ISSN 2664-4541

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NATURAL RESOURCES AND DEVELOPMENT 210

Nature-based solutions and the bioeconomy

Contributing to a sustainable and inclusive transformation of agriculture and to the post-COVID-19 recovery

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COVID-19 RESPONSE

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United Nations publication
ISSN: 2664-4541 (electronic version)
ISSN: 2664–4525 (print version)
LC/TS.2022/43
Distribution: L

Printed at United Nations, Santiago
S.22-00229

This publication should be cited as: L. E. Meza and A. G. Rodríguez, "Nature-based solutions and the bioeconomy: contributing to a sustainable and inclusive transformation of agriculture and to the post-COVID-19 recovery", *Natural Resources and Development series*, No. 210 (LC/TS.2022/43), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2022.

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Abstract

Nature-based solutions (NBS) stand at the forefront of efforts to address the multiple dimensions of global environmental change. This document reviews the synergies among multiple objectives that these solutions can offer to achieve greater sustainability in agriculture and to strengthen the bioeconomy in Latin America and the Caribbean, with a view to recovery from the COVID-19 pandemic. It describes a set of NBS that have the potential to generate synergies between the environmental objectives of the Rio conventions and that propose a road map for transformational change in the agricultural sector. The document identifies the global agreements and national frameworks that represent opportunities for promoting NBS in the sector. It reviews perceptions related to the development of NBS in the agricultural sector and their potential for upscaling in the region, as revealed by a consultation with experts. It also presents case studies showcasing the diversity of NBS applications in Latin American and Caribbean agriculture. It explains how NBS offer a triple-win formula —in environmental, social and economic terms— and underscores the importance of making progress in the measurement of those benefits to demonstrate their positive impact when implemented in a sustained manner over time. Its recommendations for upscaling NBS in agriculture are based on a review of documents and experiences, as well as on discussions with stakeholders from across the region. The document's main messages include the following: (a) the need to strategically analyse the type of public investments that can be made to support the improvement of agro-environmental management and thus create global public goods through NBS, highlighting technical assistance as part of the support to be provided; (b) the need to create the right incentives and/or redirect those that already exist, so that investments can be focused on the promotion of NBS and their synergies; and (c) the priority of investing in research, development and innovation with a focus on ecological management, environmental restoration, bioprospecting and the economic assessment of the benefits of NBS, in order to promote a new paradigm of sustainable bioeconomic development in the region.

Introduction

The impact that human societies have on the planet is reflected intensely in nature. Faced with the global environmental challenges of biodiversity loss, climate change and desertification, the 1992 United Nations Conference on Environment and Development generated a global response to address each of those challenges through the creation of three conventions. Known as the Rio conventions, they are the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD) and the Convention on Biological Diversity (CBD). Almost thirty years later, the coronavirus disease (COVID-19) pandemic has highlighted the delicate relationship that exists between development and nature, as well as the ongoing planet-wide environmental challenges.

In Latin America and the Caribbean, the pandemic has had widespread economic, social and health repercussions and has deepened pre-existing social gaps and the challenges of low productivity, all of which are compounded by biodiversity loss, land degradation and vulnerability to climate change (ECLAC, 2021a). On the one hand, agriculture is a driver of environmental degradation, and on the other, it is a victim of its consequences. Climate change is expected to have major negative impacts on the region's agricultural productivity,[1] job creation and sectoral gross domestic product (GDP) by 2030 (Bárcena and others, 2020). Similarly, in a worst-case scenario assessed, a collapse of ecosystems could cause a decline of up to 12% in the region's agricultural revenue, together with a drop of 2.2% in GDP (Johnson and others, 2021).

While an urgent response to the pandemic's impact is needed, the building of resilience and the transformation of the development model in the medium and long term cannot wait. Nature-based solutions (NBS) are an option for harmonizing development and ecosystem protection. In the agrifood system in particular, NBS can help balance productivity and resilience goals and support co-benefits between climate action, the fight against desertification and biodiversity loss, as required by the agenda for regional productive transformation.

The Economic Commission for Latin America and the Caribbean (ECLAC) proposes the bioeconomy as a technical and productive paradigm for regional agricultural development and activities based on

[1] As used in this document, agriculture includes crops, fruit trees, livestock and forestry. Although fishing and aquaculture are included in the broad sense of the term, those subsectors are excluded from the present analysis.

biological resources. The bioeconomy strengthens interconnections between: (i) the sustainable use and management of biodiversity and its components, (ii) sustainable and regenerative agriculture, and (iii) nature-based solutions (ECLAC, 2020c). NBS provide a framework for responding to those concerns through sustainable initiatives for the region's economic recovery from the ongoing pandemic and its long-term sustainable transformation.

ECLAC, under its cooperation programme with the Republic of Korea, is carrying out a project to improve national capacities for the development of NBS in agriculture, as part of the bioeconomy push in the region. This document has been prepared under the aegis of the cooperation programme to identify and analyse nature-based solutions that generate synergies between the environmental objectives of the Rio conventions and have the potential to promote a sustainable economic recovery in the aftermath of COVID-19, focusing on the conservation, sustainable use and restoration of biological resources and the development of the bioeconomy in Latin America and the Caribbean.

The document is divided into six sections. The first analyses the Rio conventions and their synergies, highlighting linkages between their objectives and functioning and showcasing relationships between the bioeconomy, the conventions, and nature-based solutions. Section two addresses the opportunities offered by the post-pandemic recovery for the sector's transformation. The third section proposes a framework for integrating a range of objectives, including key definitions, and for compiling NBS applicable to agriculture that have potential synergies for the recovery process. Section four assesses opportunities for promoting NBS in agriculture, based on global environmental agreements and the applicable national strategic frameworks. The fifth section reports on perceptions, collected by means of a survey, regarding NBS in the sustainability of regional agriculture. Section six presents case studies of NBS applied to agriculture. Finally, the seventh section offers conclusions and some recommendations for upscaling NBS in pursuit of sustainable agriculture and for bolstering the development of the bioeconomy and the region's post-pandemic recovery.

Also included are three annexes on strategic frameworks for the deployment of NBS in agriculture, the evolution of the literature on nature-based solutions and a description of a set of nature-based solutions in agriculture that offer the potential for synergies among the Rio conventions.

I. Nature-based solutions and the global environmental conventions

Nature-based solutions (NBS) support the conservation, restoration and improved management of land and natural processes, to create environmental, economic and social benefits based on the emulation of biological principles, processes and systems. As such, they have become a key concept for jointly tackling the challenges of climate change, biodiversity loss and land degradation, which are the issues addressed by the Rio conventions. The food system and agriculture depend on plants, animals and microorganisms, and on their interactions at the genetic, species and ecosystem levels. Food production has traditionally used nature-based options, but today they must be revitalized and expanded, especially on account of the need to reactivate the sector and move towards a more sustainable food system.

A. Nature-based solutions and related concepts

Understanding the complexity of interactions between people and nature has been a philosophical issue throughout the history of human societies. Díaz and others (2018) emphasize the leading role that culture plays in how we conceptualize and perceive nature.

In the 1980s, science conceived the idea of ecosystem services to understand the contribution of biodiversity and ecosystems to societies, but it was the Millennium Ecosystem Assessment that popularized it (Díaz and others, 2018; Osaka, Bellamy and Castree, 2021). More recently, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) coined the term "nature's contributions to people" (NCP) as a broad conceptual framework for the linkages that exist between nature and people. Bastos and Palme (2022) explain that the concepts of natural capital and bioeconomy combine economics with natural sciences to illustrate the relationships and dependencies between human society and the environment.

Ducarme and Couvet (2020) note that although nature conservation is a major social concern today, its conceptualization remains elusive. The authors conclude that the incorporation of new terms into the field of conservation represents an effort to deploy other means of conservation, adopting new values and protecting different elements of "nature" such as, for example, important species and landscapes in farmland, local varieties or socioecosystemic processes.

NBS are one of the most recent conceptualizations to be added. They represent a set of options for responding to a problem —generally an environmental one— based on promoting or recreating natural processes (Palomo and others, 2021; Osaka, Bellamy and Castree, 2021). Their definition is closely linked to ecosystem management since, in general, they aim at improving one or more ecosystem services, thus addressing a specific problem and generating benefits in many other dimensions (Palomo and others, 2021; Davies and others, 2021) (see box 1).

While the term was coined by the World Bank in 2008 to showcase how green infrastructure could complement traditional grey infrastructure, its later conceptualization was proposed and promoted by both the International Union for Conservation of Nature (IUCN) and the European Commission, along with other international agencies (Eggermont and others, 2015; Nesshöver and others, 2017; Osaka, Bellamy and Castree, 2021). The definitions coined by the European Commission and IUCN are the most widely used. While IUCN emphasizes the conservation and restoration of biodiversity, the European Commission focuses on the cost-effectiveness of solutions and the opportunities for innovation they offer (Nesshöver and others, 2017; Hanson, Wickenberg and Alkan, 2020; Davies and others, 2021).

Box 1
Main definitions of NBS in use

IUCN defines NBS as "actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham and others, 2016).

The European Commission defines them as solutions "inspired and supported by nature [that are] cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience" (European Commission, 2015).

The Organisation for Economic Co-operation and Development (OECD) proposes a definition whereby NBS are "measures that protect, sustainably manage or restore nature, with the goal of maintaining or enhancing ecosystem services to address a variety of social, environmental and economic challenges" (OECD, 2020a).

Nature's contributions to people are "all the contributions, both positive and negative, of living nature (i.e. diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to the quality of life for people. Beneficial contributions from nature include such things as food provision, water purification, flood control, and artistic inspiration, whereas detrimental contributions include disease transmission and predation that damages people or their assets. Many NCP may be perceived as benefits or detriments depending on the cultural, temporal or spatial context" (IPBES, 2022).

Source: E. Cohen-Shacham and others (eds.), *Nature-based solutions to address global societal challenges*, Gland, International Union for Conservation of Nature (IUCN), 2016; European Commission, *Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities: final report of the Horizon 2020 expert group on 'Nature based solutions and re naturing cities'*, Brussels, 2015; Organisation for Economic Co-operation and Development (OECD), "Nature-based solutions for adapting to water-related climate risks", *OECD Environment Policy Paper*, No. 21, Paris, 2020; Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), "Report of the Plenary of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on the work of its sixth session", Bonn, 2018 [online] https://ipbes.net/sites/default/files/ipbes_6_15_add.2_spm_americas_english.pdf.

NBS offer an overarching framework that brings together and builds on a number of previously existing concepts, applied in specific settings and at different scales to achieve the greatest social and ecosystemic benefits (Nesshöver and others, 2017; Randrup and others, 2020; Hanson, Wickenberg and Alkan, 2020; Davies and others, 2021). Those approaches include ecological engineering, green infrastructure, blue infrastructure, the ecosystem approach, ecosystem-based mitigation and adaptation, the landscape approach, ecosystem services, natural capital and others.

In addition to the different definitions in use, there has been a constant evolution of the term. Linked to the response to climate change, Griscom and others (2017) propose the concept of nature-based climate solutions. In turn, UNCCD (2020) uses the term "land-based solutions" to jointly address the issues of land degradation and post-pandemic recovery. Howes and others (2020) use the term "nature-based health solutions", calling for the conservation of biodiversity as a source of medicines. Annex 2 shows the evolution of the literature produced regarding NBS.

Palomo and others (2021) attribute the recent ascendancy of NBS to their potential to generate multiple benefits in win-win situations. Nesshöver and others (2017) emphasize that NBS make it possible to go beyond visions focused on short-term profitability alone. The benefits include their lower cost compared to traditional alternatives and the possibility of generating multiple positive environmental impacts, together with such social benefits as job creation and income opportunities to improve the resilience of communities and the economy. NBS are a concept that works at the interface between scientific disciplines, public policies and their practical applications, with a wide versatility and range of action (Dorst and others, 2019; Hanson, Wickenberg and Alkan, 2020; Herrmann-Pillath, Hiedanpää and Soini, 2022).

NBS are not completely uncontroversial. Doubts exist about the supposedly lower risks and investment levels required, their degree of maturity as promising alternatives, the possible trade-offs they may entail and their technocratic nature that may ignore social considerations and give rise to responses focused on the short term that harm biodiversity or neglect other important climate change mitigation actions (Dasgupta, 2021; Seddon and others, 2021, Simelton and others, 2021; Osaka, Bellamy and Castree, 2021). McElwee and others (cited by Smith and others, 2019) state that there are many unresolved areas of uncertainty regarding the measurement and assessment of ecosystem services, which affects the evidence of their effectiveness and the policy options to be developed. These limitations can be extended to NBS, particularly in developing countries (Seddon and others, 2021; Simelton and others, 2021).

IUCN has established eight principles for nature-based solutions, whereby they embrace standards for nature conservation (P1), maintain biological and cultural diversity (P5), are determined by site-specific contexts (P3), are applicable at the landscape scale (P6), can be implemented alone or in an integrated manner with other solutions to societal challenges (P2), produce societal benefits in a fair and equitable way (P4), and address trade-offs between economic benefits and ecosystems (P7) and are an integral part of policy frameworks (P8) (Cohen-Shacham and others, 2019).

Herrmann-Pillath, Hiedanpää and Soini (2022) argue that conceptual developments in environmental and sustainability science are driven by the need for communication among researchers, policymakers and implementing agencies, in order to build the commitment of various parties. Since NBS arise at the interface between science, policy and practice, as an approach they have the advantage of being understood by and close to practitioners implementing solutions related to ecological issues at different scales; thus, they are defended and promoted by various actors in international and local environmental arenas (Osaka, Bellamy and Castree, 2021; Herrmann-Pillath, Hiedanpää and Soini, 2022).

This document focuses on the range of NBS that support the post-pandemic recovery and the development of the bioeconomy; hence, it concentrates on those that: (i) include solutions inspired by natural processes, (ii) focus on options that produce triple-impact benefits (environmental, social and economic) and the cost-effectiveness of solutions, and (iii) explicitly address the building of resilience, which is a key issue for the post-pandemic scenario and the transformation of food systems.

B. The Rio conventions and nature-based solutions

In the 1980s, as countries recognized the extent of global environmental and climate degradation, their concern about curbing its impacts grew. The conventions on biological diversity, climate change and desertification —also known as the Rio conventions, as they arose from the United Nations Conference on Environment and Development ("the Earth Summit"), held in Rio de Janeiro in 1992— were the instruments adopted to jointly counter environmental problems.

The three conventions, which have been ratified by all 33 Latin American and Caribbean countries (ECLAC, 2021c), establish a general framework for coordinating intergovernmental efforts in pursuit of shared environmental objectives.

1. Interrelated objectives and functioning of the conventions

The Rio conventions are intrinsically linked, in that they address interdependent issues and, therefore, their objectives are also related (see box 2). The CBD addresses the loss of biodiversity, the UNCCD deals with desertification, drought and soil degradation and the UNFCCC aims to check global climate change.

Box 2
Objectives of the Rio conventions

Convention on Biological Diversity (CBD): Its purpose is "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources". The agreement covers all ecosystems, species and resources (United Nations, 2021a).

United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD): Its objective is to combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification, particularly in Africa, through effective action at all levels, supported by international cooperation and partnership arrangements, in the framework of an integrated approach, with a view to contributing to the achievement of sustainable development in affected areas (United Nations, 2021b).

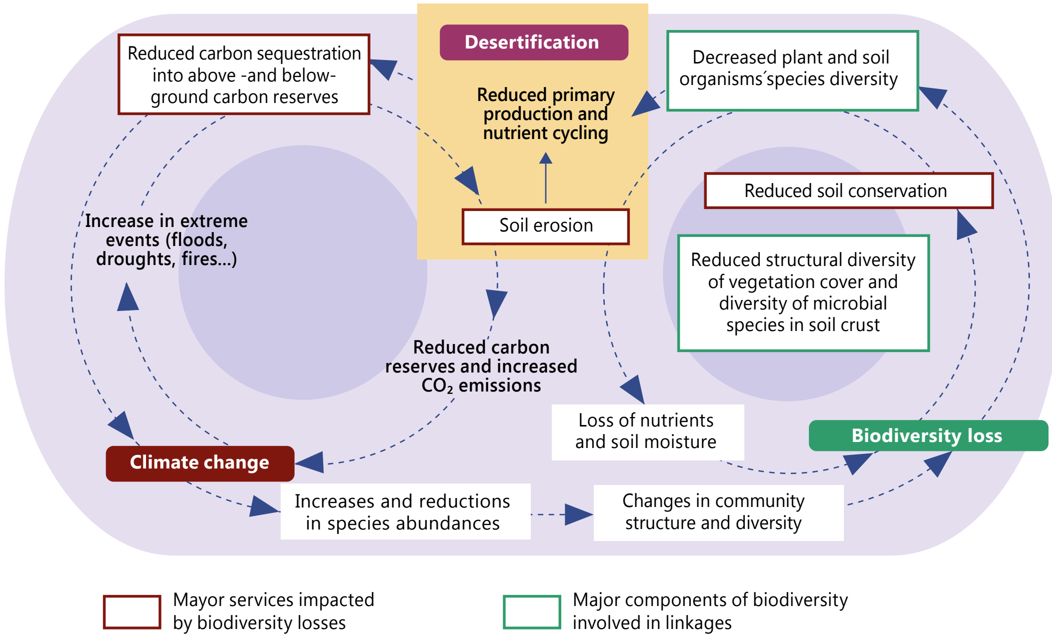
United Nations Framework Convention on Climate Change (UNFCCC): Its objectives are to stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system, within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner (United Nations, 2021c).

Source: United Nations, Convention on Biological Diversity, New York, 1992; "Preparations for the Post-2020 Biodiversity Framework", 2021a [online] https://www.cbd.int/conferences/post2020; "The Rio Conventions Pavilion 2021–2022", 2021 [online] http://www.riopavilion.org/; "United Nations Convention to Combat Desertification", 2021 [online] https://www.unccd.int/.

The carbon cycle and the water cycle are the two most important processes for life on the planet, both of which depend on biodiversity and have links to climate change and land degradation (United Nations, 2021d). To understand the synergies that exist between the Rio conventions' objectives, the Millennium Ecosystem Assessment Board (2005) proposed a framework of linkages and feedback loops that identifies ecosystem services and the impacted components of biodiversity, the carbon cycle, nutrient cycling, soil erosion, biodiversity abundance and structure (plants, soil organisms, insects, others) and extreme events (see diagram 1).

In addition to their interrelated objectives and subject matters, the conventions have similar operating structures, which include such common elements as: (i) strategic frameworks with planning for the achievement of their aims, (ii) the conventions' constituent and/or operative bodies, (iii) national implementation and reporting mechanisms, and (iv) the Conferences of the Parties (COP), which bring together the member countries' representatives annually to examine the progress made. Annex 1 expands on this review of the strategic frameworks.

Diagram 1
Linkages and feedback loops between desertification, climate change and biodiversity loss



Source: Millennium Ecosystem Board, *Ecosystems and Human Well-Being: Desertification Synthesis*, Washington, D.C., World Resources Institute (WRI), 2005.
Note: The major components of biodiversity loss (in green) directly affect major ecosystem soil services (in bold). The internal loops connect desertification with biodiversity loss and climate change through soil erosion. The outer loop interrelates biodiversity loss and climate change, as drops in primary output and microbial activity reduce carbon sequestration and contribute to global warming. Climate change, in turn, negatively affects biodiversity in several ways. Changes in community structure and diversity are expected because different species will react differently to elevated CO_2 concentrations.

The three conventions are supported by panels of experts who prepare reference reports and who, in specific papers, have addressed the interrelations between the conventions and agriculture. In 2018, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) issued a thematic assessment report on land degradation and restoration and its relationship to biodiversity and ecosystem services. Likewise, in its 2019 special report, the Intergovernmental Panel on Climate Change (IPCC) extensively analysed interactions between land degradation and climate change and assessed options that could generate co-benefits for natural capital and the Sustainable Development Goals (SDGs). The IPBES-IPCC 2020 scientific workshop jointly addressed the biodiversity loss and climate crises, highlighting the extraordinary role of agriculture in achieving combined and at-scale environmental and social objectives.

The three conventions' shared funding mechanism is the Global Environment Facility (GEF), which was established around the time of the Earth Summit. Subsequently, with the greater focus placed on climate action, other specific mechanisms have emerged, including the Green Climate Fund (GCF) and the Adaptation Fund. For its part, the UNCCD has its Global Mechanism, which helps to mobilize financial resources for the countries by raising awareness and coordinating with different donors. NBS are present in the funding lines of all these facilities.

The implementation of the conventions requires that countries comply with certain common requirements, which include: (i) the development of national regulatory and policy frameworks, (ii) the establishment of national and international financing mechanisms, (iii) public awareness and education, (iv) the creation of information repositories, and (v) a commitment to research and technology transfer.

Clearly, developing countries need to make greater efforts to integrate environmental challenges into their planning and respond to their convention commitments. Hence, from the onset, efforts have been made to identify options that allow for coordinated actions and a better catalysing of investments at the national level; the results of these attempts to jointly operationalize environmental actions have been variable, however.

2. NBS in operationalizing synergies between the Rio conventions

Davis and others (2021) note that the 2030 Agenda and its Sustainable Development Goals (SDGs), the work on natural capital and, more recently, nature-based solutions represent conceptualizations and efforts intended to jointly address the interdependence of sustainable development challenges.

Recognizing the interrelationships that exist between the Rio conventions —both from an ecosystem perspective and in their institutional approach— several of the articles and decisions of the respective Conferences of the Parties (COP) have encouraged the search for synergies, especially at the national implementation level, in order to reduce the duplication of efforts. Thus, in 2001, the Joint Liaison Group (JLG) was established to promote the exchange and dissemination of information, collaboration among national focal points and cooperation among the three conventions. The Rio Conventions Pavilion is a platform for raising awareness and sharing information about the latest practices and scientific findings related to the co-benefits of convention implementation, as well as for preparing and sharing joint documents.

During the 2000s, the member countries conducted self-assessments to analyse their national institutional and organizational capacities for implementing the Rio conventions and to set priorities for action. The aim was to generate at-scale projects that would synergistically address priority environmental problems. The ecosystem approach was identified early on as an option for jointly addressing the impacts of climate change, adaptation, mitigation, land degradation and the conservation and sustainable use of biodiversity (Secretariat of the United Nations Framework Convention on Climate Change, 2004). In 2015, the 2030 Agenda and the Sustainable Development Goals (SDGs) bolstered the three conventions' comprehensive take on development and cross-cutting approach to environmental challenges (Davies and others, 2021).

NBS represent a starting point for achieving synergies between environmental objectives, in that they condense a series of strategies for restoring ecosystems and biodiversity, or for enhancing their conservation, so that ecosystem services and socioeconomic benefits can be produced and a series of challenges can be responded to in a multidimensional way (Palomo and others, 2021; Pörtner and others, 2021). Although they primarily refer to the protection of biodiversity, Griscom and others (2017) note that NBS could cost-effectively provide more than one third of the mitigation of the greenhouse gases that cause rising temperatures, with co-benefits in soil productivity, water and other ecosystem services. In turn, the UNCCD recognizes the potential of NBS for land degradation neutrality.

NBS are being included the countries' main action frameworks, such as: (i) the nationally determined contributions (NDCs) and long-term climate strategies of the Paris Agreement, (ii) national biodiversity strategies or plans, in line with the goals and objectives of the Post-2020 Global Biodiversity Framework, and (iii) national voluntary land degradation neutrality targets (see table 1).

In 2017, the executive secretariats of the Rio conventions issued a joint declaration for the establishment of a project preparation mechanism for large-scale initiatives combining actions on land degradation, biodiversity loss and global warming. In 2020, the secretariats reiterated the proposal for the mechanism to take advantage of the synergistic enforcement of the conventions, but this time alluding to NBS as a basis for the creation of synergistic projects that would allow countries to scale up transformative actions and access financing and technical support.

Table 1
Summary of strategic and implementation frameworks of the Rio conventions and their links with NBS

Description	Convention on Biological Diversity	United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa	United Nations Framework Convention on Climate Change
Global strategic frameworks	Post-2020 Global Biodiversity Framework (road map to 2050)	Land degradation neutrality	Paris Agreement
National frameworks for action	National biodiversity strategies and action plans	National voluntary land degradation neutrality targets	Nationally determined contributions (NDCs) Long-term climate strategies
Role of NBS	While NBS were explicitly included in one of the targets of the Post-2020 Global Biodiversity Framework (draft zero), the term was subsequently modified to refer broadly to the contributions of nature	NBS have an obvious potential to rehabilitate, conserve and sustainably manage soil and water resources	NBS can contribute to both greenhouse gas mitigation and climate change adaptation. Accordingly, many Latin American and Caribbean countries have specifically included NBS in their plans. NBS play a leading role in the updated NDCs and long-term climate strategies of Latin American and Caribbean countries

Source: World Business Council for Sustainable Development (WBCSD), *Accelerating business solutions for climate and nature. Report I: mapping nature-based solutions and natural climate solutions*, Geneva, 2020; Secretariat of the Convention on Biological Diversity (2020), "First Draft of the Post-2020 Global Biodiversity Framework: Note by the Co-Chairs", Montreal, 2021; official websites of the Rio conventions.

Interactions between climate change, land degradation and biodiversity are now broadly acknowledged. In addition, the technical and political consensus is that NBS allow comprehensive approaches, which could also reduce the agreements' implementation costs for the countries and facilitate access to funding sources (UNCCD, 2021). The IPCC and IPBES joint report (Pörtner and others, 2021) states that country reporting on the conventions provides a significant opportunity for aligning national climate change objectives and biodiversity conservation goals.

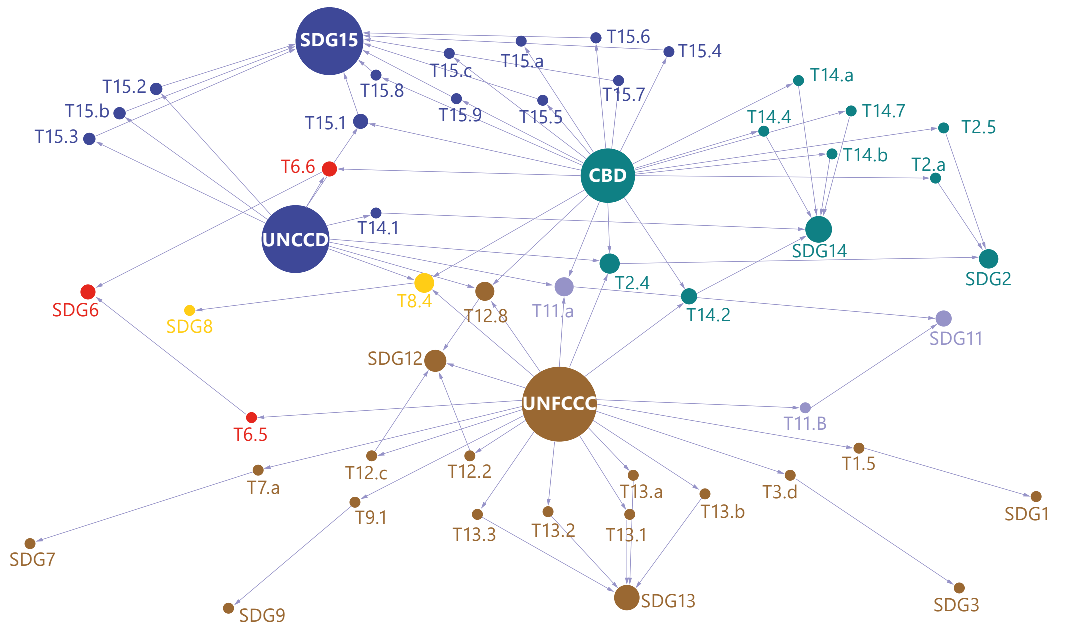
3. Linkages between the Rio conventions and the Sustainable Development Goals

Ecosystems are involved in the Sustainable Development Goals that address life on land (Goal 15), the planet's oceans (Goal 14), climate change (Goal 13), water (Goal 6) and, more broadly, the food supply (Goal 2), sustainable consumption and production (Goal 12), energy (Goal 7) and all the SDGs in general, as they are the basis of life on the planet (Yang and others, 2021).

To illustrate the relationships between the Sustainable Development Goals (SDGs) and the Rio conventions, the following were mapped: (i) linkages between the SDG targets for which the conventions are relevant, and (ii) the relationships between the targets and the corresponding SDGs. The results, shown in diagram 2, indicate the existence of three large clusters associated with each of the conventions. The United Nations Framework Convention on Climate Change is linked to Goals 1, 3, 7, 9, 12 and 13; the Convention on Biological Diversity is linked to Goals 2 and 14; and the Convention to Combat Desertification is linked to Goal 15.

Goal 2, while it is most closely associated with the Convention on Biological Diversity's cluster, is linked to all three conventions through target 2.4, which states: "By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality." Thus, that goal would be the most relevant for forging synergies among the three conventions through nature-based solutions in agriculture.

Diagram 2
Linkages between the Rio conventions and the Sustainable Development Goals



Source: Prepared by the authors, on the basis of the NodeXL tool [online] https://www.smrfoundation.org/nodexl/.

Adopting NBS in rural landscapes and agriculture is essential in achieving the goals set. IPCC and IPBES recommend increasing sustainable agricultural and forestry practices, such as diversification of crops and planted forest species, agroforestry and agroecology. Pörtner and others (2021) estimate that improved management of croplands and grazing systems, soil conservation and reduced fertilizer use offer an annual climate change mitigation potential of between 3 and 6 gigatons of carbon dioxide, in addition to improved climate change adaptability and biodiversity benefits.

