Biodiversity Management and Ecosystem Services

Contents

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Biodiversity Management and Ecosystem Services

This guide provides contextual information on the function that biodiversity plays in delivering nature's benefits to humans, also known as 'ecosystem services'. The document, developed by JNCC, demonstrates how the ecosystem service maps produced by Environment Systems for the EO4cultivar project can be used to help inform decision making through the implementation of ecosystem-based management.

What is biodiversity and how does it support society, the economy and ecosystem services?

Biological diversity (Bio-diversity) is a term used to describe the variability among living organisms from terrestrial, marine and aquatic ecosystems; this includes diversity within species, between different species and the ecosystems of which they are part.[1]

Biodiversity interacts with the abiotic environment at different levels (i.e. soils, minerals, water, atmospheric conditions etc.), all of which differ between locations to create unique ecosystems. 'Ecosystem' describes the dynamic complex of plant, animal and micro-organism communities, and the non-living abiotic environment, functioning as a complete system.

The planets' ecosystems support all life on earth and therefore can be considered to be providing ecosystem goods and services upon which human well-being and the global economy depends. Biodiversity has declined rapidly over the last 50 years, which will affect the provision of many ecosystem services and impact on the benefits that people receive from nature.[2]

Colombia is considered one of the world's megadiverse countries as it hosts around 10% of global biodiversity. Worldwide, it ranks first in bird and orchid species diversity and second in plants, butterflies, freshwater fishes and amphibians. Colombia is made up of 314 types of ecosystems, meaning the country has a rich complexity of ecological, climatic, biological and ecosystem components.[3]

Biodiversity, Ecosystem Resilience and Landscape Connectivity

Biodiverse ecosystems are maintained by functions operating at the species, ecological community and landscape scale. These functions help ecosystems resist negative disturbances, such as invasive species invasions or pest outbreaks, or enables them to quickly recover after a disturbance has taken place, such as following a flood or fire.[4] Ecological traits refer to how an organism interacts with the environment and with other species. These traits vary amongst species in the ecosystem, so the more biodiverse an ecosystem is, the more resilient it is to disturbance, the more likely it will recover from disturbance, and there is greater likelihood the ecosystem will continue providing ecosystem services.

How connected one habitat type is to another similar habitat determines to what degree species can disperse throughout the ecosystem. If there is high connectivity between habitats, species from the surrounding area may disperse easily into the area and colonise it, helping to maintain the community and support the ecosystem function and resilience. In contrast, isolated habitats can have decreased function making them less able to adapt to change and therefore less resilient; meaning the ecosystem services they deliver are also less stable.[5] Whilst connectivity is generally considered to be a positive factor, it can also facilitate the spread of disease and invasion by alien species, which can be a threat to biodiversity.

Adopting a Landscape Approach to Managing Biodiversity and Ecosystem Services

Sustainable and resilient agricultural systems are required to feed the human population, but one of the consequences of agricultural intensification has been landscape simplification and biodiversity loss. Production landscapes often contain only high yield crop monocultures and very little non-crop habitat. This has led to natural habitat areas being greatly reduced and becoming more fragmented.

There are numerous evidence sources showing that the diversity of plants, birds, mammals, and arthropods has drastically declined in agricultural landscapes. In addition to reduced species richness, ecological traits and functional diversity are also declining. There are clear indications that vital ecosystems services such as pollination,[6 7], pest suppression[8 9] and groundwater recharge[10 11] in intensified agricultural landscapes are being severely impacted.[12]

Multi-functional landscapes are likely to be required in the future to maintain long-term sustainable agricultural productivity, whilst simultaneously supporting biodiversity, ecological function and ecosystem services. To mitigate current trends of biodiversity and ecosystem function loss, actions will be required to alter the landscape structure at scales far larger than individual farms. This will require a context specific and coordinated multi-stakeholder approach to ensure landscape design addresses the multitude of requirements in a sustainable and efficient manner (Table 1). Key tools required to facilitating this approach are landscape mapping and modelling of ecosystem services, such as the outputs developed under EO4cultivar.

