standardization is necessary for the VRI to be introduced as a component of the SILR.

Table 7 | Qualification and normalization of VRI values

VERY HIGH (INFORM)	POOR (IRV)	HIGH (INFORM)	REGULAR (IRV)	MEDIUM (INFORM)	GOOD (IRV)	LOW (INFORM)	VERY GOOD (IRV)	VERY LOW (INFORM)	EXCELLENT (IRV)
6.9-10	0-0.1	4.7-6.8	0.11-0.25	2.8-4.6	0.26-0.50	1.3-2.7	0.51-0.75	0.0-1.2	0.76-1
6.9	0.025	4.7	0.11	2.8	0.26	1.3	0.51	0	0.76
7.9	0.05	5.4	0.15	3.4	0.3	1.8	0.55	0.40	0.85
8.9	0.075	6.1	0.2	4.0	0.4	2.2	0.65	0.80	0.95
10	0.1	6.8	0.25	4.6	0.5	2.7	0.75	1.20	1

Landscape Governance Index (LGI)

The Landscape Governance Index (LGI) measures the governance situation for the management of a given landscape. Governance refers to the process of interaction and integration between various organizations and individuals with different pow-ers, authorities and responsibilities based on rules and traditions, which are oriented towards ensuring the provision of ecosystem services (food, water, biodiversity, tourism, etc.) (Cundill and Fabricius 2010; Robinson, Dearden and Orozco 2012). So far, there is no governance monitoring for landscape management or even a natural resource manage-ment in the country, so in order to include the LGI in the SILR, primary information was collected.

With this objective, a tool to be used in focus groups was created; the MARN technicians in the different landscapes of the country can also apply it. The tool is an adaptation of the methodology proposed by Robinson et al. (2012), with some elements from UNDP (2018) and Cundill and Fabricius (2010), and is structured in three components: (a) governance capacities, (b) governance process and (c) governance outcomes. Each of these components contains a number of indicators representing different dimensions of governance:

1. Coordination
2. Resources
3. Deliberation
4. Leadership
5. Shared vision
6. Access, use and generation of information
7. Adjusting decisions to the context
8. Management and regulatory instruments
9. Equity
10. Promotion and capacity to learn from past experiences
11. Accountability

(See Annex 14 for more detail on each of these indicators)

The LGI is calculated from the application of a tool through focus group sessions with key actors in landscape management. The selection of focal groups should be made through a random sample in the territories of interest and among the relevant stakeholders for restoration. The Social Landscapes Methodology, developed by WRI (2018), in parallel with random sampling, can become significant tools for the identification of focus groups. In the case of El Salvador, the focus groups were not selected randomly but with the support of MARN technicians in charge of each conservation area, thus ensuring the participation of multiple stakeholders in the landscapes. The tool/questionnaire presents five response options for each indicator, through which the corresponding dimension of governance is rated. The average score for the eleven questions –which correspond to each of the indicators and are analyzed and discussed in a participatory manner in the focus group– represents a LGI that takes values between 1 and 5. An LGI of 0 (zero) will indicate a completely disjointed and dysfunctional state of governance. An LGI of 5 will indicate that the maximum has been reached in each of the governance dimensions.

Once the LGI has been obtained, it needs to be standardized in order to be part of the SILR (see Table 8).

Table 8 | Rating and normalization of values for the Landscape Governance Index, regarding the values of the SILR

Rating	LGI Values	Normalization
Excellent	4.1 to 5	0.76 to 1
Very Good	3.1 to 4	0.51 to 0.75
Good	2.1 to 3	0.26 to 0.50
Regular	1.1 to 2	0.11 to 0.25
Poor	0 to 1	0 to 0.1

The analysis of the governance situation broken down into eleven aspects or dimensions is a useful tool for the self-analysis of the participating stakeholders. It encourages the discussion of issues that are often not taken into account and allows actors to clearly visualize the aspects on which they are strongest and those on which they still need to work, for example on their shared vision of the landscape.

It is important to mention that governance can lead to improvements through restoration actions, so it is a catalyst for the success of such actions proposed for the landscape.

RESULTS OF THE APPLICATION OF SILR TO A LANDSCAPE OF INTEREST IN EL SALVADOR:

EL IMPOSIBLE-BARRA DE SANTIAGO, APANECA-ILAMATEPEC

The SILR proposal was applied in a landscape prioritized by public policies through the PREP, since this would not only result in a methodology that could be replicated in other areas of the country, but would also show the impacts of the restoration actions being carried out in a specific landscape.

As it was shown in the previous section, the SILR is made up of various indexes that are calculated using different methodologies. The results obtained for each of these are presented below.

Results of the Water Quality Index (WQI)

To obtain the WQI in the target landscape, data from this index prepared by MARN was taken based on the information generated by the various stations located in the landscape and then averaged to obtain the WQI for the entire landscape. For landscapes where there are no measurement stations at relevant sites, it is important to determine whether other nearby stations can serve as approximations or whether certain areas within the landscape should be considered out of coverage and thus the scope of the index should be reduced.

Although restoration actions in the landscape began in 2016, the WQI for the landscape was calculated for 2011, which was 61.5. For 2017, it was 72.5, which shows an improvement in water quality from "good" to "very good", according to Table 3. The results were normalized for inclusion in the SILR. With this normalization, the WQI resulted in 0.61 and 0.73 for the years 2011 and 2017 respectively.

Landscape Biodiversity Index (LBI)

As described in the previous section, the LBI is a combination of five indexes of landscape ecology[13].

The obtained indexes were analyzed along Table 4 for their interpretation, classification and normalization.

LBI for the year 2011

The analysis started with the Perimeter-Area Fractal Dimension (PAFRAC) of the classes of interest (broadleaf forest, coniferous forest, salt forest, shaded coffee, unshaded coffee and shrubs), which resulted in an average of 1.33 (see Table 9). According to Table 4, this value classifies the PAFRAC as "regular" and when normalized, a value of 0.31 is obtained.

The Percentage of Landscape Index (PLAND) occupied by the interest classes is 60.94%. According to the same Table 4, it is classified as "excellent" and when normalized it produces a value of 0.9.

The Number of Patches Index (NP) in the classes of interest is 0.44 and, according to Table 4, it shows a high level of fragmentation –especially in the broadleaf forest. The normalized value turns out to be 0.44 (see more detailed tables of normality in Annex 5).

The Largest Patch Index (LPI) reports a value of 26.83% for shaded coffee and 8.26% for broadleaf forest. This results in the two highest values for this index, which means that the largest patch of shaded coffee occupies 26.83% of the landscape because this category does not present greater fragmentation. However, broadleaf forest is only 8.26% of the landscape because of its fragmentation. In addition, the index for the mangrove forest is 1.62, which places it in the category "very good" and, when normalized, a value of 0.7 is obtained.

The Contagion Index (CONTAG) is 56.70, which places it in the category "very good". This normalized value is 0.56. The LBI is then calculated with the normalized values:

$$\text{LBI} = \frac{(\text{PAFRAC}+\text{PLAND}+\text{NP}+\text{LPI}+\text{CONTAG})}{5}$$

$$\text{LBI} = \frac{(0.31 + 0.9 + 0.44 + 0.7 + 0.56)}{5}$$

LBI= 0.58

LBI for the year 2017

The Perimeter-Area Fractal Dimension (PAFRAC) of the classes of interest reaches values of 1.49 for broadleaf forest, 1.37 for shaded coffee, 1.36 for mangrove forest and 1.4 for shrubs. Based on Table 4 it would be classified as "regular". As a result of the normalization the value obtained is 0.40.