Sustainable agriculture is vital for achieving environmental objectives and, accordingly, the three conventions address this issue from their different perspectives.

C. The bioeconomy as a paradigm for agricultural development in Latin America and the Caribbean

This document takes bioeconomy to mean the production, utilization, conservation and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes and services in all economic sectors aiming toward a sustainable and inclusive economy. According to this definition,[2] which is derived from the communiqués issued by the International Advisory Council on the Global Bioeconomy (IACGB) in the framework of the Global Bioeconomy Summits (IACGB, 2015, 2018 and 2020), the bioeconomy is inherently linked to the provision of ecosystem services and the management of biological resources (plants, animals, microorganisms, genetic resources and biomass, including organic waste and residues).

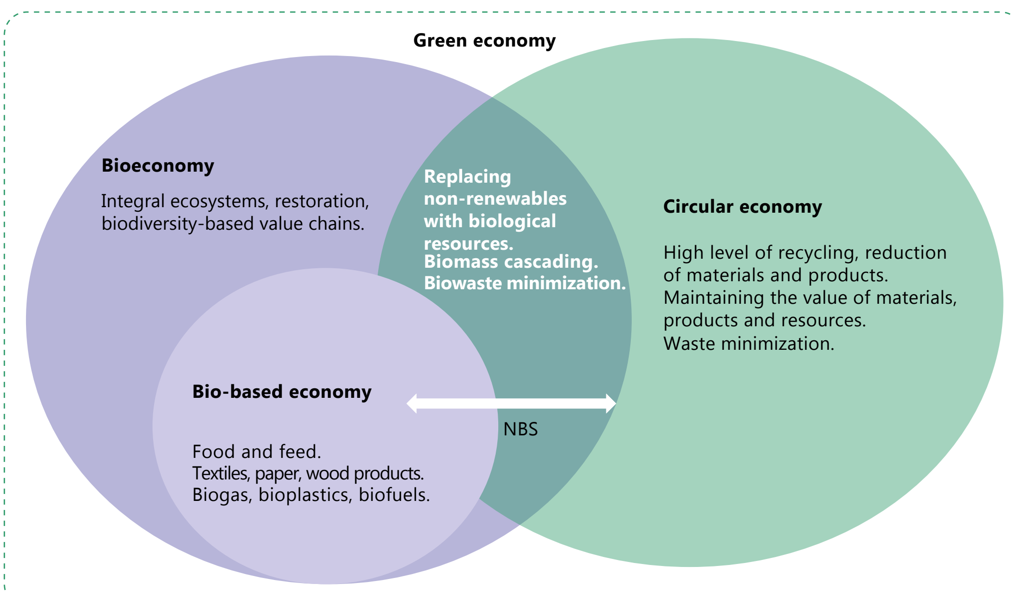
[2] The original definition adopted in the communiqués of the 2015 and 2018 Global Bioeconomy Summits speaks of "the production, utilization and conservation of biological resources". The communiqué of the 2020 Global Bioeconomy Summit (IACGB, 2020) recognizes that the bioeconomy is critical not only to protect biodiversity and ecosystems, but also to restore them as regards agriculture, marine systems, freshwater systems and urban areas. The definition was therefore broadened to include "the regeneration of biological resources" as a central element of the bioeconomy. This expanded definition is the one adopted by the National Bioeconomy Strategy of Costa Rica (Government of Costa Rica, 2020).

The bioeconomy is a conceptual framework that is positioning itself globally as a road map for sustainable development (D'Amato, Bartkowski and Droste, 2020; Kardung and others, 2021; Bastos and Palme, 2022). While this framework was initially restricted to the production of energy, food, and materials, a new bioeconomic framework is emerging based on integral ecosystems and new value chains based on local biodiversity (Bastos and Palme, 2022).

Neill, O'Donoghue and Stout (2020) report that there have been criticisms of the potential negative impacts of the bioeconomy, especially as regards the production of energy crops and the use of genetic resources; consequently, their contribution to sustainability must be properly defined, measured and communicated. In line with those concerns, Rodríguez, Rodrigues and Sotomayor (2019) set out a series of requirements for a sustainable bioeconomy in Latin America and the Caribbean. One series of criteria include social aspects such as job creation, social inclusion and rural territorial development. Other requirements are diversifying production, adding value to primary production and making intensive use of knowledge and innovation, together with issues related to environmental objectives such as better environmental management of production, contribution to decarbonization, care of biological resources and ecosystem services. Similarly, FAO (2021a) has proposed a framework of aspirational principles and criteria for a sustainable bioeconomy, grouped into four clusters: environment, economy, governance and society.

As the bioeconomy encompasses several bio-based value chains and economic activities that depend on biodiversity, it has the potential to help conserve or restore habitats, improve knowledge about biodiversity, enhance livelihoods and increase social participation (Bastos and Palme, 2022). ECLAC (2020b) proposes that the bioeconomy be the technical and productive paradigm for the regional development of agriculture and other activities based on biological resources, since it strengthens interconnections between various different areas: (i) sustainable use and management of biodiversity, (ii) sustainable and regenerative agriculture, and (iii) nature-based solutions. In this way, several general frameworks and development paradigms are combined (see diagram 3).

Diagram 3
NBS and relationships between the bioeconomy, bio-based economy, green economy and circular economy



Source: Prepared by the authors, on the basis of M. Kardung and others, "Development of the circular bioeconomy: drivers and indicators", *Sustainability*, vol. 13, No. 1, Basel, Multidisciplinary Digital Publishing Institute (MDPI), 2021.

The bioeconomic approach provides a framework for including these concerns in short-term post-COVID economic recovery initiatives and the long-term transformation of food systems. We argue that these objectives can be achieved through the application of agroecological principles and NBS in agriculture. It also argues that Latin America can move towards a new stage of development through innovation based on biodiversity applications for more sustainable food production, leveraging NBS that increase resilience, allow the replacement of agrochemicals and promote environmental restoration, among other nature-based strategies.

Because of its links with biological resources, the bioeconomy proposes development pathways that include a wide range of NBS, including the protection and improvement of ecosystem services, the eco-intensification of agriculture and agroecology, bio-based processes for environmental remediation in soils and water, the prospecting of biodiversity for the development of new products and uses, the reappraisal of residual biomass, the generation of biomaterials, biopharmaceuticals and a series of other innovative options based on and inspired by nature (see section II.D, which identifies innovations highlighted by the Scientific Group for the 2021 United Nations Food Systems Summit related to biosciences, digital technologies and NBS).

II. Post-pandemic recovery and the transformation of food systems

The COVID-19 pandemic has created an unprecedented crisis, both for public health and through its impact on employment and livelihoods, social services, trade and the global economy. Latin America and the Caribbean account for one third of the world's pandemic deaths, with the risk that the 2030 Agenda will not be achieved as the pandemic's effects remain present for many years to come (ECLAC, 2022c).

Recovery from the pandemic demands major efforts but, at the same time, it represents an opportunity to transform the development model, if the intensity of the short-term response is combined with long-term objectives. Comprehensive investments are required to generate economic growth, employment, the development of value chains and the reduction of environmental impacts, while restoring natural capital and creating new productive capacities (ECLAC, 2020b). Agriculture and the food system[3] as a whole offer unique opportunities for a deep and transformative reconfiguration in the context of the recovery.

This transformative change includes the contributions of the bioeconomy to regional development and to both sustainable agricultural production and food security, to new opportunities for the creation of decent jobs in new bio-based value chains, especially for women and youth, to the generation of technological capabilities and innovations focused on sustainability and to knowledge for the conservation, management and sustainable use of biodiversity (ECLAC, 2020b).

A. The two-way relationship between nature and agriculture

Agriculture is vitally dependent on ecosystems for food production and it is therefore particularly affected by climate change, biodiversity loss and environmental degradation (Springmann and others, 2018; Loboguerrero and others, 2018; Vanberger and others, 2020). At the same time, the sector is a driver of both direct and indirect environmental degradation.

Agriculture has adopted intensive production methods to respond to increasing food demand from a growing population with changing consumption patterns (Pörtner and others, 2021). The expansion of

[3] The food system comprises the wide range of activities related to the production, processing, transportation, preservation and consumption of food (United Nations, 2021f).

agriculture has led to changes in land use and agricultural landscapes, to the detriment of biodiversity (IPBES, 2019). The overuse of synthetic fertilizers and pesticides impacts water and soil resources, contaminating aquatic and terrestrial ecosystems (FAO, 2021b). And, together with its linkages in the food system, it generates almost one third of the greenhouse gas emissions that cause global warming (Steffen and others, 2015; Springmann and others, 2018; FOLU, 2019; Bárcena and others, 2020; FAO, 2021b).

Several authors have argued that as a result of demographic shifts and rising income levels, the food system's environmental impacts could increase by between 50% and 90% by 2050, exceeding safe planetary limits for humankind if adequate containment actions are not implemented (for example, Steffen and others, 2015; Willet and others, 2019). After 2050, the risk of falling yields would increase as a result of climate change, especially if global average temperatures rise above 2 °C and in combination with other drivers of change. Falling or stabilizing yields in the current major production areas could trigger an expansion of cropland elsewhere —either into natural ecosystems, marginal arable land or intensified exploitation of already cultivated land— which would potentially have consequences for increased land degradation (IPCC, 2019) and biodiversity loss (Pörtner and others, 2021).

Latin America and the Caribbean is a mega-biodiverse region, with the planet's greatest variety of species and ecosystems, a quarter of its mangroves and half of its tropical forests. However, overexploitation of natural resources and pollution threaten its natural capital and, consequently, its regional development (Alpízar and others, 2020; Bárcena and others, 2020). In Central America, 14% of the land suffers some degree of degradation; the situation, however, is more serious in South America (17%) (FAO, 2021c). Erosion in some Latin America and the Caribbean countries affects 15% of cultivated land and forecasts indicate it could reach 60% (FAO, 2021b). Desertification threatens a major portion of the region. Droughts are expected to increase under climate change scenarios as the end of the century approaches, affecting Central American countries in particular (IPCC, 2019).

Agriculture uses more than one third of the region's total land area, consumes 75% of its freshwater resources and generates almost half of its greenhouse gas emissions (Morris and others, 2020). FAO (2021b) warns that Latin America and the Caribbean has the world's highest average pesticide use per hectare of cropland. Synthetic fertilizer use has risen and is expected to continue to expand, causing increased soil contamination and acidification in the future, along with problems of pollutants in surface and groundwater bodies (FAO, 2021b).

In the forestry sector, nearly 300 million hectares of forest in Latin America and the Caribbean are considered degraded and 350 million ha have already been deforested (Vergara and others, 2016). Of the 15 countries with the largest net losses of primary forests in the world, nine are in the region. There are 31 eutrophicated zones in water bodies and 19 marine dead zones, and almost a quarter of the world's environmental conflicts occur in the region (ECLAC, 2022c).

Nature provides pharmaceutical products for the treatment of a number of diseases. Howes and others (2020) highlight the potential of plants and traditional knowledge from Latin America and the Caribbean in contributing to medicine. The authors state that protecting biodiversity can generate hitherto unexplored nature-based health solutions. A high number of medicinal plants are assumed to exist given the region's biodiversity; however, the authors note that only a minor fraction of its flora has been assessed, and much of it is being lost. These elements relate to the third pillar of the CBD, which refers to "the fair and equitable sharing of the benefits arising from the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding" (United Nations, 1992).

Despite the region's natural riches, its food security has been declining since 2014, and there is a dichotomy in which part of the population lacks sufficient food while others consume large amounts of foodstuffs that are not very nutritious. Some 60% of the adult population is overweight and 20% are obese. In 2019 there were about 190 million food insecure people but, due to the COVID-19 pandemic, in 2020 that figure rose by 30%: 267 million people are food insecure and nearly 60 million people are going hungry (FAO and others, 2021). An unhealthy diet correlates with a higher risk of chronic non-communicable diseases, and overweight and obesity are also associated with COVID-19 risks (FAO and others, 2021). Just as more diversified agriculture has a better productive and environmental performance (Tamburini and others, 2020), a varied diet, rich in plant-based foods and with fewer animal-based sources, could benefit both human health and the environment (Willet and others, 2019).

Given the urgency of moving towards a more sustainable future —in terms both of how we produce and what we consume— in 2021 the United Nations convened the First Food Systems Summit to discuss potential ways to transform the food system. One of the five pathways for change entailed boosting food production in a nature-positive way and at scale. In turn, that pathway encompassed four dimensions: (i) the knowledge gap, (ii) incentives to use biodiversity in production systems, (iii) policies needed to allow more diverse systems, and (iv) financial investment and incentive mechanisms. The protection of agrobiodiversity and NBS were at the centre of the proposal for transformation enshrined in this pathway.

B. Nature-based solutions for agricultural sustainability

As a sector that is interconnected and interdependent with nature, agriculture offers opportunities for pursuing actions to contain and mitigate global environmental change. Vanbergen and others (2020) identify a spectrum of agricultural production models that are more in tune with nature and that can help bring about the level of systemic transformation required. In food production, ecosystem management includes the integrated management of land, water and living resources, an issue that is widely embraced by the NBS concept.

According to IUCN, NBS entry points for addressing food security include: (i) the protection and management of wild species and genetic resources (especially fish), (ii) the supply of water for irrigation, (iii) the restoration, conservation and management of ecosystems to provide services and help stabilize food availability, access and use during periods of natural or climatic disaster and political instability. Examples include protecting plants from pest and disease outbreaks, jointly addressing water security and food security, forest landscape restoration strategies and resolving land tenure issues (Cohen-Shacham and others, 2016).

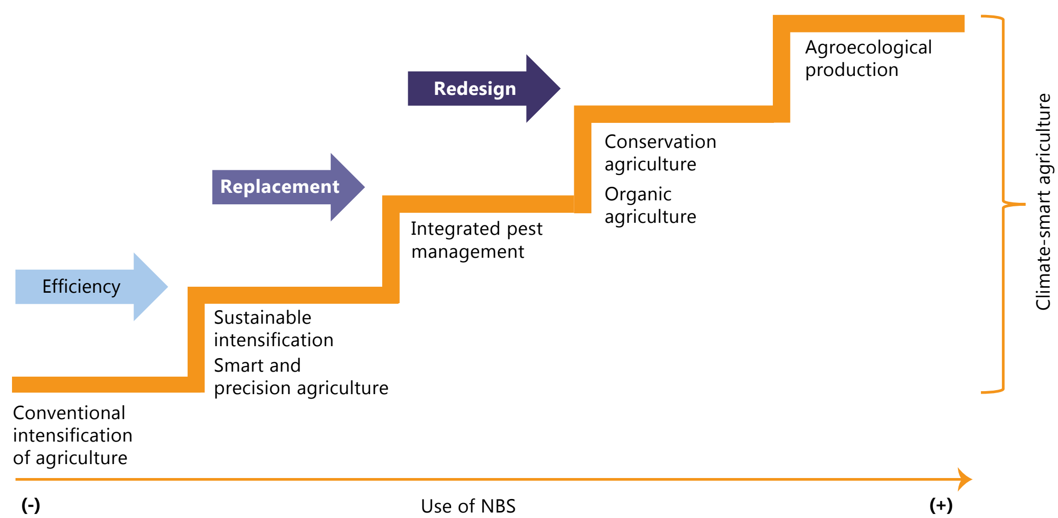
Agriculture (including crop raising, forestry, livestock, fisheries and aquaculture) is governed by natural cycles and depends on several ecosystem services, and their maintenance and improvement is critical for moving towards a sustainable intensification of food production. In its efforts to optimize food production and processing, agriculture made early use of genetic selection, the promotion of pollinators, the biological control of insect populations, the use of beneficial organisms (for fertilization, pathogen control and food processing) and other techniques. The use of beneficial microorganisms is traditional in agronomic management, from the ancient use of yeasts for food preservation and processing to the use of natural biological controllers of the pests and diseases that attack crops and plantations. The most recent examples include the use of fungi of the *Trichoderma* genus to control crop diseases, insects of the genus *Chrysoperla sp*. that attack insect pests, and nitrogen-fixing bacteria of the genus *Rhizobium*.

Sustainable land management in agriculture uses tillage and mulching practices, the application of conditioners to improve soils, integrated water management and the deployment of green infrastructure (or bioengineering) for soil and water management. Fernandes and Guiomar (2018) explain that bioengineering focuses on protecting biodiversity and ecological functionality in pursuit of slope stabilization, wetland restoration and waterway protection, on reducing the effects of surface runoff and erosion, on fire control and on the recovery or reversal of land degradation processes, including pollution.

These different practices are based on the management of an ecosystem (agroecosystem or marine or aquatic ecosystem) and can be classified by certain types of agriculture or agricultural techniques (agroecology, integrated landscape management, conservation agriculture, climate-smart agriculture and others). Iseman and Miralles-Wilhelm (2021) note that many agricultural NBS are aligned with the emerging field of "regenerative agriculture", even though its scope is still vague and there is no single accepted definition (Newton and others, 2020; Pörtner and others, 2021). The different agricultural techniques use overlapping principles that do not allow a clear distinction to be drawn between one type and another (Smith and others, 2019; Tamburini and others, 2020; Vanbergen and others, 2020). Nevertheless, several of their practices can be defined as NBS because they involve the workings of nature.

Vanbergen and others (2020) propose a classification of agricultural production models based on how they carry out production intensification: through efficiency, substitution of production inputs or the ecological redesign of the landscape to different degrees. The classification includes: (i) conventional intensification of agriculture, (ii) sustainable intensification of agriculture, (iii) integrated pest management, (iv) ecological agriculture, (v) conservation agriculture, (vi) diversified agriculture, (vii) agroecological agriculture, (viii) ecological intensification, and (ix) climate-smart agriculture. These models vary in their reliance on nature and technology, as well as in the levels of transformational change they require to attain greater sustainability; however, all the types in the classification make use of NBS to some degree. As the world moves towards a more sustainable model for agriculture, progressively higher levels of adaptation of the agricultural management system with nature-based approaches are required (see diagram 4).

Diagram 4
Continuum from conventional to ecological intensification, by way of agricultural production management alternatives based on efficiency, substitution and redesign



Source: Prepared by the authors, on the basis of A. Vanbergen and others, "Transformation of agricultural landscapes in the Anthropocene: Nature's contributions to people, agriculture and food security", *Advances in Ecological Research*, vol. 63, Amsterdam, Elsevier, 2020.

Iseman and Miralles-Wilhelm (2021) stress that the profitability of agricultural NBS —with their positive impacts on productivity, livelihood resilience and landscape restoration— ensures their adoption and continued use by producers. Miralles-Wilhelm (2021) highlights the emergence of innovative NBS approaches in the field of bioprospecting —i.e. the exploration of biodiversity in search of new resources of social and commercial value— and gives the example of the commercial formulation of biofertilizers based on nitrogen-fixing bacteria. The authors emphasize the need to pursue NBS developments in bioprospecting.

C. NBS and the challenge of post-COVID reactivation

1. The situation to overcome

The pandemic hit Latin America and the Caribbean as it was facing a triple crisis in the economic, social and environmental spheres. Between 2011 and 2019, the region was enmeshed in a more pronounced economic slowdown than most of the rest of the world. Inequality is a structural aspect of the region that is expressed both in income and multidimensionally (health, education, life expectancy, informal employment, gender gaps). Environmental degradation is another cause for concern in the region (ECLAC, 2020b and 2021a).

In 2019, the poverty rate in Latin America and the Caribbean was 29.8%, with extreme poverty totalling 10.4%, representing 187 million and 70 million people, respectively (ECLAC, 2022a). In 2020, the pandemic pushed a further 17 million people into poverty (for a total of 204 million) and an additional 11 million into extreme poverty (for a total of 81 million) compared to the 2019 figures. There was no improvement in 2021: the number of poor people fell only marginally (to 201 million) while the population living in extreme poverty increased to 86 million (ECLAC, 2022a). The incidence of poverty is higher in rural areas of Latin America and the Caribbean. It is estimated that 22% of the population lacks access to safe drinking water, 34% have no connection to the Internet and 45% do not have bank accounts (Lustig and Tommasi, 2021). According to ILO data, 85% of agricultural jobs are informal (with the total rising to 92% among women and 99% among young people). Rural areas lack safety nets and adequate health services and sanitation; together with the digital divide, this makes it difficult for rural dwellers to cope with the economic consequences of COVID-19 (FAO, 2020).

The region's countries have not been able to decouple their growth from natural resources, and environmental degradation endangers efforts to overcome poverty and build regional development (ECLAC, 2020b). Adopting a multisectoral approach to environmental issues remains a challenge. Environment ministries continue to lead the implementation of the Rio conventions, with sometimes scarce resources and only secondary participation by the main productive sectors involved. Only 18% of countries have agencies for biodiversity knowledge (Sánchez, 2021). In the context of the pandemic, the budget for environmental care has been reduced in several Latin American and Caribbean countries: an ECLAC analysis in 11 countries detected a 35% drop in spending on environmental protection in the 2019–2020 period, and that it barely accounted for 0.2% of public spending in 2020 (ECLAC, 2021b).

ECLAC reported a 7.7% contraction in the region's gross domestic product (GDP) in 2020 and projected a growth rate of 6.2% for 2021 (ECLAC, 2022a). However, the Commission calculates a return to pre-pandemic levels no earlier than 2023 (if annual growth of 1.8% is maintained). In addition, public debt in Latin America and the Caribbean rose by almost 11 percentage points, reaching an average of 56.3% of GDP (ECLAC, 2021b). The region continues to record high numbers of COVID-19 infections and fatalities.

Along with continuing to contain the pandemic, the region's governments must reactivate their economies, but with less money and greater investment demands, and they must orient public spending strategically. Unfortunately, the reactivation investment channelled into green initiatives in Latin America and the Caribbean in 2020 was less than 0.5% of the total, far below the target set (ECLAC, 2021b). Investment for reactivation can still offer an opportunity for a more resilient and sustainable development model, focused on the most vulnerable, with alternatives that are both low cost and offer high social and pro-nature returns.

2. Nature-based solutions and the recovery

This document uses "post-pandemic recovery" to refer to the series of measures aimed at the immediate recovery of rural economies and livelihoods, while promoting structural changes that can reduce the likelihood of future crises and increase the resilience of the agricultural sector. The aim is to "build back better", with a positive focus on nature, to halt biodiversity loss, in keeping with long-term emission reduction targets, and to build resilience to the effects of climate change (Cook and Taylor, 2020; OECD, 2020c).

Natural capital projects have a high economic multiplier effect (Nair and Rutt, 2009; cited by UNEP, 2021). According to Rodríguez and Seymour (2022), nature-positive policies could generate more than US$ 10 trillion annually in new trade volumes, along with 395 million new jobs by 2030. WWF/ILO (2020) notes that policies and interventions using NBS support decent work, produce and maintain natural capital and, in many cases, are low-cost investments that bolster employment, productivity and economic activity. NBS jobs tend to be relatively low-skilled, thus providing opportunities for groups particularly affected by the pandemic (Dasgupta, 2021).

Low productivity in agriculture often correlates with the depletion of natural capital and the reduction of key ecosystem services, resulting in low incomes. Thus, NBS can improve agricultural productivity and, at the same time, improve the jobs and livelihoods of sector workers (WWF/ILO, 2020). Sustainable agriculture, through NBS, could generate almost 80 million jobs by 2030, over 90% of them in developing countries, together with business opportunities worth up to US$ 4.5 trillion a year by 2030 (Nature4Climate, 2020).

It is estimated that restoring 160 million hectares of degraded agricultural land would generate US$ 84 billion in annual economic benefits, increasing the incomes of smallholder farmers in developing countries by between US$ 35 billion and US$ 40 billion per year (Cook and Taylor, 2020). Vergara and others (2016) calculate that the restoration of 20 billion ha in Latin America and the Caribbean would generate US$ 1,140 dollars of profit per hectare, which is equivalent to a net present value of about US$ 23 billion over a 50-year period. The gains would come from timber and non-timber forestry products, ecotourism revenue, increased agricultural productivity, the value of carbon sequestration and the avoidance of food insecurity losses.

The report by Vivid Economics (2021) analyses the post-pandemic recovery potential of green stimulus packages, measured by five criteria: (i) the immediacy of the response, (ii) job creation per dollar invested, (iii) long-term transformation (stimulates innovation and sector reform, generates revenue, reduces future costs), (iv) transition, with incremental funding that can be discontinued at any time, and (v) whether it allows social distancing. The results indicate that NBS in agriculture (reforestation, wetland restoration and investments in forest management) offer the best response to the COVID-19 crisis, with the highest score in all the dimensions analysed.

Despite all their advantages, NBS are not receiving the funding required. In 2018, the agriculture, forestry, land use and natural resource management sector received only 3% of all climate finance and 7% of public finance. Similarly, the investments being made for the post-pandemic recovery have a much smaller environmental component than expected, and they still rely on traditional approaches (UNEP, 2021). OECD (2021) estimates that only 17% of total resources have been allocated to green investment. In addition to the meagre amounts involved, most of the resources allocated to the recovery have not been aligned with the Sustainable Development Goals.

In a region where fiscal resources are scarce, NBS represent the way forward for smart investments, although few countries are making investments in the right direction. ECLAC (2022b) warns that recovery measures in Latin America and the Caribbean have been focused on maintaining or compensating for consumption, at the cost of weakened public services, territorial oversight and other social and governmental monitoring functions; as a result, vulnerability to environmental impacts and dependence on fossil fuels are rising.

D. The United Nations Food Systems Summit, the bioeconomy and nature-based solutions

Recognizing the potential of food systems to advance the 2030 Agenda for Sustainable Development and the achievement of most of the SDGs, in October 2019 United Nations Secretary-General António Guterres convened a Food Systems Summit for 2021 (United Nations, 2021f) as part of the decade of action to achieve the SDGs by 2030.

The Summit, which took place on 23 and 24 September 2021, underscored the call for the transformation of food systems to make them more sustainable, inclusive and resilient and able to deliver safe and nutritious food. The Summit emphasized that this transformation of food systems is key to strengthening their contribution to the economy and livelihoods, to ensuring food and nutritional security, to reducing poverty and ethnic, gender and territorial inequalities, to health, food security and nutrition, to the conservation and sustainable use of biodiversity and to climate action.

Food systems can also contribute to the recovery from the crisis triggered by the COVID-19 pandemic. In his call to action, the United Nations Secretary-General stated that food systems could lead to recovery in three key ways: working for **people** (nutrition for health and well-being), for the **planet** (production in harmony with nature) and for **prosperity** (an inclusive, transformative and equitable recovery in line with the 2030 Agenda). As regards to the planet, the Secretary-General stressed that it was possible to feed a growing world population and, at the same time, to protect our environment, but he emphasized that this demanded sustainable production and consumption methods and nature-based solutions.

The process towards the 2021 United Nations Food Systems Summit included national, independent and global dialogues, online consultations and calls for the submission of innovative solutions. As a result, a series of coalitions, initiatives, alliances, associations, networks, knowledge and resources have emerged, which have been grouped into four areas of action: (i) nourishing all people, (ii) promoting nature-based production solutions; (iii) promoting equitable livelihoods, decent work and empowered communities; and (iv) building resilience to vulnerabilities, shocks and stresses. The area of nature-based production solutions includes issues related to agroecology and regenerative agriculture, aquatic and blue foods, sustainable livestock, agricultural innovation to confront climate change, the creation of a global soil centre, and efforts to stop and reverse biodiversity loss. The clusters and coalitions related to the nature-based production solutions area of action are listed on table 2.

Table 2
United Nations Food Systems Summit 2021: clusters and initiatives, partnerships and coalitions related to the nature-based production solutions area of action

Solution clusters	Initiatives, partnerships and coalitions
Deforestation-free and conversion-free food supply chains	Transformation of food systems through agroecology
Repurposing public support to food and agriculture	Coalition for aquatic and marine foods
Land-freshwater nexus	Resize the livestock industry
Transformation through innovation for nature-positive production	Global sustainable livestock raising
Transformation through agroecology and regenerative agriculture	Restoration of grasslands, scrublands and savannas through sustainable extensive livestock-based food systems
Agrobiodiversity	Global action agenda to promote positive innovation for nature
Aquatic and blue foods	Coalition of Action for Soil Health (CA4SH)
Indigenous peoples' food systems	Reorientation of public support for food and agriculture
Grasslands and savannas	Deforestation- and conversion-free food supply chains
Aligning data, stakeholders and evidence for nature-positive production	Better data decisions for nature-positive production
Global soil hub	Land and fresh water
	Agrobiodiversity

Source: United Nations, "Solution Clusters: Game Changing Propositions" [online] https://foodsystems.community/game-changing-propositions-solution-clusters/.

Similarly, the Scientific Group for the 2021 United Nations Food Systems Summit (Von Braun and others, 2021) proposed seven recommendations on science-driven innovations that should be pursued in orchestration for the successful transformation of food systems. In the area of bioeconomy, emphasis was placed on the relevance of innovations related to biosciences and technologies for people's health, the productivity of systems and ecological well-being (see also box 3). Similarly, as regards NBS, the focus was placed on innovations aimed at maintaining —and, where necessary, regenerating— productive soils, land and water, and at protecting the agricultural genetic base and biodiversity.

