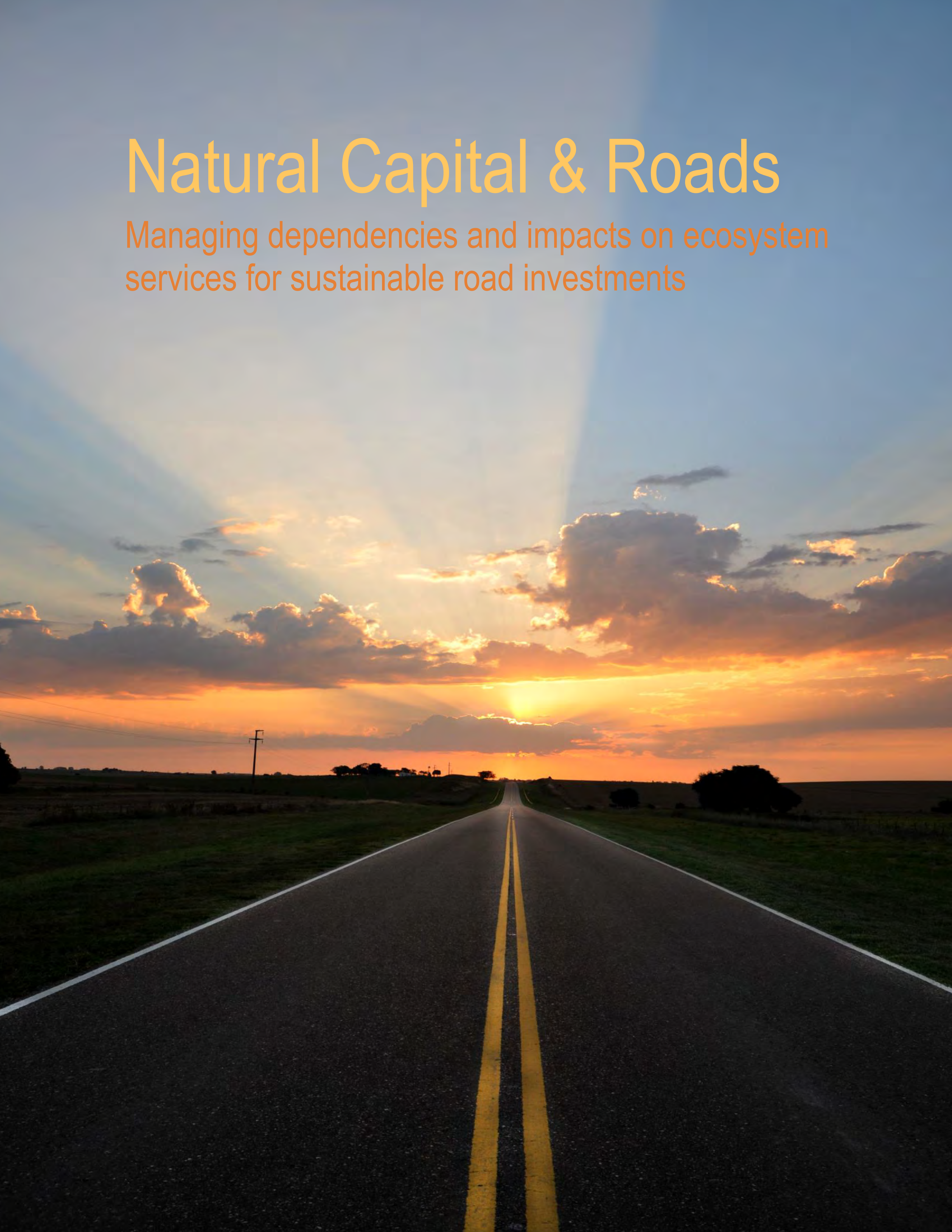
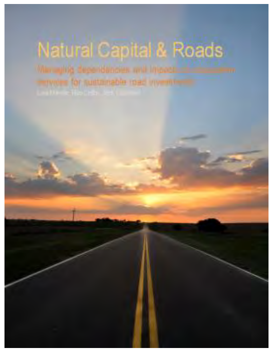
Natural Capital & Roads

Managing dependencies and impacts on ecosystem services for sustainable road investments





Natural Capital & Roads: Managing dependencies and impacts on ecosystem services for sustainable road investments provides an introduction to incorporating ecosystem services into road design and development. It is intended to help transportation specialists and road engineers at the Inter-American Development Bank as well as others planning and building roads to identify, prioritize, and proactively manage the impacts the environment has on roads and the impacts roads have on the environment. This document provides practical examples of how natural capital thinking has been useful to road development in the past, and how ecosystem services can be incorporated into future road projects.

Natural Capital & Roads was written by Lisa Mandle and Rob Griffin of the Natural Capital Project and Josh Goldstein of The Nature Conservancy for the Inter-American Development Bank. The document was designed and edited by Elizabeth Rauer and Victoria Peterson of the Natural Capital Project. Its production was supervised by Rafael Acevedo-Daunas, Ashley Camhi, and Michele Lemay at the Inter-American Development Bank.

The **Natural Capital Project** is an innovative partnership with the Stanford Woods Institute for the Environment, the University of Minnesota's Institute on the Environment, The Nature Conservancy, and the World Wildlife Fund, aimed at aligning economic forces with conservation.

The Nature Conservancy is the leading conservation organization working around the world to protect ecologically important lands and waters for nature and people.

The **Inter-American Development Bank (IDB)** is the main source of multilateral financing in Latin America. They support efforts by Latin America and the Caribbean countries to reduce poverty and inequality, and aim to bring about development in a sustainable, climate-friendly way.

All images courtesy of IDB unless otherwise noted.

List of Abbreviations

BES Program– Biodiversity and Ecosystem Services Program within the IDB

EIA – Environmental Impact Assessment

GDP – Gross Domestic Product

GIZ – German Agency for International Cooperation

IDB – The Inter-American Development Bank

InVEST – Integrated Valuation of Ecosystem Services & Tradeoffs

LAC – Latin America and the Caribbean

NatCap – The Natural Capital Project

NGO – Non-Governmental Organization

PES – Payment for Ecosystem Services

RIOS – Resource Investment Optimization System

TNC – The Nature Conservancy

USDA – United States Department of Agriculture

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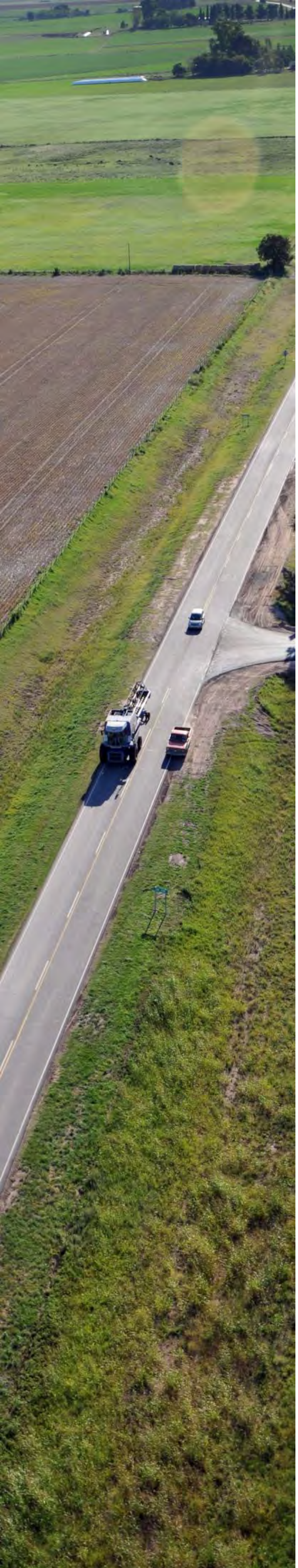


Executive Summary

Roads are a cornerstone of economic development in Latin America and the Caribbean. Ecosystems, such as forests, wetlands, and mangroves, provide important benefits by protecting roads from natural hazards such as landslides and flooding, and reducing deterioration by protecting against erosion. However, these benefits often are not taken into account when making decisions about where and how to improve roadways, with possible severe consequences for both the road project and for surrounding communities.