The Percentage of Landscape Index (PLAND) occupied by the classes of interest is 67.68%, classified as "excellent". This normalized value turns out to be 0.97.

The Number of Patches Index (NP) in the classes of interest shows that the fragmentation of the landscape continues to be considerable, but that this fragmentation has decreased, especially in the broadleaf forest, from 41,127 fragments in 2011 to 2,311 fragments in 2017. These classes still account for a good percentage of the landscape. The results can be classified as "good". The resulting normalized value is 0.58.

The Largest Patch Index (LPI) reports a value of 27.58% for shaded coffee and 14.14% for broadleaf forest. These are the two highest values, which means that the largest patch of shaded coffee occupies 27.58% of the landscape because this category does not present greater fragmentation. In addition, the index for mangrove forest is 1.61. This would place it in the category "very good", according to Table 4. The resulting normalized value is 0.79 (see Annex 6).

Table 9 | Results from the Fragstats program for the classes of interest

Indexes per Year/Land use classification	Percentage of Landscape (PLAND		Number of Patches/ Fragments (NP)		Largest Patch Index (LPI)		Perimeter-Area Fractal Dimension (PAFRAC)		Contagion Index (CONTAG)	
	2011	2017	2011	2017	2011	2017	2011	2017	2011	2017
Broadleaf forest	21.11	28.01	41127	2311	8.26	14.14	1.33	1.49	56.70	59.86
Conifer forest	0.30	0.32	392	51	0.09	0.10	1.27	1.27		
Salty forest	2.34	2.32	587	41	1.62	1.61	1.27	1.36		
Scrubs	4.85	4.07	62413	27866	0.07	0.05	1.31	1.40		
Other crops	2.79	0.94	11915	351	0.10	0.17	1.30	1.22		
Basic grains	16.37	7.13	98151	34965	1.07	0.27	1.31	1.37		
Fruit trees	0.74	0.55	348	193	0.21	0.08	1.28	1.24		
Pastures	9.01	14.20	23370	33059	0.41	1.91	1.26	1.39		
Sugarcane	2.99	3.51	639	122	0.78	0.82	1.25	1.19		
Unshaded coffee	1.03	0.91	1191	31	0.31	0.15	1.34	1.34		
Shaded coffee	31.34	32.05	7599	338	26.83	27.58	1.31	1.37		

The resulting normalized value is 0.79 (see Annex 6). The Contagion Index is 59.86, which places it in the category "very good" in Table 4. The normalized value is 0.66.

The normalized value is 0.66. Then, the LBI for the year 2017 would be:

$$\text{LBI} = \frac{(\text{PAFRAC+PLAND+NP+LPI+CONTAG})}{5}$$

$$\text{LBI} = \frac{(0.40 + 0.97 + 0.58 + 0.79 + 0.66)}{5}$$

LBI= 0.68

The results of the LBI for both years, 2011 and 2017 (Figure 6), are very satisfactory, in part because this landscape contains the most important protected natural area in the country, the largest area of shaded coffee and an important mangrove area. However, the change in indexes between 2011 and 2017 is noticeable, due to the natural regeneration process as well as from restoration actions initiated since 2016 in the landscape, which show an increase from 0.58 in 2011 to 0.68 in 2017.

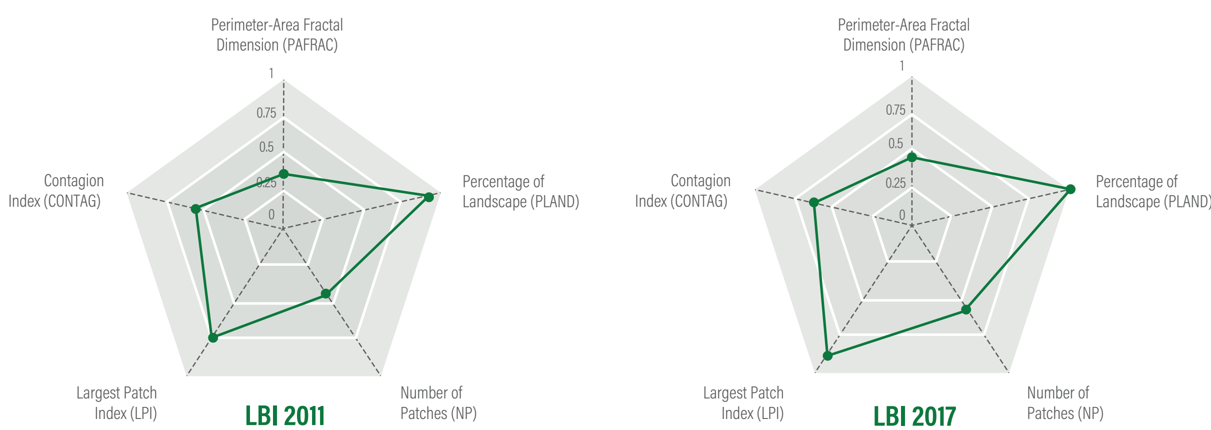
Carbon Equivalent Index (CO_2eI)

As already mentioned in the first part, the CO_2eI is given by

$$CO_2\text{eI} = \frac{(\text{Current } CO_2\text{e gain - Minimum value})}{(\text{Maximum value - Minimum value})}$$

The first step for the calculation was the determination of the index thresholds. The maximum value is the maximum amount of stored carbon equivalent that would be obtained if the entire area proposed in El Salvador's Action Plan for Ecosystem and Landscape Restoration were actually restored. From Figure 5, the number of potential hectares of restoration for each of the practices proposed in the Action Plan was calculated for the landscape under study. By multiplying these hectares by the values of the carbon equivalent balance per hectare, according to calculations made by Raes et al. (2017), the amount of carbon equivalent stored for each practice was obtained. The sum of the values obtained represents the maximum value of carbon equivalent stored during the period of analysis, which would be obtained by implementing all the proposed practices in the landscape. With these calculations, the maximum value of carbon equivalent stored in the area of interest is 1,263,357.90

Figure 6 | Results from the Landscape Biodiversity Index 2011 and 2017



Source: own-elaboration

tons during the period from 2016 to 2022, according to the Action Plan. However, if the period from 2016 to 2030 is taken into account, the maximum value would be 2,707,195.50 tons of carbon equivalent[14] (see Table 10). For practices not contemplated within this plan –such as reforestation or restoration of secondary forests– the tool developed by Global FLR CO_2 Removals Database (Bernat et al. 2018).

The minimum value represents the amount of carbon equivalent that would be stored in the event that the restoration actions were not carried out, which is theoretically 0 (zero).

Table 10 | Calculation of the maximum expected value of stored carbon equivalent

Restoration actions	Potential hectares to be restored	Potential factor tCO_2e/ha/ year captured	Potential tCO_2e stored for 2022 *	Potential tCO_2e stored for 2030**
Gallery forest restoration	903.61	6.35	40,165.46	86,068.85
Coffee renovation < 800 m	1,560.07	1.55	16,926.76	36,271.63
Coffee renovation 800-1200 m	12,503.33	1.35	118,156.47	253,192.43
Coffee renovation > 1200 m	17,871.05	1.35	168,881.42	361,888.76
Silvopastoral system	3,253.53	0.5	11,387.36	24,401.48
Sugarcane harvest	2,755.91	0.09	1,736.22	3,720.48
Mangrove restoration	0.00	6.7	0.00	0.00
Cacao agroforestry system (1)	0.00	3.3	0.00	0.00
Cacao agroforestry system (2)	14,160.56	4.7	465,882.42	998,319.48
Agrosilvopastoral system	0.00	1.85	0.00	0.00
Agrosilvopastoral system basic grains	14,973.53	4.2	440,221.78	943,332.39
Reforestation (Bernoux et al. 2011)	0	25.30	0.00	0.00
Secondary forest (Bernoux et al. 2011)	0	11.73	0.00	0.00
Total	67,981.59		1,263,357.90	2,707,195.50
			Maximum value (2016-2022)	**Maximum value (2016-2030)**

**Values for the period 2016-2022*

*** Values for the period 2016-2030*

To calculate the current gain in stored carbon equivalent, annual reports on restoration actions carried out by MARN were used. These reports include the type of restoration practice, the hectares restored and their location, among other aspects. These reports give information on the number of hectares that have been restored during the period of analysis and the type of practice that has been applied. Each type of practice and the corresponding hectares are multiplied by the corresponding carbon balance factor and this results in the carbon equivalent stored by each of the practices. The sum of these values represents the carbon equivalent stored for the period under review (Table 11). It is important to note that the restoration practices being carried out are not limited to the list set out in Table 10 and that these include other activities, such as secondary forest management and reforestation activities.