The scientific opportunities for bioscience-related innovations highlighted by the Scientific Group included the following: genetic engineering, genome editing, alternative sources of protein (including more plant-derived and insect-derived proteins) and sources of essential micronutrients, cell factories, microbiome and soil and plant health technologies, plant nutrition technologies, and animal production and health technologies. To ensure that poor communities are not left behind, the Scientific Group stressed that governments must invest in capacity- and knowledge-building to develop and use biosciences and digital technologies, which should be supported by development partners. It also emphasized the need to ensure that indigenous peoples and the local population in general receive the benefits of the innovations resulting from their interactions and exchanges of information with scientists (Von Braun and others, 2021, p. 15–16).

In terms of NBS-related innovations, the Scientific Group highlighted the need to advance knowledge on phytogenetic and microbial diversity, in consideration of local climatic variability, as well as to take advantage of beneficial soil microorganisms to improve the structure of depleted soils, their carbon sequestration capacity and their productivity. It also spoke of the use of modern portable digital devices for the field measurement and remote sensing of soil carbon as opportunities for both climate policy and productive plant nutrient management. Likewise, it underscored the importance of agroforestry innovations in contributing to large-scale productive land use while providing positive ecological and climatic ecosystem services (Von Braun and others, 2021, pp. 16–17).

Box 3
Bioeconomy and food systems

As part of the Science Days activities of the 2021 United Nations Food Systems Summit, a side event was held with the title "Bioeconomy for a biodiversity-and-science-based sustainable development of food systems in Latin America and the Caribbean". It was organized by the Economic Commission for Latin America and the Caribbean (ECLAC), the UNESCO Regional Office for Science for Latin America and the Caribbean, the UNESCO/UNITWIN Chair on Biotechnology and SDGs of Colombia and the SDG Centre for Latin America and the Caribbean at the University of The Andes in Colombia.

There was an agreement concerning the importance —especially in a region home to two of agriculture's centres of origin— of promoting the sustainable use of agrobiodiversity as a central element in strategies to increase the resilience of agriculture in the face of climate change, to provide alternatives for rural livelihoods and to diversify diets with nutritious foods. Also highlighted was the need to enhance ecosystems, to reward good agri-environmental practices, to promote crop rotation and good soil and water management practices and to work for the recovery of degraded soils (for example, to increase carbon sink services).

The panel highlighted the need for more dialogue between traditional and modern scientific knowledge, more assertive communication (for example, with consumers, among different bioeconomies and among bioeconomy stakeholders), consensus-building (including between the scientific community and the private sector) and promoting convergences (for example, public-private, incentives, investments, public policies).

Source: Prepared by the authors.

III. Evaluation of nature-based solutions in agriculture with synergies for recovery

NBS currently represent an alternative that can contribute synergistically to the achievement of the global goals of the Rio conventions. Mouat and others (2006) propose a definition of **synergies** within the scope of the conventions: "when the considerable efforts of intergovernmental institutions, governmental institutions, non-governmental organizations and other bodies are utilized together in the hope of solving some particular problem." This definition emphasizes coordination among different actors to solve a problem.

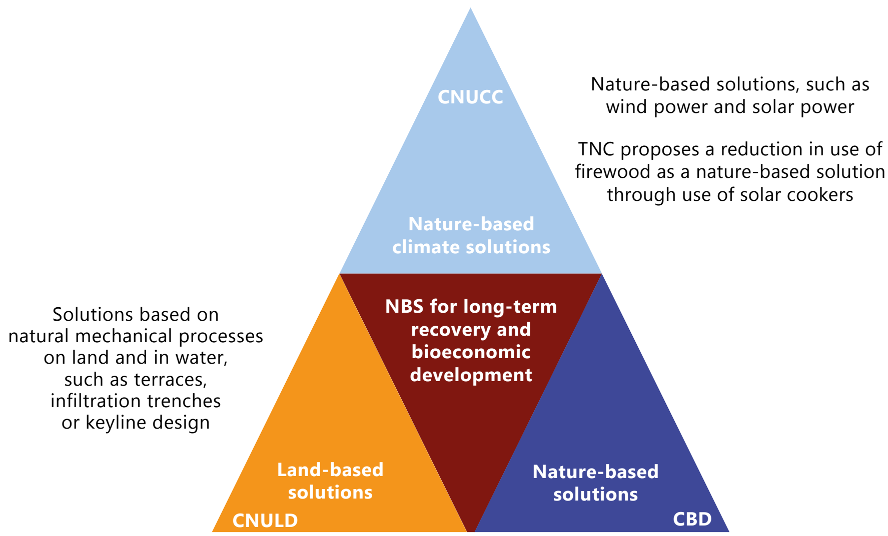
In the context of this document, synergy is achieved through NBS that simultaneously address desertification, climate change and biodiversity loss objectives, in addition to supporting post-pandemic recovery and the transformation of the agricultural sector in Latin America and the Caribbean in the direction of sustainable bioeconomic development.

This section compiles and analyses a selection of NBS applicable to agriculture, and it presents an evaluation of their synergies according to the proposed definition.

A. Analysis framework

Overlapping areas —where NBS can assist in the pursuit of two or more global environmental objectives, thereby contributing to sustainable agricultural recovery in agriculture and long-term bioeconomic development— were identified. Diagram 5 depicts the scope of the synergies sought. From there, a series of requirements or criteria to guide the selection of the NBS can be inferred, and those are presented on table 3.

Diagram 5
Scope of NBS with synergies among the conventions to support recovery and long-term development



Source: Prepared by the authors.

Table 3
Criteria guiding the selection of NBS that offer synergies between environmental objectives, recovery and the transformation of the regional agricultural sector through bioeconomy

Synergies between global environmental objectives – NBS that:	Synergies with the transformative recovery (short to medium term) – NBS that:	Synergies with sustainable bioeconomic development (long term) – NBS that:
Prevent, reduce or halt biodiversity loss. Restore natural capital and ecosystem services. Restore agroecosystems on agricultural lands and restore functionality to degraded ecosystems. Promote agroecological principles and the conservation of agrobiodiversity. Address climate change adaptation and/or mitigation. Are aligned with net zero greenhouse gas emissions. Increase climate resilience and do not increase climate risk. Contribute to land degradation neutrality. Do not promote the expansion of the agricultural frontier to the detriment of forests and natural ecosystems. Promote sustainable land management, prevent land degradation or promote land reclamation. Avoid environmental externalities or the risks of potential unforeseen impacts.	Have a positive effect on income generation, livelihood diversification and job creation in the agricultural sector. Are cost-effective and cost-efficient compared to other solutions, on appropriate and comparable time scales. Allow for the fair and equitable distribution of the economic benefits generated by the solution. Promote equity and the reduction of territorial and social gaps by catering to vulnerable groups (women, young people, family farmers, indigenous communities). Promote transparency and governance.	Promote innovation for economic diversification and the creation of new value chains. Decouple growth from low-value-added exploitation of natural resources Leverage and promote technological innovations towards triple-impact sustainability. Promote the development of human capacities. Build resilience and help avoid future crises (health, economic, climatic, other).

Source: Prepared by the authors, on the basis of A. Rodríguez, M. Rodrigues and O. Sotomayor, "Towards a sustainable bioeconomy in Latin America and the Caribbean: Elements for a regional vision", *Natural Resources and Development series*, No. 191 (LC/TS.2019/25), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2019; World Bank, "Proposed sustainability checklist for assessing economic recovery interventions", Bonn, NDC Partnership, 2020; United Nations Food Systems Summit Secretariat; E. Cohen-Shacham and others, "Core principles for successfully implementing and upscaling nature-based solutions", *Environmental Science and Policy*, vol. 98, Amsterdam, Elsevier, 2019.

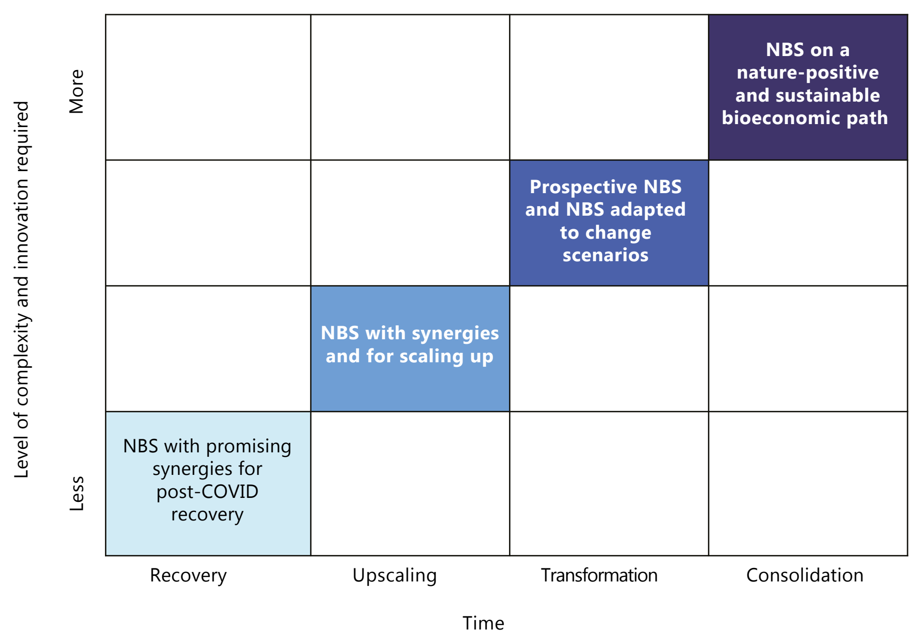
Although NBS projects should be designed for the greatest socioeconomic and ecological benefits and not just economic profitability, some authors call for caution because NBS are not always the easiest or cheapest alternatives to implement. The search for NBS that pursue multiple objectives can generate negative impacts and trade-offs, with risks of conflict and lower long-term resilience (Nesshöver and others, 2017; Seddon and others, 2020; Dasgupta, 2021).

Pörtner and others (2020) say that in seeking ecosystem service improvements and climate change mitigation, the balance between synergistic benefits and trade-offs will depend on the scale of the landscape, the type of biome and the sectoral uses considered in the options. According to the authors, it is more feasible to create multiple benefits at scale in a landscape through spatial planning. As regards the potential antagonisms between the objectives of climate change mitigation and biodiversity conservation, the evidence suggests that there are more areas of synergy with mutual benefits than with adverse impacts (Smith and others, 2019; Pörtner and others, 2020 and 2022).

De Lamo and others (2020; cited by Tobin de la Puente and Mitchell, 2021) claim that NBS are most effective when biodiversity conservation and emissions mitigation are given equal weight in climate and biodiversity goals, respectively. NBS projects concentrated in areas with shared targets could deliver 95% of the maximum estimated biodiversity benefits and meet about 80% of carbon sequestration targets, compared to projects that focus more on one outcome than the other.

Thus, the study analyses a subset of NBS that ideally have a positive impact on all three global environmental challenges, or at least two of them, while remaining neutral with respect to the others. In other words, the NBS sought are those that maximize co-benefits, with zero or minimal trade-offs. Some NBS are easier to implement and more geared towards short-term recovery, but solutions applied on a larger, temporal or landscape scale, or that include innovations that enable long-term structural transformation, will be required over time (see diagram 6, which portrays the progression in implementation complexity).

Diagram 6
Time frame of NBS for a sustainable transition



Source: Prepared by the authors.

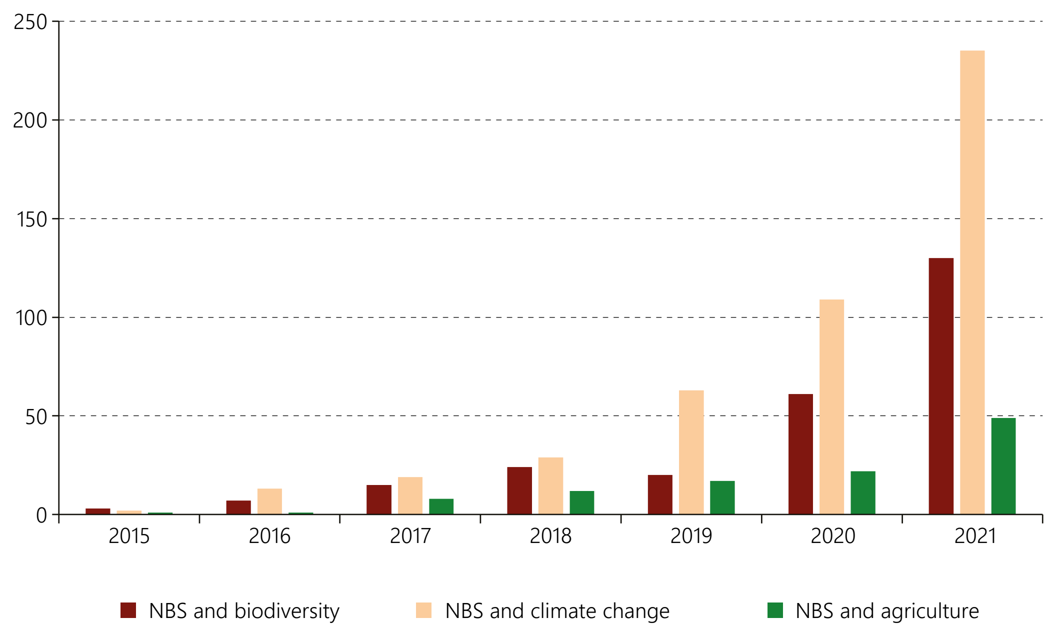
The search for transformative structural change must address the improvement of ecosystems, seek solutions that address long-term trends (such as future food demand and projected changes in climate) and also include innovation and the generation of human capital to promote regional development.

B. Methodology for compiling nature-based solutions applicable to agriculture

The compilation of NBS applicable to agriculture and with synergies between environmental challenges and post-pandemic recovery was supported by systematic reviews (meta-analyses) that in turn report on the social, environmental and economic co-benefits of the options studied. Tamburini and others (2020) state that the main advantage of the meta-analysis methodology is that it allows summaries and generalizations to be drawn from a body of relevant scientific evidence. This is possible when a large number of original studies are available, which also serves to indicate the state of knowledge of a given subject.

At the same time, although the scientific and grey literature on NBS has grown exponentially in the last five years (see annex 2), few of those studies are explicitly linked to agriculture (Simelton and others, 2021). Using the scientific article search engine in the Scopus database, a search for related terms was conducted, which revealed a lower volume of results for the term "agriculture": hence the importance of relying on systemic reviews.

Figure 1
Publications indexed in combined searches for the term NBS and related concepts, Scopus, 2015–2021
(Number of publications)



Source: Prepared by the authors, on the basis of Elsevier, Scopus [online database] https://www.scopus.com/.

The compilation of NBS was based on three global reports: (i) Smith and others (2019), corresponding to chapter VI of the IPCC Special Report on Climate Change and Land Degradation, (ii) the work of Somarakis, Stagakis and Chrysoulakis (2019) on the NBS Handbook developed as part of the European Union's ThinkNature Project, and (iii) the work of Miralles-Wilhelm (2021) as part of the partnership between FAO and The Nature Conservancy (TNC), which analyses agricultural NBS that simultaneously contribute to productivity and biodiversity conservation.

Smith and others (2019) conducted a meta-analysis of scientific literature with options for addressing land degradation and climate change, together with an analysis of the impact of those options on five dimensions: (i) climate change mitigation, (ii) adaptation to climate change, (iii) desertification,

(iv) land degradation, and (v) food security. While the authors do not categorize these options as NBS, many of them meet the definition and are applicable to food production. This work is the only one that assesses the implementation costs of some of the options analysed, based on information available in the literature reviewed.

Miralles-Wilhelm (2021) focused on NBS specifically for agriculture, through a summary of the scientific literature on applied solutions in agricultural landscapes —forests, grasslands, croplands and wetlands— complemented by grey literature for the case studies reviewed. This work assessed conservation co-benefits in four categories (biodiversity, water, soils and air), and confirmed that NBS can jointly work towards environmental and productivity objectives.

Meanwhile, in the NBS development handbook, Somarakis, Stagakis and Chrysoulakis (2019) studied a large universe of NBS cases to propose a typology and assess the co-benefits associated with the solutions in terms of biodiversity, climate change, relationship with ecosystem services and an indication of the potential for green job creation. Although this work is more focused on the urban environment, some NBS typologies applicable to rural landscapes were selected.

The studies in question reveal some knowledge gaps. For example, almost all of them lack data for assessing the economic and social aspects of NBS. Smith and others (2019) and Miralles-Wilhelm (2021) note that there is a bias in scientific research towards options that address the challenges of climate change mitigation. Miralles-Wilhelm (2021) reports that the literature on NBS dedicated to climate change adaptation and land, water and biodiversity conservation, as well as the analysis of other co-benefits, is smaller in proportion and more geographically concentrated. Smith and others (2019) conclude that there is still a lack of consistency and systematization for a global repository of integration efforts.

Likewise, most of the compilations reviewed do not include biological remediation solutions to address soil and water contamination problems, nor do they include solutions related to the use of biodiversity or agricultural residual biomass to generate new products with commercial or social value. In this document, those shortcomings were partially addressed with a review of scientific and grey literature from different sources.

Simelton and others (2021) address an issue ignored by most compilation studies: the scale of impact and effectiveness of NBS applications, which has implications for planning. Using that model, this document includes an indicative distinction based on scale.

Finally, with regard to the post-pandemic recovery, different actors are counting on NBS to reactivate the economy. The arguments for this are that the investments involve hiring low-skilled workers who require minimal training and, therefore, more jobs are created per unit invested, and that they are in line with long-term environmental and social objectives (WWF/ILO, 2020; Dasgupta, 2021). Thus, the criteria for assessing NBS in the post-pandemic recovery included the following aspects of solutions: (i) implementation costs, (ii) potential for job creation, and (iii) contribution to food security.

C. Classification of nature-based solutions

The literature on NBS suggests many possible approaches and categorizations. One of the most common approaches for classifying them is the problem or challenge that the proposed solution seeks to address. In addition, classifications have been made based on the approaches involved (ecosystem management, ecosystem-based adaptation, ecological engineering, others) or the type of landscape or biome where a solution is deployed (forests, crops, pastures, wetlands). As already seen, however, NBS constitute a framework that can draw on several of the above approaches, in a mixed landscape and at different scales.

The first and most frequently cited NBS classification is the one put forward by Eggermont and others (2015), which covers three categories based on the degree of solution intervention and the ecosystem services involved (see table 4). The authors note that the division between the three types of NBS is not definitive: hybrid solutions remain a possibility, which can evolve spatially to account for a gradient of functionality (such as protected areas and adjacent managed areas), or can change over time, such as when an ecosystem is artificially restored and subsequently, once established, is placed under a conservation regime (Eggermont and others, 2015).

Table 4
Types of nature-based solutions and their descriptions

Type of NBS	Description
Type 1	Natural landscapes. With no or minimal intervention in ecosystems, with the aim of maintaining or enhancing the provision of a range of ecosystem services within and beyond the preserved ecosystems. This type of NBS covers areas where people live or work sustainably, including nature conservation areas and national parks.
Type 2	Multifunctional landscapes. Sustainably managed and multifunctional ecosystems and landscapes that enhance the provision of specific ecosystem services. This category is related to the benefits of natural system agriculture and forestry, agroecology and diversified agricultural landscapes.
Type 3	Restoration and design of new landscapes. Intrusive management of ecosystems and the creation of artificial ecosystems. This type of NBS is linked to concepts such as green and blue infrastructure and to objectives such as the restoration of degraded or contaminated areas.

Source: H. Eggermont and others, "Nature-based solutions: new influence for environmental management and research in Europe", *GAIA: Ecological Perspectives for Science and Society*, vol. 24, No. 4, Munich, Oekom, 2015.

As part of its conceptual framework, IUCN has proposed five categories of NBS, depending on the ecosystem-based approaches involved: (i) restorative NBS (ecological restoration, forest landscape restoration and ecological engineering), (ii) subject-specific NBS (ecosystem-based adaptation and mitigation, ecosystem-based disaster risk reduction, climate sequestration services), (iii) infrastructure NBS (natural infrastructure and grey infrastructure), (iv) management NBS (integrated coastal management, integrated water resource management), and (v) protective NBS (area-based conservation approaches, including area management and other effective area-based conservation measures) (Cohen-Shacham and others, 2019).

As part of the efforts to broaden the scope of NBS action, other concepts such as nature-intrinsic solutions, nature-derived solutions and nature-inspired solutions have emerged in the literature. Nature-derived solutions relate to physical or chemical processes occurring in nature: solar energy, for instance, which —although it comes from a natural source— is not based on ecosystem functions (WBCSD, 2020). In agriculture, the practice of soil solarization could be considered a type of nature-derived solution, as it is a disinfection process that uses ultraviolet light from the sun. Nature-inspired solutions are based on biological processes for the design and production of original materials, structures and systems: for example, biomimicry (WBCSD, 2020). The use of yeast and fermentation processes for food production could be considered a nature-inspired solution. If the IUCN principles —which include an explicit adoption of nature conservation standards— are followed, however, the latter two categories of solution would be excluded.

For NBS that can be applied to the agrifood system, a paper from Wageningen University (Keesstra and others, n.d.) proposes a classification into three categories: (i) intrinsic NBS, (ii) hybrid NBS, and (iii) inspired NBS. Intrinsic NBS promote better use of natural ecosystems for the provision of multiple ecosystem services: for example, through measures that increase fish populations in a body of water to bolster food security. Hybrid NBS are based on the modification of managed or restored ecosystems: for example, re-establishing traditional agroforestry systems with commercial tree species. Inspired NBS involves the creation of new ecosystems or new process technologies that copy ecosystems to sustainably increase service delivery: for example, the use of waste heat to purify water through thermal and electro-membrane processes. The authors suggest that inspired NBS target a specific process, while in intrinsic NBS the complete ecosystem offers a range of services to address a specific case.

Miralles-Wilhelm (2021) classifies NBS used in food production into two groups: (i) those that apply to the conservation or rehabilitation of natural ecosystems, and (ii) those used for the enhancement and/or recreation of natural processes in modified or artificial ecosystems. In turn, Simelton and others (2021) propose a framework of NBS for agricultural landscapes. The authors' work is based on a systemic review of the literature on NBS used by agriculture, but primarily focused on Asia. They offer a sectoral typology based on four essential functions of NBS in agriculture: (i) sustainable practices, with a focus on production, (ii) green infrastructure, focusing on engineering aims such as water, soil and slope stabilization, (iii) improvements, for the restoration of plants, soils and water and for climate change mitigation, and (iv) conservation, focusing on interconnections between ecosystems and biodiversity. The improvement category resembles type 3 proposed by Eggermont and others (2015), the conservation category is similar to their type 1, while the first two categories could be considered a subdivision of type 2.

Since the classification of NBS as they apply to agriculture is not a settled issue, this document uses the classification of Eggermont and others (2015). The aim is to report on actions in agricultural and rural landscapes related to the conservation and protection of nature carried out by producers (type 1), and to report on restoration solutions (type 3) that address the main problems of soil and water contamination that, in addition to causing environmental deterioration, constrain the development of sustainable agriculture. While most NBS used in food production and agriculture fall mainly under type 2 and thus the proposal of Simelton and others (2021) provides a useful distinction, all the classification models entail significant overlaps between categories.

The selected NBS include examples of nature-inspired solutions currently in use in food production that fall into type 3 of the Eggermont and others (2015) classification in ecosystem restoration, which offer a high potential for transformation as part of a circular and sustainable bioeconomic development model.

From the meta-analysis studies, 21 solutions applicable to agricultural landscapes were identified. Of these, five are type 1, eleven are type 2 and five are type 3 (see table 5). A definition of each solution, as well as examples of its implementation and/or co-benefits, is included in annex 3.

Table 5
List of nature-based solutions applicable to agricultural landscapes

Type 1. Natural landscapes	Type 2. Multifunctional landscapes	Type 3. New landscapes
Creation of protected areas or conservation zones	Agricultural diversification	Reforestation and forest restoration
Management of native forests	Integrated pest management	Restoration and reduction of peatland conversion
Maintenance of riparian ecosystems as natural flood protection	Use of local seeds	Green infrastructure for integrated water management
Reduced conversion of natural grasslands into cropland	Soil conservation agriculture	Erosion reduction infrastructure
Fire risk management	Agroforestry	Biological remediation of contaminated soils
	Forestation with improved plantations	Biological wastewater treatment (biodepuration and/or bioremediation)
	Improved grazing land management	
	Use of biochar	
	Use of beneficial microbes to increase natural soil fertility	
	Bioprospecting of biodiversity and residual biomass (biocosmetics, biopharmaceuticals, biomaterials, bioremediators, biochemicals)	

Source: Prepared by the authors, on the basis of G. Somarakis, S. Stagakis and N. Chrysoulakis, *Nature-Based Solutions Handbook*, The Hague, ThinkNature, 2019; P. Smith and others, "Interlinkages between desertification, land degradation, food security and GHG fluxes: synergies, trade-offs and integrated response options", *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, Geneva, Intergovernmental Panel on Climate Change (IPCC), 2019; A. Rodríguez, M. Rodrigues and O. Sotomayor, "Towards a sustainable bioeconomy in Latin America and the Caribbean: Elements for a regional vision", *Natural Resources and Development series*, No. 191 (LC/TS.2019/25), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2019; F. Miralles-Wilhelm, *Nature-based Solutions in Agriculture: Sustainable Management and Conservation of Land, Water, and Biodiversity*, Virginia, Food and Agriculture Organization of the United Nations/The Nature Conservancy (FAO/TNC), 2021.

While bioenergy can be analysed as a NBS, there is considerable disagreement in the literature regarding its impact. IPBES (2018a) states that large-scale bioenergy production can lead to competition with other land and forest uses, threatening biodiversity and food security. In other cases, bioenergy from high-yield crops could be a productive option that offers soil restoration benefits. Bioenergy production using agricultural residues is a viable option in certain contexts, provided it does not interfere with soil nutrient recycling.

The use of biochar, which is derived from the pyrolysis of plant residues and used as a soil conditioner, is analysed as a NBS in its own right, given that the literature reports a significant number of cases with benefits for soil fertility and carbon sequestration (Smith and others, 2019).

In addition, the broad category of bioprospecting —both of residual biomass and biodiversity— has been included. This encompasses innovative applications in specific contexts with win-win situations between productive, environmental and social well-being objectives; examples include bio-based products that, through the action of microbial processes on waste, produce alternatives to plastic, food, feed, chemicals and other valuable products. Biodiversity studies applied to remediation, cosmetics and alternative pharmaceuticals, among others, are also included.This report uses the term "agroforestry" to cover options that include tree or shrub planting both among agricultural crops and in silvopastoral systems. The Latin American and Caribbean country strategies for climate change that were reviewed address the promotion of silvopastoral systems (SPS) and agroforestry systems (AFS) as part of NDCs, treating them separately. Silvopastoral systems combine trees and shrubs with forage grasses, improve animal nutrition and produce co-benefits such as improved soil productivity and increased carbon accumulation (Murgueitio and others, 2011; cited by Hoque and others, 2022). The inclusion of tree and shrub species is beneficial for both climate change adaptation and mitigation.

D. Analysis of the synergies offered by nature-based solutions

The synergies offered by agricultural NBS were examined in light of two sets of criteria. First, the contribution of NBS to the environmental objectives of the Rio conventions was analysed, covering such factors as: (i) the protection of biodiversity, (ii) adaptation to climate change, (iii) climate change mitigation, and (iv) neutrality in land degradation. Second, their co-benefits for post-pandemic recovery were examined, including: (i) potential for job creation or income generation, (ii) implementation costs, and (iii) contribution to food security. The evaluation of the positive or negative impacts of each of the NBS examined was conducted using information from the previously mentioned secondary sources (see table 6).

Table 6
Assessment of NBS and their synergies with environmental goals and the post-pandemic recovery

NBS	Synergies between environmental objectives					Recovery			Scale
	Biodiversity	Climate change adaptation	Climate change mitigation	Desertification	Land degradation	Job creation	Implementation costs	Impact on food security	Farm (F), Landscape (L)
Type 1: Natural landscapes									
Establishment of protected areas or conservation zones	+++	++	+++	+++	+++			+	F, L
Native forest management	+++	++	+++	+++	+++		Medium	++	F, L
Maintenance of riparian ecosystems as natural flood protection	+++	+++	++	++	++				F, L
Reduced conversion of natural grasslands into cropland	++	+	+++		+++		Low	–	F, L
Fire risk management	+++	++	+++	+	+		Medium	+++	F, L
Type 2: Multifunctional landscapes									
Agricultural diversification	+++	+	+++	++	+++	Yes	Low	+++	F
Integrated pest management	++	n/d	n/d	n/d	n/d				F
Use of local seeds	+	n/d	+++	n/d	n/d			+++	F
Conservation agriculture	++	+	++	+++	+++			+/-	F
Agroforestry (silvopastoral systems and agroforestry systems)	+++	+++	+++	+++	+++	Yes	Low	+++	F
Forestation with improved plantations	+/-	++	+++	+++	+++			—	F
Improved grazing land management	+++	++	++	++	+++	Yes	High	+++	F, L
Biochar	+	+++	n/d	n/d	+			—	F
Use of beneficial microbes to increase natural soil fertility	++	+	+	+	++			+++	F

Table 6 (concluded)

NBS	Synergies between environmental objectives					Recovery			Scale
	Biodiversity	Climate change adaptation	Climate change mitigation	Desertification	Land degradation	Job creation	Implementation costs	Impact on food security	Farm (F), Landscape (L)
Type 3: Restoration and design of new landscapes									
Reforestation and forest restoration	+++	+++	++	+++	+++		Medium	+	F, L
Restoration and reduction of peatland conversion	+++	++	n/d	–	++	Yes	Low	—	F, L
Erosion reduction infrastructure	+++	+/-	+++	+++	+++		Medium	+++	F, L
Green infrastructure for integrated water management	+++	++	+++	+	+	Yes		+++	F, L
Biological remediation of contaminated soils	n/d, likely +	n/d, likely +	++	++	++			+++	F, L
Biological wastewater treatment (biodepuration)	++	++	n/d	-	++	Yes			F

Legend:

Positive impacts (+)	High +++	Medium ++	Low +	Variable +/-
Negative impacts (-)	High ---	Medium --	Low -	n/d = No data]

Source: Prepared by the authors, on the basis of P. Smith and others, "Interlinkages between desertification, land degradation, food security and GHG fluxes: synergies, trade-offs and integrated response options", *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, Geneva, Intergovernmental Panel on Climate Change (IPCC), 2019; G. Somarakis, S. Stagakis and N. Chrysoulakis, *Nature-Based Solutions Handbook*, The Hague, ThinkNature, 2019; F. Miralles-Wilhelm, *Nature-based Solutions in Agriculture: Sustainable Management and Conservation of Land, Water, and Biodiversity*, Virginia, Food and Agriculture Organization of the United Nations/The Nature Conservancy (FAO/TNC), 2021.