Table 1. Relative levels of ecosystem services provided by landscapes under varying levels of management intensity. Potential management goals are reflected in terms of the landscape context. In all cases, preservation or improvement of regulating and maintenance ecosystem services is required to maintain all other services. Adapted from Landis (2017).[16]

Landscape Type	Ecosystem Service Characteristics and Potential Management Goals
Highly Intensified	Ecosystem services: High in provisioning services (i.e. food production), often provide low levels of regulating, maintenance or cultural ecosystem services. Management goal: Restore ecological integrity to maintain high levels of production and mitigate drivers of negative environmental impacts.
Moderately Intensified	Ecosystem services: Often provide a balanced set of services. Whilst production yields may be more modest than intensively managed areas, other ecosystem services such as soil retention, water infiltration and recreational opportunities are relatively higher. Management goal: Increase sustainable use and improve overall multifunctionality of the landscape.
Less Intensified	Ecosystem services: Production yields are comparatively low, but this is compensated by increases in regulating, maintenance and cultural ecosystem services. Management goal: Production in Key biodiversity areas or pristine habitats should be avoided to maintain landscape function and resilience. If provisioning services are to be moderately increased this should be done in a manner that maintains current levels of delivery of other ecosystems services; whilst recognising there will be likely trade-offs in terms of losses of these other ecosystem services.

Using Ecosystem Service Modelling to Inform Biodiversity and Ecosystem Service Management

The EO4cultivar project has modelled ecosystem service delivery and produced ecosystem service maps. These can help inform ecosystem-based management interventions that support sustainable management of biodiversity in production landscapes and surrounding areas. The habitat and specific ecosystem service maps can be used to help land managers identify the best locations for improving biodiversity, ecosystems, and the services they provide at a landscape and individual farm scale.

Models utilise multiple datasets at several different scales. When interpreting the maps, users must consider the source data and the scale at which the source data has been captured. A site visit and impact evaluation should take place before any interventions commence.

- ***Habitat Map*** – This map has been produced for the area of interest study region, which is situated within the Magdalena Department on the Caribbean coastline in northwest Colombia. The area of interest contains the Frio and Sevilla watersheds and includes parts of the Cienega and Sierra Nevada protected areas. The habitat map helps provide a baseline of type, extent and distribution of current land uses and different habitat classes and helps to detect change over time. The map can be used to help inform decisions at a landscape and farm level by helping to guide potential sustainable land-use practices that consider natural habitats.

- ***Places with habitat of key importance for biodiversity*** - This map shows areas of natural or semi-natural habitat that are likely to contain high levels of biodiversity. These areas are likely to support ecosystem services such as soil quality and pollination maintenance, food provision, and surface water regulation. These habitats are core components of ecological networks, helping to facilitate gene flow between species populations and increase ecological resilience to environmental disturbances.

- ***Places delivering multiple ecosystem service benefits: key areas for biodiversity and surface water regulation*** – This map identifies areas of source grassland, woodland, and wetland habitats which coincide with areas providing high surface water regulation. The structure and naturalness of the vegetation in these areas provides high biodiversity value whilst the physical characteristics of living organisms combine with the characteristics of the soil, geology and topography and together they provide high levels of surface water regulation.

- ***Opportunities to enhance surface water regulation in the Rio Frio catchment*** - This map shows sites with agriculture and grassland landcover where management interventions could be potentially implemented to improve surface water regulation to slow the flow of water runoff into the River Frio.

- ***Ecological Network Connectivity – Woodland, Grassland and Wetland Ecosystems*** - These three maps show the existing ecological networks for different habitats, within which plant and animal species can move to maintain genetic diversity and sustain viable populations that ensure the maintenance and resilience of the ecosystems. The core network is likely to provide higher levels of ecosystem services, such as the ability to clean water or regulate water runoff, provide natural resources and support human activities of cultural value (e.g. ecotourism). Within the network, habitat restoration interventions are likely to be more effective as propagules, pollinators, seed dispersers and other important species will be available colonise and maintain newly restored areas.

- ***Opportunities to strengthen ecological networks*** - These two maps show places where it should be possible to restore or create new habitat to strengthen the existing ecological networks and enhance biological and genetic diversity. Investing in ecosystem restoration or enhancement in these areas is likely to deliver results quicker, be less labour intensive and less prone to fail and therefore provide a more effective investment of resources.

- ***Opportunities to deliver multiple ecosystem services: ecological connectivity and surface water regulation*** - The map shows places where it should be possible to restore or create new habitat to strengthen the existing grassland, wetland or woodland ecological networks to enhance biodiversity, while simultaneously enhancing the level of surface water regulation. Surface water regulation and biodiversity are important ecosystem services in their own right. Identifying places which provide multiple ecosystem services can help inform the decision-making process when prioritising areas for land management action and deliver best value-for-money.