Table 11 | Restoration actions reported by MARN in the period 2016-2018 and estimated carbon equivalent captured

Year	Restoration actions	Ha. in restoration process	Factor used	Factor $tCO_2eq/ha/year$	Years	Total tCO_2eq
2016	Mangrove ecosystem/Restoration based on sustainable use of natural resources	1,640.00	Mangrove restoration	6.35	3.00	31,242.00
	Conservation and sustainable use of natural forests	683.00	Secondary forest	11.73	3.00	24,034.77
2017	Conservation and sustainable use of natural forests	4,261.80	Secondary forest	11.73	2.00	99,981.83
	Coffee/Sustainable agroforest systems (SAS)	1,006.60	Agroforestry system basic grains	4.20	2.00	8,455.44
	Mangrove ecosystem/Restoration based on sustainable use of natural resources	338.80	Mangrove restoration	6.35	2.00	4,302.76
	Sustainable diversified system	3,293.00	Agroforestry system basic grains	4.70	2.00	30,954.20
	Management of crop residues	59.50	Sugarcane harvest	0.09	2.00	10.71
	Agroforest systems (SAF, in Spanish)	43.50	Agroforestry system basic grains	4.20	2.00	365.40
	Reforestation	250.00	Reforestation	25.30	2.00	12,650.00
2018	Conservation and sustainable use of natural resources	450.00	Secondary forest	11.73	1.00	5,278.50
	Sustainable diversified system	925.00	Cacao agroforestry system (2)	4.70	1.00	4,347.50
Total area in restoration process (ha)		**12,951.20**				**221,623.11**

For the 2016-2018 period, MARN reported a total of 12,951.20 hectares in process of restoration with different practices for this landscape. These hectares represent 19% of the total potential area to be restored, according to the Action Plan. By multiplying the number of hectares corresponding to each practice by its carbon equivalent factor, the carbon equivalent stored is obtained. The sum of these values gives a total of 221,623.11 tons of carbon equivalent stored in the landscape for the period under study. Then the CO_2eI would be:

$$CO_2eI = \frac{(\text{Current } CO_2e \text{ gain - Minimum value})}{(\text{Maximum value - Minimum value})}$$

$$CO_2eI = \frac{(221{,}623.11 - 0) \text{ t de } CO_2e)}{(1{,}263{,}357.90 - 0) \text{ t de } CO_2e)}$$

$$CO_2eI = 0.18$$

Table 5 qualifies this value as “regular”. This takes into account the period corresponding to the Action Plan. However, if we take into account the time period set in order to meet the Bonn Challenge target, the CO_2eI would be 0.08, a value that is nevertheless small. It should be taken into account that the restoration actions started only three years ago and that there are still 12 years left to meet the target set for 2030.

It is important to note that the tons of stored carbon equivalent obtained through the previous calculation probably underestimates the value of that carbon stored in the landscape, which does not come exclusively from restoration actions, but also from natural regeneration processes. To verify this, an analysis was made using the last two land use maps of the country made by MARN. The maps correspond to the years 2011 and 2017. The analysis takes into account only the area corresponding to the landscape and selects the areas that in 2011 appear under agricultural use –specifically basic grains– which in 2017 fell actually under the broadleaf forest category. This area totals 5776.24 hectares. According to the analysis, they represent a natural regeneration process. However, further analysis is needed to determine whether the changes are due to a particular reason such as land abandonment or simply to differences in land use mapping methodologies.

Additional Workday Index (AWI)

The following formula was used to calculate the AWI:

$$AWI = \frac{(\text{Current additional workdays - minimum value})}{(\text{Maximum value - Minimum value})}$$

The maximum number of workdays expected for the landscape was obtained from the Map of Priority Restoration and Opportunities for Transition to Restoration in the landscape under study, which reports the number of potential hectares of restoration for each of the practices proposed in the Action Plan, in the same way as for the CO_2eI. By multiplying these hectares by the number of workdays required –based on calculations made by Raes et al. (2017)– the number of days required for each of the proposed practices in the landscape is obtained. The resulting sum of the values would be the maximum number of workdays that would be needed to implement all the restoration practices in the landscape. In our case, this corresponds to 27.1 million workdays (see Annex 12).

The minimum value represents the amount of workdays generated if restoration actions are not carried out, which is theoretically 0 (zero).

Additional work is given by the number of additional workdays generated from the base year, which in this case corresponds to the year 2016, because that year the implementation of restoration actions in the landscape began. Using MARN reports, the hectares restored for each type of practice are obtained and these are multiplied by the work factors, according to Raes et al. (2017). Thus, the total additional workdays generated in the landscape during the period 2016-2018 corresponds to 2.6 million workdays. Therefore:

$$\text{AWI}= \frac{\text{(Current Additional Workdays – Minimum Value)}}{\text{(Maximum Value - Minimum Value)}}$$

$$\text{AWI}= \frac{\text{(2.6-0) million workdays)}}{\text{(47.3-0) million workdays}}$$

AWI= 0.05 (for the period 2016-2030)

AWI= 0.10 (for the period 2016-2022)

Table 12 presents the AWI ratings. According to the table, the AWI value of 0.05 falls in the "poor" category.

Table 12 | AWI Rating Values

Range of AWI values	Rating
0 to 0.1	Poor
0.11 to 0.25	Regular
0.26 to 0.5	Good
0.51 to 0.75	Very Good
0.76 to 1.0	Excellent

The values obtained for this index are consistent with the fact that the actions started only three years ago and that there are still 12 more years of work to be done until 2030. So far only 19.05% of the maximum number of expected hectares have been restored. It is important to mention that some of the restoration actions being carried out in the land-scape are not precisely those proposed in the Action Plan. This is because the actions proposed follow technical and economic criteria, but in the territory, the governance aspects and the very perceptions of the local stakeholders about what they consider to be important for their landscapes, play a fundamental role when deciding and carrying out these actions. In the specific case of this landscape, restoration actions that are not contemplated in the Action Plan are being carried out in areas such as Barra de Santiago, while in other areas reforestation is being carried out, an action that is not contemplated in the Plan either.

There is an effort on the part of MARN authorities, within the framework of the Bonn Challenge Baro-meter, to map all restoration actions by the public and private sectors (Dave et al. 2018), but it is important to insist on the need to document them, for specific actions may have been possibly carried out but they have not been reported to MARN, and therefore have not been accounted for. This means that the values obtained for the index represent conservative parameters.

Vulnerability Reduction Index (VRI)

As explained in the previous section, the VRI is calculated from the values of the Natural Hazard Index, which takes only into account the variables of the population affected by floods and landslides, adjusts the population to the proportion of the municipality within the landscape and then follows the same methodo-logy for the calculation of the Index for Risk Management prepared by MARN (see Annex 13).