As noted by Smith and others (2019), thirteen of the solutions analysed generate positive impacts in all the areas evaluated, and a further five options lack a broad scientific basis supporting the existence of synergies but are presumed to generate co-benefits in all the dimensions evaluated. Meanwhile, three options generate mixed results: they can generate positive synergies when implemented with certain safeguards to avoid negative impacts on food security (when competition for land use exists) or on biodiversity (use of exotic and monoculture forest species).

An assessment of implementation costs and job creation potential was conducted for only a small group of NBS. It should be noted that in addition to being scarce, the cost data come from the results of research that was not necessarily conducted in Latin America and the Caribbean and, as such, this reference point requires corroboration. As has been pointed out, the absence of economic assessments is a major shortcoming, especially in developing countries.

The compilation seeks to expand options in rural territories that will lead to the transformation of the food system in Latin America and the Caribbean and to new patterns of regional growth. However, an assessment of the contribution of NBS involving the various applications of biodiversity bioprospecting and the use of residual biomass (pharmaceuticals, cosmetics, materials, remediation, biochemistry, energy) was not feasible: given the breadth of this set of applications, there are no systemic studies to evaluate their synergies and co-benefits.

Similarly, although phyto- and bioremediation studies indicate the advantages of using plants and microorganisms, respectively, to treat contaminants in a cost-effective manner, they tend to focus on species with local interventions (Simelton and others, 2021). Some cases report bioremediation in soils for the management of contamination caused by chemical fertilization and salinity (Smith and others, 2019; FAO, 2021b; Simelton and others, 2021). Biological remediation for wastewater treatment is analysed by Pavlidis and Karasali (2020) and Rodríguez (2017), from which some extrapolations were drawn.

In terms of their transformational potential, most of the agricultural landscape NBS address long-term challenges and trends, as several of them aim at building resilience and improving productivity. NBS have the capacity to continue in the medium and long term, improving the overall condition of the ecosystems where they are implemented and contributing with results to the SDG targets. However, only some of these solutions provide diversification of value chains, with intensive use of innovation and the creation of the human capital needed to trigger a genuine transformation in the agricultural development path of Latin America and the Caribbean.

IV. Opportunities for promoting nature-based solutions in agriculture

The global agenda demands commitments from countries and the consequent development of national enabling frameworks for the fulfilment of those commitments, including in the food production sector. Recently, broad recognition has been given to the central role of agriculture in the fulfilment of the 2030 Agenda for Sustainable Development, in advancing the climate agenda and in combating desertification and biodiversity loss.

While the incorporation of global environmental commitments into national agendas is a burden for public institutions and budgets, it is also true that they represent an opportunity to undertake substantive transformations, which attract funding and promote innovation.

This section analyses country commitments that represent an opportunity for the promotion of NBS in agriculture and the main national policy frameworks that mention NBS in connection with the agricultural sector. A variety of cases in five countries (Chile, Colombia, Costa Rica, Guatemala and Uruguay) are described for illustrative purposes. Also identified are the financial opportunities for the achievement of the goals set by the countries as regards NBS in agriculture.

A. Global agreements and their national and sectoral incorporation

Interest in the contribution of NBS to the global environmental agenda has increased markedly in recent years, with a wide range of organizations generating evidence and other actors promoting their incorporation into multilateral debate venues (Davies and others, 2021; Osaka, Bellamy and Castree, 2021).Currently, NBS are being included as part of major strategic frameworks, such as: (i) the Paris Agreement, (ii) the Post-2020 Global Biodiversity Framework, and (iii) national voluntary land degradation neutrality targets (see table 1).

NBS are an important element in climate action, ever since their recognition as one of the priority areas for action of the United Nations Climate Action Summit in September 2019 (Samaniego and others, 2022). Particularly during 2021, NBS were at the centre of discussions regarding progress with the Paris Agreement, at the UNFCCC Conference of the Parties (COP26) and in the development of the Post-2020 Global Biodiversity Framework.

A recent global dialogue on the role of agriculture and food production in the Post-2020 Global Biodiversity Framework concluded that a coordinated approach was needed to address biodiversity loss, climate change and land and ecosystem degradation, and to better align action in pursuit of food security and biodiversity. Nature-based solutions are seen as a positive framework for strengthening the planning and implementation of sector policies and programmes (FAO, 2021d).

B. National strategic frameworks that include nature-based solutions

The following paragraphs offer an overview of how national strategic frameworks are incorporating NBS in response to Rio convention commitments. Particular mention is made of measures related to agriculture, which are summarized in Table 7.

1. Paris Agreement

The Paris Agreement provides two instruments for national-level climate action: nationally determined contributions (NDCs) and long-term climate strategies. All the countries of Latin America and the Caribbean have signed the agreement and submitted their NDCs. Given the weight of agriculture in the generation of greenhouse gas emissions, the sector stands at the forefront of the countries' commitments. Around 46% of the total emissions of Latin America and the Caribbean come from the sector, including forestry, land use and land-use change, and agriculture.

In studying the most recent updates of the NDCs of 17 Latin American and Caribbean countries, Samaniego and others (2022) highlight that agriculture is a priority sector for mitigation in 15 countries, while 16 countries also prioritize adaptation actions; these actions involve a series of NBS.

The five countries in this study have submitted their first NDCs. Costa Rica, Colombia and Chile made updates at the end of 2020, while the 2017 contributions of Guatemala and Uruguay remain in force. Uruguay is in the process of drafting its second NDC. Four of the five countries have submitted their long-term climate strategies.

The NDC of **Colombia** includes targets in the agricultural sector, including agricultural measures that can be considered NBS covering almost 4 million hectares: silvopastoral systems (3.6 million ha), and grassland restoration, improved grassland, trees in paddocks and green fences, forage diversification, forest plantations, etc. (300,000 ha by 2030). Also included are agroforestry systems with timber species for cocoa (150,000 ha) and part of the land turned over to coffee cultivation (20,000 ha). Biomethane generation as part of livestock management is also mentioned. In the sugarcane sector, measures such as the restoration of natural services, soil conservation, and wastewater management and treatment are included. The document explicitly refers to the use of NBS for disaster risk management and the management of marine ecosystems, among other purposes (Government of Colombia, 2020a). Likewise, Colombia's long-term climate strategy contains ten references to NBS and, specifically, to the opportunities they offer for jointly addressing the challenges of climate change, biodiversity loss, health and food security. The strategy notes that NBS are key in the agriculture, forestry and other land use (AFOLU) sector as a carbon sink, and the priority actions at the country level include silvopastoral systems and forest plantations, in addition to conservation and restoration measures in natural ecosystems (moorlands, mangroves) (Government of Colombia, 2021).

The 2050 National Decarbonization Plan of **Costa Rica**, which is the country's long-term climate strategy, covers ten pillars, two of which are dedicated to agriculture. Pillar 8, on the promotion of agrifood systems, includes references to the bioeconomy and waste recovery, as well as a mechanism for recognizing the ecological benefits of sustainably managed farms. Likewise, pillar 9, which deals with the consolidation of a low-carbon livestock model, covers the upscaling of nationally appropriate mitigation actions (NAMAs) in the livestock sector based on mixed and integrated production systems (silvopastoral systems) as well as the increase of biodiversity on farms. Finally, the plan's pillar 10 makes specific mention of nature-based solutions and proposes that they serve as the basis for consolidating a management model for rural, urban and coastal territories that facilitates the protection of biodiversity and the increase and maintenance of forest cover and ecosystem services. The NDC references NBS for biodiversity protection and also defines a specific target of 69,500 ha under silvopastoral and agroforestry systems (Government of Costa Rica, 2021).

Chile's long-term climate strategy considers NBS in key sectors, with particular attention to sustainable land management in agriculture (biochar in soils, nutrient management and fertilizer reduction, inclusion of trees on croplands and carbon enhancement in grazing soils). It also proposes implementing forestry NBS, such as reforestation and forest restoration, the protection and restoration of wetlands and the creation of artificial wetlands. In turn, the NDC highlights the restoration of a million hectares of landscapes by 2030 and, while it mentions NBS, it does not refer to a particular sector (Government of Chile, 2021).

While **Uruguay's** NDC does not explicitly refer to NBS, it does speak of the reversal of forest degradation, silvopastoral systems, direct seeding and peatland protection, and it sets the goal of placing one million hectares of livestock production (10% pasture) under a natural field approach with good production practices. The natural field production approach entails a series of measures that could be typified as NBS, including grassland restoration and renaturation, soil conservation measures and other actions related to herd management (Government of Uruguay, 2017).

Guatemala's NDC does not refer to any particular approach, but it does highlight the REDD+ programme to reduce forest degradation and deforestation as well as mentioning forest protection mechanisms (Ministry of Environment and Natural Resources, 2021). However, qualified informants from the Ministry of Agriculture have stated that the country is promoting the ecosystem-based approach to agriculture to respond to climate change and improve the sector's productivity. In turn, the National Low Carbon Development Strategy aims to reduce 59% of its greenhouse gas emissions by 2050 through specific actions in the energy, agriculture, waste, land use, forestry, industry and transportation sectors. In the agricultural sector, it includes soil conservation measures, agroforestry systems, woody fruit plantations, efficient use of nitrogen fertilizers, improved pastures and rational grazing, silvopastoral systems and integrated manure management (Ministry of Environment and Natural Resources, 2021).

In all the national climate action instruments reviewed, references are made to NBS —either implicitly or explicitly— including measures that are specific to the agricultural sector. Since they are generally more recent, the long-term climate strategies tend to use the term NBS itself. NBS have been highlighted in the updated NDCs of several Latin American and Caribbean countries (Costa Rica, Chile, Colombia, Mexico and Panama), while another group of countries (Argentina, the Dominican Republic, Honduras and Nicaragua) follows the ecosystem-based adaptation approach (Samaniego and others, 2022).

2. National biodiversity strategies or plans

The 2011–2020 Strategic Plan for Biodiversity and its Aichi Targets guided the countries' work over the preceding decade. Thus, countries developed their National Biodiversity Strategies, with different planning horizons. Progress with the Aichi Targets was modest, and a new Post-2020 Global Biodiversity Framework (GBF) is currently under discussion and should enter into force in 2022.

In 2015, the 2030 Agenda for Sustainable Development took up the challenge of biodiversity loss: the issue was addressed by Goal 14 and Goal 15 in particular, but also by Goal 2 on phyto- and zoogenetic resources for agricultural production and sustainability, by Goal 6 as regards aquatic ecosystems, by Goal 11 for cities and land consumption and by Goal 12 regarding sustainable production and consumption.

In the 2017–2030 National Biodiversity Strategy of **Chile**, the silvoagricultural sector is identified as a source of impacts on biodiversity. Its goals are: (i) to identify practices with a negative or positive impact on native species and their habitats (2020), (ii) to create a system that incentivizes good practices and discourages bad ones (by 2030); and (iii) to observe sustainability criteria in 50% of the activities that affect native species and the quality of their habitats in the forestry and livestock sector (2030). The sixth report to the Convention on Biological Diversity (Ministry of the Environment, 2019) describes progress in: (i) the creation of the National Certification System for Organic Agricultural Products (174,000 ha), (ii) the adoption of the International Treaty on Plant Genetic Resources for Food and Agriculture in 2016, (iii) the National Rural Development Policy, with specific objectives for biodiversity and ecosystem services in the wine sector, (iv) the development of a Sustainable Agriculture Protocol, and (v) a handbook for biological conservation in vineyards. The System of Incentives for the Agro-environmental Sustainability of Agricultural Soils (SIRSD-S) is also covered by the report. In the forestry sector, mention is made of different policies and programmes for sustainable forest management involving the deployment of different forestry certification schemes. Other areas covered by the report include the progress made with the development of economic instruments and standards for restoration and the establishment of priorities for wetland conservation. The 2021–2030 National Landscape Restoration Plan sets the goal of restoring a million hectares and its principles include a reference to NBS (CONAF/MINAGRI/MMA, 2021).

Colombia has adopted a 2016–2030 Biodiversity Action Plan and a National Policy for the Management of Biodiversity and Ecosystem Services. The voluntary SDG report (2018) showcases progress with the development of a Payment for Environmental Services Policy (2017), which provides for the delivery of monetary or in-kind incentives for actions relating to the preservation and restoration of forests, moorlands, wetlands and other strategic ecosystems (National Planning Department, 2018).

In **Costa Rica**, the 2016–2025 National Biodiversity Strategy sets several national targets involving agriculture and NBS. In the areas of zoogenetic and phytogenetic diversity, it proposes initiatives to rescue wild relatives of important crops (goal 22), to conserve endangered native forest species (goal 23) and to rescue traditional seed production practices (goal 24). In the area of biodiversity associated with health and production systems, it proposes improving knowledge through an inventory of important agroecosystems (goal 25) and an inventory of relevant species (pollinators, biological controllers and others) (goal 26) (Government of Costa Rica, 2021).

Notable in **Guatemala's** 2012–2022 National Biodiversity Strategy and Action Plan are the strategic activities linked to the development of productive models that promote the sustainable use of biodiversity and its ecosystem services (9.5 and 9.6) and the development of a National Biotrade Programme (CONAP, 2012). Sources at the Ministry of Agriculture, Livestock and Food state that its institutional strategy is the promotion and adoption of ecosystem-based agriculture.[4]

In **Uruguay**, the 2016–2020 National Biodiversity Strategy proposes, as goals for 2020, placing 80% of country's agricultural land under rules that contribute to the maintenance of biodiversity and ecosystem services, and the enforcement of guidelines for the conservation of natural grasslands in 80% of the area turned over to livestock raising (Ministry of Housing and Territorial Planning, 2016).

3. National voluntary land degradation neutrality targets

Land degradation neutrality, introduced by the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD) in 2015, is a voluntary national target for countering degradation through sustainable land management and restoration to which many Latin American and Caribbean countries have adhered. Land degradation neutrality defines an appropriate level of land resources needed to support ecosystem service functions and food security (UNCCD, 2020).

Land degradation neutrality is covered by target 15.3 of the Sustainable Development Goals (SDGs), which aims to "combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world" (Gichuki

[4] Personal communication with ministry officials.

and others, 2019). Indicator 15.3.1 in particular refers to the proportion of degraded land within the total area, a metric that is currently being explored by several countries in order to establish their baselines.

Uruguay is developing the National Land Degradation Neutrality Target Setting Programme. In its 2018 voluntary national report on SDG implementation, Uruguay reported progress with the development of regulations and institutions. The document describes two tools mediated by the Ministry of Livestock, Agriculture and Fisheries that, among other actions, contribute to the achievement of target 15.3: (i) land use management plans, intended to minimize erosion in soils used exclusively for agricultural purposes, and (ii) the sustainable management of livestock in natural pastures, with various actions aimed at the restoration of pasturelands (Government of Uruguay, 2018).

Guatemala highlights the formulation of its National Policy to Combat Land Degradation, Desertification and Drought, the updating of the National Action Programme to Combat Desertification and Drought (PROANDYS) and the preparation of indicators and a baseline for land degradation, desertification and drought in the Dry Corridor, with an emphasis on the Departments of El Progreso and Baja Verapaz (Ministry of Environment and Natural Resources, 2021). Guatemala has committed a million hectares to the restoration challenge.

Costa Rica has set itself the goal of achieving land degradation neutrality by 2025, based on data to be identified in 2020. In its second voluntary SDG report, the country noted positive trends in the indicators for Sustainable Development Goal 15, such as the progress made in sustainable forest management between 2017 and 2018, with a net change in forest area of 0.54%, attributable to the 2011–2020 National Forestry Development Plan. The goals set out in the 2019–2022 Bicentennial National Development and Public Investment Plan reinforce the land degradation neutrality goals through: (i) the National Policy for Adaptation to Climate Change, which proposes the management of 5,000 hectares under an ecosystem-based adaptation approach, (ii) the Forestry Plantations for Landscape Restoration programme, (iii) the Payment for Environmental Services programme, (iv) agroforestry and silvopastoral projects, and (v) financing mechanisms for the management, conservation and sustainable development of forest resources and biodiversity. As part of Initiative 20x20, the country has undertaken to avoid the degradation of a million hectares of landscape (Canet, 2018).

The voluntary land degradation neutrality targets of **Colombia** translate into eight measures to achieve land degradation neutrality by 2030, across an area of almost 150,000 ha. They include, by 2030: (i) the restoration of at least 9,000 ha of pasture cover in forests in the Caribbean region, (ii) the improvement of at least 9,000 ha of pasture cover in silvopastoral systems, (iii) improving the productivity of at least 2,000 ha of soils turned over to crops and/or pasture with agroforestry production systems in the Caribbean and Andean areas (Departments of Sucre, Santander and Boyacá), (iv) the conservation of at least 22,000 ha of dry forests across the country, (v) enhanced natural vegetation quality for at least 580 families in the Guajira region by promoting the planting of forest species, (vi) the restoration of at least 3,200 ha of dry forest in the Guajira region, (vii) the restoration of at least 100,000 ha of degraded land nationwide within the framework of Colombia's national target under Initiative 20x20 in Latin America and the Caribbean, and (viii) the inclusion of guidelines and measures that promote the appropriate use of land and the preservation of its functions and ecosystem services in at least five territorial planning instruments (Ministry of Foreign Affairs, 2018).

Chile defined nine measures to achieve land degradation neutrality by 2025, which are set out in the 2016 plan of the National Forestry Corporation (CONAF). This plan involves interventions on around 565,000 ha, including: (i) afforestation, revegetation, restoration and forest management programmes in 80 of the country's communes, (ii) strengthening wood energy by means of firewood certifications (16,000 ha), (iii) afforestation and revegetation with native species in keeping with the new Forestry Development Act (140,000 ha), (iv) ecological restoration in degraded native forests and woodlands (20,000 ha), (v) ecosystem restoration plans following forest fires (10,000 ha), (vi) forest management cordons to prevent forest fires (8,000 ha), (vii) the development of woodland management plans (70,000 ha), (viii) phytosanitary protection of native vegetation resources through integrated forest pest management (300,000 ha), and (ix) buffer strips for livestock activity in zones adjacent to protected areas (800 ha). In addition, the System of Incentives for the Agro-environmental Sustainability of Agricultural Soils (SIRSD-S) programme, which is aimed at the restoration of productive soils, has progressively expanded to cover 87,000 hectares in 2016 (Ministry of the Environment, 2019).

Box 4
The Bonn Challenge

The Bonn Challenge is a voluntary implementation instrument for the three Rio conventions that seeks to achieve the Aichi Biodiversity Targets of the Convention on Biological Diversity and the objectives of land degradation neutrality and climate change mitigation (Gichuki and others, 2019). Pledges made under the Bonn Challenge have been bolstered through regional collaboration platforms, such as Initiative 20x20 in Latin America and the Caribbean in 2014 (Gichuki and others, 2019).

Many countries have made ambitious pledges, including the following restoration commitments (in millions of hectares) made by governments and other agencies in Latin America and the Caribbean: Argentina (1); Brazil (12); Brazil – Atlantic Forest Restoration Pact (1); Chile (0.5); Colombia (1); Costa Rica (1); Ecuador (0.5); El Salvador (1); Guatemala (1.2); Guatemala – Association of Private Nature Reserves of Guatemala (0.04); Honduras (1); Mexico (8.5); State of Campeche (0.75); State of Quintana Roo (0.7); State of Yucatán (0.55); Nicaragua (2.7); Panama (1); Peru (3.2).

Source: L. Gichuki and others, *Reviving Land and Restoring Landscapes: Policy Convergence between Forest Landscape Restoration and Land Degradation Neutrality*, Gland, International Union for Conservation of Nature (IUCN), 2019.

The cases reviewed corroborate that NBS are present in the countries' frameworks for responding to their national Rio convention commitments. Specific applications of NBS to the agricultural sector or rural landscapes are identified, with measures and targets that can overlap between the conventions (see table 7). In some cases, references are made to regulatory mechanisms or incentives for upscaling the proposed measures. One example of regulations that promote NBS is Law 7779, on Soil Use, Management and Conservation, in Uruguay. The Payment for Environmental Services (PES) systems in Costa Rica and Colombia offer examples of incentive systems, as do the support programmes for implementing nationally appropriate mitigation actions (NAMAs), which include technical assistance, credit support and others. As progress on reporting developments towards the 2030 Agenda's SDG targets becomes more standardized, countries should reduce their reporting on progress with the conventions and, at the same time, set more comprehensive —and perhaps more ambitious— targets.

Table 7
Inclusion of NBS in national strategies linked to climate change, land degradation and biodiversity commitments

Convention	UNFCCC – Paris Agreement		UNCCD	CBD
National strategy	Nationally determined contribution	Long-term climate strategy	Voluntary land neutrality commitment	National biodiversity strategy
Chile	Restoration of 1 million ha of landscapes by 2030. Refers to NBS without specifying sectors. The 2021–2030 National Landscape Restoration Plan (December 2021) sets out the road map for meeting the goal with an explicit reference to NBS.	Includes NBS in agriculture: biochar in soils derived from residual biomass, nutrient management and reduced fertilizer use, planting trees on croplands and carbon enhancement in grazing soils. Also refers to reforestation and forest restoration, the protection and restoration of wetlands and the creation of artificial wetlands.	The 2016 CONAF plan defines nine (9) measures to achieve land degradation neutrality by 2025, covering 565,000 ha with phytosanitary and pest monitoring, forest and post-fire restoration, forest management for fire prevention, and forest management plans. 0.5 million ha committed under Initiative 20x20. Under SDG 15.1, the degraded area baseline for land degradation neutrality is reported to be lacking. The SIRSD-D programme covers actions for the recovery of agricultural land.	Under the 2017–2030 National Biodiversity Strategy, progress is reported with clean production agreements (69% in the agrifood sector), a protocol for sustainable agriculture and public-private experiences in the care of biodiversity. In the forestry sector, a number of forestry certification systems are in place.
Colombia	Measures on 4 million ha, including silvopastoral and agroforestry systems in cacao and coffee, improved pastures and their restoration, trees in paddocks and green fences, fodder diversification, forestry plantations. NBS for disaster risk management, and the management of marine ecosystems.	Prioritized NBS include silvopastoral systems and forest plantations, in addition to conservation and restoration measures in natural ecosystems (moorlands, mangroves).	Colombia has adopted eight (8) measures to achieve land degradation neutrality by 2030, covering about 145,200 ha. Forest conservation and restoration actions, Initiative 20x20 with 1 million ha, pastureland restoration actions in the Caribbean, silvopastoral systems and improvement of crop and pasture soil productivity through agroforestry systems. Sustainable Land Management Policy in force in the country.	2016–2030 Biodiversity Action Plan in force in Colombia. National Policy for the Management of Biodiversity and Ecosystem Services. Payment for Environmental Services Policy (2017).
Costa Rica	Identifies some NBS for biodiversity protection, in addition to specific targets of 69,500 ha under silvopastoral and agroforestry systems	Costa Rica's National Plan for Decarbonization by 2050 has 10 pillars. Pillar 8 on agriculture and Pillar 9 on livestock refer to NBS applied in the sector. Pillar 10 explicitly refers to NBS as a territorial management model.	Definition of land degradation neutrality goals remains ongoing. Based on a 2020 assessment, Costa Rica will achieve land degradation neutrality by 2025. 1 million ha committed to Initiative 20x20.	The 2016–2025 National Biodiversity Strategy proposes improving knowledge on biodiversity associated with production systems, with inventories of agroecosystems and relevant species and targets related to phyto- and zoogenetic resources.

Table 7 (concluded)

Convention	UNFCCC – Paris Agreement		UNCCD	CBD
National strategy	Nationally determined contribution	Long-term climate strategy	Voluntary land neutrality commitment	National biodiversity strategy
Guatemala	Pays considerable attention to forestry issues, without explicitly mentioning NBS measures. Includes reforestation, afforestation and forest loss prevention actions.	The National Low Emissions Development Strategy includes specific actions in the agriculture, waste, land use, forestry, and other sectors. These include silvopastoral and agroforestry systems, improved pastures, soil conservation, fruit plantations, better use of fertilizers and manure management.	National Policy to Combat Land Degradation, Desertification and Drought, and the updating of the National Action Programme to Combat Desertification and Drought (PROANDYS). Ongoing calculation of the land degradation baseline in the Dry Corridor. 1 million ha committed to restoration.	The 2016–2020 National Biodiversity Strategy calls for the development of production models that promote the sustainable use of biological diversity and its ecosystem services, and the development of a National Biotrade Programme. The Ministry of Agriculture, Livestock and Food identifies the adoption of ecosystem-based agriculture.
Uruguay	Includes measures to reverse forest degradation, silvopastoral systems, direct seeding, peatland protection, good natural-field agricultural practices in one million ha of livestock production (10% of the country's pastureland).	Under development, 2021.	Definition of specific land degradation neutrality goals currently in process. At the sectoral level, land use management plans are in place to minimize erosion in agricultural soils; together with the sustainable management of livestock in natural pastures, with pasture restoration actions.	The 2016–2020 National Biodiversity Strategy sets, as a target for 2020, 80% of agricultural land under guidelines that contribute to the maintenance of biodiversity and ecosystem services, and 80% of livestock land under guidelines for the conservation of natural grassland.

Source: Prepared by the authors based on documents from the Conventions.

4. National bioeconomy strategies

Latin America has a vast potential for the development of the bioeconomy as an alternative for diversifying production and adding value in rural areas, especially in the agricultural and agroindustrial sectors. The bioeconomy is an alternative for territorial specialization that requires innovation and can lead to structural change with sustainability (Rodríguez, 2017).

The bioeconomy offers pathways to development that include a wide range of NBS, including the ecointensification of agriculture, agroecology, the rescue of agrobiodiversity and prospective and sustainable uses of biodiversity, the protection and improvement of ecosystem services and the development of new products based on the exploration of biowaste, along with other nature-based and nature-inspired options.

The bioeconomy as a technoproductive development paradigm has been adopted by some of the region's countries. Costa Rica and Colombia adopted bioeconomy strategies in 2020 (Government of Costa Rica, 2020; Government of Colombia, 2020b), developed under the leadership of their science ministries and bringing together many sectors, including agriculture, to propose a cross-sectoral vision of development. These two examples demonstrate that the advantage of the bioeconomic approach is that it places the appreciation and care of biodiversity and natural resources at the centre of national development.

Uruguay is also developing a bioeconomy strategy, while Chile and Guatemala have expressed interest in the undertaking. In Chile, progress has been made with studies on circularity in agriculture, and in Guatemala, at the request of the National Secretariat of Science and Technology, ECLAC has developed a baseline study for the drafting of a national bioeconomy strategy.

In addition to allowing the harmonious integration of several sustainable development objectives, including the sustainable use and protection of biological diversity, bioeconomy strategies offer another opportunity, in that they require the construction of new institutional arrangements and interactions among actors to overcome traditional knowledge silos and improve the coordination of institutional action.

C. Funding and cooperation

Implementing the Rio conventions demands investments, and these are normally public given the value of the public goods they generate. Public funding is channelled through national government budgets and official development assistance, which pools donations for developing countries. The Global Environment Facility (GEF) was created to support the implementation of the conventions. Subsequently, the Green Climate Fund (GCF), the Adaptation Fund and other initiatives have capitalized on multilateral contributions to implement actions at the global and national levels.

In the context of the recovery, calls have been made for nature to be placed at the centre of post-pandemic investment. Since NBS offer the advantage of jointly responding to various global environmental challenges, both countries and donors see them as preferred options for the implementation of the UNFCCC, the CBD and the UNCCD. Currently, under the auspices of the three conventions, several funding sources have lines of financing for restoration actions, ecosystem protection and other options within the NBS framework.

In the post-pandemic recovery, investment should be redirected by means of a package of incentives and institutional reforms to unlock barriers to the adoption of NBS (UNEP, 2021; Palomo and others, 2021). Funds should focus on leveraging the increased benefits and synergies that NBS offer. However, according to UNEP (2022), currently only US$ 133 billion a year is earmarked for nature-based solutions, and it suggests that by 2030, NBS investments would need to at least a three-fold increase in real terms to meet climate change, biodiversity and land degradation targets. In comparative terms, private contributions in pursuit of national and international goals have been much lower than public contributions. Of total spending on NBS, 86% comes from public funds and only 14% from private finance (UNEP, 2022).