Using Ecosystem Service Maps to Inform Management Decisions

Table 2 provides examples of how the mapped ecosystem service outputs can be used to inform ecosystem-based management measures to help conserve biodiversity and maintain the ecosystem services that support agricultural production.

The modelled outputs can be used to consider other industries that could benefit from ecosystem-based management. For example, mangrove and wetland restoration could support local fisheries and woodland enhancement could offer opportunities for shade grown coffee, agroforestry or ecotourism.

Earth observation data is a first step to identifying areas for potential restoration or biodiversity enhancement. Areas should be subjected to subsequent feasibility and impact assessments. For example, poorly planned reforestation that converts existing biodiversity rich grassland or wetland habitats may result in a loss of overall ecosystem function across the landscape.[13]

Any activities should always consider existing environmental policies and legislation, particularly those relating to nationally and internationally protected areas. These are discussed in the final section of this document.

Table 2. How to use ecosystem service maps to enhance biodiversity.

Measure type	How to use map	Affiliated management guidance
Enhance and restore natural areas to reduce environmental risk exposure.	Consult habitat map and the map that shows areas of key importance for biodiversity. Use these to identify the habitat types that should be a priority focus for restoration efforts. Consult the maps that show the ability of the land to moderate surface water runoff and the key areas for biodiversity and surface water regulation. Identify areas that provide benefits to both water regulation and biodiversity conservation. Refer to ecological connectivity maps to identify areas where restoration can improve connectivity between fragmented habitat patches. For the Rio Frio catchment: Look at the maps showing opportunities to enhance surface water regulation in the catchment and cross-reference with map showing opportunities to deliver multiple ecosystems services; that being ecological connectivity and surface water regulation.	In this context, restoration activities in the upper catchment can slow the flow through the system and provide benefits, such as reduced flood risk, to a wider area in the lower catchment. More localised and small-scale interventions may provide resilience to flood events at the farm or town level. Options for specific management actions may include: • Conservation of core habitat areas and avoid disturbance of areas supporting ecosystem services. • Reforestation in the upper catchment to slow the flow of water through the watershed. • Preservation of grassland to act as flood plains. • Restoration of riparian habitat to slow water flow into main channel • Mangrove and wetland restoration to provide coastal protection.
Enhancing and maintaining ecosystem resilience and landscape sustainability by improving existing biodiversity in the landscape	Use the habitat map to identify the types of natural habitat that exist within the landscape. Consult the ecological connectivity maps to identify how well connected different natural areas are.	Consider enhancing and protecting 'natural' areas. This may be done by creating suitable buffers around field margins as required by some sustainability certification schemes. Global G.A.P. suggest that producers should plan to convert unproductive areas (e.g. low-lying wet areas, woodlands,

Enhancing and maintaining ecosystem resilience and landscape sustainability by improving existing biodiversity in the landscape contd	Use the map showing places of high biodiversity importance and opportunities for improving connectivity to identify areas where interventions will enhance ecosystem integrity through improved habitat connectivity. Use this process to draw conclusions on the resilience of different sites and the potential risk of them declining and resulting in the loss of ecosystem service provision.	areas of impoverished soil, etc.) to conservation areas for the encouragement of the natural flora and fauna. Identify areas where ecosystem restoration (e.g. reforestation of forest margins and Cienega mangroves) can provide habitat connectivity but also provide shading for irrigation canals to reduce evaporation during high temperatures, improve riverbank stability to reduce sedimentation during rain events and enhance coastal protection from mangroves and wetland vegetation. Strategic planning that enhances connectivity will improve overall habitat extent and improve ecosystem resilience by enabling functional communities to persist within the landscape by reducing habitat fragmentation, increasing ecosystem resilience to disturbances. Interventions may consider the delivery of multiple ecosystem service benefits to ensure maximum impact from investment in activities designed to enhance biodiversity, whilst improving resilience of multifunctional landscapes.
Establish biodiverse polycultures to enhance ecosystem services	Use the habitat map and the map showing places of key importance for biodiversity to locate degraded or unproductive land that could be enhanced by establishing low input, organic, marginal land polyculture that has low impact and enhances ecological integrity.[14] Consult ecological connectivity maps and water regulation maps to identify where landscape design could improve ecosystem resilience and deliver multiple ecosystem services.	Matching the right polycultures to available resources and environmental conditions will need systems to be composed of a mixture of suitable species. Species included in this type of management will need to be considered in terms of both their direct commercial value, as well as the value of their ecological function.[15] Farming systems will need to be based on perennial polycultures and may include shade gown coffee, mixed orchard, mixed trees and crop alleys, forest gardens, mixed crops or pastures. Agroforests can provide a high-quality habitat matrix in fragmented landscapes. Biodiversity conservation efforts can benefit from the habitat that crops such as shade grown coffee and cacao can provide.[16] Landscape context and configuration are important factors to consider when establishing new ‘biodiversity friendly’ production areas.[17]