The value of the index for this landscape for 2017 is 3.8, on a scale of 0 to 10. This is quite consistent with the forest and shaded coffee forestry present in the landscape, which positively influences the reduction of vulnerability to floods and landslides.

Landscape Governance Index (LGI)

To calculate the LGI, the methodology outlined in the previous section was followed. MARN technicians working in the conservation areas within the landscape under study were involved for this and, at their suggestion, three focus groups were organized in three different areas of the landscape, one with the Apaneca-Ilamatepec Biosphere Reserve Committee, another with local stakehodlers in Barra de Santiago and a third with a group of local stakeholders in Tacuba, who are organizing around the management of El Imposible National Park. Figure 7 shows the LGI broken down into its components for the three areas in which the analysis was carried out.

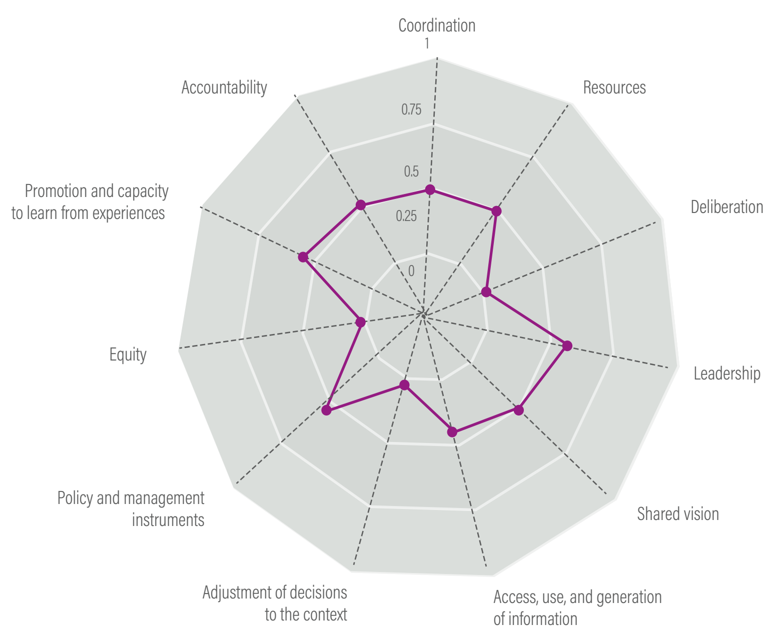
A LGI was obtained for each of the three zones: 0.26 in El Imposible, 0.54 in Barra de Santiago and 0.52 in the Apaneca-Ilamatepec Biosphere Reserve. These results were consistent with expectations, according to previous interviews with MARN technicians. In the area of El Imposible, the organization is incipient and recently a co-management agreement has been formalized between MARN and the Municipality of Tacuba for the administration of a part of the natural area.

The governance in Barra de Santiago is being consolidated and turned out to be the highest, as the social organization around the protection and sustainable use of the mangrove has been strengthened over the years, reaching an important level of coordination, as well as a shared vision. However, its management is quite restricted to the mangrove, with few or no links to El Imposible National Park, which was evidenced in aspects such as “management and regulation instruments” that, although working to regulate extraction, have not worked with the group of sugarcane growers whose crops threatens or takes over the mangrove.

The Index in the Apaneca-Ilamatepec Biosphere Reserve also scores well. The committee is consolidating, its vision and management at the landscape level is much more comprehensive and has a more pluralistic composition than in the Barra de Santiago group, but its operation is more recent.

The average of the three zones reported a Landscape Governance Index of 2.83, which is classified as “good” on a scale of 1 to 5, with much potential for improvement. In all three sites where focus groups were organized, participants showed great interest in an institutionalized use of the instrument for periodic self-assessment.

Figure 7 | Landscape Governance Index



Source: self-elaboration

Table 8 shows the normalization of the LGI with the scale of the Sustainability Index for Landscape Restoration (ranging from 0 to 1). Based on the values in this table, a Landscape Governance Index of 0.44 is obtained, which rates as "good".

SILR Aggregation

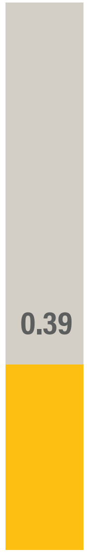
Once each of the components of the Sustainability Index for Landscape Restoration has been obtained, the index can be calculated by averaging all the values[15] (see Figure 10).

For this specific case:

$$\textbf{SILR=} \frac{(CO_2eI + LBI + WQI + AWI + VRI + ILG)}{6}$$

The value of the Sustainability Index is 0.41 if the Restoration Action Plan's target is set to 2022, and 0.39, when the target is set to 2030. Figures 9 and 10 clearly show how the aspects of biodiversity and water quality have the best scores. This is largely due to the fact that the most important protected natural area in the country (the El Imposible forest) is located in this landscape, as well as the most important shaded coffee area in El Salvador and a considerable area of mangroves.