In Latin America and the Caribbean, public recovery investment has had a very low environmental component, with only a couple of countries reporting investments in sustainable agriculture. The absence of investments in ecosystem restoration —through such measures as payments for ecosystem services, the bioeconomy or nature-based solutions— leaves the region on a path that does not promote sustainability (ECLAC, 2022b).

Decoupling production and environmental degradation is one of the most effective policies for protecting nature and the best path towards agricultural sustainability (IPBES, 2018b; Johnson and others, 2021). Ding and others (2021) note that agricultural subsidies have doubled globally since 2000 and currently stand at around US$ 700 billion, and that their incorrect allocation is driving deforestation and other impacts on nature. One area of opportunity for governments is the **redesign and redirection of subsidies that harm nature** in restoration actions and the promotion of NBS in agriculture. Redirected harmful subsidies could be used to pay agricultural producers for environmental services, thus discouraging deforestation and bridging the gap in funding for nature protection and restoration (Ding and others, 2021; Johnson and others, 2021).

The World Bank (Johnson and others, 2021) points out that, along with the redesign and redirection of harmful agricultural subsidies, the most effective policy to protect nature and avoid economic losses from an eventual collapse in ecosystems is to increase public investment in **agricultural research and development (R&D) for the sustainable intensification of production** in current agricultural areas and to discourage the expansion of cultivation into new lands. Unfortunately, in most Latin American and Caribbean countries, R&D investment in agriculture remains below 1% of GDP, which is the minimum recommended by the United Nations (Johnson and others, 2021). Information and evidence are key to overcoming the challenges facing a broader implementation of NBS and to overcoming the cultural factors that shape how they are understood (Pörtner and others, 2021; Tamburini and others, 2020).

The private sector also offers opportunities for financing NBS for the restoration and conservation of ecosystem services in agricultural landscapes, which constitute socially beneficial public goods. The Green Climate Fund (GCF, 2022) emphasizes the need to remove the obstacles facing actions to conserve, restore and sustainably manage ecosystems. It highlights the existence of **areas of opportunity for investment** in: (i) nature-based funds using public-private partnerships, (ii) green and blue bonds aimed at raising capital to finance green economy activities, (iii) natural infrastructure through incentives from risk finance providers and insurers, (iv) carbon markets with new types of credit combining the benefits of climate adaptation with carbon credits for corporate buyers, (v) innovative next-generation schemes for ecosystem service payments, and (vi) a portfolio of financially viable and scalable ecosystem-based approaches produced through the realignment of private and corporate foundations and philanthropy.

At the national level, intersectoral interconnections and **institutional arrangements** can contribute to coherent policies and instruments for upscaling NBS. **Governance issues** among actors implementing NBS need to be improved, including links with knowledge generators and public-private partnerships (Watkins and others, 2019).

In Latin America and the Caribbean, cooperation between countries can support the upscaling of NBS in the agricultural sector. One example of this cooperation is the Platform of Latin America and the Caribbean for Climate Action on Agriculture (PLACA), a regional mechanism for voluntary collaboration among the region's countries that focuses on the productive development of climate-adapted, low-emission agriculture. PLACA offers a venue for collective exchanges of experiences in analyses and metrics, the development of funding mechanisms and NBS implementation methods. In addition, the Korea-Latin America Food & Agriculture Cooperation Initiative (KoLFACI) supports the development of research and extension projects, including topics related to NBS (box 5).

Box 5
KoLFACI Cooperation Initiative

The Korea-Latin America Food & Agriculture Cooperation Initiative (KoLFACI) is a multilateral cooperation effort focused on sharing knowledge and experiences in agricultural technology and extension services to promote sustainable agricultural development among 12 Latin American countries (Colombia, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama, Paraguay, Peru and the Plurinational State of Bolivia) and the Republic of Korea.

Since 2014 KoLFACI has driven numerous research, development and innovation projects addressing agricultural productivity issues through extension, technology exchange and research, several of which involve nature-based solutions. For example, projects have been carried out in the following areas: (i) improving soil fertility and crop productivity through manure composting, (ii) drought tolerance in beans under climate change, (iii) varieties, pruning methods and fertilization to increase sustainable smallholder coffee production, (iv) efficient use of organic and biological fertilizers for soil improvement, and (v) improved water management.

The participants in the initiative are the countries' ministries of agriculture and, in particular, their research, technical assistance and rural extension agencies. Regional research centres that support specific projects also participate, such as the Tropical Agricultural Research and Higher Education Center (CATIE) for cacao and coffee and the International Center for Tropical Agriculture (CIAT) for beans.

Source: Korea-Latin America Food & Agriculture Cooperation Initiative (KoLFACI).

Latin American and Caribbean governments have access to multilateral and bilateral public funds to implement projects related to the implementation of the conventions' agendas. With fewer and fewer options for accessing official development assistance, countries have created **national financial mechanisms** to ring-fence public and private funds in order to meet their national commitments. Tobin de la Puente and Mitchell (2021) state that along with creating mechanisms for the better execution and realignment of investments in nature, transparency and monitoring mechanisms must be put in place to verify their effectiveness.

Given that financing is a key issue for upscaling NBS, a list of the most promising funding opportunities for Latin American and Caribbean countries should be compiled.

V. Perceptions of nature-based solutions for agricultural sustainability

This section describes the methodologies and tools used to gather perceptions of NBS in agriculture. It includes information on the problems that can be addressed through NBS, their potential for upscaling, and incentives and constraints for their adoption.

A. Method

1. Survey on perceptions of nature-based solutions

A survey was conducted to gather perceptions of NBS in agriculture from a range of Latin American and Caribbean stakeholders. It had three main objectives: (i) to reveal the extent of NBS deployment in agriculture and perceptions about them in the region, (ii) to identify barriers and incentives for their implementation, and (iii) to define priorities for upscaling NBS in the transition to more sustainable agriculture.

The questionnaire was prepared on the basis of prior information-gathering processes, including: (i) the bibliographic review on NBS, (ii) the questionnaires on practices of the World Overview of Conservation Approaches and Technologies (WOCAT), and (iii) the study by Fougères and others (2022) on gender inclusion, indigenous peoples and local communities in NBS. The survey was assembled virtually and shared as a Google Form.[5]

The survey was partially structured, with a total of 28 questions: 20 multiple choice and 8 open-ended. It was organized into five sections:

(i) Description of respondents (six questions)

(ii) Identification of environmental problems in the agricultural sector (four questions)

(iii) Use of NBS and obstacles to their implementation (five questions)

(iv) Proposal and description of a NBS (nine optional questions)

(v) Incentives for promoting NBS in the agricultural sector

[5] See [online] https://forms.gle/SruiaU2NHkSW9UtP9.

The survey targeted a broad group of stakeholders knowledgeable about the agricultural sector in Latin America and the Caribbean. The database was prepared by the ECLAC Agricultural Development and Biodiversity Unit and contained 218 contacts to whom an invitation to complete the form was sent by email. Of the total number of invitations, 70 responses to the survey were received (32.1%), and, of those 70 respondents, 40 answered the optional section IV.

The survey was conducted between 18 and 25 October 2021. The Google Form allowed the online responses to be collected as they were received and provided some aggregate analysis of the responses automatically. Section C presents the main results of the survey in full.

2. Selection of pilot countries

This first approximation of potential NBS for upscaling was used to identify a portfolio of projects that could be useful to promote synergies between the Rio conventions and to contribute to a sustainable post-COVID economic recovery, to be deployed in five pilot countries in Latin America and the Caribbean. The countries were selected on the basis of a set of guidelines, as shown on table 8.

Table 8
Countries and their compliance with the selection criteria for the development of project ideas

Country	Bioeconomy strategy	PLACA status	Survey participation
Chile	No, but interest in developing a strategy exists. A circular economy study for the agriculture and livestock sector has been conducted.	Proposed PLACA and served as its chair for the first year, 2020–2021.	The largest number of country participants in the NBS survey, accounting for around 19% of the total. Has a case study on a prior NBS experience.
Colombia	Has a bioeconomy strategy.	Joined PLACA in 2021.	11% of the survey participation.
Costa Rica	Has a bioeconomy strategy.	Co-chaired PLACA in 2021-2022.	Second highest survey participation (14%). Has one NBS case study.
Guatemala	Has expressed interest in pursuing activities towards the development of a strategy.	Founding member of PLACA.	4.3% of the survey participation. Ministry of Agriculture, Livestock and Food expressed specific interest in conducting NBS outreach and training activities.
Uruguay	Strategy under development by an Inter-Institutional Working Group on Sustainable Bioeconomy.	Chaired PLACA in 2021-2022.	Low survey participation (5.7%), but has a NBS case study.

Source: Prepared by the authors.

The first criterion was for the countries to have national bioeconomy strategies (Colombia, Costa Rica), or to be developing such strategies (Uruguay), or to have expressed interest in taking steps towards their development (Chile, Guatemala, Ecuador and Mexico). The second criterion was their participation as member countries in the Platform of Latin America and the Caribbean for Climate Action on Agriculture (PLACA). This criterion was strategically adopted on account of: (i) the alignment of NBS and the platform's objectives, and (ii) the demonstration effect that the activities carried out in the platform countries could have, favouring exchanges of experiences and upscaling. Finally, the information available for the development of the project idea was evaluated, either through the availability of NBS case studies in agriculture analysed at the preliminary stage or through the level of participation of the countries in the NBS survey.

3. Multi-stakeholder dialogues

One objective of the ECLAC cooperation programme with the Republic of Korea was to conduct a regional discussion to identify NBS with synergies between global environmental objectives, regional bioeconomic recovery and development, and to identify gaps and opportunities for their implementation and upscaling in the region. To that end, two types of online dialogues were designed: (i) regional events with a broad scope, (ii) focus groups with various stakeholders. Table 9 summarizes the meetings held and the formats used.

Table 9
Date and participants of NBS project brainstorming meetings

Meeting name	Meeting date	Meeting purpose	Format, participant type and meeting link
Nature-Based Solutions for Agriculture: Towards Sustainable Recovery and Transition.	5 August 2021.	Present the scope of NBS in regional agriculture. Identify synergies relevant to climate action, biodiversity, and land degradation with potential for the recovery period. Identify barriers to implementation in the region and strategies to overcome them.	Open virtual workshop. Two-hour duration: one session with four presentations and a session with invited panellists to discuss incentives and barriers for NBS adoption in the region. Attended by 155 people, mainly stakeholders from the agricultural sector in Latin America and the Caribbean.
Promoting Sustainable Agriculture in the Republic of Korea: Policy Framework and Illustrative Cases for Latin America and the Caribbean.	9 September 2021.	To learn about the experiences of the public, social and academic sectors in the Republic of Korea in promoting the sustainability of agriculture and to draw lessons for Latin America and the Caribbean.	Open virtual workshop, with presentations of four case studies from the Republic of Korea. Mass public participation from the Latin American and Caribbean agricultural sector.
Virtual workshop with PLACA working groups.	30 November 2021.	To present the results of the survey on the use of NBS in regional agriculture to ministry officials.	Working group on public policies through strategic collaboration. Attended by 11 participants, five representing officials from four countries.
	7 December 2021.	To present the work on NBS carried out by ECLAC and discuss its potential links with the PLACA working groups' 2022 work plans.	Working group on knowledge sharing and best practices. Attended by 14 people, eight of whom were ministry officials from six countries.
Informal multi-stakeholder dialogues on the Post-2020 Global Biodiversity Framework for Latin America and the Caribbean.	10 and 12 August 2021.	To discuss with stakeholders the issues that remain unresolved in the draft Post-2020 Global Biodiversity Framework.	This event was not organized under the cooperation agreement between ECLAC and the Republic of Korea. Participation was seen as an opportunity to understand how NBS and agriculture are being integrated into the Post-2020 Global Biodiversity Framework. Dialogue with 60 CBD experts and negotiators from Latin America and the Caribbean. The dialogues were conducted under Chatham House rules.

Source: Prepared by the authors, on the basis of Economic Commission for Latin America and the Caribbean (ECLAC), "Soluciones basadas en la Naturaleza para la agricultura: hacia una recuperación y transición sostenible", Santiago, 2021 [online] https://www.cepal.org/es/eventos/soluciones-basadas-la-naturaleza-la-agricultura-recuperacion-transicion-sostenible; "Promoting Sustainable Agriculture in the Republic of Korea: Policy Framework and illustrative cases for Latin America and the Caribbean", Santiago, 2021 [online] https://www.cepal.org/en/events/promoting-sustainable-agriculture-republic-korea-policy-framework-and-illustrative-cases.

B. Main outcomes

1. Description of respondents

Two thirds of the respondents identified as men (66%) and one third as women (34%). Practically all the respondents were university graduates (99%), including 27% with postgraduate degrees. Respondents were mainly employed in the government sector (46%) and academia (31%) (table 10).

Table 10
Characteristics of respondents
(Numbers and percentages)

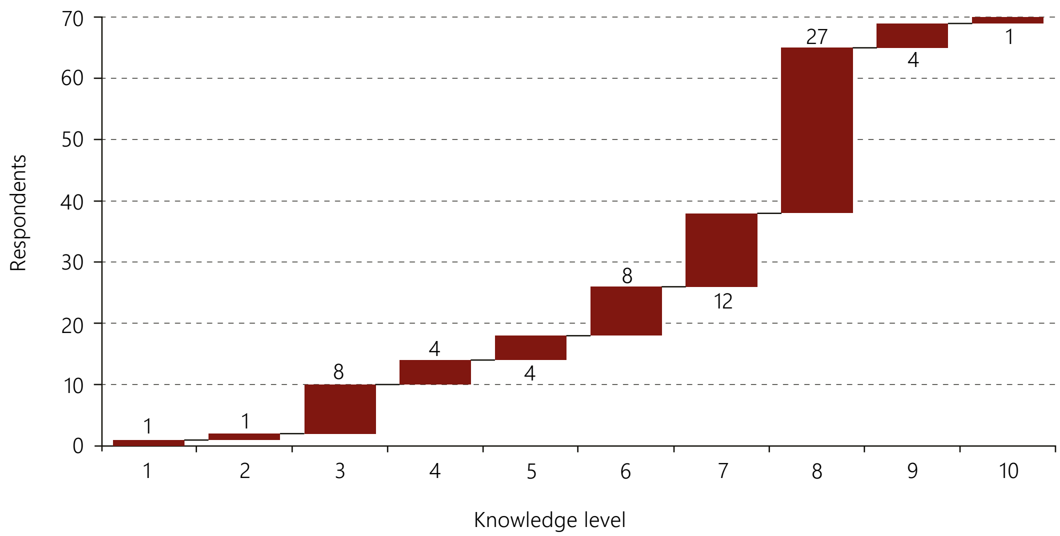
	Number	Percentage
Sex		
Female	24	34.3
Male	46	65.7
Total	70	100.0
Schooling		
Higher education	50	71.4
Postgraduate degree	19	27.1
Other	1	1.4
Total	70	100.0
Type of organization represented		
Government institution – policymaker	32	45.7
Research/academia	22	31.4
Non-governmental organization/ foundation/civil society	4	5.7
International organization/donor/cooperation agency	3	4.3
Food producer or producers' association	3	4.3
Other	6	8.6
Total	70	100.0
Country		
Chile	13	18.6
Costa Rica	10	14.3
Mexico	10	14.3
Colombia	8	11.4
Argentina	6	8.6
Nicaragua	5	7.1
Peru	5	7.1
Uruguay	4	5.7
Guatemala	3	4.3
Bolivia (Plurinational State of)	2	2.9
Dominican Republic	2	2.9
Ecuador	1	1.4
Honduras	1	1.4
Total	70	100.0

Source: Prepared by the authors.

Survey responses were received from 13 of the region's countries. The countries with the highest number of participants were Chile (13), Costa Rica (10), Mexico (10), Colombia (8) and Argentina (6). The respondents were exclusively Spanish-speaking.

The respondents were specialists and self-rated themselves as knowledgeable about NBS, with an average score of 8 on a scale from 1 ("no knowledge") to 10 ("expert") (figure 2). Addressing the survey to an expert target audience made it possible to gather informed opinions about the topic under analysis.

Figure 2
Respondents' self-reported level of knowledge
(Scale of 1 to 10, where 1 is "no knowledge" and 10 is "expert knowledge")



Source: Prepared by the authors, on the basis of total received responses.

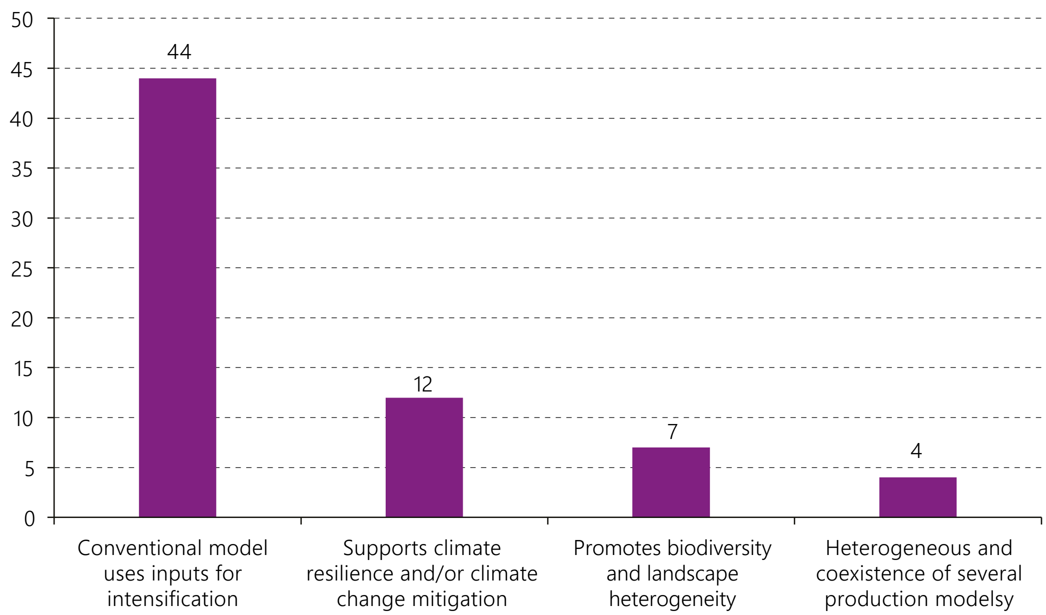
2. Environmental problems facing the sector and their solutions

This section was intended to reveal the main environmental problems faced by the agricultural sector and the solutions that can be applied to them. Questions were asked about three factors: (i) dominant production models, (ii) environmental problems of the agricultural sector, and (iii) socioeconomic issues in the agricultural sector that could be addressed through NBS.

The dominant production model was of the conventional type (63%) with the use of external inputs for productive intensification (figure 3). Only 17% identified a dominant model that supports resilience towards or mitigation of climate change. The question did not allow the selection of more than one option; hence, by design, it excluded the possibility of the coexistence of several productive models without a dominant one, or the identification of productive transition processes. This could be considered a limitation of the survey.

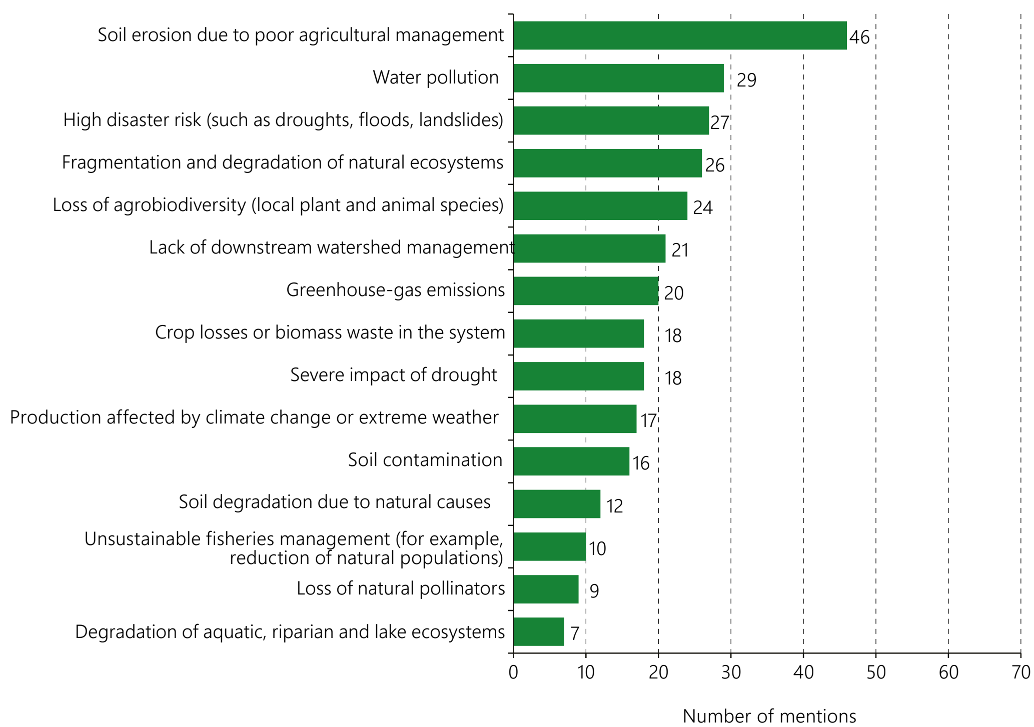
Regarding the environmental problems to be addressed by NBS in the respondents' specific contexts, the most commonly cited problem was soil erosion due to poor agricultural management, with nearly 50 mentions (figure 4). Water pollution (29 mentions), disaster risk (27), habitat fragmentation (26) and loss of agrobiodiversity (24) were also frequently reported by participants as significant issues to be addressed by NBS.

Figure 3
Identification of the dominant production model
(Number of mentions, N = 70)



Source: Prepared by the authors, on the basis of total received responses.

Figure 4
Environmental problems in the agricultural sector to be addressed through NBS
(Number of mentions)[a]

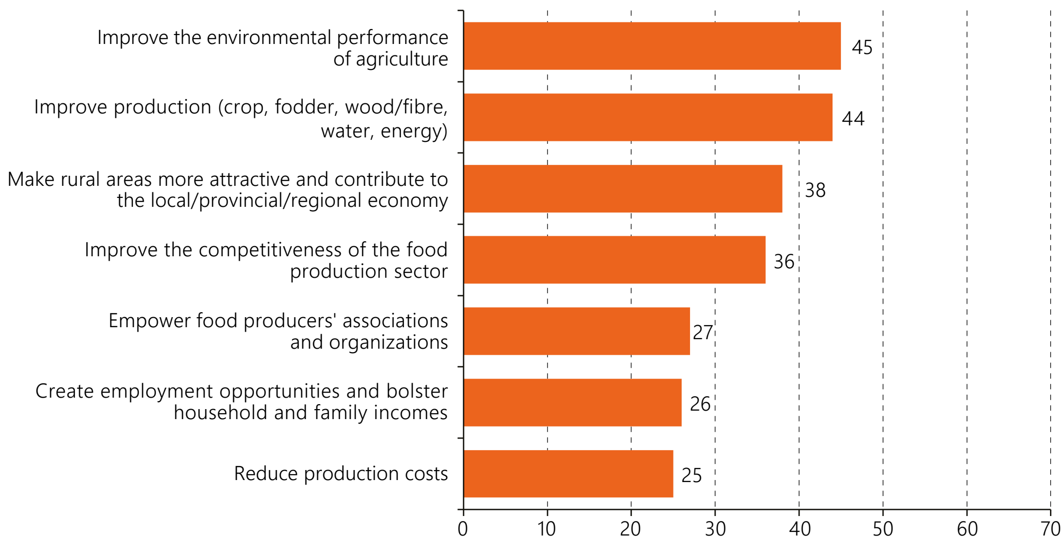


Source: Prepared by the authors, on the basis of total received responses.

[a] The numbers indicate the number of respondents who selected the option from the predetermined list. Respondents were able to select more than one option.

Asked to identify the socioeconomic aspects that can be addressed by NBS, the respondents mainly pointed to improvements in the environmental performance of agriculture (65% of the responses) and agricultural production (63%). More than 50% of the respondents said that NBS can make rural areas more attractive by contributing to the local economy. Similarly, more than half of the participants said they believe that NBS can improve the sector's competitiveness (figure 5). Notably fewer respondents (36%) believe that NBS are aimed at reducing production costs, an issue that is often highlighted in the literature on NBS.

Figure 5
Socioeconomic aspects to be addressed by NBS
(Number of mentions)[a]



Source: Prepared by the authors, on the basis of total received responses.
[a.] The numbers indicate the number of respondents who selected the option from the predetermined list. Respondents were able to select more than one option.

3. Perceptions on the use of nature-based solutions and barriers to their adoption

The third section of the survey explored how widespread NBS are in certain production contexts, along with their complexity and implementation costs, and sought to identify some of the barriers to their wider adoption by producers.

(a) Perceptions on the importance, complexity and cost of nature-based solutions

A predefined list of 16 options was provided to collect perceptions regarding the importance of certain NBS. The list was produced through a review of the literature and included the following:

(i) natural conservation areas (woodlands on farms/estates, coastal and marine areas)

(ii) soil conservation (for example, no-tillage, crop rotation, cover crops)

(iii) practices to enhance or restore soil biodiversity

(iv) soil recarbonization

(v) soil or water bioremediation

(vi) biological treatment of wastewater

(vii) agrosilvopastoral systems

(viii) crop diversification

(ix) biological control of pests and diseases

(x) use of traditional bioinputs (for example, compost)

(xi) use of modern bioinputs (derived from biotechnological applications)

(xii) rescue and use of traditional varieties

(xiii) development and use of improved resistant varieties

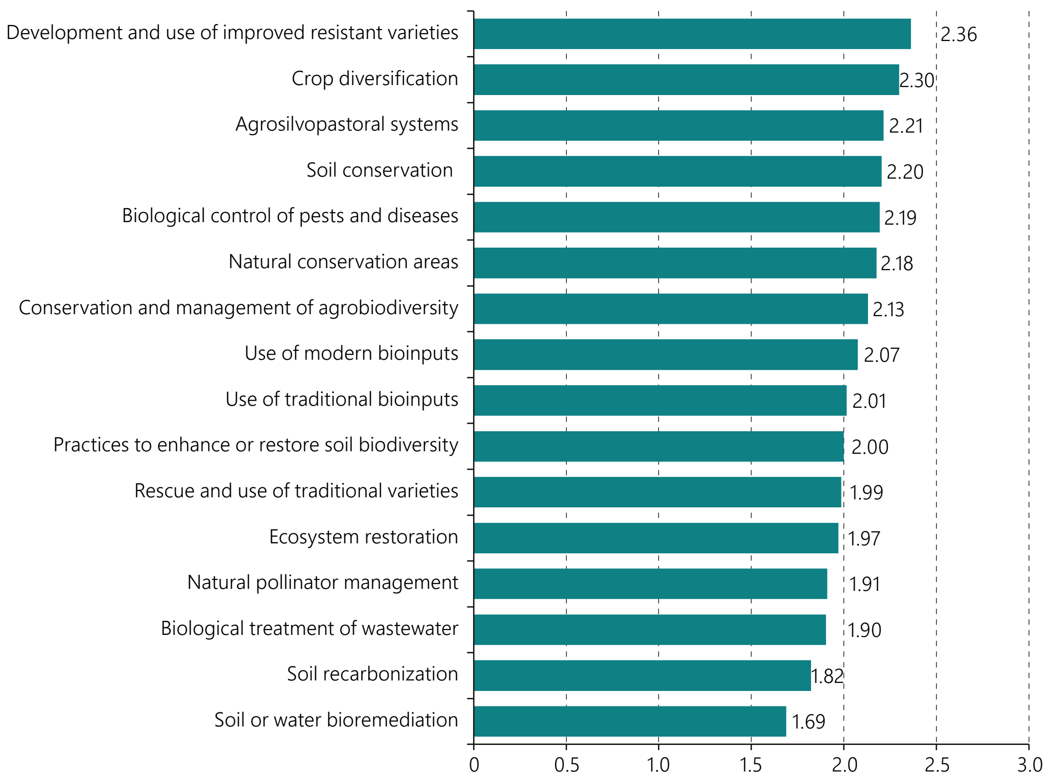
(xiv) conservation and management of agrobiodiversity

(xv) natural pollinator management

(xvi) ecosystem restoration (such as natural landscapes, riverside ecosystems, wetlands)

The development and use of resistant improved varieties was the most important nature-based practice for the sector, with the highest number of "important" or "very important" ratings (values greater than or equal to 2 in figure 6). Ranked second in importance was the group of practices corresponding to crop diversification, agrosilvopastoral systems, soil conservation and conservation of inter- or intra-farm natural areas. Biological treatment, recarbonization and bioremediation of soils were ranked as lower priorities.