Restoration of degraded habitats or unproductive land for reduced soil erosion and improved water quality	Consult the soil erosion map to identify areas presenting high risk of soil erosion. Refer to the habitat map to identify existing habitat types in the area of interest, such as areas of degraded forest, unproductive cropland, or bare ground. Consider opportunities maps and ecological connectivity maps to select habitat types and locations to maximise biodiversity and ecosystem services benefits and enhance the likelihood of restoration persisting in the long term.	Soil erosion maps indicate sources of soil erosion and identify sites for targeting action. Restoration should consider existing habitats and land uses to ensure activities complement existing natural areas and benefit from natural regeneration effects. Working to restore landscape connectivity will enhance the likelihood that regenerated areas persist and adapt to environmental changes. Options for specific management actions • Target restoration on slopes presenting high erosion risk. • Wetland and mangrove restoration to improve water filtration capacity. • Identify overgrazed areas and implement grazing strategies to reduce soil erosion.
Enhance and restore natural areas to improve water regulation and availability	Consult maps showing the ability of the land to moderate surface water runoff and the key areas for biodiversity and surface water regulation. Use these maps in conjunction with the ecological connectivity maps to identify areas where restoration can benefit both biodiversity and increase water regulation through the landscape and facilitate ground water recharge.	Undertake land management to improve interception of rainfall and increase water infiltration into the soil to recharge aquifers. Management options may include: • Plant vegetation to trap condensation in the air and retain it within the hydrological system within the landscape. • Maintain and enhance vegetation around wetlands and irrigation infrastructure to reduce water loss from evaporation. • Maintain and protect natural and semi-natural wetlands.
Increase regulation and maintenance of biodiversity mediated ecosystem services (i.e. pollination* and natural pest control)	Use the habitat map to identify the types of natural habitat that are in proximity to the production area which would benefit from an increase in ecosystem services such as pollination or natural crop pest control. Consult the ecological connectivity maps to identify areas where restoration can facilitate movement of beneficial species through the landscape to improve enhance ecosystem service delivery in areas where pollinators or crop pest predators are unable to access. *This ecosystem service was not specifically mapped. SENCE can be used to produce pollination maps.	It is important to identify the native species that provide these ecosystem services and consider what ecological conditions they require in order to provide the particular functions that are sought. It is critical to consider what amount of biodiversity is required to deliver the desired services and to what extent this is achievable within the bounds of the proposed intervention (i.e. habitat requirements, such as refugia, for beneficial species). As well as the positive benefits, it is important to consider any potential dis-benefits that may be unintentionally realised, such as introduction of pest species or invasive non-native species.

Biodiversity in the North Eastern Colombian Caribbean Region

There are two internationally important protected areas in the projects area of interest, the Sierra Nevada de Santa Marta Biosphere Reserve and National Park and the Ciénaga Grande de Santa Marta Biosphere Reserve.

Sierra Nevada de Santa Marta Biosphere

The biosphere comprises of the Tayrona National Park (562 km2) and the Sierra Nevada de Santa Marta (SNSM) (6750 km2) and reaches to an altitude of 5700m.[18] It has been identified as one of the world's most irreplaceable protected areas (Figure 1).[19 20 21]

The biospheres northern edge runs along the Caribbean Sea, the western edge ends at the alluvial plane of the Magdalena River and the Cienaga Grande, the Cesar and the Ranchería River valleys create the southern border.[22]

Figure 1. Different habitats of the Sierra Nevada de Santa Marta, ranging from highly endemic Paramo in the high altitudes (3300m-5000m) and Neotropical Northern Andean Montane Forests (below 3300m). Source: Flickr used under Creative Commons License.