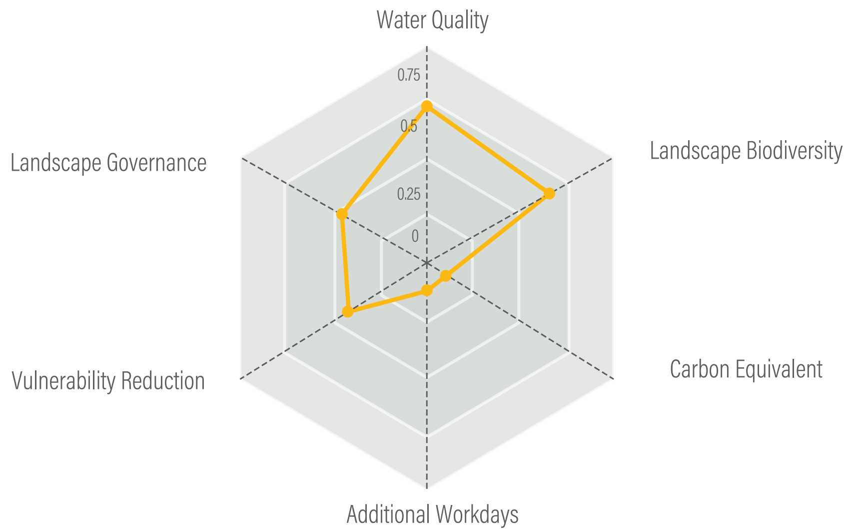
Figure 8 | Sustentability Index 2018



Source: self-elaboration

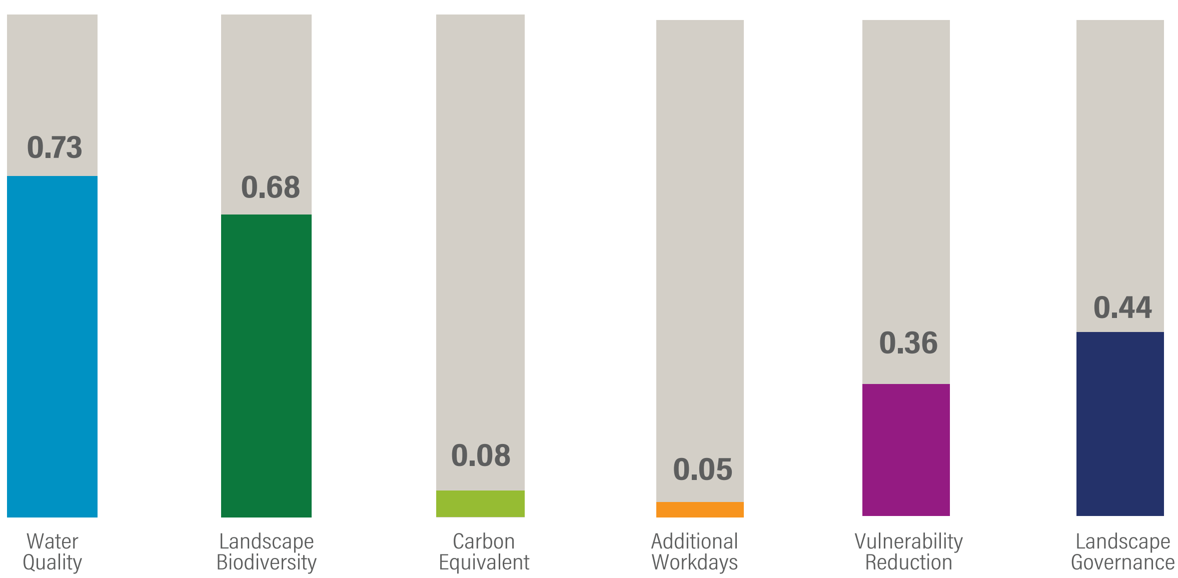
This has a great weight in terms of biodiversity, but if the land use maps of 2011 and 2017 are analyzed, the decrease in mangrove areas is notorious. On the other hand, water quality has improved in almost all the country's rivers. In fact, rivers with "good" water quality have increased by 27% according to MARN's Water Quality Report 2017.

Figure 9 | SILR in El Imposible-Barra de Santiago and Apaneca-Ilamatepec



CO_2eI and AWI reflect more clearly the impact of restoration actions on carbon equivalent storage and additional workdays because the values included in the formula come from the list of restoration actions generated by MARN. In this sense, they reflect the progress of restoration actions in the landscape. So far, 12% of the area targeted for restoration by 2030 has been advanced. Due to this modest progress, the Carbon Equivalent and Additional Workdays Indexes are low (Figure 10).

Figure 10 | SILR of El Imposible-Barra de Santiago and Apaneca-Ilamatepec by its components



Source: self-elaboration


NUESTRA AREA NATURAL PROTEGIDA
BARRA DE SANTIAGO
AREA DE RECUPERACIÓN DE DIFERENTES ESPECIES Y HABITAT
DEL COCODRILO-MACHORRA-AVES
PROHIBIDO TERMINANTEMENTE:
1- PROHIBIDO LA PESCA Y LA CACERIA - PORTACIÓN DE ARMAS DE FUEGO.
2- PROHIBIDO TRANSITO EN LANCHAS GRANDES CON MOTORES RUIDOSOS.
3- NO ENTRAR CON JETSKY, MOTORES RUIDOSOS, ALTA VELOCIDAD.
4- PROHIBIDO TIRAR BASURA DE CUALQUIER CLASE: LATAS, BOTELLAS, PLASTICOS
5- PROHIBIDO ENTRAR A MANGLARES HACIENDO BULLA O MUSICA ALTO VOLUMEN
PORQUE DISTORCIONA EL ESTADO DE ANIMO DE LAS ESPECIES
Guarda Recursos
habitantes Barra de Santiago

IMPLICATIONS OF THE SILR

Besides its contribution on monitoring some of the impacts of restoration, the SILR has also the potential to contribute to strengthening restoration efforts and managing ecosystems and landscapes. As discussed below, the Index can help to identify important interrelationships occurring in the landscapes in which it is applied, to define more precise criteria for prioritizing and locating restoration actions within the landscape, and to promote efforts that strengthen social capital and governance of the landscape.

Restoration, impacts and interrelations in the landscape

Together with other restoration indexes that are being implemented (such as the Restoration Barometer (IUCN 2018) and the REDD+ indicators), the SILR can be part of a broader monitoring, reporting and verification system that reports on the country's progress in terms of Adaptation-based Mitigation. To the extent that restoration actions are implemented more broadly across the country's diverse landscapes, the Index can be easily applied and integrated into broader monitoring systems.

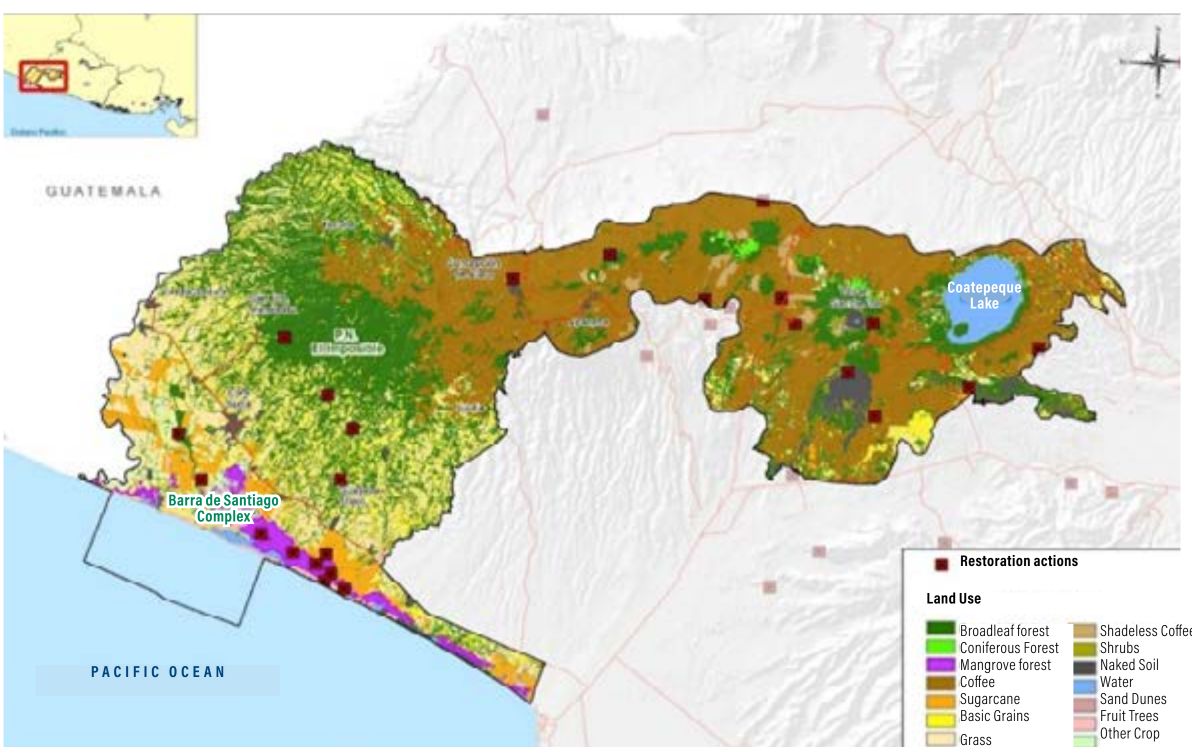
Unlike indicators that reflect averages at the national level, the SILR can contribute to the systematic monitoring of restoration impacts in each of the landscapes where it is applied, since it is easily aggregated at the national level. At the landscape scale, when it is combined with studies at project or farm scale, the Index has the potential not only to report on the behaviour of restoration impacts on crucial aspects such as water, biodiversity and soil, but also to identify critical interrelations that may be affecting landscape performance, such as the relationship between upstream restoration actions and downstream water availability or quality. It is also relevant to consider the other land use dynamics that are occurring and not just the restoration actions that have been taken. This is particularly important, since restoration actions occur not only in the landscape, but also through other actions that various stakeholders develop to ensure their forms of life, such as in agriculture, energy and touristic activities. The Index can help promote greater coordination efforts and generate synergies between sectoral public policies.