This document illustrates how incorporating ecosystem services into road project design and development can lead to more sustainable, cost-effective roads while maintaining or enhancing the additional benefits nature provides to the region’s citizens, from clean water and air, to food and timber.

Drawing on case studies from Latin America and the Caribbean, this document shows how roads both depend on and impact ecosystem services, and provides guidance on how to identify which ecosystem services are critical to road development in a number of different contexts. Finally, it highlights a number of practical ways in which ecosystem services information can be incorporated into different stages of road project planning to improve road sustainability and maximize the benefits to society.

I. Roads & Ecosystem Services

Including ecosystem services in road design and construction can enhance sustainability of roads and increase benefits to transport agencies and road users, while avoiding unintended negative consequences to surrounding communities.

Using ecosystem services to develop sustainable road projects

The Inter-American Development Bank (IDB) plays a catalytic role throughout Latin America and the Caribbean (LAC) in advancing road projects that drive efficient and equitable economic development and improve people's quality of life. Ensuring that these investments are made with minimal environmental impact is critical to achieving the IDB's goal of producing sustainable and inclusive growth, and to delivering lasting, positive results for road users and affected communities.

As the IDB and the LAC region expand their focus on sustainable infrastructure projects, roads provide an important opportunity to demonstrate how to create more economically beneficial and resilient projects by incorporating strategies that take advantage of benefits from the environment. Roads are exposed to floods, landslides, storms, and other natural hazards. **Taking proactive steps to reduce a project's exposure to environmental risks can result in reduced costs for constructing and maintaining a road investment.**

Construction and operation of roads can also have negative impacts on water, air, and land resources. Minimizing these unintended consequences can ensure that benefits to road users do not come at the expense of degraded environmental quality. **Accounting for and managing natural capital – the stock of natural ecosystems that produces benefits to people in the form of ecosystem services – can result in projects that are more cost effective, have enhanced net economic benefits for road users and communities, and are more resilient in the face of climate change, urbanization, and other social and environmental changes.** This interdisciplinary approach focuses on benefits to people and nature, and is a tool for more informed and sustainable decision-making and planning.

Ecosystem services are the benefits people derive from nature that support and fulfill human life. These benefits include food, clean and abundant water, clean air, reduced exposure to natural hazards, and many others. Integrating ecosystem services into planning, implementing, monitoring, and evaluating road projects opens up the opportunity to “put nature to work” to reduce risks to roads (e.g., flooding, landslides) and to create safer and more reliable road projects, supporting equitable economic development. For example, a road project along a coastline might benefit from protecting critical areas of mangrove forests that buffer the road’s exposure to storm surge. Furthermore, protecting this forest could provide areas for sustainable fuelwood collection by local communities, protection of biodiversity, and other environmental and social benefits. Mapping and quantifying the value of these benefits, and incorporating this information in project design and execution, can improve road project feasibility and outcomes.

This report describes how an understanding of natural capital and ecosystem services can be used to develop more sustainable road projects – effective and reliable roads that can meet today’s needs with minimal impacts to the surrounding environment and natural resources. It introduces the concept of ecosystem services, describes road dependencies and impacts on ecosystem services, provides guidance on prioritizing ecosystem services for road projects and highlights a number of opportunities for integrating ecosystem services information into project planning.

Implementing this type of ecosystem services-based strategy systematically across IDB’s road projects can contribute to several of the Transport Division’s strategic principles and priority areas[1], including:

- **Promotion of sustainable and inclusive growth**
- **Construction and maintenance of socially and environmentally sustainable infrastructure**
- **Incorporation of social and environmental considerations in infrastructure planning at local, national, and regional levels**
- **Increasing the contribution of biodiversity and ecosystem services to sustainable development**
- **Promotion of a multi-sector agenda**

IDB's Biodiversity and Ecosystem Services Program

The IDB's innovative Biodiversity and Ecosystem Services (BES) program was created in 2013 to help fulfill the promise that wise management of biodiversity and ecosystem services can contribute to inclusive and sustainable economic growth and human development. The Latin America and Caribbean (LAC) region contains nearly 50% of the world's forests, more than 30% of available freshwater, and 40% of the world's biological diversity, leading to the region's designation as a "biodiversity superpower." As LAC countries continue to grow in size and affluence in the coming decades, demand for energy and water is expected to increase by up to 50% and 25% respectively, along with growing demand for other natural resources. The environmental richness of the region, combined with recent and projected growth, means that there is great opportunity to make smart investments now to ensure that natural capital and the benefits it provides continue to sustain economic growth.

The BES program leverages the IDB's unique position to create opportunities and utilize the region's comparative advantage in biodiversity and ecosystem services for inclusive and sustainable growth. To accomplish these goals, the BES program is pursuing four lines of action:

1. **Integrating the value of biodiversity and ecosystem services into key economic sectors**
2. **Investing in priority regional ecosystem conservation**
3. **Supporting effective environmental governance and policy**
4. **Creating new sustainable development business and opportunities**

The BES program's success depends on collaboration with and participation from sectors and individuals throughout the IDB, as well as from member countries, the private sector, NGOs, and local communities. The BES program is excited to work with the Transport Division and its government counterparts to account for the values of ecosystem services throughout their project cycles for the benefit of economic development and human well-being.

Types of ecosystem services

Ecosystem services are provided by both natural and human-managed areas, and can be grouped into four categories[2]:

1. **Provisioning services** such as food, water, and timber
2. **Regulating services** are processes by which ecosystems help to regulate the environment such as water purification and flood risk reduction
3. **Cultural services** such as recreational and educational activities, and the aesthetic and spiritual fulfillment that comes from connecting with nature
4. **Supporting services** which are the ecological functions needed to support the production of services in the preceding three categories, such as nutrient cycling and soil formation

Definitions

Biodiversity
The variety of all living things. This includes diversity within species, between species, and between ecosystems.

Ecosystem
A dynamic community of living organisms (plants, animals, microorganisms) and their non-living environment interacting as a functional unit[24].

Ecosystem services
Benefits that people derive from nature that support and fulfill human life.

Natural capital
The stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future. It is the extension of the economic notion of capital (manufactured means of production) to goods and services from the natural environment[33].

Sustainable
Sustainable projects or activities are those that can be implemented in a way that allows for current development and benefits while maintaining the integrity of natural resources for future generations to use and enjoy.

Which ecosystem services are important to roads?

The table below provides a description of some of the ecosystem services that are often important to road projects. Project developers in some cases can use natural areas (e.g., mangroves, forests, wetlands) or surrounding agricultural and other types of working lands to reduce natural hazard risks to roads. Integrating such landscapes into road design also can reduce the likelihood of unintended consequences of degraded water quality, increased flood risk, or other negative impacts of poorly designed roads. Additional information on integrating these services into road projects is provided in the sections that follow.