Thirty six rivers make up the SNSM watershed, these feed directly into the ocean via tributaries such as the Magdalena River and Cienega, creating a range of both freshwater and estuarine ecological niches.[23] The SNSM formation rose several kilometres between the Miocene and Upper Pleistocene epochs and is considered a bio-geographic island, separate from the rest of the Andes range.[24]

The varied extreme of altitudes, combined with its tropical location, represents almost the complete spectrum of climates and ecosystems found not only in Colombia, but in all tropical America. Nine biome types can be found in the SNSM. These include dry tropical forest, very dry tropical forest, semi desert, tropical rain forest, sub Andean woodland, Andean woodland, Paramo, Tundra and permanent snow. This diversity of climatic conditions has given rise to a high diversity of flora and fauna.[23]

The greatest plant diversity in the SNSM is located between 1000 and 2500 m. These mountain forest habitats support many endemic species of plants and animals. Vascular flora of interest are the Melastomataceae, that include 20 genera and 86 species, 21 of which are endemic to Colombia and 15 of those are endemic to the SNSM.[25]

The SNSM has five endemic lizard species. The Endangered Walker's Sierra frog (Geobatrachus walker) is endemic to tropical moist montane forests of the SNSM and is the only species in the monotypic genus Geobatrachus.[22]

Repeated colonisation by Andean birds, coupled with subsequent divergence, has created 70 endemic bird taxa.[26,27] This constitutes an extremely high levels of endemism for a continental site covering less than 6,000 km².[28] Most of the restricted-range bird species occupy a wide altitudinal range between the temperate and tropical zones, where most inhabit humid forest and forest edge habitats.[29]

Due to extensive deforestation, two endemic bird species are now considered threatened. The Santa Marta Parakeet (Pyrrhura viridicata) numbers fewer than 3,200 individuals and is confined to less than 200 km² of its remaining habitat. The Santa Marta bush tyrant (Myiotheretes pernix) is restricted to a limited altitudinal range where suitable habitat extent has been greatly reduced in coverage.[28]

The high level of plant and animal endemism, particularly in the middle and high attitude biomes, were key drivers in the SMSN being granted Biosphere Reserve Status.[30,31,32,33] The effective ecological isolation of the region's biomes, coupled with the intense evolution of highland species, are key factors behind the appearance of endemism.[34] The Páramos are a particularly important centre of speciation that have given rise to plant genera such as Cabreriela, Castenedia and Raouliopsis.[35] There are at least 125 species of endemic angiosperms, of these 61 occur only in the paramo, with 32 species belong to the family Asteraceae.[36]

Cienaga Grande de Santa Marta

The Ciénaga Grande de Santa Marta (CGSM) ecoregion is the largest delta-lagoon system in the Colombian Caribbean, covering 3,812 Km². There are 757 Km² of more than 20 interconnected lagoons; the two main water bodies are the Ciénaga Grande de Santa Marta (450 Km²) and the Pajaral swamp (120 Km²) (Figure 2).

The lagoon complex regulates the flow of the Magdalena River, and those flowing down from the SNSM. It also regulates rainfall and evapotranspiration regimes, providing a significant volume of moisture to the SNSM.[37] The CGSM was designated as a wetland of international importance under the Ramsar Convention in 1998 and a UNESCO Biosphere Reserve in 2000.[38]

The CGSMs high water column biomass and aquatic primary production makes it the most productive coastal lagoon in the tropics. The high level of biological production supports not only a wide array of species, but also seven fishing villages built in the CGSM with a total population of approximately 20,000 persons, 3,200 of whom are fishermen.[39]

Besides the open water of the lagoons, the estuarine delta of the CGSM comprises of dry forest, riparian forests, freshwater marshes and mangroves.[40] The CGSM supports a wide array of phytoplankton and invertebrates, making it an important feeding and breeding ground for other species.[40]

In terms of abundance and diversity, mollusks constitute one of the most important groups in this ecosystem. They are represented by approximately 98 species, 66 genera and 48 families, with community composition and distribution defined by salinity regime and substrate characteristics.[41]

At least 26 species of reptiles, 19 species of mammals, and 200 species of birds have been recorded in the CGSM's mangrove forest[42,43] and the Sevilla and Fundación rivers are used by the West Indian Manatee (Trichechus manatus) and American Crocodile (Crocodylus acutus), both species are listed as vulnerable on the IUCN red list index.[40,44]

Figure 2. The Ciénaga Grande de Santa Marta Ramsar Site is the largest estuarine system on the Caribbean coast of Colombia. In addition to its rich biodiversity, the lagoon system supports the economy of the region. Around 3,600 people directly depend on these wetlands for fisheries. The CGSM is home to 122 species of bony fish and the production rate of fisheries is around three times higher than the average production in other areas along the Colombian Caribbean coast. Source: Flickr used under Creative Commons License.