A particularly relevant suggestion for the application of the SILR is the promotion of protocols and the formalization of information exchange agreements generated by government entities other than MARN. A concrete example is the database on soil quality in various sites in the country which is being generated by CENTA and which is expected to be maintained and expanded in the future within the framework of the Global Soil Partnership. For this work, a collaboration agreement was promoted between the Centro de Investigación y Desarrollo en Salud (Center for Research and Health Development, CENSALUD in Spanish) of the University of El Salvador and the General Directorate of the Environmental Observatory at MARN, through which CENSALUD will systematically share water quality samples in the area of Barra de Santiago to be analyzed in the laboratory of the Environmental Observatory in order to expand water quality sampling in the mangrove area.

Prioritization and location of restoration actions

In certain landscapes, restoration actions can be better oriented, according to more appropriate criteria, towards the characteristics and dynamics of the landscape. In this sense, the location of specific restoration actions will be determined, for example, by the need to improve the status of key resources such as soil and water, or by their importance for agricultural production, rather than by the attempt to use or promote an increased carbon capture. In the case of the landscape under study, the need to continue promoting restoration actions in the mangrove zone is evident, but this is also the case in other areas of influence that include sugarcane production zones and even in areas outside the perimeter of the landscape, because these have clear implications in the mangroves located west of the Barra de Santiago (see Figure 11). In this sense, the analysis of each of the components of the SILR, accompanied by a spatial and temporal analysis based on the land use maps, can also contribute to improve the selection criteria as well as the location of restoration actions in order to prioritize areas within the landscape which require restoration interventions. For example, promotion programs supported by the FIAES can focus on areas where the biodiversity or water sub-indexes have had greater reductions, or where levels of governance are higher. This can lead to the definition of calls for project proposals such as those promoted by the country's environmental funds, influence the location of other projects supported with resources from various cooperation entities, and promote processes of productive reconversion with private investment, such as those implemented for sugarcane harvesting. Likewise, the Index provides information that can be used to trace efficiency levels of restoration actions in the landscape.

Figure 11 | El Imposible-Barra de Santiago-Apaneca-Ilamatepec Biosphere Reserve: restoration actions



Source: self-elaboration

Although it is not suggested to modify the perimeter of the landscape selected for the application of the Index, the proximity of the restoration actions being implemented in the coffee zone –i.e. the predominant land use in the Apaneca-Ilamatepec Biosphere Reserve– may be generating impacts not only within the landscape, but also outside it (in the case of micro-basins, for example). Figure 12 shows how other restoration actions outside the landscape could also have an impact, along with those in the interior of the landscape, in this southern coastal zone of the country. Therefore, more detailed studies are recommended (see Figure 11). In the context of a prolonged crisis situation of coffee cultivation, restoration actions contribute economically, socially and environmentally within the landscape, but also outside of it, since such actions can help avoid deforestation processes, changes in land use, and even the removal of carbon reservoirs.

Restoration, social capital and landscape governance

In addition to monitoring, the Sustainability Index for Landscape Restoration has the potential to contribute to the expansion of landscape and ecosystem management tools. As we have seen, the Index synthezises landscape performance and considers several dimensions of crucial importance for an Adaptation-based Mitigation.

The Index also shows the performance of various stakeholders in the landscape, not only those who are directly responsible for land use and the imple-

mentation of restoration actions such as producers (sugarcane and coffee farmers, basic grain producers, cattle ranchers, etc.), but also other stakeholders such as municipalities, territorial organizations or cooperatives, among others, which through their actions promote strategies with clear impacts on the landscape. The Index can contribute to the feedback of impacts derived from other initiatives than restoration, such as local-territorial development plans, strategies to promote basic grain production and food security, and incentives for sugarcane production.

Therefore, the Index is a tool that reflects the environmental performance of the set of actions in the landscape, both for its actors and for other external stakeholders. With this logic, the SILR and its elaboration process –particularly in this case the process of building the Governance Index– can contribute to strengthening local-territorial institutions. In the absence of other indicators, the SILR not only fills a strategically important gap in landscapes, ecosystems and territories, but can also favour greater attention to restoration at a local-territorial scale and integrate various agendas and management instruments at that scale, including linking restoration to local planning processes, but above all, the lifelihood strategies of those who most depend on natural resources. The Index can also be an indicator of degradation if each component reports lower values based on a baseline. The Biodiversity Index is particularly useful for determining forest degradation or deforestation, as it is sensitive to tree cover losses.

No less important is the fact that restoration actions in the landscape also help improve the conditions of social capital and thus the governance systems of the landscape. The restoration actions supported in the mangroves of Barra de Santiago have not only had an impact on the restoration of the mangrove and the maintenance of its ecological functions, but also on the strengthening of the governance conditions of local organizations and communities, and with it, on the strengthening of the capacities of interlocution with sugarcane producers, who still see the mangrove areas as potential areas for the expansion of sugarcane cultivation.

NOTES

1. An initiative led by the German government, the Global Partnership on Forest Landscape Restoration and the International Union for the Conservation of Nature (IUCN), which established commitments to restore 150 million hectares of degraded land globally by 2020 and 350 million hectares by 2030.

2. In support of the Bonn Challenge, the 20x20 Initiative is an effort led by Latin American and Caribbean countries that aims to change the dynamics of land degradation. In the short term, it seeks to start restoration on 20 million hectares by 2020 and have 30 million hectares in restoration reflected at National Determined Contributions (NDCs) by 2030.

3. Fragstats is an open source software created in 1995 by Dr. Kevin McGarigal and Barbara Marks at Oregon State University. It works essentially in raster format. Available online at https://www.umass.edu/landeco/research/fragstats/fragstats.html [Accessed January 2020]

4. The fractal dimension index will be analyzed for the classes of interest (broadleaf forest, coniferous forest, mangrove, shaded coffee).

5. The total class area is not part of the LBI, however, it was calculated to use the values in the calculation of the Carbon Equivalent Index (CO_2eI) and the Additional Workdays Index (AWI).

6. The percentage of landscape will be analyzed for the class of interest or the sum of the classes of interest (broadleaf forest, coniferous forest, mangrove, shaded coffee). The maximum value is considered to be 70% since landscapes with exclusive presence of forest or coffee plantations are not considered.

7. The carbon equivalent balance is defined as the net balance of all greenhouse gases (GHG) expressed in CO2 equivalents that are emitted or retained by the implementation of restoration practices (FAO 2017).

8. In the 1990s, the Soil Science Society of America promoted the concept of soil quality and later established quantitative indicators for that quality.

9. According to opinions from experts. Interview with Mr. Jaime Tobar, Coordinator of the Agriculture, Soil and Water Program at Catholic Relief Services (CRS), July 23, 2018.

10. In El Salvador, the process of adapting the sub-national INFORM model from the Global and Regional LAC Index has been completed with the participation of nine government institutions that make up the INFORM El Salvador Team, and with the support of UNDP, UNICEF and OCHA as agencies of the United Nations System that are executing the project "Implementation and use of INFORM as a tool for humanitarian and development decision-making based on disaster risk information in Central America with ECHO funds".

11. For more details: http://www.inform-index.org/

12. There is an automated platform in Excel format, designed by the INFORM team, which allows the risk management index and each of its three components to be calculated in a uniform manner by simply entering the values of the population affected each year in each of the countries. In each country, adaptations for this index are made according to the specific conditions for climatic events; however, the platform used is the same.