Ecosystem Service	Importance to Road Projects
Flood regulation 	**Protecting or restoring vegetation in key locations upstream of roadways can reduce flood risk to roads.** Vegetation reduces peak storm flows and flood height by enhancing soil infiltration and increasing water storage, reducing storm runoff. Avoiding constrictions in floodplains from road construction or other development can also reduce road flooding by providing room for water to flow during flood events.
Coastal storm protection 	Coastal ecosystems such as marshes, mangroves, sea grass beds, and reefs slow waves and reduce coastal erosion and flooding. **Protection and restoration of coastal ecosystems can reduce exposure of coastal roads to flooding and erosion, particularly during storm events.** When coastal ecosystems are degraded or cleared for development, either directly or indirectly as a result of road construction, the risk of damage to coastal property and people increases.
Erosion control 	Vegetation holds soil in place and captures sediment, preventing erosion and keeping sediment out of drainage systems and waterways. **Vegetation that is maintained or restored upstream of roadways reduces the amount of sediment in runoff and storm water from reaching roadways.** This reduces sediment scour to roads and bridges, lowering infrastructure and vehicle maintenance costs. Exposed roadsides and unpaved roads are often sources of sediment themselves. Roads can also facilitate the conversion of natural vegetation to other land use types that are less effective at retaining sediment, such as agricultural fields or adjacent paved areas.

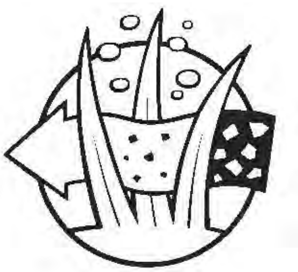
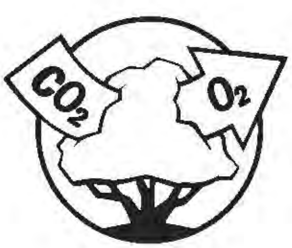
Landslide prevention 	Vegetation can help to stabilize soils and hillsides, contributing to the prevention of landslides in risk-prone areas. **Protecting and restoring vegetation uphill of roads can reduce the risk of a landslide impacting a road.** This in turn can result in reduced safety concerns for road users, reduced maintenance costs, and enhanced road use reliability.
Water quality regulation 	When roads replace or lead to the conversion of vegetation, they can impact water quality by reducing the ability of ecosystems to filter and retain pollutants. **Vegetation and soils help to maintain clean water by removing pollutants.** Wetlands are particularly effective as they can slow flow long enough for pollutants to be taken up by vegetation. Restoration or construction of vegetation that improves water quality can be a cost-effective way of mitigating road impacts and ensuring road project compliance with regulatory requirements.
Air quality regulation 	Air pollution has negative consequences for human health and is associated with respiratory and cardiovascular diseases, as well as some forms of cancer. Roads, and especially the traffic they generate, reduce air quality. **Vegetation can help to mitigate these impacts of roads on air quality by trapping and filtering pollutants.** Restoration of vegetation that reduces air pollution can serve as a cost-effective means of offsetting road impacts on air quality and ensuring regulatory compliance of the road project.
Carbon sequestration and storage for climate regulation  	The consequences of increased carbon dioxide and other greenhouse gases in the atmosphere are felt by people around the world through the impacts of climate change on rainfall patterns, storm frequency and severity, temperature, and sea-level rise. By storing carbon in vegetation, ecosystems keep carbon dioxide out of the atmosphere, where it would otherwise contribute to climate change. **Restoration of vegetation can offset carbon emissions associated with road construction, leading to a carbon-neutral project.** It can also help offset the CO_2 from increased road traffic and conversion of vegetation which can happen directly or indirectly from road construction.

Table 1. A number of ecosystem services are particularly important to road projects, either because roads depend on these services to reduce risk from natural hazards and rates of deterioration, or because roads can reduce the benefits these services provide to people. Images courtesy of The Economics of Ecosystems and Biodiversity (TEEB), ©Jan Sasse for TEEB.

Steps for integrating ecosystem services into road planning

Following the steps outlined below can help streamline the integration of ecosystem services information into road project planning, design and implementation. The remaining sections of this document provide additional details and examples of how these steps can be addressed to improve project feasibility and project outcomes. In practice the particulars will depend on the point in the project cycle at which ecosystem services are being considered (see Section V and Figure 4) and the project context, though examples of possible questions are provided here for each step of the process.

1

- Define specific decision and scope
  Is this a country-level screening or an analysis of alternatives for a particular project?

2

- Identify and prioritize relevant ecosystem services
  Which serrvices matter most to the road and to people in the project area?

3

- Determine key questions and metrics needed
  Is monetary valuation required, or a measure of the relative risk of environmental hazards?

4

- Assess ecosystem service outcomes
  Which approach and tools can answer key questions, given data and resource availability?

II. Roads Depend On, and Benefit From, Ecosystem Services

Key Points:

1. *Considering where important ecosystems and people are relative to a road is key to identifying and implementing effective strategies to manage the benefits from ecosystem services.*
2. *Conserving or restoring ecosystems to reduce hazard risks to roads may also provide benefits to downstream communities, such as reduced flood risk or improved water quality. In such cases, road projects could benefit from multi-sector planning by identifying coordinated and cost-effective strategies to manage ecosystem services.*

When floods, landslides, and other hazards affect roads, they compromise access and safety for road users and people living in affected areas users, require increased expenditures for repairs, and may decrease a project's longevity. While some level of risk will always be present, a key part of project design is to use environmental and geotechnical analyses to reduce the exposure and vulnerability of roads and their users to hazards.

The concept of ecosystem services provides a useful perspective for thinking about the exposure of roads to hazards from the surrounding landscape, and for turning this understanding into a risk mitigation strategy. **An *ecosystem service dependency* is a situation in which ecosystems provide a benefit to a road project.** As an example, consider the case of a road that is exposed to flooding. Protecting wetlands adjacent to and upstream of the road might be an important component of an ecosystem services-based strategy for flood regulation. Conversely, if the wetlands were degraded or paved over, this could severely compromise the flood regulation service, putting the road, its users, and surrounding communities at greater risk and result in more frequent and costly repairs when flood damages occur.

As this example highlights, appropriate identification of ecosystem service dependencies requires taking a landscape-level perspective that extends well beyond the road's right of way (Fig. 1). If project developers only considered the road's right of way, important and cost-effective opportunities to reduce hazard exposure can be missed. Empowered by an understanding of how a road project depends upon and benefits from ecosystem services, project developers and affected stakeholders will be better positioned to answer questions such as the following:

- *How do ecosystem services affect a road project?*
- *Which route for a new road maximizes economic return on investment with minimum ecosystem risk?*

- *Which segments of a road are most sensitive to the degradation of ecosystem services in the surrounding landscape?*
- *How might the road project result in land use change, and what might the impacts of this be in terms of degraded ecosystem services increasing risk exposure for the road and its users?*
- *How might different scenarios of climate change affect ecosystem services provision and alter risk exposure for the road and its users?*