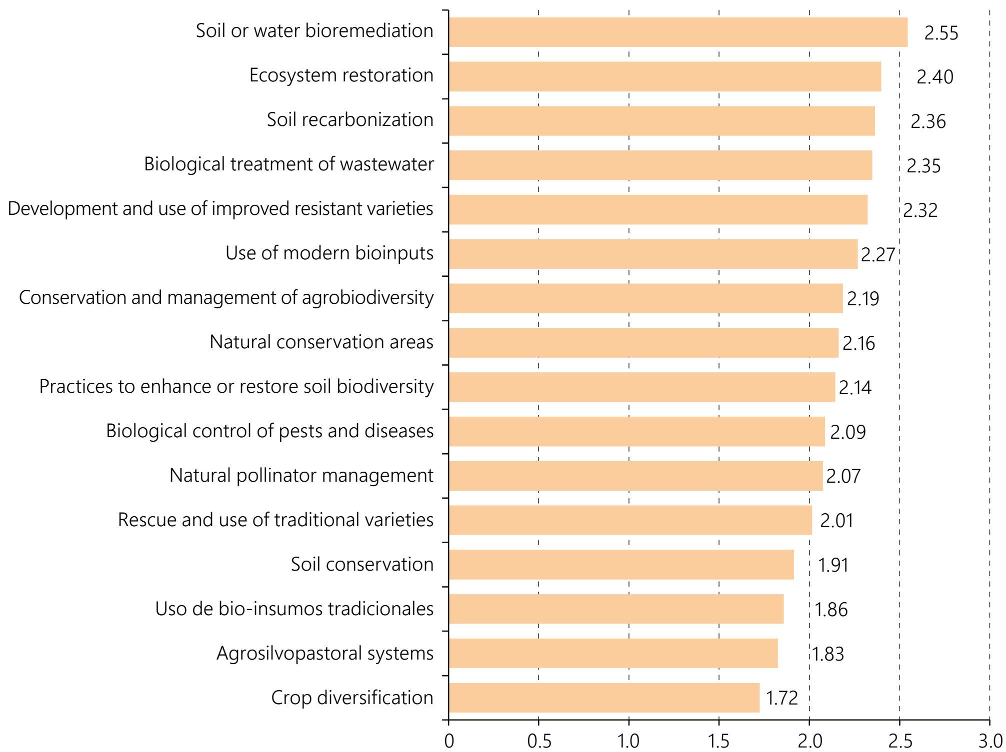
Figure 6
Perceived importance of NBS for agriculture
(1 = less important; 2 = medium importance; 3 = more important)



Source: Prepared by the authors, on the basis of total received responses.

Soil and water bioremediation, ecosystem restoration and soil recarbonization were identified as the NBS alternatives with the most complex implementation requirements. Crop diversification was perceived as the easiest strategy to implement, along with agrosilvopastoral systems, the use of traditional bioinputs and soil conservation practices (figure 7).

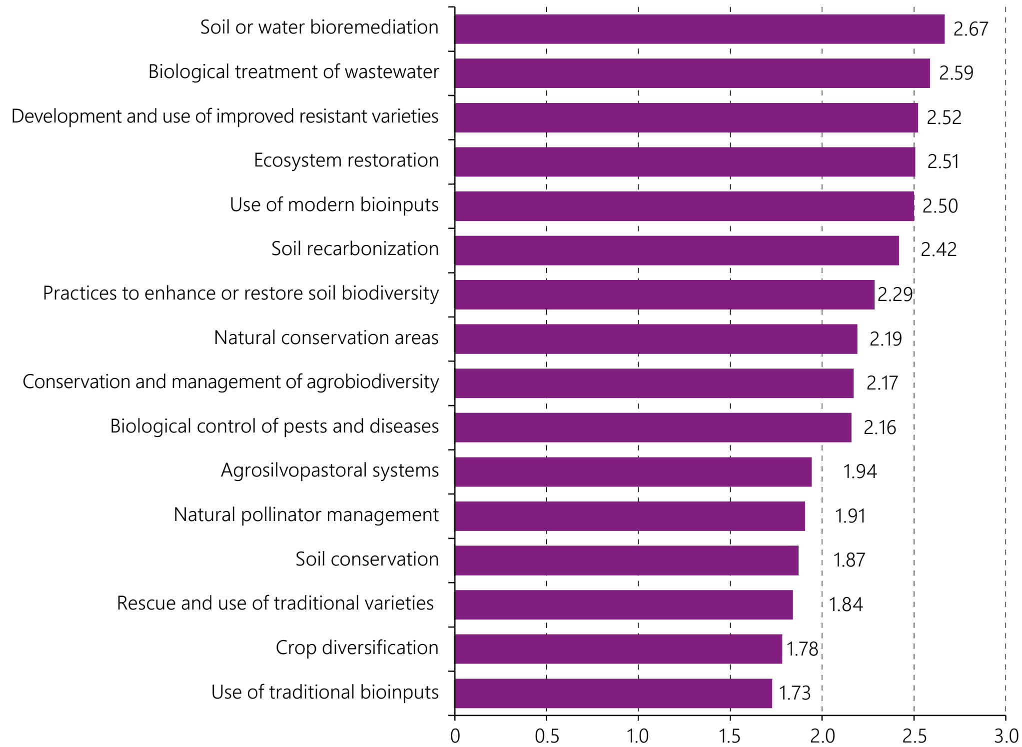
Figure 7
Perceived complexity of NBS for agriculture
(1 = less complex; 2 = medium complexity; 3 = more complex)



Source: Prepared by the authors, on the basis of total received responses.

Soil or water bioremediation, biological wastewater treatment and the development and use of resistant improved varieties are the practices perceived to have the highest implementation costs (figure 8). The development and use of resistant improved varieties is another practice deemed to be among the most important (figure 6). The use of traditional bioinputs (for example, compost), crop diversification, the rescue and use of traditional varieties, soil conservation, natural pollinator management and agrosilvopastoral systems are perceived as having with lower implementation costs.

Figure 8
Perceived cost of NBS in agriculture
(1 = lower cost; 2 = intermediate cost; 3 = higher cost)



Source: Prepared by the authors, on the basis of total received responses.

Table 11 summarizes the survey's perceptions of the importance, complexity and cost of NBS in agriculture. The NBS with the best perceptions are those that are deemed to be most important and whose complexity and implementation costs are low. Four well-known NBS are prominent in this category: agrosilvopastoral systems, crop diversification, soil conservation and the use of bioinputs. NBS in this category have the best perceptions of scaling-up potential.

The opposite situation applies to those NBS perceived as more complex and costly and less important (possibly because of their complexity and cost). This group includes those NBS that require agricultural R&D processes, because of their deployment in specific contexts, or that demand greater knowledge on the part of farmers. This is the case with ecosystem restoration, biological wastewater treatment, soil recarbonization and the bioremediation of soils and water. The upscaling of NBS in this category would require greater agricultural R&D efforts, training processes for farmers and incentives to encourage their adoption.

A third category of interest comprises those NBS perceived as important but more complex and costly. Similar to the NBS in the second category, they require agricultural R&D processes and knowledge on the part of producers. These include the development and use of improved varieties, biological control of pests and diseases, natural conservation areas, conservation and management of agrobiodiversity, use of modern bioinputs and practices to improve or restore soil biodiversity. The upscaling of NBS in this category would also require greater agricultural R&D efforts, farmer training processes and incentives to reduce adoption costs.

The final category covers those NBS deemed less important as well as less complex or costly. It includes two NBS associated with farming systems that are more focused on conservation and low environmental impact: the rescue of traditional varieties and the management of natural pollinators. Upscaling this type of NBS requires generating more knowledge about their importance.

Table 11
Summary of perceptions of importance, complexity and cost of NBS in agriculture

Importance	Complexity – Cost	
	Low-Medium[a]	Medium-High[b]
Low-Medium[a]	Rescue and use of traditional varieties[c] Natural pollinator management[c]	Ecosystem restoration Biological treatment of wastewater Soil recarbonization Soil or water bioremediation
Medium-High[b]	Crop diversification Agrosilvopastoral systems Soil conservation Use of traditional bioinputs	Development and use of improved resistant varieties Biological control of pests and diseases Natural conservation areas Conservation and management of agrobiodiversity Use of modern bioinputs Practices to enhance or restore soil biodiversity

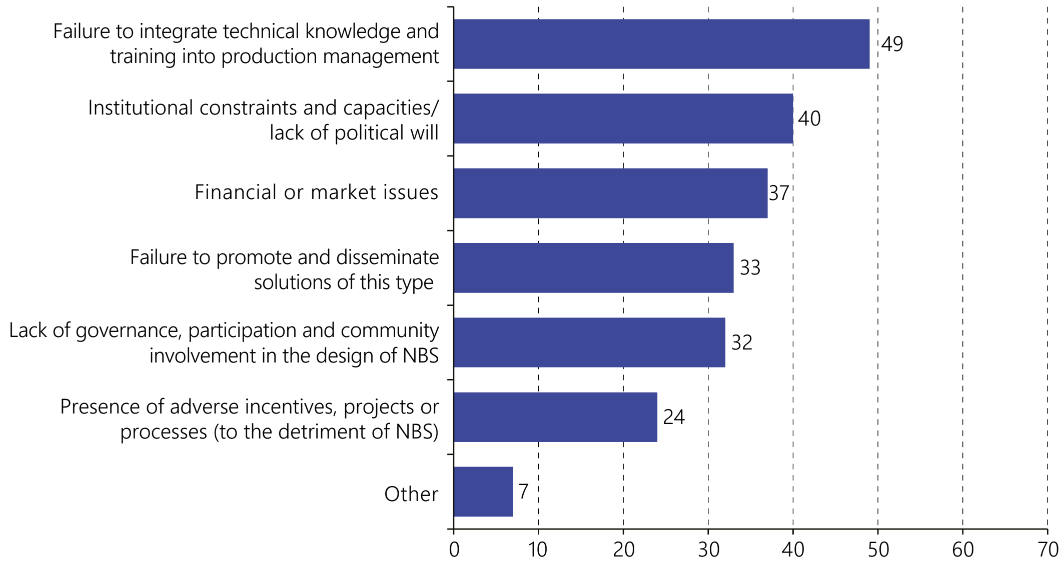
Source: Prepared by the authors.
[a] Values below 2, as defined on figures 6, 7 and 8.
[b] Values equal to or greater than 2, as defined on figures 6, 7 and 8.
[c] Perceived to be of low to medium cost and importance, and of medium to high complexity.

(b) Barriers to the adoption of nature-based solutions

Most of the respondents pointed to the failure to integrate technical knowledge and training in production management as one of the main barriers to the adoption of NBS in agriculture. In second place, they identified institutional constraints and capacities and the lack of political will. Financial and market issues were ranked third. Finally, the failure to promote and publicize solutions of this type, the lack of community governance, participation and involvement in the design of NBS, and the presence of unfavourable incentives, projects or processes (to the detriment of NBS) were among the other factors identified (figure 9).

It is interesting to note that the barriers are very closely linked to the areas in which the respondents work, most of whom (77%) are active in academia or government institutions. Hence, those actors have the capacity to influence the improvement of training and technical knowledge and to address institutional considerations that would promote the adoption of NBS.

Figure 9
Perception of constraints on the adoption of NBS in agriculture
(Number of mentions, N = 70)



Source: Prepared by the authors, on the basis of total received responses.

4. Incentives and actors in the promotion of nature-based solutions

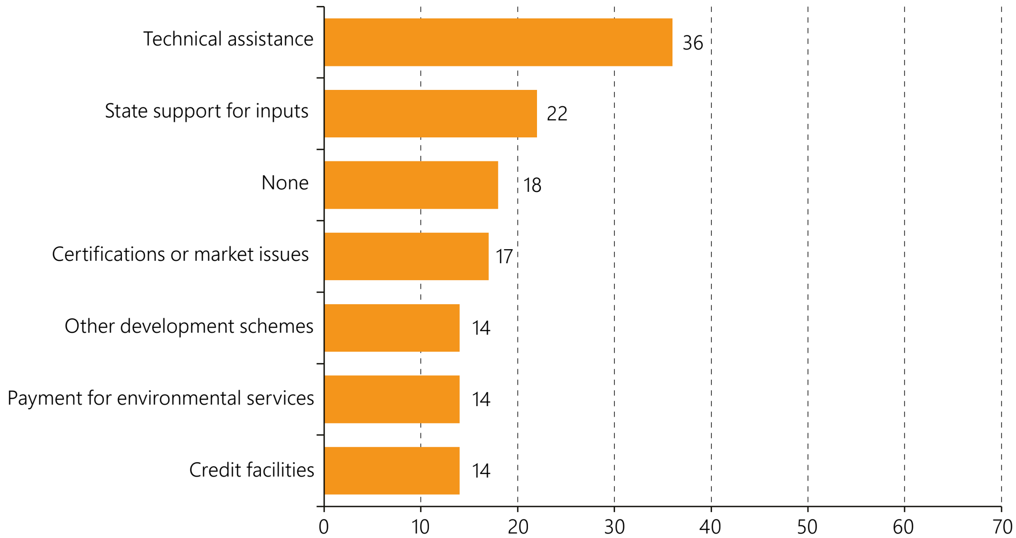
This section of the questionnaire sought to reveal the incentives that exist for the use of NBS in agriculture, and to identify the key actors involved in their promotion.

The respondents mainly identified technical assistance and government support for inputs as the incentives that exist to encourage agriculture's adoption of NBS. A number of respondents said there were no such incentives in their particular contexts. Options associated with payment for environmental services schemes or credit facilities were reported less frequently (figure 10).

The respondents said that universities and research centres were the main advocates of NBS (figure 11), followed by NGOs and civil society organizations, and by central governments and ministries.

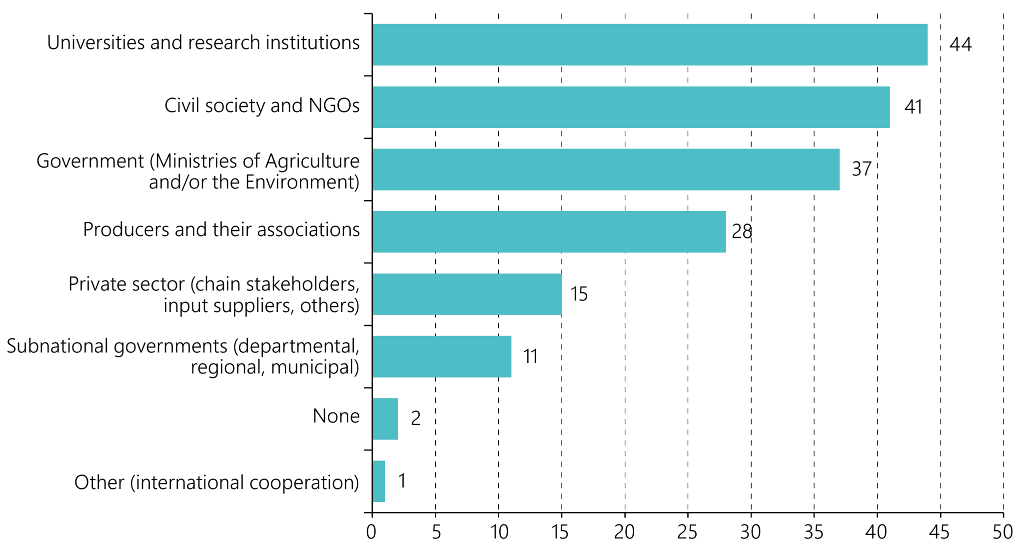
Two open-ended questions were also included, to explore perceptions of rules and regulations that encourage NBS and the research and/or knowledge required to promote them. Several national environmental laws were mentioned, dealing with protected areas, woodlands, climate change, water quality, soil conservation, green growth and rural development laws. The implementation of those laws, with incentive schemes and related technical support, was also referred to: for example, soil use and management plans in Uruguay, the Programme for the Recovery of Degraded Soils in Chile, and the Payments for Environmental Services Programme in Costa Rica.

Figure 10
Incentives favouring the adoption of NBS in agriculture
(Number of mentions, N = 70)



Source: Prepared by the authors, on the basis of total received responses.

Figure 11
Actors promoting NBS
(Number of mentions, N = 70)



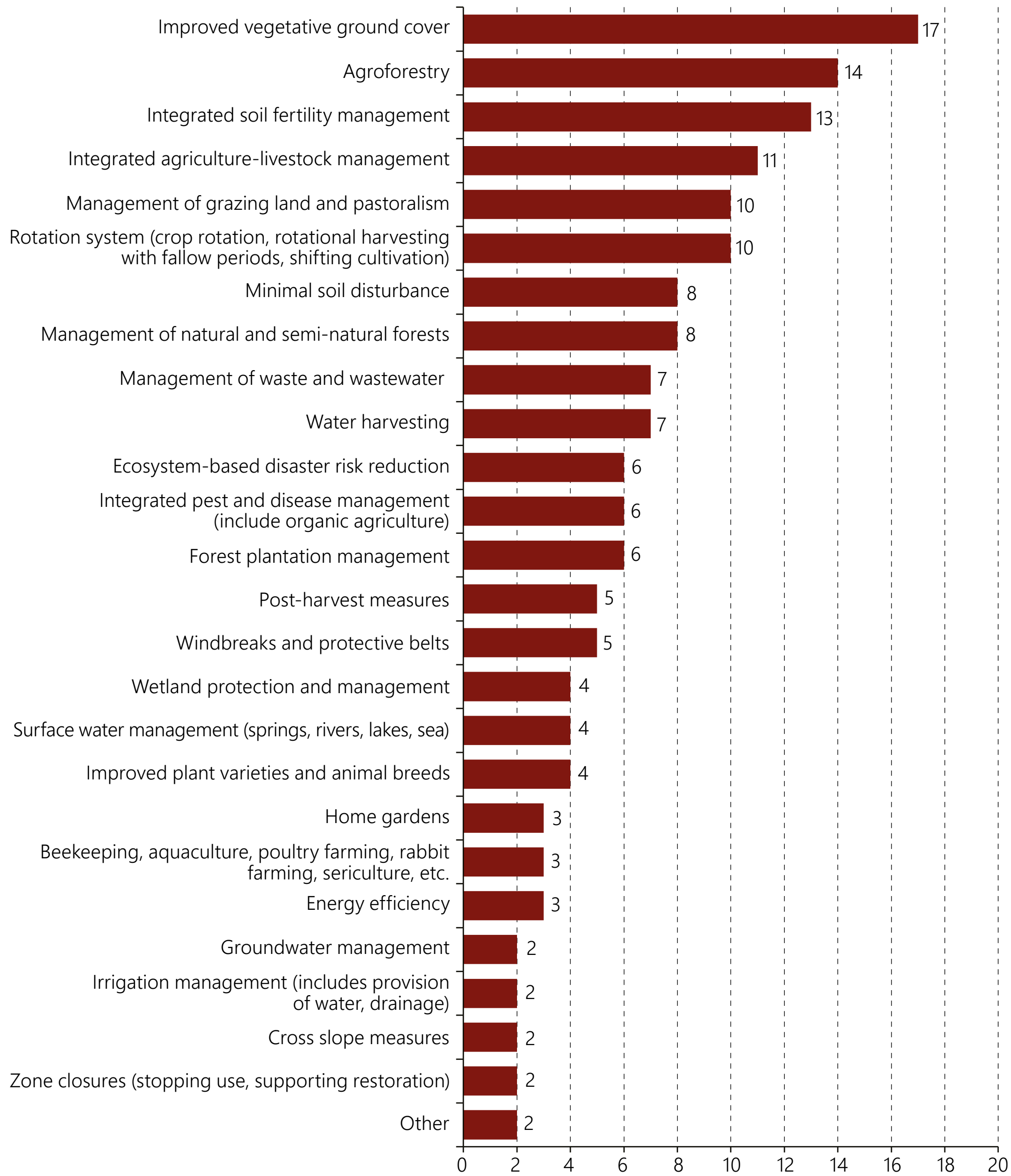
Source: Prepared by the authors, on the basis of total received responses.

Of the research and/or knowledge required to promote NBS, the respondents spoke of applied onsite research, along with basic research in microbiology, genetic resources and other areas. Others frequently identified included economic assessments of ecosystem services and cost-benefit analyses of NBS, as well as a reappraisal of traditional knowledge. References were also made to social aspects of NBS, such as interdisciplinary work and networking, as part of a collaborative economy.

5. Characterization of nature-based solutions for upscaling

The survey included an optional response section in which the respondents were asked (through an open-ended question) to propose an NBS that, in their particular context, was suitable for adoption and upscaling. They were then asked to classify the chosen NBS according to a predefined list of 26 options. The results are presented in figure 12.

Figure 12
NBS suitable for upscaling
(Number of mentions, N = 40) [a]



Source: Prepared by the authors.
[a] The question allowed the selection of up to three options.

A large number of the responses involved soil-related issues (cover, fertility and degree of disturbance). Agroforestry, integrated cropping and livestock farming, and rotational systems were also frequently mentioned as options. Except for water harvesting, options involving water management and irrigation were less frequently selected.

6. Discussion

The survey results must be analysed with an awareness that most of the respondents were knowledgeable people from the agricultural sector with ties to the public and academic spheres. Although they are key actors in the NBS promotion process, they are not responsible for implementation or the final beneficiaries. Therefore, collecting information from those actors remains a pending task.

NBS are recognized as being present in agricultural production in the countries of Latin America and the Caribbean. In terms of the environmental problems that NBS can solve, there was a predominance of responses that identified erosion and soil degradation due to poor practices. Consequently, the respondents showed a preference for solutions aimed at soil conservation, improved soil fertility and reduced soil disturbance. In general, such measures help deal jointly with climate change, improvements in soil biodiversity and land degradation.

Another notable aspect was the high profile given to the traditional agricultural practice of developing and improving resistant varieties, presumably because of its importance in dealing with climate change in regional agriculture. However, it should be noted that at this point, there is still no consensus regarding the scope of this nature-based practice. The topic of modern genetic breeding is not addressed in the NBS literature.

The literature on agricultural NBS tends to focus on sustainable production systems and synergistic crop selection (Peters and others, 2017), the reintroduction of forgotten crops and the rescue of varieties or endogenous germplasm that may offer better adaptability. In line with the above, the second most important practice identified by the respondents was crop diversification and integrated agrosilvopastoral systems.

Issues related to soil and water restoration through bioremediation techniques were not assigned a high importance, probably because the participants believed that measures of this kind were highly complex and costly and that other simpler solutions were required first. In general terms, only some solutions are perceived to have high implementation and maintenance costs. This assumes the majority are highly accessible to farmers and indicates they could potentially be addressed by moderate investment policies.

The main obstacles to greater adoption of NBS include the need to integrate technical knowledge and practical training, as well as institutional constraints and a lack of political will. This may be a bias derived from the characteristics of the survey respondents, who see aspects related to their own fields of action as more relevant. Consequently, several respondents suggested that overcoming the main barriers to adoption required a greater dissemination of NBS, training programmes and applied research methods, together with a quantification of their benefits.

These results indicate general trends that are useful for understanding the use and ownership of NBS in the Latin American and Caribbean agricultural sector. However, a broader review and discussion with other stakeholders —farmers in particular— is needed to further explore the constraints on the adoption of NBS, as well as to discuss options for scaling them up in specific contexts.

VI. Case studies of nature-based solutions in Latin America and the Caribbean

This section presents selected cases of NBS applied to agriculture in the countries of Latin America and the Caribbean that provide examples of how synergies between the objectives of the Rio conventions can be built. In addition, the cases showcase innovative approaches to: (i) promoting NBS and overcoming traditional barriers to adoption, (ii) contributing to improvements in the productivity and livelihoods of producers, and (iii) creating new chains and added value from biodiversity (table 12).

Table 12
Cases of NBS applied to Latin American and Caribbean agricultural landscapes

Country	Initiative name	NBS involved	Promoters and support mechanisms
Costa Rica	Productive landscape management in the Jesús María River Basin.	Ecosystem restoration. Reforestation. Integrated water and watershed management. Soil and water bioengineering.	Loss of soil and productivity. Multistakeholder partnership. Technical assistance. Governmental support and international cooperation.
Ecuador	The Amazonian chakra connected to biotrade.	Agroforestry system. Biodiversity bioprospecting. Productive diversification.	Income diversification. Market access. Support from national and subnational governments and international cooperation.
Chile	Protecting Mediterranean ecosystems in vineyards.	Management of areas of native woodland. Renaturalization of landscapes.	Market trends. Initiative by the private sector and researchers.
Uruguay	Improved livestock breeding on natural pastureland.	Improved grazing land management. Reduced conversion of natural grassland.	Market demands. Country's international UNFCCC commitments.

Table 12 (concluded)

Country	Initiative name	NBS involved	Promoters and support mechanisms
Central America	Ecosystem-based adaptation: CASCADE Project (Ecosystem-based Adaptation for Smallholder Subsistence and Coffee Farming Communities in Central America).	Agroforestry systems. Erosion and wind control infrastructures. Soil conservation practices. Management of riparian woodlands or woodland fragments.	Climate change adaptation for small producers of basic grains and coffee. International cooperation, linking science and practice.

Source: Prepared by the authors.

A. Restoring life through the landscape approach (Costa Rica)

The Jesús María River Basin has been classified as the most degraded in Costa Rica by the country's Advisory Commission on Land Degradation (CADETI). Located on the Pacific coast, it comprises a landscape of forests, coffee plantations, fruit trees, mangroves, pastureland, crops, bodies of water and urban areas. It covers an area of 35,280 hectares, rising from sea level to a height of 1,400 metres, and consists of several sub-basins that flow into the Pacific Ocean through the Tivives wetland. That wetland, with its mangrove and estuary system, is a Protected Wildlife Area (CADETI, 2021a).

The basin has experienced declines in biodiversity, agricultural productivity and water availability due to unsustainable agricultural practices, deforestation and changes in land use. The loss of natural forest cover has left the landscape fragmented, with some patches of primary forest in the main river corridors and mangroves. Unsustainable practices have led to increased soil erosion, landslides and sedimentation in the lower reaches of the watershed. Sediments from erosion reach the port of Caldera, forcing the government to invest millions in dredging the port (UNDP, 2021).

The main crops in the basin are coffee, rice, sugar cane and fruit. Combating erosion and halting soil degradation is a key task, as soil is the basis for agriculture and farmers' livelihoods. Farmers are restoring natural habitats through an integrated landscape approach and the application of NBS, including: (i) ecosystem restoration, (ii) integrated water and watershed management, (iii) erosion reduction, and (iv) forest restoration.

With support from UNDP through the Global Environment Facility (GEF) Small Grants Programme, over the past decade CADETI has conducted a series of integrated landscape-level initiatives. From the outset, a plan was established with agreed long-term objectives for landscape and seascape management, including the establishment of a mechanism to evaluate its results.

The task of setting the baselines, led by the communities in 2013, highlighted the need to improve the way scientific knowledge is shared at the decision-making and community levels. The assessment revealed that improving resilience and the recovery of degraded natural resources required stakeholders to have good data available. The evaluations also highlighted the sustainability of productive activities at the local and regional levels, together with the need to promote new technologies and practices such as water harvesting, stone walls to prevent erosion and the use of biodigesters.

The first activities focused on the construction of runoff water reservoirs to reduce erosion in the basin. In the second phase, native timber species and fruit trees were replanted to generate commercial activities and improve livelihoods in the medium term. The third phase focused on the restoration of degraded lands through silvopastoral systems to reduce soil loss. The fourth phase centred on mitigating soil degradation. Finally, the aim of the fifth phase is work towards a transition to organic production.

Improved access to water and to sustainable agricultural and soil conservation practices have increased the productivity of coffee and other agroforestry production systems. Zero-grazing livestock production systems were implemented along with silvopastoral systems in 150 stables, 313 hectares in fodder banks, green fences, silos and grazing paddocks. The projects included water collection, storage and management through the construction of small reservoirs.

Through a practical training module, farmers have learned techniques for the construction of protection canals and soil terraces, the use of organic fertilizers, water infiltration in soils and other soil conservation practices. Some 280 farmers have been trained in organic farming systems and have visited other projects to exchange best practices. A training handbook for agricultural extensionists was produced that describes 44 sustainable practices implemented in the basin.

A partnership between project leaders and three government departments produced a planning tool that farmers can use to monitor agricultural production and that also disseminates soil conservation practices. Another partnership with the academic institution CATIE produced a series of publications documenting traditional and scientific knowledge on best practices implemented in the target landscape.

Among the most notable results, more than 750 sustainable farm evaluations and plans have been produced and 86,000 hectares have been positively influenced, both directly and indirectly, through the pursuit of conservation and sustainable production activities. About 15,000 ha are under various payment for environmental services (PES) schemes, while another 1,273 ha of forests are under improved forest management and forest regeneration by farmers, Administrative Associations of Communal Aqueduct and Sewer Systems (ASADAS) and public-private reserves not covered by payments for environmental services. More than 6,500 people (approximately 40% of them women) have improved their knowledge of conservation practices. With nearly 40 communal aqueducts, springs have been protected and hydrogeological and infrastructure studies have been carried out (UNDP, 2021).

The "productive landscape" approach has gradually refined a field-tested methodology for addressing threats to biodiversity, involving multiple stakeholders working at the landscape level. The methodology recognizes that interactions are complex and entail behavioural and cultural barriers, and it has adopted a networked, adaptive and emergent design approach.

Prins and others (2017) identify the following success factors: (i) producer ownership of good practices, (ii) the combination of tangible and intangible aspects (practices under farm plans, awareness raising, confidence building, constructive approach to conflicts), (iii) two-way communications with a common agenda, (iv) development of human and social capital, (v) innovation and responsiveness to increase producers' resilience, (vi) linking actions and results, (vii) gradual construction of a shared identity and vision among a wide range of actors with clearly defined roles and complementarities, and (vii) the creation of a critical mass of capabilities and united wills to address larger and more complex problems.