Biodiversity and Ecosystem Services

Biodiversity plays a significant role in directly providing goods and services, as well as regulating and maintaining ecosystem properties that underpin the delivery of ecosystem services.   Conservation management of biodiversity is vital to the ongoing sustainability of agricultural production globally as multi-functional production landscapes often rely upon natural areas within the surrounding landscape as a source of soil fertility, natural crop pest control, maintaining the water supply and reducing risk posed by environmental hazards, such as flooding.[2] Other ecosystem services that are provided, maintained or regulated by biodiversity include:

- ***Soil formation and fertility***
  Soil formation and fertility is an essential component of a productive ecosystem, providing essential nutrients for soil grown produce. More than 99% of total worldwide food supply is produced on land. Diverse soil biota facilitates the formation of fertile soils and improves crop production. One square metre of soil frequently supports around 200,000 invertebrates and billions of microorganisms.[3]

- ***Harvest of food and pharmaceuticals from wild natural resources***
  Each year around US$90 billion of food and related products are harvested from the world's forests and used by approximately 300 million people worldwide.[3] Up to 50% of the approved pharmaceuticals developed are directly or indirectly derived from natural resources.[46]

- ***Biomass and recycling of organic wastes***
  Nearly 50% of the total photosynthetic production on land is used by humans, including managed forests and agricultural production. Agriculture and other human uses of ecosystems produces 38 billion metric tonnes of organic waste globally each year. These waste products are recycled by a variety of decomposer organisms that reprocess nutrients and makes them available for future primary production.[47]

- ***Nitrogen fixation***
  Nitrogen fixation is essential for plant growth and without it biomass production is limited. Biological nitrogen fixation occurs naturally through nitrogen fixing plants and microbes and is often used as an alternative to chemical nitrogen fertiliser.[5]

- ***Greenhouse Gas sequestering***
  Sequestration of carbon dioxide by trees and other natural vegetation mitigates against increased global warming. Unmitigated rising temperatures and resultant changes in global rainfall patterns are likely to alter crop production. Working with natural solutions to mitigate the impacts of global warming are essential to the sustainability of agricultural crop production. Forested areas near to crops can also contribute to nitrogen fixation and increase soil fertility.[45]

- ***Bioremediation of chemical pollution***
  Microbes and plants can degrade contaminant materials (i.e. chemicals and heavy metals) in soils and act as a biological decontamination process. This can occur naturally or be artificially enhanced to treat polluted sites and filter hazardous waste from water. The presence of a greater number of microorganisms in the soil ecosystem provides greater bioremediation potential. These complex processes are dependent on environmental conditions and can be limited if high levels of toxicity occur. It is important to note any bioengineering must be subjected to biosafety procedures to avoid health or environmental hazards.[48]

- ***Genetic resources and biotechnology***
  Commercial crops possess a narrow genetic base, making them vulnerable if changes in environmental conditions do not suit their biological requirements. Induced variation techniques are becoming more important to provide new genetic varieties that have traits that will enable food crop plants to adapt to environmental change. Due to the global loss of biodiversity in natural ecosystems, genetic resources are being drastically eroded and this inhibits the potential of future biotechnology advances. This reduces potential for human food systems to adapt to new socio-economic and environmental conditions.[49]

  For example, the fungus Fusarium oxysporum f. sp. cubense tropical race 4 (Foc-TR4) is posing a serious threat to banana plantations globally. Breeding resistant cultivars from banana crop wild relatives is expected to provide invaluable additional resources to develop resistant crop plants.[50]

- ***Pollination***
  Pollinators such as bees, butterflies, birds and bats contribute to the maintenance, diversity and productivity of agricultural and natural ecosystems. Pollinator diversity depends on ecosystems that are rich in diverse vegetation. Even self-pollinated crops, such as the banana, rely on animal-pollinated wild relatives to provide the genetic diversity that is essential for crop improvement and resilience to disease.[45]