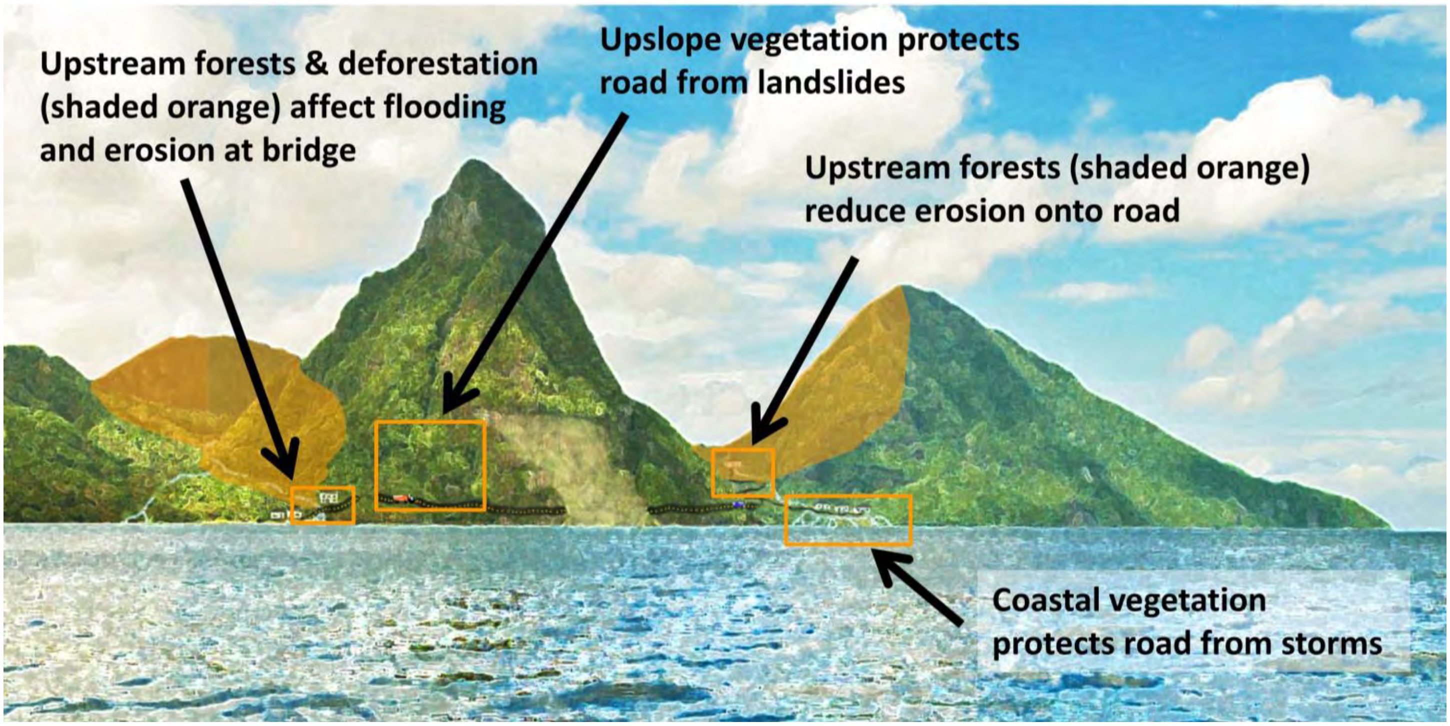


Figure 1. Roads depend on the surrounding landscape to control flooding and erosion and reduce risks from natural hazards such as landslides and coastal storms. Different road segments depend on different parts of the landscape for different services. These areas that provide benefits to particular road segments are referred to as "servicesheds." Conservation, restoration, and good management of these "serviceshed" areas can help minimize road construction and maintenance costs and maximize benefits.

There are three overarching benefits to incorporating ecosystem services dependencies into road projects with resulting enhancements to a project's economic returns and sustainability:

1. **Improving the identification of which road projects or design alternatives are best to pursue in light of contributions from ecosystem services**
2. **Informing where new economic activities will be most compatible in the landscape surrounding and enhanced by the road so that policies and incentive structures can be complementary**
3. **Enabling proactive identification of regions that are most sensitive to ecosystem degradation where intended or unintended activities (e.g., illegal resource extraction) would most strongly compromise ecosystem services provided to a road**

This information would enable project developers to take proactive steps to reduce the likelihood of these negative impacts occurring.

Servicesheds

When incorporating ecosystem services into road design, it is important to know where on the landscape ecosystem services are being provided to protect the road (Fig. 1). **A serviceshed is the area that supplies a particular ecosystem service to specific people or places**[3]. The key value of a serviceshed is to provide a clear linkage between where an ecosystem service is provided in a landscape and where and to whom the benefits accrue. Servicesheds are also useful in identifying who may lose ecosystem services with road development, so that mitigation activities can be targeted to benefit those communities.

For flood regulation and several other ecosystem services that are important to roads (e.g., erosion control, landslide prevention, water quality regulation), the serviceshed, or ecosystem service supply area, will be the upslope and/or hydrological contributing area from which water runoff, erosion, or a landslide would originate. Similarly, for coastal storm protection, the serviceshed would be the offshore and coastal areas across which storms travel. For air quality regulation, the supply area would be determined by air patterns and where vegetation is located that can remove pollutants originating from the road.

Once the serviceshed area is determined, institutional factors (e.g., identifying who owns and manages the lands upslope of a road from which runoff occurs) and physical factors (e.g., determining if there is any existing flood control infrastructure that could protect the road) inform how road project developers can be proactive and strategic in using this knowledge to harness the protection value of the environment. For example, in the case of flooding, this information could be used to develop a management plan for protecting or restoring ecosystems within the serviceshed to maximize the contribution of ecosystem services to flood mitigation for the road, as part of a strategy that is blended with conventional site-level engineering components.

Avoiding unintended consequences before they occur:
Establishment of the Braulio Carrillo National Park in Costa Rica

Building and improving roads is a central component of economic development to deliver positive benefits for increased mobility, access to markets, and social services. However, these same factors also open up the possibility for roads to facilitate unsustainable land-use change and illegal activities. These unintended impacts can compromise the safety and reliability of the road project, undermine a project's ability to meet its environmental obligations, and harm local communities in the long run. To maximize net economic benefits, a key strategy is to anticipate future unintended changes and develop actions during the planning phase that are implemented *before or at the same time as* road construction or improvement.

A real-world example of this coordinated approach comes from Costa Rica in the 1970s where the construction of a new highway from San José to Puerto Limón was coordinated with the establishment of the Braulio Carrillo National Park. Traveling across the Cordillera Central region, the Limón highway played an important role in providing relatively remote areas on the Caribbean side with improved market access and mobility. At the same time, the planned route would be impacting areas of high conservation value, which raised concerns among environmental groups.

Establishing the national park before the highway was built was critical to the success of this project. This foresight prevented uncontrolled spread of settlements and illegal activities in the area. Because such encroachment was prevented, the park remains a valuable provider of ecosystem services. The protection afforded by the park has maintained healthy ecosystems that provide source water protection for downstream communities. The park also serves as an important area for biodiversity protection in Costa Rica. It supports the altitudinal migrations of resident birds by stretching along an elevational gradient. This same feature also provides potential for species to adapt to climate change. While establishing a protected area will not always be a practical or effective strategy, this example illustrates the need for road project planners to anticipate how intended and unintended changes resulting from the road will impact the surrounding region, and take proactive steps to protect or restore ecosystem services that will protect the road from hazards and avoid unintended consequences for affected communities.

Evaluating ecosystem services in the context of multi-sector infrastructure planning

The IDB is promoting a multi-sector approach for future work in the infrastructure sector, recognizing the important interactions among sectors and the fact that investments are generally irreversible, specific, and large-scale[1]. An ecosystem services approach that identifies how different types of infrastructure depend on ecosystem services provided by the surrounding region is a practical way to integrate ecosystem services into multi-sector planning efforts that include road projects. To realize synergies and avoid unintended consequences, coordination needs to occur at early scoping and planning phases, as well as throughout project implementation.

A key strength for such an approach is that **investments in ecosystem protection or restoration can result in multiple benefits that matter to policy-makers and planners focused on different sectors**[4].

For example, roads, reservoirs, hydropower plants, and municipal water supplies are all negatively impacted by sediment erosion, landslides, and floods that further exacerbate erosion. This shared exposure to hazards opens up the opportunity to identify regions on the landscape where actions to improve land management practices would reduce risks to multiple sectors and likely do so more cost-effectively for each sector. Other examples could be road expansion projects that are coordinated with targeted investment in sustainable agricultural enterprises or reforesting areas near roads to minimize local air quality impacts on human health and sequester carbon dioxide to mitigate climate change.

From an environmental perspective, a coordinated multi-sector strategy should lead to planning that improves where infrastructure projects are sited to maximize their potential to benefit from ecosystem services and minimize their cumulative negative impacts.