Since 2011, CADETI has worked in partnership with the UNDP Small Grants Programme, with financial support from the GEF and funds allocated through the Ministry of Environment and Energy, in the Barranca basins and the Montes del Aguacate Biological Corridor, in addition to the Jesús María River Basin. More than 50 community initiatives have been implemented in such undertakings as landscape restoration, soil conservation, sustainable production, integrated water resource management, firefighting and solid waste management. The results in the three basins will allow them to be replicated and scaled up in other watersheds (the Tárcoles River Basin and the Paso de las Lapas Biological Corridor) (CADETI, 2021a).

The partnership between the communities, grassroots organizations and NGOs in the area, their commitment and the support of State institutions (Ministry of Environment and Energy, National System of Conservation Areas (SINAC), Ministry of Agriculture and Livestock, Costa Rican Institute of Aqueducts and Sewers, National Learning Institute), universities and other organizations have undoubtedly been key to the success of this initiative.

B. Chakra: a traditional agroforestry model connected with biotrade (Ecuador)

Ecuador is a country with an extremely varied geographic landscape and extraordinary biological diversity, hosting around 15% of the planet's endemic species. One third of its territory is protected and 51% is covered by natural woodlands. The Amazon region contains large areas of untouched natural forest and the vast majority of the forest biomass (80%) (Ministry of the Environment, Water and Ecological Transition, 2016).

However, mainly because of agricultural expansion and illegal logging, the country has experienced significant changes in its forest cover. Between 2008 and 2014, an average of 98,000 ha per year were deforested and average annual emissions from deforestation totalled 38.5 $MtCO_2eq$. More than 99% of the deforested land was turned over to agriculture. Although the expansion of the agricultural frontier is largely driven by livestock production (65%), it also includes crops for local and subsistence markets such as maize and other basic goods, palm oil, cacao and coffee production (Ministry of the Environment, Water and Ecological Transition, 2016).

Ecuador is the largest exporter of fine aromatic cacao, accounting for 63% of world exports. The crop is produced mainly by small farmers, and it is estimated that 100,000 families are involved in its production and that the sector provides 500,000 jobs (ECLAC, 2016). Although production predominantly uses monoculture methods (over 80%), in the Ecuadorian Amazon cacao is produced in a mixed agroforestry system.

The Kichwa people of the Ecuadorian Amazon have developed the chakra, which is an agroforestry system that allows the sustainable use of the rainforest by combining the best Ecuadorian aromatic cacao, the controlled extraction of timber, the production of staple foods (cassava, plantain, others) and the conservation of medicinal plants. Torres and others (2015) counted about 25 crops in the chakra. In addition, one of the main characteristics of the chakra system is its floral diversity and density of timber species, most of which regenerate naturally. Torres and others (2015) state that recent research has determined that the point of origin of cacao is in the Ecuadorian Amazon, possibly around the Napo River, and a greater diversity of cacao has emerged with the development of the Chakra system.

The size of cacao plots within an Amazonian chakra ranges from 0.5 to 4 ha, and they are generally located in remnant areas of primary and secondary forests, or on fallow lands (Torres and others, 2015). Some measurements of carbon storage in chakra systems indicate a relatively high amount of sequestration compared to primary forest in the same area (Jadán, Torres and Günter, 2012; cited by Torres and others, 2015).

Over time, agricultural species with commercial value —such as fine aromatic cacao, coffee, vanilla and guayusa— have been integrated into the chakra system. The development of the value chain from the leaves from the guayusa (*Ilex guayusa*) represents bioprospecting of the local biodiversity, based on the traditional knowledge of the communities that used this crop as an energizing tea.

The Runa Foundation, a non-profit NGO based in the United States, conducts scientific and community-based participatory research. Its commercial branch markets guayusa tea, which is mainly destined for export. The product has a number of certifications: organic, fair trade, GMO-free. A number of Kichwa producers' associations provide the raw material, and a social support fund has been created thanks to the income from certified guayusa.

In the Province of Napo, several associations of Kichwa producers (such as Kallari Chocolates, Wiñak, Tsatstayaku and Amanecer Campesino) have emerged; they have marketing strategies and they work on the different stages in the cacao value chain and offer their certified chocolate bars to domestic and foreign customers. They also produce and sell vanilla, guayusa and handicrafts. This and other initiatives in the area have been supported by both international cooperation and different productive projects of the national and subnational governments.

Ecuador has been pursuing biotrade since 2001. In the bioeconomic sphere, the Ministry of the Environment, Water and Ecological Transition promotes it through the strengthening of value chains for products from different regions of the country for the use and exploitation of wild species of native flora and fauna, and for tourism, while guaranteeing the food sovereignty of the communities pursing the productive initiatives by means of an ecosystemic and adaptive approach.

The diversification of production with cacao, vanilla and guayusa, produced under the chakra system, is an example of the potential for noble productive linkages, with co-benefits in the creation of value, the generation of sources of income and the building of resilience for the communities involved. In addition to the benefits for climate change adaptation and mitigation and the conservation of biodiversity, livelihoods have been improved and local communities empowered.

C. "Pairing wine and science" for the protection of ecosystems (Chile)

Mediterranean ecosystems are important biogeographical areas with a great diversity of flora, accounting for 20% of the world's floral diversity across only 5% of the planet's surface. They are present in only five regions in the world, one of which is Central Chile. This ecosystem has been listed as one of 35 areas of global conservation importance called "biodiversity hotspots" (Ministry of the Environment, 2014). Hotspots are assigned conservation priority on account of their endemism and the levels of threats they face (Arroyo and others, 2006). Despite its high diversity of fauna and flora species (23% of the vascular flora is endemic), less than 1% of this ecosystem is covered by the National System of State-Protected Wilderness Areas (SNASPE) (VCCB, 2021). It is estimated that about 45% of the country's original woodland cover has been lost and that 76% of the remaining woodland is seriously endangered (Arroyo and others, 2006).

The Chilean Mediterranean area is home to almost half of the country's population. Historically, urban growth, agriculture and overgrazing have fragmented the sclerophyll forest, as a result of which natural resources have been overexploited, soil nutrients have been depleted and both productivity and biodiversity have been reduced (Ministry of the Environment, 2019). This area is undergoing a process of desertification and it is projected that it will be particularly affected by climate change (Ministry of the Environment, 2014). In turn, the loss of native forest implies a reduction in the potential for carbon sequestration to mitigate climate change.

The Mediterranean ecosystem is the heartland for wine production both worldwide and in Chile. For the past 20 years or so, the wine industry has been adapting its processes towards greater sustainability in response to the demands of international markets. The idea for the Wine, Climate Change and Biodiversity Programme (VCCB) arose in 2008 from the scientific partnership between the Institute of Ecology and Biodiversity (IEB) and Austral University of Chile (UACh), which proposed it to a group of wine companies located in the Mediterranean ecosystem. The wineries involved in this initiative agree to protect the ecosystems in their areas where endangered species have been recorded, and conservation targets are set for their estates, with design and management adjustments to promote biodiversity and adaptation to climate change. Through applied scientific research and collaboration processes between the scientists and producers, steps are taken to identify and create private conservation areas in agricultural estates (VCCB, 2021).

Together, the wineries participating in this initiative protect nearly 26,500 ha of Mediterranean ecosystem in Chile's central valley. Flora and fauna baselines have been determined for 56% of the area under private protection and 2,108 people have received training (72% of whom are workers in the wine sector). On average, for each productive hectare, 4.2 hectares of native vegetation are placed under protection (ECLAC, 2021a). Accordingly, in the 2017–2030 National Biodiversity Strategy, the Ministry of the Environment (2017) highlights that in the agricultural sector, agreements between industries have been particularly beneficial for biodiversity conservation and cites this programme as a specific example.

D. "Natural pastureland": a solution for climate change mitigation (Uruguay)

Agriculture is a fundamental part of Uruguay's economy and accounts for 70% of all its exports. The farm sector contributes nearly 75% of the country's greenhouse gas emissions, 46% of which originate from the enteric fermentation of 12 million head of cattle. Methane is the main greenhouse gas the country produces, with livestock responsible for 91% of total emissions of that gas. For this reason, adaptation and mitigation in the beef and dairy sectors have been made priorities in national policies for both climate change and agricultural production (Ministry of Livestock, Agriculture and Fisheries, 2021).

Grasslands protect and replenish soil fertility, erosion control and flood buffering, and they are the mainstay of livestock production in Uruguay. In the beef cattle sector, improved livestock management and the natural pastureland (*campo natural*) method allow for more resilient, less carbon-intensive and more productive agroecosystems, with benefits for farmers and society. This is because natural grasslands are the basis for livestock feeding and constitute the country's dominant form of land cover (around 70%).

Since 2010, the Ministry of Livestock, Agriculture and Fisheries has pursued several projects to promote the sustainable intensification of livestock farming. The natural pastureland improved livestock management approach addresses the barriers that constrain the adoption of climate-smart practices and technologies, particularly by small-scale farmers. Those limitations include the lack of: (i) awareness about the threats of climate change, (ii) knowledge about the benefits of sustainable management alternatives, and (iii) appropriate incentives and technical assistance to guide the transition. In recognition of cultural barriers, a "co-innovation" approach was adopted in the implementation of pilot projects. This approach involves a strategic and systemic redesign of farm management, which is carried out in an interdisciplinary way and in conjunction with the farm's entire family and team. The participation of all the stakeholders involved encourages conscious behavioural changes through collective and individual learning and ensures the relevance, applicability and adoption of solutions.

In many cases, low productivity is due to excessive stocking rates that result in overgrazing and low forage productivity. Therefore, a decrease in the number of animals may be required, resulting in lower gross emissions. Increased animal fertility, higher productivity and improved diet quality significantly reduce "reproductive overhead" and avoid unnecessary greenhouse gas emissions.

The changed system is based on the following principles:

- Adequate forage allocation by managing grazing intensity over time. This allows for better grass growth through a higher leaf area index and helps synchronize the energy needs of livestock with the year-round forage supply.
- Strategic feed supply. Forage based on body condition score to improve overall herd yields.
- Improved cow fertility through strategic feed allocation, concentration of the mating period and early or temporary weaning.
- Improved herd management: maintenance of a higher ratio of productive/unproductive animals by, for example, improving reproductive management, reducing first calving ages, controlling mating and calving, and the use of strategic supplements.
- Planting stands of trees for shade and shelter.
- Guaranteed access to water in all paddocks.

The good natural pastureland management practices adopted in Uruguay have proven to be beneficial for meat productivity, the efficient use of natural resources and farmers' incomes. But other important ecosystem services have also benefited, including greenhouse gas regulation, soil regeneration, clean water supplies, nutrient recycling and the provision of genetic material, pollination, recreation, and cultural, aesthetic and educational heritage. The temperate natural pasturelands of Uruguay are part of the *campos* biome, which is highly biodiverse and productive. Such grasslands are rare in the world and are threatened by land use change. The value of natural pasturelands must be restored, through nature-based solutions, with livestock farming methods that conserve and utilize pastures to produce high quality protein and nutrients (Ministry of Livestock, Agriculture and Fisheries, 2021).

E. Nature-based adaptation to climate change (Central America)

Central America is an area of great biodiversity but, at the same time, it is one of the parts of the world most vulnerable to climate variability and change. Drought, associated with the El Niño phenomenon, recurrently affects the geographical area known as the Dry Corridor and fuels complex situations of food insecurity. In addition, the subregion often suffers from excessive rainfall that leads to flooding. It is also affected by tropical storms and hurricanes. Recently, hurricanes Iota and Eta in 2020 caused economic losses, displacements and heavy casualties.

Central American agriculture largely comprises small farmers. Approximately 50% of countries' agricultural GDP and 70% of the food they consume come from small-scale agriculture, which also provides livelihoods for around 2.4 million families (Viguera and others, 2018). Food security in Central America depends mainly on maize, rice and beans. With some commercial exceptions, maize and beans are for domestic consumption. Rice production is important in Nicaragua, Costa Rica and Panama. Some countries supplement their food needs with beans and rice imported from China, and with maize from the United States and Mexico (Imbach and others, 2017).

Coffee is one of the most important cash crops, with a significant number of small producers grouped in cooperatives, especially in Costa Rica. Various studies suggest that most of the subregion's countries will experience falling coffee yields and reductions in the land suitable for its cultivation due to climate change (Hannah and others, 2017). Given the sensitivity of bean crops to drought and high temperatures, output in Central America is projected to fall by more than 20% by 2050 due to climate change. Meanwhile, the drop in maize yields could reach 15% as early as 2025, in certain circumstances with deficient soils (Eitzinger and others, 2013; cited by Imbach and others, 2017).

Climate change poses a major threat to agriculture, as the output of the subregion's main crops is expected to decrease significantly as temperatures rise. Most smallholder farmers have limited capacity for adaptation and a high dependence on ecosystems and biodiversity, both for ecosystem services such as pollination and water provision and for the generation of income from tourism (Hannah and others, 2017). Viguera and others (2018) note that adaptation to climate change through ecosystem-based adaptation practices has advantages both in economic terms and in the technical feasibility of implementation by family farmers.

The CASCADE (Ecosystem-based Adaptation for Smallholder Subsistence and Coffee Farming) research project was created to support family farmers in adapting to climate change. Implemented in Guatemala, Honduras and Costa Rica over a period of six years (2012–2018), it was led by the NGO Conservation International and put into practice by the Tropical Agricultural Research and Higher Education Center (CATIE) and the Centre for International Cooperation in Agronomic Research for Development (CIRAD), with funding from the Government of Germany through the International Climate Initiative. Ecosystem-based adaptation strategies were identified and evaluated with producers of both subsistence basic grains and coffee (Conservation International, 2022).

As already noted, the ecosystem-based adaptation approach is encompassed by the NBS framework. The distinction is that, as its name indicates, the primary objective of the ecosystem-based adaptation approach is adaptation to climate change, although it usually entails other benefits in terms of greenhouse gas mitigation and biodiversity conservation. In agriculture, ecosystem-based adaptation can include a variety of practices based on ecosystem management, ecosystem services and biodiversity. Ecosystem-based adaptation offers an option for small producers who lack the resources and capacity to access other adaptation alternatives, such as agricultural insurance or the adoption of new technologies (such as improved seeds, irrigation systems or increased use of fertilizers and pesticides) (Vignola and others, 2015; cited by Harvey and others, 2017).

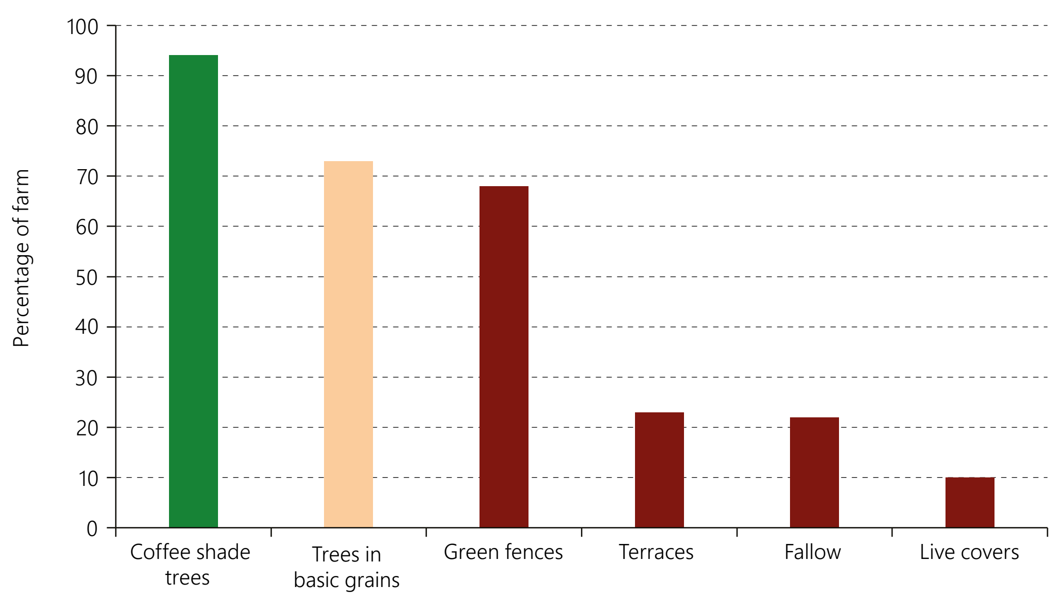
Examples of ecosystem-based adaptation practices at the plot or farm scale include the use of agroforestry systems, creating windbreaks, soil conservation practices, green fences and crop diversification (cultivars or animal breeds) to reduce production losses. At the landscape level, examples include riparian forest conservation or restoration and forest conservation in upland areas to prevent erosion and landslides (Harvey and others, 2017). All these examples can be categorized as NBS.

The work of Viguera and others (2018) summarized the project's main findings. The authors note that most small-scale Central American farmers are already perceiving changes in the climate and are already adopting adjustment measures. According to one survey, 95% of farmers recognized changes in the climate, and 46% of them were already implementing practices. A higher number of coffee producers (59%) were applying adaptation measures than producers of basic grains (36%).

The ecosystem-based adaptation measures employed by producers were mainly the use of agroforestry and landscape restoration (58%) and agroecological practices (soil and water conservation and reduction of agrochemicals) (30%). Other traditional options —including the increased use of agrochemicals (27%) and technological practices (27%) such as the use of irrigation systems, improved varieties or changing the agricultural calendar— were less frequently used by farmers. The project systematized a list of eight ecosystem-based adaptation measures and evaluated their benefits in three areas: (i) climate adaptation, (ii) mitigation of climate change, (iii) other co-benefits, such as food security, income diversification, productivity, connectivity and biodiversity. Such cross-benefits are present in practically all the practices evaluated.

The most common practices implemented were agroforestry systems, either with the use of scattered trees by producers of basic grains or with trees planted to shade the coffee crop, followed by green fences and barriers, windbreaks, soil cover and minimum tillage (see figure 13) (Viguera and others, 2018).

Figure 13
Usage frequency of ecosystem-based adaptation practices
(Percentage of farms)



Source: B. Viguera and others, "Adaptación basada en ecosistemas: una opción de adaptación de la agricultura al cambio climático en Centroamérica", *Policy Brief*, Turrialba, Conservation International/Tropical Agricultural Research and Higher Education Center (CATIE), 2018.

Viguera and others (2018) state that the current use of ecosystem-based adaptation practices depends on a range of factors, including farm size, land tenure and the dominant crop in the landscape. The authors recommend a suitable policy framework, budget allocations and viable financial options for family farmers to adapt their production to climate change by implementing and upscaling ecosystem-based adaptations.

Whether they are called ecosystem-based adaptations or nature-based practices, the techniques listed above are not new to farmers. The study showed that small farmers have the experience and knowledge to use ecosystem-based practices, and that they can see the benefits of implementing them. However, producers require support to enable them to expand adaptation practices. Coffee growers are mainly asking for technical support, while producers of basic grains require access to improved seeds, and the two groups agree on access to finance and incentives.

The experience of the CASCADE Project underscores the importance of linking science and practice to measure, quantify and better inform policy decisions. The project is also interesting from a governance perspective, in that nature conservation stakeholders work with the food production sector to generate relevant technical and scientific information for policymaking. The project produces information in different formats that can be accessed by a variety of audiences (extensionists, producers, policymakers) and used to promote the upscaling of measures.

F. Lessons learned from the case studies

Nature-based solutions are specific to a territorial context. NBS are generally not applied in isolation, but as part of a broader approach that uses a series of them in a sequence that requires a long-term vision.

The example of the Chilean vineyards shows that nature conservation is not incompatible with agriculture and that, on the contrary, they can be mutually reinforcing. Landscape management on private land can extend conservation beyond protected areas in fragmented ecosystems as part of a renewed agro-environmental agenda.

The Chakra case illustrates how traditional knowledge coupled with commercial innovation has favoured agricultural productivity, generating a new value chain (guayusa) with access to new markets and has strengthened local communities' capacities and territorial governance.

Adopting participatory approaches and forging multi-stakeholder partnerships helps build trust, identify common and/or complementary objectives, create local innovations and overcome cultural barriers that hinder the adoption of NBS. The participation of farmers from the beginning of the process —as in the examples from Costa Rica and Uruguay— confirms the importance of generating co-construction and co-innovation for the design and implementation of solutions.

Producers need to be able to see the benefits of adopting and applying NBS, whether in productivity, income or access to certain markets.

The political commitment and involvement of different government institutions makes it possible to harmonize and organize incentives, programmes and actions for the implementation of NBS and to ensure their continuity over time. The cases of Chile and Costa Rica demonstrate how joint interactions between the environment and agriculture sectors can play a key role in success. Governance is essential in involving all territorial stakeholders and determines the success of NBS, especially at the landscape scale.

Technical support is a fundamental element among the enabling conditions for promoting NBS, as is financing for the investments necessary. Ministries of agriculture, academics and nongovernmental organizations are being asked to play a renewed role in technical assistance and rural extension. Technical and scientific information can rescue local knowledge and, at the same time, measure and showcase the co-benefits of NBS.

The implementation of NBS demands innovations in different dimensions: in the multidisciplinary approach required to collect information and design a set of techniques and processes, in the participation of producers, in governance in decision-making, in the promotion of co-learning and co-construction, in the design of new commercial strategies and in the mechanisms for their promotion.

VII. Conclusions and recommendations

This study has catalogued a group of nature-based practices in food production that, if care is taken in their design, have the potential to address the challenges of climate change, land degradation and biodiversity loss, while at the same time placing the agricultural sector on a path towards greater economic and social sustainability.

The review of cases and the survey among sector experts showed that these solutions are being used by agricultural producers in Latin America and the Caribbean and that there are lessons to be drawn from their application. However, they need to be scaled up to attain their full potential in the region, to improve the performance of agriculture and to avoid future environmental damage and its associated economic and social impacts.

This closing section proposes some key messages from the work carried out, together with a series of recommendations for progress towards the development of a sustainable and nature-positive bioeconomic path.

A. Selected conclusions

The main messages of this document include the following:

- There is an urgent need to transform food production to ensure it is produced in a nature-positive way. The Latin American and Caribbean region is biodiverse and rich in natural resources, which is the basis for its status as a global net producer of food. Nevertheless, the sector is threatened by the challenges of climate change, biodiversity loss and land degradation.
- The COVID-19 pandemic in the region has deepened social problems, highlighting the lags faced by rural areas and the most vulnerable groups and drawing attention to productivity problems. The post-pandemic recovery offers an opportunity to transform the agricultural sector in Latin America and the Caribbean by addressing the vulnerability of family farmers and narrowing territorial productivity gaps through more sustainable and resilient alternatives.

- Nature-based solutions (NBS) could be a triple-win formula: environmentally, socially and economically. The review conducted identified a series of NBS that are used in food production and that allow for the forging of synergies that favour biodiversity and the fight against climate change and land degradation. These must be at the heart of the recovery of rural livelihoods.
- Although there is a general perception in Latin America and the Caribbean that NBS are cost-effective options, progress must be made with measuring the benefits they generate in order to demonstrate their positive economic impact when they are implemented in a sustained manner over time.
- Latin America and the Caribbean needs to scale up the deployment of NBS while recalling that they are specific to the particular conditions of a given territory and ecosystem. The range of solutions must also be broadened, especially as regards ecosystem restoration and the exploration of new uses for residual biomass and local biodiversity. There is a knowledge gap in this area that must be addressed urgently.
- NBS are used in all types of agriculture and production intensification techniques, but they are more frequent in production models based on ecosystem management. The cases analysed and the survey conducted show that Latin American and Caribbean farmers need support to apply them in a more comprehensive manner.
- Latin American and Caribbean governments should strategically analyse the type of public investment they can make to support agro-environmental management and generate global public goods through NBS. The correct incentives must be created, and useless or harmful ones must be redirected, in order to focus investments on the promotion of NBS and their synergies.
- The generation and exchange of knowledge is vital to resolve the cultural issues that constrain the adoption of NBS. One key aspect identified by the respondents is offering a renewed focus on technical assistance and rural extension as part of the public support to be provided.
- Investment in agricultural research, development and innovation focused on ecological management, environmental restoration, bioprospecting and an economic reappraisal of the benefits of NBS is needed to promote a new paradigm of sustainable bioeconomic development in the region.

B. Recommendations

Reforming food systems is essential if global goals are to be met, including those of the Rio conventions and the 2030 Agenda for Sustainable Development. This study shows that there are several solutions that can be implemented in agricultural production and landscapes to contribute to global environmental objectives and pandemic recovery needs. The following paragraphs set out a number of recommendations for the expansion of NBS in the food production sector.

1. Strengthening the contribution of nature-based solutions in agriculture and the bioeconomy to post-pandemic recovery

Because of its ties to biological resources, the bioeconomy offers development pathways that include a wide range of NBS that are important to the sustainable development of agriculture: the protection and enhancement of ecosystem services, eco-intensification of agriculture and agroecology, and bio-based processes for environmental remediation in soils and water.

Since the bioeconomy represents a non-sectoral approach, its central requirement is the interconnection and coordination of policies in various areas, such as productive development, innovation, environmental concerns and investments. These elements are central to what ECLAC has called a big push for sustainability, which recognizes the bioeconomy as one of the drivers for a sustainable and inclusive recovery from the global crisis caused by COVID-19.

The policy and investment coordination and interconnection issues that are a key element in the bioeconomy approach and in the implementation of NBS are of particular relevance in the post-COVID context, since the pandemic's impact on public revenues means that reactivation must take place against a backdrop of severe fiscal constraints. In this situation, governments can intelligently target low-cost investments through NBS in the agrifood sector in order to address reactivation concerns (employment, poverty, food security) and offer a more sustainable future for regional agriculture.

The bioeconomy also emphasizes the importance of considering the specific biological resources available in the design of strategies for their development. Similarly, the design of NBS is context-specific to the particular ecological and sociocultural conditions in a given territory, but common aspects that favour their implementation and adoption by producers can be identified. Institutional actors must produce compilations of the most promising NBS to respond to their commitments and strategic frameworks, taking into account the maximization of co-benefits and their potential appropriation by producers.

Cultural aspects also exist that influence the understanding of natural approaches and the preference for certain solutions over others. Both the cases reviewed and the survey carried out revealed a demand for training in NBS knowledge and management. Along with strengthening rural extension services to provide producers with that support, Latin American and Caribbean countries need to make progress with technical and scientific information and evidence for a broader implementation of NBS.

At the landscape level, forms of governance for the design and implementation of NBS must be promoted, with the creation of multi-stakeholder partnerships in the territories that allow for the co-construction, appropriation and long-term monitoring of the solutions implemented.

Funding is a key issue in upscaling NBS. In the short term, the flow of investment for post-pandemic economic recovery must catalyse some of the NBS efforts, especially those linked to job creation. Furthermore, in terms of strategic vision, broader inclusion of NBS is desirable in initiatives for the development of the bioeconomy, as instruments for implementing a comprehensive vision of development based on the good use of biological resources.

2. Contributing to an agroecological transition by upscaling NBS that promote synergies between the global environmental conventions

In the medium term, investment must be redirected through a package of incentives and institutional reforms that unblock barriers to the adoption of NBS. Upscaling NBS requires involving financial sector institutions to create investment portfolios and mobilize funds for NBS at the national level.

An important part of the change of mentality is assimilating the fact that it is easier and cheaper to prevent ecosystem damage than to reverse it, and that sometimes reversal is simply not feasible. Progress needs to be made with comprehensive economic evaluations, using multidimensional methodologies and time frames that allow the economic benefits of NBS to be correctly measured, so that arguments in favour of NBS can be taken to decision makers.

Agricultural subsidies that are harmful to nature and that cause detrimental environmental impacts in Latin America and the Caribbean must be reversed. To this end, the existing incentive mechanisms must be studied and options for redesigning and redirecting agricultural subsidies for restoration actions and promoting NBS in agriculture must be proposed, in order to create a constant flow of investment for the upscaling of NBS.

Along with mechanisms for better allocation and realignment of investment in nature, transparency and monitoring mechanisms must be put in place to verify its effectiveness (Tobin de la Puente and Mitchell, 2021).

One key aspect in ensuring these solutions over time is investment in knowledge to develop science-based incentives. Research, development and innovation has a high impact on sustainability (Johnson and others, 2021), especially when focused on ecological management, environmental restoration, bioprospecting and the multidimensional reappraisal of nature.

3. Strengthening the integration of NBS into agricultural transformation strategies and into equitable, nature-positive bioeconomy initiatives

NBS as a bioeconomic development pathway allow for the reappraisal of biological resources in the broadest sense: both the economic value and intrinsic values of biodiversity and the functions it performs.

The development of integration frameworks at the country level can raise the policy relevance of NBS. These policy developments will require the role of NBS to be defined as part of national bioeconomy strategies.

With regard to the development of reference centres for prospective NBS, Rodríguez, Rodrigues and Sotomayor (2019) highlight the progress made by Latin American and Caribbean countries that have designed development strategies based on the bioeconomy. Other countries may join this path, and some of them may offer valuable reference points in the development of the enabling conditions that will make it possible to promote new NBS.

Governments need to invest in human capital in the life sciences as well as across disciplines in the service of nature-positive economic and social progress. Cooperation between regional knowledge centres will play a key role in this endeavour.

Research must explore new value chains based on biodiversity as part of a renewed development of the agricultural sector in Latin America and the Caribbean, where innovation and environmental stewardship go hand in hand, following the principles of a sustainable and nature-positive bioeconomy.

The conclusion of this document coincided with the emergence of conflict between the Russian Federation and Ukraine, which is affecting the global supply of grains and fertilizers and fuelling increases in food prices, with impacts on Latin America and the Caribbean and incalculable repercussions for global food security.