13. A considerable advantage of the use of such indexes with respect to biodiversity counts, whether of flora or wildlife, is their low cost. Only two things are required: the land use map of the year to be analyzed and the Fragstats (open access) software, or a similar one.

14. The analysis period corresponds to the years between 2016 and 2030. 2016 marks the year when the restoration actions in the pilot landscape started and 2030 is the year set for the fulfilment of the Bonn Challenge goals. However, it is also worth considering the period from 2016 to 2022, as this includes the implementation of El Salvador's Action Plan for Ecosystem and Landscape Restoration.

15. The Soil Quality Index was not calculated due to the absence of information at the time of the analysis. However, since this information currently exists in the country, it was considered important to include this component in the SILR so that it could be calculated in the future.

BIBLIOGRAPHY

Bernal, B., Murray, L.T. and Pearson, T.R., 2018. Global carbon dioxide removal rates from forest landscape restoration activities. Carbon balance and management, 13(1).

Bey, A., Sánchez-Paus Díaz, A., Maniatis, D., Marchi, G., Mollicone, D., Ricci, S., Bastin, J.F., Moore, R., Federici, S., Rezende, M. and Patriarca, C., 2016. Collect earth: Land use and land cover assessment through augmented visual interpretation. Remote Sensing, 8(10).

Buckingham K., Ray S., Morales A., Singh R., Maneerattana O., Wicaksono S., Chrysolite H., Minnick A., Johnston L., and Arakwiye B. 2018. Mapping Social Landscapes: A Guide to Identifying the Networks, Priorities, and Values of Restoration Actors. World Resources Institute Guide Book.

Brown, R.M., McClelland, N.I., Deininger, R.A. and Tozer, R.G. 1971. Water quality index-do we dare?, Water Sewage Works, 117(10).

Cairo P. 1995. La Fertilidad Física de suelo y la Agricultura Orgánica en el Trópico. UNA - Managua, Nicaragua.

Cantú, M.P., Becker, A., Bedano, JC., and Schiavo, H.F. 2007. Evaluación de la Calidad de Suelos Mediante el Uso de Indicadores e Índices. Ciencia del Suelo, 25(2), 173-178. Available at: http://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S1850-20672007000200008&lng=es&tlng=en. [Accessed December 7 2018].

CENTA. 2015. Guías técnicas. San Salvador, El Salvador: Centro Nacional de Tecnología Agropecuaria y Forestal. Available at: http://www.centa.gob.sv/2015/guias-tecnicas/

Cobar A., 2016. Plan de Desarrollo local sostenible del Área de conservación El imposible-Barra de Santiago, El Salvador. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. 79 p. Available at: http://reddlandscape.org/wp-content/uploads/2016/09/Plan-de-Desarrollo-Local-Sostenible-en-el-ACEIBS-compressed.pdf

Commoner, B., 1971. The Closing Circle: Nature. Man and Technology.

Consejo Salvadoreño del Café. 2018. Estadísticas de producción por empleo al 31 de octubre de 2018. Available at: www.csc.gob.sv/estadisticas/

Cundill, G., Fabricius, C. 2010. Monitoring the governance dimension of natural resource co-management. Ecology and Society 15(1).

Dave, R., Saint-Laurent, C., Murray, L., Antunes Daldegan, G., Brouwer, R., de Mattos Scaramuzza, C.A., Raes, L., Simonit, S., Catapan, M., García Contreras, G., Ndoli, A., Karangwa, C., Perera, N.,Hingorani, S. and Pearson, T. 2019. Second Bonn Challenge progress report. Application of the Barometer in 2018. Gland, Switzerland: IUCN.

Duarte, N., Figueroa, M., Hernández, L., & Aguilar, V. 2011. Impacto de la preparación del suelo sobre las características físicas del suelo, calidad y rendimiento de las raíces de yuca (Manihot esculenta Crantz), variedad algodón, Nueva Guinea-RAAS. La Calera, 11(17), 26-32. Available at: http://repositorio.una.edu.ni/2363/1/ppf07u58.pdf.

ECLAC (Economic Commission for Latin America and the Caribbean), CAC (Central American Agricultural Council), COMISCA (Council of Ministers of Health of Central America), CCAD (Central American Commission for Environment and Development), COSEFIN (Council of Ministers of Finance/Treasury of Central America and Dominic Republic), SIECA (Secretariat of Central American Economic Integration), SICA (Central American Integration System), UKAID (United Kingdom Department of International Development) and DANIDA (Danish International Development Agency). 2015. Climate Change in Central America: Potential Impacts and Public Policy Options, (LC/MEX/L.1196/Rev.1), Mexico City, Mexico. Disponible en https://www.cepal.org/en/publications/39150-climate-change-central-america-potential-impacts-and-public-policy-options

Fundación Programa Regional de Investigación sobre Desarrollo y Medio Ambiente-PRISMA. 2013. Mitigación basada en la Adaptación (MbA) Potencialidades y desafíos para responder al cambio climático en Centroamérica. Policy Brief. San Salvador, El Salvador.

Fundación Programa Regional de Investigación sobre Desarrollo y Medio Ambiente-PRISMA. 2015. Mitigación basada en Adaptación: Enfrentando el cambio climático en El Salvador y Centroamérica. PRISMA, San Salvador, El Salvador.

Fundación Programa Regional de Investigación sobre Desarrollo y Medio Ambiente-PRISMA. 2017. Monitoreo de la restauración: elementos críticos para una hoja de ruta.

Ghisolfi, E. 2011. Contenidos de materia orgánica: Relación con la fertilidad del suelo en siembra directa (Vol. 3). Eduvim.

Gobierno de El Salvador-GOES. 2012. Política Nacional del Medio Ambiente, aprobada por el Consejo de Ministros el 30 de marzo de 2012. Gobierno de El Salvador, San Salvador.

Gobierno de El Salvador- GOES. 2013. Readiness Preparation Proposal (R-PP) (Version of the 19th February 2013). Ministerio de Ambiente y Recursos Nautrales (MARN)/Forest Carbon Parnership, El Salvador.

Hans W. Fassbender, HW., Bornemisza, E. 1987. Química de suelos con énfasis en suelos de América Latina. IICA.

IPCC 2013. Cilmate Change 2013. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Acervoer, T.F., D. Qin, G.-K. Pla-ttner, M.Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)] Cambridge University Press. Cambridge. Cambridge, United Kingdom and New York, NY.USA
Kongsager, R., Corbera, E. 2015. Linking Mitigation and Adaptation in Carbon Forestry Projects: Evidence from Belize. World development 76:132-146.

Ministerio de Medio Ambiente y Recursos Naturales –MARN. 2012. Informe de la calidad del agua de los ríos de El Salvador 2011. Available at: http://www.marn.gob.sv/descarga/informe-de-calidad-de-agua-de-los-rios-de-el-salvador-2011/

Ministerio de Medio Ambiente y Recursos Naturales-MARN. 2013. Segunda Comunicación Nacional sobre Cambio Climático. Ministerio de Medio Ambiente y Recursos Naturales. San Salvador, El Salvador.

Ministerio del Medio Ambiente y Recursos Naturales-MARN. 2017. Informe de la calidad del agua de los ríos de El Salvador 2017. San Salvador.

Ministerio del Medio Ambiente y Recursos Naturales-MARN. 2017a. Plan de acción de restauración de ecosistemas y paisajes de El Salvador con enfoque de mitigación basada en adaptación, Proyecto 2018-2022, San Salvador.

Ministerio del Medio Ambiente y Recursos Naturales-MARN. 2018. Inventario Nacional de Bosques de El Salvador. San Salvador.