III. Road Impacts on Natural Capital and Ecosystem Services

Key Points:

1. *The connectivity and access made possible by roads provide vital benefits to people, but can also have important negative feedbacks on ecosystem services. Erosion control, water quality regulation, flood regulation, and climate regulation are some of the ecosystem services commonly lost with road development.*
2. *Strategic placement of roads, along with good design and engineering of new and existing roads, can reduce many of the direct impacts roads have on ecosystem services. When best practices are not followed, mitigating the direct impacts of roads can be very expensive.*
3. *The greatest impacts roads have on natural capital often come from their indirect effects, such as the conversion of areas along roads from natural vegetation to agricultural production. Anticipating and appropriately managing these indirect impacts is critical to ensuring that roads contribute to development in a sustainable way.*

Roads are an important driver of economic growth and improve people's quality of life. They connect people to basic services, such as education and health care, in addition to providing access to markets, expanding employment opportunities and reducing production costs[1]. Roads play a critical role in development and economic prosperity. Rural roads help bring development to local markets and economies[5] and reduce poverty[6]. Similarly, expenditures on public road infrastructure have been found to contribute significantly to the productivity[7] and economic performance of private industry[8]. When developed strategically, roads play a pivotal role in economic growth.

At the same time, roads may have severe negative consequences for surrounding ecosystems and the people who rely on them, both by directly impacting the local environment and by enabling deforestation and other land use change in surrounding areas. When roads are built without adequate consideration of their potential impacts – both direct and indirect – roads can undermine the development benefits they are intended to provide and compromise future opportunities for growth. Agriculture, fishing, forestry, and tourism together comprise 15% of Latin American and the Caribbean's GDP, employ 17% of the region's workforce and make up 50% of total exports[1]. These economically important sectors depend on ecosystem services, such as the provision of clean water, flood mitigation, and erosion control, which may be compromised with poorly managed road development.

Considering the important benefits of roads alongside their potential negative impacts can help reduce unintended consequences of road development and maximize roads' development benefits. It is important to understand, minimize, and be transparent about trade-offs between road development and other benefits, such as ecosystem services flowing from natural capital, in order to make informed decisions about how to best serve societal needs, as well as to make prudent use of the scarce funds available for road development.

This section identifies key ecosystem services commonly impacted by roads. It also describes the direct and indirect pathways by which roads affect ecosystem services and illustrates the importance of considering both kinds of impacts when making decisions about where and how to build new roads and improve existing roads.

Mechanisms of road impacts on ecosystem services

By altering vegetation and soils, roads can have far-reaching impacts on ecosystem services important to economic growth and human well-being. In particular, erosion control, flood regulation, coastal protection, water quality, and climate regulation are frequently impacted by roads (Table 1).

When assessing road impacts, it is therefore important to consider not just the impact to ecosystems in terms of the number of hectares affected, but also how those changes affect the flows of benefits to people who may be located more distantly from the impact site. In the case of roads through protected areas, for example, road development or improvement is likely to affect not just the protected area itself but also the benefits provided to close-by and downstream communities.

Roads can also affect ecosystem service provision indirectly by increasing access to natural areas and natural capital. When accompanied by sustainable management, roads can facilitate increased timber production, tourism, and recreational opportunities. In the absence of good governance and management, however, the increased access to natural areas facilitated by roads can deplete natural capital by increasing timber harvest and hunting or reducing the recreational and tourism benefits of areas valued for their isolation, biodiversity, or aesthetic quality.

Direct impacts of roads on ecosystem services

The direct impacts of roads can extend great distances into the surrounding landscape, especially for areas and people located downstream of roads (Fig. 2). Roads have been implicated in declines in economically and culturally important fisheries due to changes in peak storm flows, increased sediment in stream water, losses of streamside vegetation, road-related landslides, and the blockage of streams by poorly designed, constructed, or maintained culverts and bridges[9].

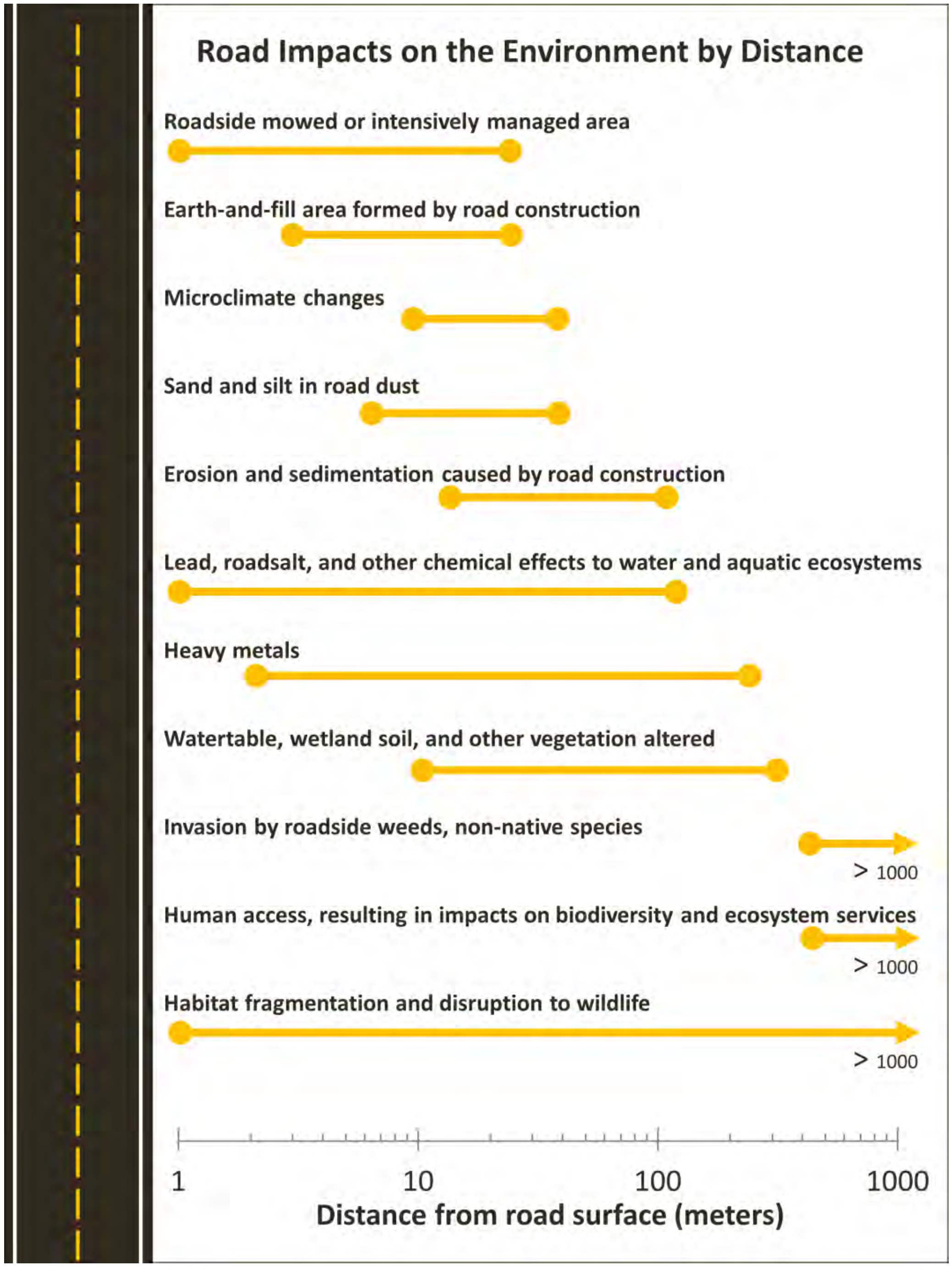


Figure 2. The range of average and maximum distances from the road across which impacts on ecosystems and ecosystem services have been documented (adapted from Figure 11.6 in *Road Ecology* by Richard T.T. Forman © 2003 Island Press. Reproduced by permission of Island Press).