- ***Wildlife and ecotourism***
  Tourism revenue in 2018 generated an estimated $US6.6 Billion for Colombia's economy[51] with wild birdwatching tourism alone attracting 278,850 tourists from North America; generating an estimated annual profit of US$9 million and supporting 7,516 jobs.[52]

Pressures Affecting Biodiversity

As the human population increases biodiversity faces growing pressures from human activity across the globe, including habitat conversion and degradation, habitat fragmentation, over harvesting of natural resources and suffering impacts from pollution. Recent global biodiversity assessments conducted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) highlights the threat posed by a continued decline in global biodiversity, key findings include:[53]

- Globally, local varieties and breeds of domesticated plants and animals are disappearing. This loss of diversity, including genetic diversity, poses a serious risk to global food security by undermining the resilience of many agricultural systems to threats such as pests, pathogens and climate change.

- Human-induced changes are creating conditions driving rapid biological evolution, with effects being seen in only a few years, or even quicker. The consequences can be positive or negative for biodiversity and ecosystems, but create uncertainty about the sustainability of species, ecosystem functions and the future delivery of nature's contributions to people (ecosystem services).

- Nature across most of the globe has now been significantly altered by multiple human drivers, with the great majority of indicators of ecosystems and biodiversity showing rapid decline.

Colombia's Convention on Biological Diversity country profile highlights several high-profile threats to national biodiversity. These include increasing social inequality, human conflict and implementation of extensive livestock and agricultural development. These pressures contribute to habitat degradation, changes in land use, over consumption of natural resources and ecosystem services. The combination of these factors is likely to heighten the impacts of climate change.[3]

Natural ecosystems in Colombia have been largely transformed for agriculture, particularly in the Andean and Caribbean regions.3 A 2017 assessment of the ecosystems in Colombia identify that 25% of ecosystems are considered Critically Endangered and 21% considered Endangered; highlighting that almost half of the Colombian ecosystems are under conditions that threaten their integrity.[54]

Pressures Affecting Biodiversity in the North Eastern Colombian Caribbean Region

In the Magdalena department incidents of wildfires are increasingly common, as burning is used as a method of land clearance which results in deforestation and threatens crops, homes and protected areas. Colombia's Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) provide a daily update on the likelihood of wildfires occurring – particularly during the dry season. The Magdalena department is considered at high risk of fire according to 2020 assessments.[55]

In Magdalena, land conversion to crops, pastures and urban areas corresponds to 22% of total landuse of the ecosystem in the region. A further 46.7% has been transformed to secondary vegetation and 1.6% has been converted to forest plantations. All of these land conversions have resulted in a substantial loss of existing natural ecosystems and increased habitat fragmentation, resulting in biodiversity loss.[56]

The remaining natural ecosystems in Magdalena suffer from a range of degrading processes caused by human activities, including industrial discharges, urban wastewater, toxic leachates from refuse, dumping of solid waste, and sedimentation due to deforestation. In coastal regions, fishing with inadequate equipment is exerting additional pressure on ecosystems. Deforestation due to expansion of agriculture, extraction of natural resources, and urbanisation are identified by CORPAMAG as factors likely to decrease the sustainable delivery of ecosystem services in the region.[20]

Following decades of uncontrolled colonisation and agricultural expansion, only 15 percent of the SNSM highland forest remains intact. Principle threats include the expansion of farms, cattle pasturelands and coffee plantations. The construction of holiday homes in the cooler climate of the mountain poses a growing threat to the region. The ranges of many endangered and endemic species are concentrated in the cooler montane forests, where these anthropogenic threats are felt most.[57]

The south-east slopes of SNSM have been extensively deforested, the western slopes have also been subjected to land clearance primarily for illegal marijuana plantations (especially during the 1980s) which were subsequently sprayed with herbicide by the government. Only the northern slope forests remain relatively intact, although active clearance continues.[29]

Existing Policies for Managing Biodiversity and Ecosystem Services

The outputs of the EO4cultivar project provide tools and ideas as to how individual practitioners can consider biodiversity and ecosystem services in the context of specific sites and the wider landscape. This is particularly valuable when considering how sustainable practices at the farm level can collectively contribute to wider strategic objectives for biodiversity.