Ministerio de Medio Ambiente y Recursos Naturales-MARN. (s.f.). Procedimiento de cálculo del índice de calidad del agua (CCME WQI). Proceso: Gestión y generación de información para la gestión de la calidad del agua.

Ndamani, F., Watanabe, T. 2017. Developing indicators for adaptation decision-making under climatechange in agriculture: A proposed evaluation model. Ecological indicators 76:366-375.

PNUD. 2018. Cuestionario de Países para el Indicador 6.5.1. Para el monitoreo y la presentación de información sobre el Objetico de Desarrollo del Milenio (ODS)6. Available at: http://iwrmdataportal.unepdhi.org/iwrmmonitoring.html

Programa Regional de Investigación sobre Desarrollo y Medio Ambiente-PRISMA. 2017. Mitigación basada en la Adaptación (MbA) Potencialidades y desafíos para responder al cambio climático en Centroamérica. Policy Brief. San Salvador.

Programa Regional de Investigación sobre Desarrollo y Medio Ambiente-PRISMA. 2015. Mitigación basada en Adaptación: Enfrentando el cambio climático en El Salvador y Centroamérica. PRISMA, San Salvador.

Programa Regional de Investigación sobre Desarrollo y Medio Ambiente-PRISMA. 2017. Monitoreo de la restauración: elementos críticos para una hoja de ruta.

Raes, L., Nello, T., Nájera, M., Chacón, O., Meza Prado, K., Sanchún, A. 2017. Análisis económico de acciones para la restauración de paisajes productivos en El Salvador. Informe final. UICN.

Reiche, C. 1991. Costo de cultivo de árboles de uso múltiple en América Central. Bib. Orton IICA/CATIE.

Robinson, L., Dearden, P., Orozco, A. 2012. Framework for Assessing Governance for Landscape-Level Ecosystem-Based Management. Draft 2.1. Available at: http://www.papr.co.ca/index.php?p=1_25_Papers.

Salazar, E., Mendoza, J., Ochoa-Gaona, S., Ku-Quej, V., Hidalgo-Mihart, M. 2016. Evaluación de la conectividad del paisaje en la región Puuc-Chenes, México, con base en los requerimientos de hábitat del jaguar (Panthera onca). Investigaciones Geográficas 92:101-115.

Thompson, LM., Troeh, FR. 1988. Los suelos y su fertilidad. Revert, S.A. Barcelona.

UICN y WRI. 2014. Guía sobre la metodología de evaluación de oportunidades de restauración (ROAM): Evaluación de las oportunidades de restauración del paisaje forestal a nivel nacional o subnacional. Documento de trabajo (edición de prueba). Gland, Suiza: UICN.

Vila, J., Varga, D., Llausàs, A., Ribas, A. 2006. Conceptos y métodos fundamentales de la ecología del paisaje. Una interpretación desde la Geografía.

ABBREVIATIONS

CENTA	Centro Nacional de Tecnología Agropecuaria y Forestal (National Center for Agricultural and Forestry Technology)
CRS	Catholic Relief Services
ENSO	El Niño Southern Oscillation
IASC	Inter-Agency Standing Committee
WQI	Water Quality Index
LBI	Landscape Biodiversity Index
CO_2eI	Carbon Equivalent Index
SQI	Soil Quality Index
LGI	Landscape Governance Index
WFI	Water Flow Index
VRI	Vulnerability Reduction Index
SILR	Sustainability Index for Landscape Restoration
AWI	Additional Workday Index
MARN	Ministry of Environment and Natural Resources
AbM	Adaptation-based Mitigation
PREP	Ecosystem and Landscape Restoration Program
PRISMA	Regional Program for Research on Development and Environment
ERM	Ecological Restoration of Mangroves
ROLAS	Network of Local Environmental Observers
IUCN	International Union for the Conservation of Nature
WRI	World Resources Institute

ANNEXES

Annexes are available at: https://onewri.sharepoint.com/:f:/t/Projects/Restoration/Ej3y6-GT5jlAnEDS6yoec38B-UsOSpbjjmZUX3zudFXLFQ?e=5yG8pl

AUTHORS

René Zamora Cristales, Doribel Herrador, Nelson Cuéllar, Oscar Díaz, Susan Kandel, Jorge Quezada, Silvia de Larios, Giovanni Molina, Madelyn Rivera, Wilfredo Morán Ramírez, Abner Jiménez, Emma Flores, María Franco Chuaire, Luciana Gallardo Lomeli and Walter Vergara

ABOUT THE AUTHORS

René Zamora Cristales. PhD in Forest Engineering and Economist, Research Coordinator for Latin America within the 20x20 Initiative at the WRI Forests Program in Washington, D.C.

Contact: rene.zamora@wri.org

Doribel Herrador. Agricultural Engineer and Environmental Economist, PhD in Geography, Researcher at the Regional Program for Research on Development and Environment (PRISMA) Foundation in San Salvador, El Salvador.

Contact: d.herrador@prisma.org.sv

Nelson Cuellar. Economist, Executive Director of the Regional Program for Research on Development and Environment (PRISMA) Foundation.

Contact: n.cuellar@prisma.org.sv

Oscar Díaz. Agricultural Engineer with a specialization in Geographic Information Systems, Researcher at the Regional Program for Research on Development and Environment (PRISMA) Foundation.

Contact: o.diaz@prisma.org.sv

Susan Kandel. Sociologist and Deputy Director of the Regional Program for Research on Development and Environment (PRISMA) Foundation.

Contact: s.kandel@prisma.org.sv

Jorge Quezada. PhD in Biological Sciences, Specialist of Technical Cabinet of the Ministry of Environment and Natural Resources of El Salvador.

Contact: jequezada@marn.gob.sv

Silvia de Larios. Economist, with a postgraduate degree in Integrated Water Resources Management.

Contact: slarios@marn.gob.sv

Giovanni Molina. Professional in Mathematics and Statistics, Geostatistics Manager for Risk Management and Climate Change of the Ministry of Environment and Natural Resources of El Salvador.

Contact: gmolina@marn.gob.sv

Madelyn Rivera. Engineer in Socioeconomic Development and Environment, Research Assistant at the Regional Program for Research on Development and Environment (PRISMA) Foundation in San Salvador.

Contact: m.rivera@prisma.org.sv

Wilfredo Moran Ramírez. Graduate in International Relations, Research Assistant the Regional Program for Research on Development and Environment (PRISMA) Foundation in San Salvador.

Contact: c.moran@prisma.org.sv

Abner Jimenez. Forest Engineering and Master in Land Management. GIZ Sector Specialist in the Green Development Fund Program for the region SICA/REDD+ Landscape region, in San Salvador, El Salvador.

Contact: abner.jimenez@giz.de

Emma Flores. Architect, Technical Advisor in Ecosystem Services Monitoring, Green Development Fund Program for the region SICA/REDD+ Landscape, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Contact: emma.flores@giz.de

Maria Franco Chuaire. Economist, Coordinator for South America within the 20x20 Initiative at the WRI Forest Program in Washington, D.C.

Contact: Maria.FrancoChuaire@wri.org

Luciana Gallardo Lomeli. Economist, Coordinator for Central America within the 20x20 Initiative at the WRI Forest Program in Washington, D.C.

Contact: Luciana.Gallardo@wri.org

Walter Vergara. Climate Change Specialist and Coordinator of the 20x20 Initiative at the WRI Forest Program in Washington, D.C.

Contact: Walter.Vergara@wri.org

ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity and human well-being.

Our Challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach
COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

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WORLD RESOURCES INSTITUTE

10 G STREET NE
SUITE 800
WASHINGTON, DC 20002, USA
+1 (202) 729-7600
WWW.WRI.ORG

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