Roads replace vegetation with paved surfaces or exposed ground, which alters hydrological processes on and around roadways. This can accelerate flows in waterways during rainstorms and increase flooding[9]. Forests roads have been found to increase mean annual floods by up to 10%[10]. Roads can also increase flooding by reducing infiltration of water. In areas dominated by plants, most rain infiltrates into the ground. Where paved surfaces occupy an increasing fraction of a watershed, more rain becomes surface runoff[11]. For this reason, flooding often increases along with the proportion of paved surfaces, resulting in greater damages to infrastructure and property, and even threatening lives.

Roads are key contributors to erosion, particularly in wet environments with steep slopes. Exposed soil along roadsides and unpaved road surfaces commonly erode, resulting in a regular flow of sediment into downstream water bodies[9]. Road construction is especially likely to exacerbate sheet erosion because of the cutbanks and fill slopes that are created up- and downslope of roads[9]. The degree of erosion depends on soil type, the depth and velocity of water flows, and the length and steepness of slope. Increased erosion and sedimentation reduces drinking water quality, diminishes the aesthetic quality of landscapes and waterways, affects freshwater fisheries that are important for food and livelihoods, and impedes hydropower production and irrigation. Roads can also lead to disturbance cascades in which water and sediment from hill slopes and stream channels are intercepted by roads and diverted through road drainage structures, eroding larger channels downslope with greater flows[9,12,13].

Minimizing direct impacts of roads to ecosystem services

The direct impacts of roads can be minimized in two ways:

1. *Siting roads in locations where impacts are likely to be low*
2. *Employing best practices in road design and construction*

Avoiding road construction in the most sensitive areas is important. The environmental impacts of roads are greatest when they are constructed along valley floors and in mid-hillslope locations, where they intercept more water than those on ridgelines[9], though ridgelines may not always be the most practical location for a road. Best management practices including stabilizing soil surfaces with vegetation, diverting surface water flows, and constructing wetlands to trap sediments and other pollutants, can help minimize erosion, control sediment, and attenuate surface flows[9,14].

By following these principles – strategic siting of roads to avoid major impacts and adherence to best practices in construction – impacts of roads on ecosystem services can be greatly reduced. The consequences of ignoring direct impacts can be substantial and costly. For example, the government of Colombia, with a loan from the IDB and assistance from the German Agency for International Cooperation (GIZ) has spent tens of millions of dollars restoring the Ciénaga Grande de Santa Marta wetlands after highway construction blocked flows between freshwater systems and the ocean, leading to a drastic dieback of mangroves and subsequent reductions in local fisheries[15,16].

The Ciénaga-Barranquilla Highway, Colombia:
The consequences of ignoring road dependencies and impacts on ecosystem services

In 1949, inadequate transportation infrastructure was identified as the largest single impediment to economic development in Colombia. The World Bank subsequently provided loans for improving ~3,000 km of Colombia's highways in order to connect major population centers with ocean and river ports, including the construction of the Ciénaga-Barranquilla highway, which began in 1956[34].

The Ciénaga-Barranquilla highway cuts across the Ciénaga Grande de Santa Marta, a mosaic of mangrove forest, dry forest, pasture, plantations, subsistence agriculture, and marine wetlands, covering thousands of square kilometers of Colombia's Caribbean coast[16]. It is the predominant source of seafood in the region, providing food to local communities as well as coastal and inland cities[16]. Most of the ~350,000 people that currently live in the region live in poverty, without access to adequate sanitation, drinking water, housing, or education[16].

Cascading effects of the Ciénaga-Barranquilla highway on ecosystem services

Construction of the Ciénaga-Barranquilla highway cut off all but one of the natural connections between the lagoon complex and the ocean[16]. This changed the hydrology of the wetland system, contributing to substantial mangrove mortality (nearly 70%) and declines in fisheries which depended on mangroves as nursery habitat. Between the 1980s and 1990s, fish biomass declined 70%[16]. In an attempt to compensate for declining catches, fishermen reduced the mesh size of their nets. With finer nets, a higher proportion of the fish caught were below reproductive size, furthering the decline of one of the most important artisanal fisheries in Colombia[16]. By 2005, fishermen saw a 41% decrease in catch volume compared to a decade prior, and experienced a 35% decrease in income, leading to increased poverty rates in villages dependent on fishing[16].

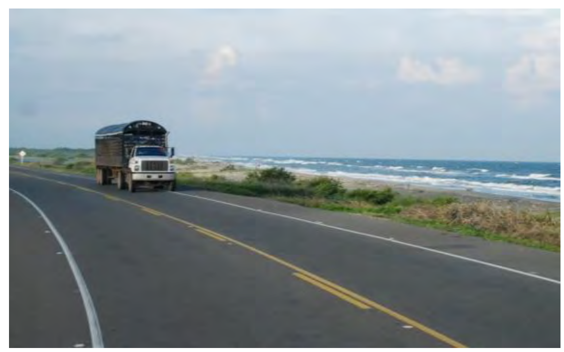
The decline of seafood, resulting from loss of mangroves and changes in hydrology, was not due to highway construction alone. These losses resulted from the cumulative impacts of infrastructure development and economic activities near and upstream of the Ciénaga Grande de Santa Marta. Road and dam construction along the Magdalena River, along with expansion of banana and oil palm plantations and cattle ranching, all contributed to the reduced freshwater flows, increased sedimentation, and increased nutrient pollution in the waterways, lagoons, and wetlands[16].

Consideration of the combined benefits and impacts of road and dam construction, along with agricultural development in a multi-sector planning framework, could have helped identify where these activities were compatible with each other, and how they could be developed to minimize impacts to fisheries, as well as to the mangrove ecosystems on which the fisheries depend.

The Ciénaga-Barranquilla highway additionally illustrates the importance of considering the indirect effects of roads. In the 40 years following the construction of the highway, mangroves declined nearly 70%[35]. This was due in part to the direct effects of the road as well as the cumulative effects of other development on hydrology and salinity. However, the road also opened up access to the mangroves for commercial wood extraction, and it was during this 20-year period of extraction that mangrove declines accelerated[16]. While wood extraction is an economic benefit, in this case it also had environmental and economic costs in the form of reduced fish landings related to the loss of mangroves. In addition to the lost nursery habitat for fisheries, mangrove declines appear to also have contributed to eutrophication and fish kills[16]. Mangroves can serve as sinks of inorganic nitrogen and phosphorous, so as mangroves declined, the ability of the ecosystem to remove nutrient pollutants from the water and buffer the effects of upstream agricultural expansion declined as well.

Restoring ecosystem services and managing dependencies

The PROCIÉNAGA project, which began in 1992, aimed to restore natural hydrological flows by re-establishing connections between the ocean and the lagoon that were blocked by highway construction, as well as connections between the lagoon and the Magdalena River. The government of Colombia, with a loan from the IDB assistance from GIZ tens of millions of dollars restoring flows[15]. However, efforts to restore the mangrove forests are ongoing.



A multi-sector approach to planning, one which considered cumulative and indirect effects, could have created a pathway towards development in the region that maximized the combined economic benefits, while averting some of the expenses of restoration and mitigation that are still accruing today. Indeed, after the PROCIÉNAGA project ended in 2000, the restored connections were not properly maintained and as a result filled with sediment, renewing fish mortality and mangrove die back[16]. In 2005, Colombia added an environmental tax to the highway toll to support dredging and other maintenance activities, along with environmental monitoring[36]. Since 2010, more than $10 million has been spent installing an artificial reef and replenishing sand to facilitate beach formation and mangrove restoration along the road in order to restore coastal protection services and reduce coastal erosion[37]. However, erosion of the road continues even with these efforts, and additional actions are needed. This document outlines some approaches that can help evaluate, and reduce, the kinds of trade-offs between infrastructure development and ecosystem service provision that occurred in the Ciénaga Grande de Santa Marta region.