Circumstances often make it impossible to take a long-term view, but ways to produce food that are less dependent on inputs already exist. Precision in the use of agrochemicals can be improved in order to minimize the volumes deployed; alternatively, biofertilizers generated from residues can be used, or the availability of nitrogen or phosphate fertilizers can be improved by means of beneficial microorganisms. With the correct focus on research and technical assistance, producers in Latin America and the Caribbean can move towards lower dependence on inputs and embark on more resilient agricultural production processes that can counter the effects of shocks of different kinds through the deployment of nature-based solutions.

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Annexes

Annex 1
Review of strategic frameworks

In order to achieve the objectives of the study, in addition to the texts of the conventions on biological diversity, climate change and desertification, various other elements were also reviewed: (i) complementary agreements, (ii) constituent and/or operating bodies, (iii) main strategic frameworks, and (iv) national implementation mechanisms. These are summarized in table A1.

Table A1
Summary of main frameworks and entities of each convention reviewed

Instruments	Convention on Biological Diversity	United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa	United Nations Framework Convention on Climate Change
Complementary agreements	Nagoya Protocol. Cartagena Protocol.		Paris Agreement. Kyoto Protocol.
Constituent and operating bodies, in addition to the Conferences of the Parties (COP)	Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA).	Global Mechanism. Science and Technology Committee (STC). Committee for the Review of the Implementation of the Convention (CRIC).	Koronivia joint work on agriculture (KJWA) of the Subsidiary Body for Implementation (SBI) and the Subsidiary Body for Scientific and Technological Advice (SBSTA). Warsaw International Mechanism for Loss and Damage.
Intergovernmental scientific support organizations (independent)	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). *Global Assessment Report on Biodiversity and Ecosystem Services* (IPBES, 2019).	Knowledge centre (hub) Global Land Outlook – 2017 (updated 2021 version).	Intergovernmental Panel on Climate Change (IPCC).
Relevant technical reports	*Regional Assessment Report on Biodiversity and Ecosystem Services for the Americas* (IPBES, 2018a).	UNCCD (2019). *The Global Land Outlook: Latin America and the Caribbean Thematic Report.*	IPCC (2019). *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems.* IPCC (2018). *Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Summary for policymakers.*

Table A1 (concluded)

Instruments	Convention on Biological Diversity	United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa	United Nations Framework Convention on Climate Change
Main strategic frameworks	Strategic Plan for Biodiversity 2011–2020 and the Aichi Targets. Post-2020 Global Biodiversity Framework: the road map to 2050.	Land Degradation Neutrality Target Setting Programme.	The first half of the century guided by countries' nationally determined contributions, and the second half of the century by the "Long-term low greenhouse gas emission development strategies".
National implementation mechanism	National biodiversity strategies and action plans.	National action plans to combat desertification and drought. Voluntary national programmes for setting land degradation neutrality targets.	Nationally determined contributions (NDCs) under the Paris Agreement. National climate change adaptation and mitigation plans, including sectoral plans.
Coordination forums between the conventions	Globally: Joint Liaison Group (JLG), Rio Conventions Pavilion. Nationally: National capacity self-assessments for the implementation of the environmental conventions.		

Source: Prepared by the authors, on the basis of Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), *Regional Assessment Report on Biodiversity and Ecosystem Services for the Americas: Summary for Policymakers*, J. Rice and others (eds.), Bonn, 2018; *Global Assessment Report on Biodiversity and Ecosystem Services: Summary for Policymakers*, S. Díaz and others (eds.), Bonn, 2019; Intergovernmental Panel on Climate Change (IPCC), *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. Summary for Policymakers*, Shukla, P. and others (eds.), Geneva, 2019; *Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Summary for policymakers*, V. Masson-Delmotte and others (eds.), Geneva, 2018; United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD), *The Global Land Outlook: Latin America and the Caribbean Thematic Report*, Bonn, 2019; conventions' official websites.

In addition, other related or complementary conventions also exist: for example, the FAO International Treaty on Plant Genetic Resources for Food and Agriculture and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are closely related to the mission of the CBD. In turn, the Ramsar Convention on Wetlands, the objective of which is "the conservation and wise use of wetlands through local and national actions and international cooperation, as a contribution to achieving sustainable development throughout the world", is linked to the missions of both the CBD and the UNCCD. The Escazú Agreement, a regional treaty, is related to the three conventions in that it deals with environmental information, public participation in decision-making processes and access to justice in environmental matters, as well as the creation and strengthening of capacities and cooperation.

Table A2 sets out the progress made with the conventions' action frameworks and, specifically, their progress in Latin America and the Caribbean.

Table A2
Description of the frameworks for the Rio conventions and their progress in Latin America and the Caribbean

Convention	Description
Convention on Biological Diversity	
Aichi Targets	From the 2011–2020 Strategic Plan for Biodiversity, which guided signatory countries and stakeholders in the conservation of biological diversity and the improvement of ecosystem services. Unfortunately, poor progress has been made with many of this road map's five goals and 20 targets. Specifically, food production was covered by targets 6 (fisheries), 7 (agriculture and forestry) and 13 (genetic erosion of cultivated plant and animal species), and, indirectly, by targets 16 (entry into force of the Nagoya Protocol) and 18 (on biodiversity practices and innovations of indigenous communities).
Post-2020 Global Biodiversity Framework	A road map to 2050 that is more ambitious in the implementation of broad-based actions to achieve a transformation in society's relationship with biodiversity and to ensure a shared vision of living in harmony with nature. NBS, along with ecosystem services, are specifically addressed by the framework's target 10. It is currently under construction and consultation, prior to its adoption at COP15, to be held in October 2021 in China.
Nagoya Protocol	A supplementary agreement to the CBD. It entered into force in 2014 with the objective of ensuring the fair and equitable sharing of benefits arising from the use of genetic resources. It provides greater legal certainty and transparency for both providers and users of genetic resources. The protocol recognizes the distinctive nature of agrobiodiversity and that genetic resources are key to food security.
Cartagena Protocol	Adopted as a supplementary agreement to the Convention on Biological Diversity and entered into force in September 2003. It seeks to protect biological diversity by regulating the movement of living modified organisms between countries. It came into force in 2003, and 30 of the 33 countries of Latin America and the Caribbean have adhered to it.
United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa	
Global Mechanism	The mechanism promotes the financing of activities planned within the framework of the convention. It does not raise or manage funds, but rather encourages and advises donors, beneficiaries, development banks, NGOs, etc.
Land Degradation Neutrality Target Setting Programme	Through this programme, the Global Mechanism and the UNCCD Secretariat, in collaboration with their partners, support interested countries in setting their national land degradation neutrality targets, including the establishment of national baselines and associated measures to achieve them. 31 countries in Latin America and the Caribbean have established land degradation neutrality targets.
UNCCD 2018–2030 Strategic Framework	A road map to guide countries in combating desertification, land degradation and drought and in aligning their related national policies, programmes, plans and processes, including their national action programmes.
United Nations Framework Convention on Climate Change	
Paris Agreement	The Paris Agreement seeks to strengthen the global response to climate change by keeping the global temperature increase this century below 2°C above pre-industrial levels, and if possible, limiting it to no more than 1.5°C. A binding agreement for its signatory countries, it came into force in 2020 and all 33 countries of Latin America and the Caribbean are parties to it.
Constituent and operating bodies of the Paris Agreement	Those linked to agriculture and food security, such as the Technology Executive Committee (TEC) and Climate Technology Centre and Network (CTCN), and the Warsaw International Mechanism for Loss and Damage. It also has operating entities for funding: GEF, GCF, Adaptation Fund.
Koronivia joint work on agriculture	KWJA is a part of the work of the convention's subsidiary bodies (SBSTA and SBI) and involves six broad areas to address issues relating to agriculture.

Table A2 (concluded)

Convention	Description
Other related agreements	
FAO – International Treaty on Plant Genetic Resources for Food and Agriculture	Adopted in 2001 at the Thirty-first Session of the Conference of the Food and Agriculture Organization of the United Nations. To date, 20 of the 33 Latin American and Caribbean countries are parties to the treaty.
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), in force since 1975, aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Thirty-two countries from Latin America and the Caribbean are parties to this convention.
Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)	The Convention on Wetlands of International Importance especially as Waterfowl Habitat was adopted in 1971. In addition to promoting the rational use of wetlands and international cooperation, the convention designates a List of Wetlands of International Importance ("Ramsar List") to ensure their effective management.
Escazú Agreement	The Regional Agreement on Access to Information, Public Participation and Access to Justice in Environmental Matters, adopted in Escazú, Costa Rica, on 4 March 2018, is the first regional environmental agreement in both Latin America and the Caribbean and the world to contain specific provisions on human rights defenders in environmental matters.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), Observatory on Principle 10 in Latin America and the Caribbean [online] https://observatoriop10.cepal.org/en; United Nations, "Countries" [online] https://agenda2030lac.org/en/countries.

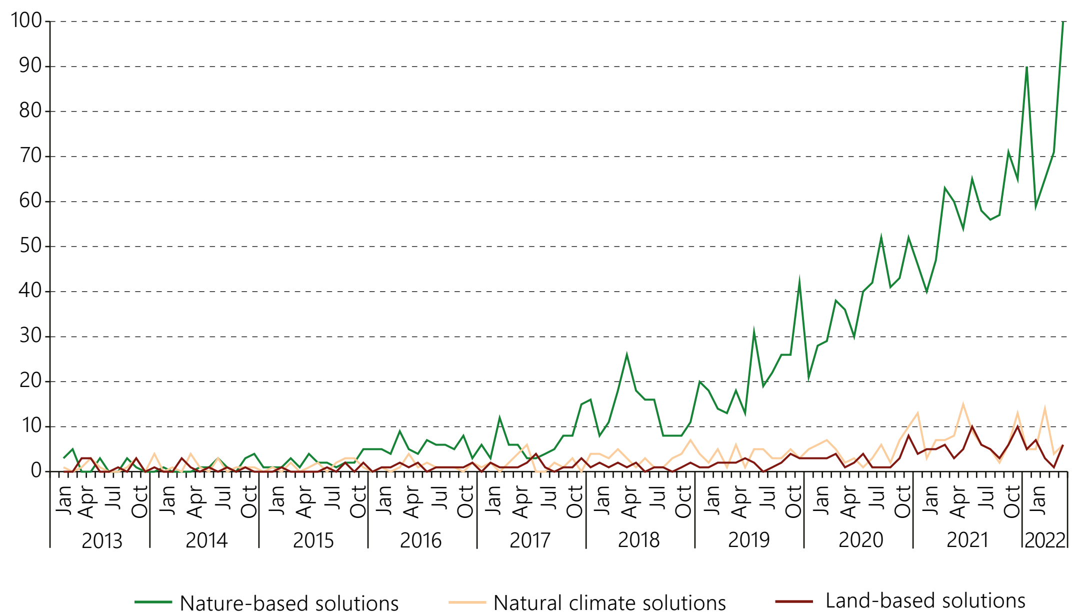
Annex 2
Evolution of the literature on nature-based solutions

The concept of NBS is relatively new. Although it first appeared in 2008, its application has increased since 2013, through the work of IUCN. Since the term emerged in the political arena, it has an important presence in both grey literature and scientific literature.

NBS in grey literature

A trend analysis was conducted at Google Trends for the period January 2013 to March 2022. Related concepts such as "natural climate solutions" and "land-based solutions", which respond to specific challenges and are directly connected to the conventions on climate change and combating desertification, respectively, were also included. High search interest was recorded in the months of September and November 2021, probably on account of the Food Systems Summit and the United Nations Climate Change Conference (COP26) respectively, where NBS received considerable attention. Maximum interest levels were reached at the cut-off date for the search (March 2022), showing that interest in searching for this concept continues to grow (see figure A1).

Figure A1
Google search interest for the NBS and related concepts, 1 January 2013–17 March 2022
(Index, 100 = maximum value)



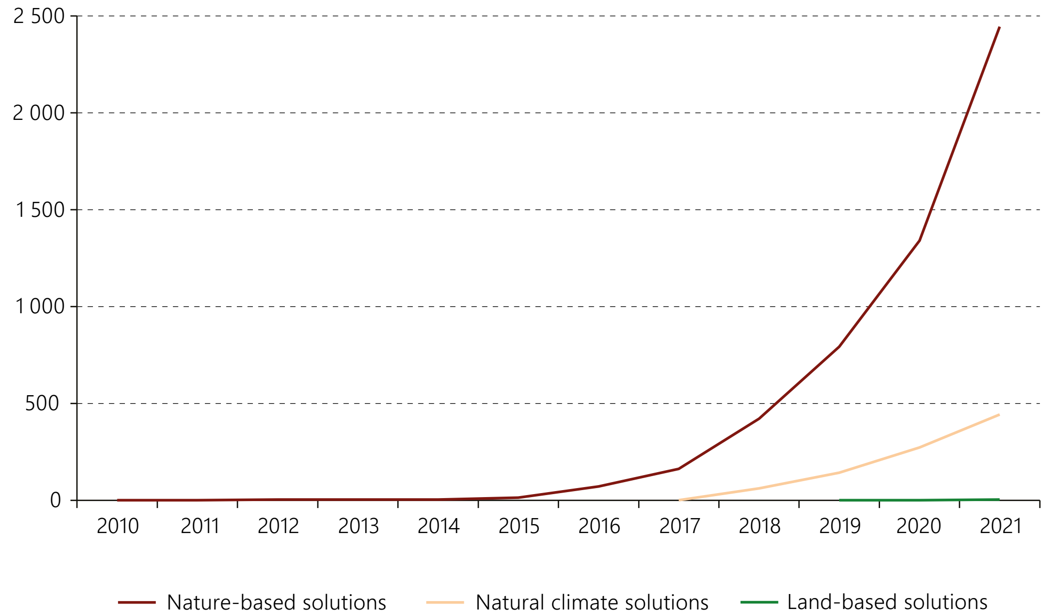
Source: Prepared by the authors, on the basis of Google Trends [online] https://trends.google.com/trends/.
Note: The numbers represent the search interest in relation to the maximum value in the specified period and region. The value of 100 indicates the maximum popularity of the term, and 0 indicates that there were insufficient data for that term.

There has been a progressive increase in position papers, guidelines and policy documents on the subject from development cooperation, NGOs, think tanks and other actors. Several international development milestones during 2021 and 2022 are linked to NBS: the start of the United Nations Decade on Ecosystem Restoration (2021–2030), the discussion and launch of the Post-2020 Global Biodiversity Framework, the Food Systems Summit and the Summit on Climate Change. All of these have a focus on the role of nature. *The Economics of Biodiversity: The Dasgupta Review*, published in February 2021, seeks to mobilize international action for biodiversity, just as *The Economics of Climate Change: The Stern Review* did for climate change.

NBS in scientific literature

Scientific publications on NBS follow a similar trend to the pattern observed in grey literature, with more articles published from 2015 onwards. This is demonstrated by a generic exploration in the search engine of the Scopus bibliographic database, as shown on figure A2.

Figure A2
Indexed publications referring to NBS and related concepts, Scopus, 2010–2021
(Number of publications)



Source: Prepared by the authors, on the basis of Elsevier, Scopus [online database] https://www.scopus.com/.

This study limited the review of the literature on NBS —grey and scientific alike— to the last five years, including the key references on which the concept is based. While the review was focused on NBS applied to agriculture, it was expanded to specific aspects of the three Rio conventions and synergies between environmental objectives, post-pandemic recovery issues and the elements of a long-term productive transformation involving the bioeconomic approach.

In line with Simelton and others (2021), the present study found that the literature on NBS in agriculture was limited, although some specific practices fell under other labels. Interestingly, scientific articles that address NBS are increasingly linked to climate change. The same is true for agriculture and NBS, but to a significantly lesser extent (figure 1).

Annex 3
Description of nature-based solutions in agriculture with the potential to generate synergies between the Rio conventions

Based on the analysis of the key literature, a selection was made of options with the potential to address a wide range of challenges and with relevance to agriculture in Latin America and the Caribbean. Each of those solutions, their scope and examples of implementation and their co-benefits are explained below.

Table A3
Agricultural NBS, co-benefits and implementation examples

NBS	Definition	Implementation examples and co-benefits
Type 1: Natural landscapes		
Establishment of conservation areas to ensure ecological connectivity	According to the CBD, these are "geographically defined area[s] ... designated or regulated and managed to achieve specific conservation objectives". The aim is to conserve and/or restore native habitats (terrestrial or freshwater) to ensure the movement of species and the flow of natural processes (ecological connectivity).	A range of mechanisms are available for implementation: land use planning, incentives or private land agreements. Private protected areas are an example of conservation in rural landscapes, which can be compatible with tourism use and subject to payments for environmental services.
Sustainable management of native and semi-natural forests	Improved forest management practices in native or naturally regenerated forests designated for timber production or multiple use. Applies to the productive management of native forests, excluding areas under extensive plantations.	Includes a series of practices such as improving natural regeneration, and the management of operations (harvesting periods, selective logging, reducing the impact of logging, closing cuts, others).
Maintenance of riparian ecosystems as natural flood protection	Wetlands, lakes and rivers that act as natural defences, buffering the speed and volume of runoff and reducing flooding risks. These ecosystems play a role in water and nutrient cycles.	This includes the exclusion of certain uses that may affect riparian ecosystems, the maintenance and/or recovery of native vegetation, remeandering to reduce the flow of rivers and watercourses and the reopening of blue corridors.
Reduced conversion of grassland to cropland	Prevention of conversion of native grasslands (tropical, subtropical and temperate) into cropland.	It can be implemented through the assignment of conservation status, zoning, oversight and the sustainable intensification of agricultural production.
Fire risk management	Fire management protects lives, property and resources. In addition to damage and losses, fires can produce various greenhouse gas emissions. Management covers the prevention, detection, control, restriction and extinction of wild fires.	The controlled and preventive use of fire is part of sustainable forest management in temperate forests and savannah ecosystems; other practices include the use of firebreaks in tropical forests. Fire management helps prevent soil erosion and land degradation and its use in pastures improves biodiversity and forage quality.
Type 2: Multifunctional landscapes		
Agricultural diversification	Agricultural diversification includes practices and products that increase resilience to climate and market risks. It involves moving from a system based on low-value agricultural products to a more diverse one, comprising a basket of products with higher added value. Its potential is influenced by market orientation, off-farm employment opportunities, livestock ownership and the available land resources.	Its aims are climate resilience and adaptation, but it could generate minor greenhouse gas mitigation benefits. It could reduce pressure on land, benefiting efforts to combat desertification and land degradation and improving food security and household income. Tamburini and others (2020) state that crop diversification has benefits in yields, soil fertility, nutrient cycling, water management and pest control.

Table A3 (continued)

NBS	Definition	Implementation examples and co-benefits
Integrated pest management (IPM)	Covers all available techniques to control pests and reduce their populations with minimal levels of pesticide use that are acceptable from economic, human health and environmental perspectives.	Includes biological pest control by means of organisms that prey on, parasitize and control populations, the use of repellents and pheromones, and mechanical population control and monitoring techniques.
Use of local seeds	Protects agrobiodiversity. Lower cost inputs that are normally more climatically resilient than commercial varieties.	Networks, seed banks and exchanges, and open-source plant breeding (i.e. produced by national agricultural research institutes).
Conservation agriculture	Conservation agriculture promotes permanent soil cover, minimal soil disturbance and the diversification of plant species. It thus prevents soil loss and allows regeneration on degraded soils.	Zero or minimum tillage, cover crops between main crop fallow periods.
Trees on farmland (fences, woodland stands, others)	Managed presence of tree and shrub species on farms. These are practices that do not fall into the agroforestry category or that do not exceed 25% of the area with trees.	Includes alley cropping, windbreaks, green fences and shelterbelts, as well as the managed regeneration of natural woodlands on farms.
Agroforestry	Agroforestry incorporates the deliberate planting of trees in agricultural crops and silvopastoral systems, allowing carbon sequestration in trees and soil.	It can increase agricultural productivity and offers producers opportunities for payments for environmental services. Examples include shade coffee, the Quezulgual system and various silvopastoral systems in Latin America and the Caribbean.
Forestation with improved plantations	The management of forest plantations on woodland includes intensive management practices in line with standards of sustainability, improved management of harvesting times and closure periods and other measures. Negative impacts for food security can arise when afforestation replaces agricultural land.	Multi-species forest plantation systems are more resilient and biodiverse. It does not include afforestation to replace native forest or to compete with agricultural land.
Improved grazing land management	Land management includes attending to both pasture management and nutrition, as well as livestock management. Better grazing land management can increase soil carbon sinks, reduce greenhouse gas emissions, improve climate resilience, help combat desertification and land degradation by optimizing stocking density and reducing overgrazing, and improve food security through increased productivity.	It involves a series of practices that aim to: (i) optimize grazing intensity according to carrying capacity, (ii) improve pasture varieties and composition (use of legumes and deep-rooted grasses, and nutrient management), (iii) improve animal health and diet, through the use of forage banks and forage diversification (i.e. cereals to reduce methane) and animal genetics, and (iv) fire management, including prevention and enhanced prescribed burning.
Biochar	Biochar is a solid product of crop residue pyrolysis. Its use as a soil conditioner improves water retention and thus improves plants' access to nutrients and water. It increases soil carbon and, in the tropics, improves yields.	It increases soil carbon and, in the tropics, improves yields. It can reduce heavy metal pollution and other impacts, helping fight desertification and land degradation. However, its benefits can be undermined if demand for it puts additional pressure on the land to supply large quantities of biomass for biochar production, affecting other uses and food security.

Table A3 (continued)

NBS	Definition	Implementation examples and co-benefits
Use of beneficial microbes to increase natural soil fertility	Different microbes (bacteria, fungi, protozoa, algae and viruses) play vital roles in soil fertility, decomposing organic matter and increasing the availability of essential macro- and micronutrients for plants. Biofertilizers contain mixtures of these microbes. In agriculture, Rhizobia, Mycorrhizae, Azospirillum, Bacillus, Pseudomonas, Trichoderma and Streptomyces are commonly used. The use of organic fertilizers, compost and biochar encourages them.	Beneficial microbes increase plant tolerance to different environmental stresses (i.e. drought, heat, cold, salinity) and resistance to insects and diseases. They reduce the demand for fertilizers, prevent chemical contamination, lower production costs and thus increase producers' profitability and incomes.
Bioprospecting of residual biomass and biodiversity: biocosmetics, biopharmaceuticals, biomaterials, bioremediators, biochemicals	Bioprospecting is the search for elements in nature (biochemicals, genes, others) in order to develop products with value in specific applications (pharmaceuticals, agriculture, cosmetics, new materials, others), thus creating new productive alternatives and adding value in rural settings. Prospecting investigates either the biodiversity of a site or the biological residues generated by food production. This task requires the creation of human capital for its development, which has a great potential to generate structural changes in rural development.	These applications allow the development of resilience and adaptive strategies through productive diversification, when safeguards are adopted for the conservation of biodiversity and the benefit of communities involved with traditional uses. One traditional form of bioprospecting in agriculture is genetic selection, which has historically been used to improve crops or animal breeds with desirable traits (pest resistance, higher productivity, etc.). More recent biotechnologies have opened up new options.
Type 3: Restoration and design of new landscapes		
Reforestation and forest restoration	Reforestation is the reintroduction of woodland to lands that previously contained forest but were converted to another use. Forest restoration involves practices that recover the ecological integrity of a degraded or deforested woodland landscape, and may include reforestation or management.	Forest restoration generates carbon sequestration and co-benefits in resilience, connectivity between woodland areas and biodiversity conservation. The use of ecologically suitable and native trees is encouraged. The conversion of native non-forest cover types —i.e. grasslands, savannas and transition areas with forest— into forest is not included.
Restoration and reduction of the conversion of peatland into agricultural land	Peat is an ancient, undecomposed plant deposit that is found in half of the planet's wetlands. Its degradation is mainly caused by drainage for agricultural use and grazing. Where possible, restoration avoids greenhouse gas emissions (from the decomposition of the plant material that forms the peat), regulates water flows and prevents flooding.	It can be implemented by assigning conservation status, zoning, oversight and land tenure regulation issues. Restoration involves rehydrating the peat and replanting with native freshwater species. There is a threshold of degradation where restoration is no longer possible.
Green infrastructure for integrated water management	Integrated water management includes strategies for the efficient, equitable and sustainable use of water in agroecosystems. It includes sustainable land management techniques, as well as specific infrastructure for water capture and storage, infiltration into soils and better use.	It involves a series of grey-green engineering technologies for water harvesting, construction of natural irrigation systems, infiltration wells, raised bed systems, wetland restoration (amunas), reservoirs and groundwater conservation systems. In Latin America and the Caribbean, Andean cultures in particular developed ancestral works for water management.

Table A3 (concluded)

NBS	Definition	Implementation examples and co-benefits
Infrastructure for reducing erosion and landslides	Fernandes and Guiomar (2018) define green infrastructure (or bioengineering) of soils as the use of materials from nature, predominantly plant-based, in combination with building materials and techniques. Erosion is the removal of soils from the surface by water, wind and tillage. It is particularly severe in Latin America and the Caribbean. Solutions include works such as terraces, green fences, contour farming (contour lines), sedimentation dikes and others. In eroded soils, the advance of erosion gullies and sand dunes can be limited with vegetative cover and barriers, or other forms of infrastructure.	Slowing erosion helps adaptation and resilience and is key to addressing desertification, which contributes to food security. In addition to green infrastructure works, conservation practices address it through reduced tillage and ground cover.
Biological remediation of contaminated soils	Nature-based soil remediation uses microorganisms (bacteria, fungi and archaea), soil macroorganisms and plants to biodegrade, stabilize or separate contaminants (FAO, 2021b). Contamination (chemical, metallic or biological) is one of the main threats to the ecosystem services provided by soil. The use of fertilizers and pesticides in agriculture is a source of soil and water pollution (Rodríguez, McLaughlin and Pennock, 2018).	Phytoremediation is the use of vegetation (trees, grasses, plants and even crops) to extract, stabilize or degrade soil contaminants. Bioremediation destroys or neutralizes various pollutants through the biological activity of certain microorganisms (Rodríguez, McLaughlin and Pennock, 2018).
Biological wastewater treatment (biodepuration)	Natural treatment systems may include one or more physical, chemical and biological processes, based on ecological principles whereby aquatic plants, algae and microbes absorb pollutants from wastewater (Mahmood and others, 2013; cited by Pavlidis and Karasali, 2020). Solutions range from the use of reed beds and construction of wetlands to bioremediation techniques using microorganisms (bacterial biofilms) or the use of enzymes to treat contaminated surface and shallow groundwater.	Wastewater treatment is an option for the reuse of increasingly scarce water. Agriculture in many places uses untreated wastewater, with varying problems, or effluent treated to at least a secondary level. Treatment allows the recovery of nutrients of value to farmers (nitrogen and phosphorus) and thus avoids contamination of wetlands and soils (FAO, 2017).

Source: Prepared by the authors, on the basis of P. Smith and others, "Interlinkages between desertification, land degradation, food security and GHG fluxes: synergies, trade-offs and integrated response options", *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, Geneva, Intergovernmental Panel on Climate Change (IPCC), 2019; G. Somarakis, S. Stagakis and N. Chrysoulakis, *Nature-Based Solutions Handbook*, The Hague, ThinkNature, 2019; F. Miralles-Wilhelm, *Nature-based Solutions in Agriculture: Sustainable Management and Conservation of Land, Water, and Biodiversity*, Virginia, Food and Agriculture Organization of the United Nations/The Nature Conservancy (FAO/TNC), 2021; G. Tamburini and others, "Agricultural diversification promotes multiple ecosystem services without compromising yield", Science Advances, vol. 6, No. 45, Washington, D.C., American Association for the Advancement of Science (AAAS), 2020; Food and Agriculture Organization of the United Nations (FAO), *Global Assessment of Soil Pollution*, Rome, 2021; *Voluntary Guidelines for Sustainable Soil Management*, Rome, 2017; N. Rodríguez, M. McLaughlin and D. Pennock, *Soil Pollution*: A Hidden Reality, Rome, Food and Agriculture Organization of the United Nations (FAO), 2018; G. Pavlidis and H. Karasali, "Natural remediation techniques for water quality protection and restoration", *Methods for Bioremediation of Water and Wastewater Pollution*, M. Imran and others (eds.), Berlin, Springer, 2020; Q. Mahmood and others, "Natural treatment systems as sustainable ecotechnologies for the developing countries", *BioMed Research International*, London, Hindawi, 2013; United Nations, *Convention on Biological Diversity*, New York, 1992.

Acronyms

AFOLU:	Agriculture, Forestry and Other Land Uses
CBD:	Convention on Biological Diversity
ECLAC:	Economic Commission for Latin America and the Caribbean
COP:	Conference of the Parties
FAO:	Food and Agriculture Organization of the United Nations
GDP:	Gross domestic product
GEF:	Global Environment Facility
GHG:	Greenhouse gas
IPBES:	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC:	Intergovernmental Panel on Climate Change
IUCN:	International Union for Conservation of Nature and Natural Resources
NAMA:	Nationally appropriate mitigation actions
NBS:	Nature-based solutions
NCP:	Nature's contribution to people
NDC:	Nationally determined contribution
OECD:	Organisation for Economic Co-operation and Development
PES:	Payment for ecosystem services
SDG:	Sustainable Development Goal
UNCCD:	United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa
UNFCCC:	United Nations Framework Convention on Climate Chang

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LC/TS.2022/43