Environment Plan for Magdalena Department

The Environment Plan for Magdalena 2018 – 2027[41] outline strategies to reduce the loss of biodiversity through sustainable resource exploitation. The National Policy for the Integral Management of Biodiversity and its Ecosystem Services (PNGIBSE) provides guidance for:

"the promotion of the Integral Management of Biodiversity and its Ecosystem Services, in order to maintain and improve the resilience of the socio-ecological systems, at national, regional, local and cross-border scales, considering scenarios of change and through the joint, coordinated and concerted action of the State, the private sector and civil society".

The Plan recognises that communities in the region depend on provisioning, regulatory and cultural ecosystem services to support livelihoods. The Plan also acknowledges that services are being over exploited, and there is urgent need to reduce the impact on biodiversity within the region to achieve sustainable development and human wellbeing.

National Biodiversity Targets

National Biodiversity Strategies and Action Plans (NBSAPs) are required by the Convention on Biological Diversity as the instrument used to translate its global targets into national action.

Colombia's NBSAP[58] identifies agricultural, mining, energy and infrastructure sectors as having a role to play in helping meet national biodiversity targets. These sectors are tasked with delivering and monitoring sustainability mechanisms to verify compliance with accountability systems established for assessing the environmental effects of productive activities.

There are some key national targets that could be considered in the context of the EO4cultivar project outputs. Individual and collective interventions between and amongst sectors could have a marked positive impact on Colombia's ambitious targets, which include:

- **Ecosystem services will be identified and valued in 3 of the 5 biosphere reserves** in the country, including those that promote health and well-being.
- **Develop adequate and differentiated biodiversity and ecosystem service management programs for occupied and transformed landscapes** and territories, and those under transformation.
- **Incorporate ecological structure in the different instruments of land use planning** and management including Planning and Management of Hydrographic Basins (Pomca) and Departmental Organization Plan (POD).
- Implement programs for the **recovery, protection and conservation (in situ and ex situ) of seeds and native varieties that are important for food security** and local economies.

- **Implement 210,000 ha of ecosystem restoration in susceptible areas** defined by the National Ecological Restoration Plan for the Rehabilitation and Recovery of Disturbed Areas.

- **Implement a National Strategy for Compensation for Biodiversity Loss**, incorporating terrestrial, freshwater, coastal, and offshore marine ecosystem components.

- **Enable the National Aquatic Resources Plan (PNRA)**, as a policy instrument based on knowledge of aquatic biodiversity (marine, coastal and freshwater), and on the sustainable management of associated ecosystem services.

- **Protection of traditional knowledge systems associated with biodiversity**, in the management cycle based on coordination with ethnic authorities and local communities.

- Undertake **strategic environmental evaluations of territories** associated with the properties assigned by the post-conflict land distribution policy.

- **Ensure at least four economic sectors have sectoral strategies for environmental responsibility** for the comprehensive management of biodiversity and its ecosystem services.

- Undertake an **evaluation of the impact and efficiency of the tax incentives associated with the management of biodiversity and its ecosystem services** to inform a proposal to reform the tax incentives that are ineffective, inefficient or contradictory.

- Sustainable production systems will be identified that **combine production and conservation actions to generate local development.** Sustainable production systems will be implemented in highly biodiverse municipalities affected by the armed conflict.

- **Management plans with sustainability indicators will be formulated in properties larger than 100 ha** according to the regional plans of 25% of the municipalities **located in ecosystems of the páramo and high Andean forest**.

- Colombia will have a **National Biodiversity and Ecosystem Services Monitoring System**, with updated and accessible information to support national, regional and local decision-making.

There are also emerging opportunities associated with engaging with these targets, as the following biodiversity commitments outline:

- Formulation and **implementation of a National Payment Program for Environmental Services** for the conservation of ecosystems of strategic interest.

- Enact mechanisms that **transfer resources from municipalities benefiting from conservation to those that assign areas to the conservation** of contributing watersheds, especially in areas of páramo and high Andean forest.

- **Five regional green business programs to be implemented under the framework of the National Green Markets Plan**. Colombia will hold a portfolio of comprehensive alternatives (supply and demand) of employment, income, entrepreneurship and value chains related to biodiversity and its ecosystem services as a contribution to a scenario for peace and well-being of the population.

- **Eco-efficiency principles related to biodiversity and its ecosystem services to be targeted across 300,000 ha** of land under agricultural production. T**echnical support processes will be carried out for 50% of small rural producers** associated with the 300,000 ha to improve capacity for entrepreneurship and sustainable business development.

- Development of **competitive value chains that incorporate biodiversity and ecosystem services as the engine of sustainable social and economic development.**

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