Images courtesy of deracamandaca.com

Looking beyond the right of way: indirect impacts of roads on ecosystem services

Roads can have far-reaching effects on the surrounding landscape and the ecosystem services they provide. Indirect impacts from road development can spread tens of kilometers from the road – even further in the case of climate change. By increasing access and reducing transportation costs, roads spur changes in local land use such as increasing timber harvests and conversion of forests to pasture or cropland. New or improved roads can also lead to changes in land management practices by allowing for easier and cheaper access year-round. Increased rates of deforestation around new roads in the Amazon have been observed across distances of 50 km or more[17–19], and even improvements to existing roads can have an impact, with higher rates of deforestation around paved roads than unpaved roads[20].

When road improvement or construction spurs changes in local land use or land management practices, these changes result in a change in ecosystem services provided from those areas.

For example, increased timber harvest from forests that are now accessible year-round because of newly paved roads could reduce carbon sequestration and increase erosion. These changes can far exceed a road's direct impact on ecosystem services. Analysis of a proposed road linking Pucallpa, Peru with Cruzeiro do Sul, Brazil suggests that conversion of natural vegetation to pasture or oil palm in areas near the road could lead to sediment levels in drinking water 1,000 times greater than would be expected from the road alone[21].

Some of the indirect impacts of roads are in fact economic benefits, providing jobs and important material goods. However, there is also a risk that the increased access to natural resources provided by roads can lead to degradation and depletion of these ecosystem goods and services. Without adequate management provisions in place and institutional capacity to support sustainable management, renewable natural resources can be overexploited, undermining both the supply of the resource and the jobs that depend on them.

The tendency for land use change to radiate out from roadways also provides an opportunity to guide development in a way that minimizes its negative environmental impacts. With knowledge of key areas of ecosystem service provision and good planning, strategic placement of roads could concentrate development in less sensitive areas while directing development away from the most sensitive areas[22].

For these reasons, **considering the indirect impacts of roads along with their direct impacts and benefits is important for ensuring that the net effect of road development is indeed beneficial, and does not undermine development objectives by reducing water quality, food availability, or other important ecosystem services.** This is especially true for indigenous communities, the poor, and other vulnerable populations who depend heavily on ecosystem services for their livelihoods and well-being[23,24].

Integrating fine- and landscape-scale perspectives for sustainable road development

To anticipate and minimize the negative impacts of roads while maximizing their development benefits, it is valuable to integrate the fine-scale perspective needed for well-engineered roads with a landscape-scale perspective that provides a more holistic picture of a road's interaction with the surrounding landscape. Taking a landscape-scale perspective also enables coordination of activities among sectors. This coordination can help prevent negative impacts (e.g., increased erosion from road construction curtailing hydropower production downstream) and, as mentioned previously, allows for identification of synergies where protecting the provision of ecosystem services benefits multiple sectors and their beneficiaries. The following sections highlight priority ecosystem services to consider in different contexts, opportunities for integrating ecosystem services into road decisions at key stages in the transportation planning process, and examples of tools to support analysis of ecosystem services.

IV. Critical Contexts for Evaluating Ecosystem Services

Based on an understanding of how roads both depend on and impact ecosystem services, the following chart provides a screening tool for identifying which ecosystem services are a high priority for evaluation. In these contexts, adapting plans based on ecosystem services information is expected to be most beneficial in terms of reducing the exposure of a road to floods, landslides, or other ecosystem-service related risks, as well as avoiding and minimizing undesirable impacts on surrounding communities. This type of screening should be conducted at the earliest possible project stage. As with any screening tool, the following guidance should be used with an understanding of local geotechnical, economic, and social factors that provide additional context for which ecosystem services are most likely to be impacted by the project and which strategies to reduce impacts and mitigate risks are likely to be most effective. Such screenings can also contribute to meeting the IDB's environmental and social safeguards.

Priority Ecosystem Services to Assess:	Air quality regulation	Carbon storage	Coastal storm protection	Erosion control	Flood regulation	Locally important natural resources	Landslide prevention	Water quality regulation
ROAD PROJECTS THAT OCCUR IN SENSITIVE ENVIRONMENTAL AREAS								
Areas with steep slopes, unstable soils and/or experiencing heavy rains				✓	✓		✓	
Arid areas with high winds				✓				
Roads alongside or crossing streams and rivers				✓	✓			✓
Coastal areas exposed to storms, especially low-lying areas			✓					
Headwater areas for downstream populations				✓				✓
Areas with active forest clearing, or the potential for forest clearing		✓		✓	✓		✓	✓

Priority Ecosystem Services to Assess:	Air quality regulation	Carbon storage	Coastal storm protection	Erosion control	Flood regulation	Locally important natural resources	Landslide prevention	Water quality regulation
ROAD PROJECTS THAT AFFECT ECOSYSTEM SERVICES IMPORTANT TO AT-RISK COMMUNITIES								
Near or upstream of vulnerable communities	✓			✓	✓	✓		✓
Areas where local livelihoods depend highly on renewable natural resources						✓		
Upstream of towns that get drinking water directly from streams				✓				✓
Projects that are part of multi-sector planning efforts	✓		✓	✓	✓		✓	✓
ROAD PROJECTS THAT MAY RESULT IN SUBSTANTIAL OR HIGH-RISK LAND USE CHANGE								
Potential for extensive clearing of natural vegetation		✓		✓	✓		✓	✓
Potential for loss of wetlands or vegetation buffers along streams				✓	✓			✓
Potential for loss of coastal habitats, especially mangroves and wetlands			✓					
Potential for urban growth				✓	✓			✓
Potential for expansion of agricultural activities				✓				✓
Potential for increased natural resource extraction		✓		✓	✓			

Figure 3. Which ecosystem services matter most depends on the context of the road and the surrounding landscape. This figure provides a checklist of priority ecosystem services to consider across a variety of common contexts.

V. Opportunities for Mainstreaming Ecosystem Services into Road Decisions

Key Points:

1. *Incorporating ecosystem services information at key points in the design and implementation of road projects can increase the economic and development benefits roads provide, while improving the durability of road investments.*
2. *Ecosystem services information can contribute to multiple aspects of road investment decisions.*
3. *Considering ecosystem services early on in the transportation planning process yields the greatest benefits.*

Incorporating ecosystem services information throughout the design and implementation of road projects can help minimize risks and maximize benefits while also enhancing social benefits. This can help achieve IDB's strategic principles for transport[1], as well as facilitate compliance with IDB's environment and safeguards requirements[25].

Many approaches and tools exist that can provide the information on ecosystem services needed to support these types of decisions. New and established scientific knowledge can also be used to develop tools tailored to the needs of IDB and its country counterparts in order to streamline this process.

This section outlines key areas of opportunity for integrating ecosystem services information into road development decisions at multiple planning levels (Figure 4), provides examples of how ecosystem services information has been used in infrastructure planning decisions, and highlights how these approaches can be tailored to road projects.

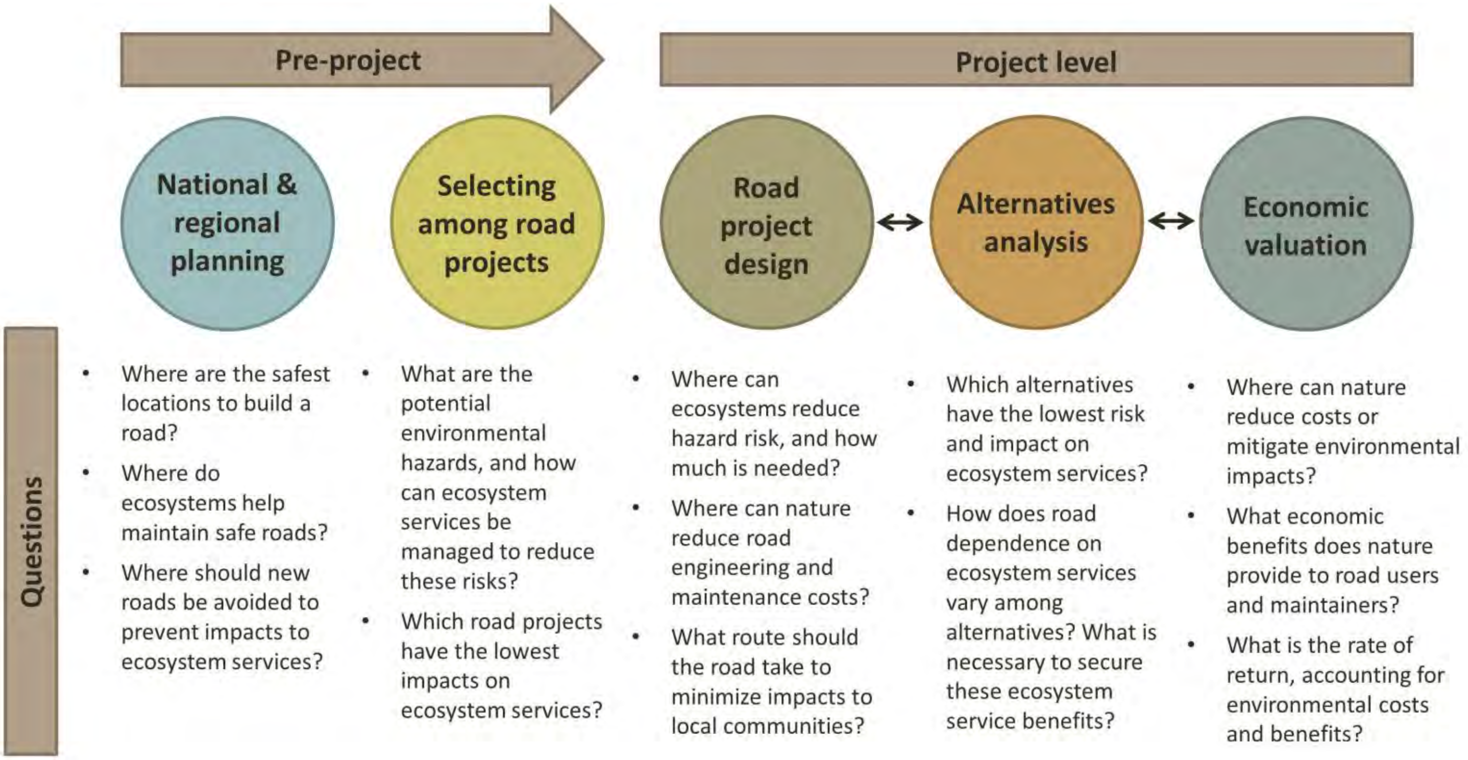


Figure 4. Opportunities for incorporating valuable natural capital and ecosystem services information into road development exist throughout the project cycle. The scale and nature of the questions that can be answered varies across stages.

National and regional level transportation planning

The greatest opportunity to maximize the benefits from ecosystem services while minimizing losses and managing dependencies comes when the relationship between roads and ecosystem services are considered even before specific projects have been defined. National or regional level screening can identify hotspots of ecosystem service provision that would be threatened by road construction or expansion, as well as reveal parts of the landscape that are less sensitive to road construction. For example, forested areas in a watershed's steep upper reaches can be both critical for maintaining drinking water supplies for downstream populations and very sensitive to road development. On the other hand, flatland areas that have already been converted for agricultural production may provide fewer water-quality regulating services and a lower-impact route for road development. Such information can help inform tradeoffs or synergies in road siting against other costs and benefits. Similarly, information on areas where roads themselves would be at risk from flooding, landslides, or other environmental threats could also be incorporated to guide road development towards low-risk areas.

Screening maps that highlight the varying sensitivity of the landscape to road construction can be incorporated into countries' transportation master plans or sector notes, and can guide road development investments by the private and public sectors in a way that both meets a country's transportation needs and maintains the natural infrastructure on which the country's citizens depend.

This form of landscape-scale planning has been successfully applied in the energy sector where it is often found that energy targets can easily be met while avoiding the most sensitive parts of the landscape[26–28]. This approach can be extended to the transport sector to

incorporate ecosystem services into transportation development planning in order to meet road development needs alongside protection of critical ecosystem services. For example, environmental and socioeconomic information could be integrated to guide new road development towards areas where landslides and erosion provide little threat to roads and road users as well as areas where runoff and sediments from roads do not pose risks to drinking water for downstream communities.

Considering ecosystem services early in the planning process can set the stage for road projects to advance more rapidly and cost-effectively, minimizing the risk of delays associated with environmental safeguards provisions. This same approach would be valuable for multi-sector planning as well as managing the cumulative effects of concurrent development activities. This would help ensure compatibility between, for example, road development and hydropower production needs, where increased sediments from road construction could impede power generation and where watershed protection could both improve bridge sustainability and reduce reservoir maintenance costs.

With the great gap between infrastructure supply and demand in Latin America and the Caribbean, there are routinely more road projects under consideration than can be approved in a given funding cycle. Landscape-scale screening can also help prioritize among projects to select those that are exposed to lower risks and/or have lower negative impacts on ecosystem services. For example, it may be better to invest in road projects in areas where risks of landslides are low or where protection of vegetation to secure a reduced risk is possible, as opposed to roads in areas where anticipated land conversion and/or climate change is likely to pose a risk to roads, leading to increased construction or maintenance costs. Clearly, these risks and impacts are just a few of many criteria that factor into project selection. However, all else being equal, projects at low risk and with fewer impacts are likely to proceed to implementation with fewer delays and to be more sustainable investments over the lifetime of the project.

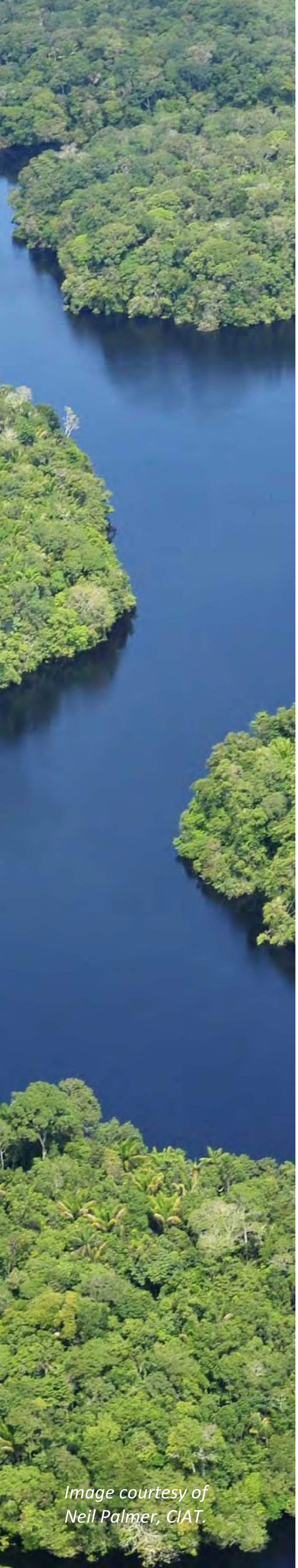


Image courtesy of Neil Palmer, CIAT.

Paving a road through the Amazon

The IDB's Acre Sustainable Development in Brazil project illustrates how considering the landscape context around a road project can contribute to project success. In this case, paving of a segment of the BR-364 highway, which connects the state capitals of Acre and Rondônia, was integrated into a larger spatial planning and sustainable development project. Based on previous road development in the Brazilian Amazon, it was clear that road paving without management or protection of surrounding forests was likely to lead to high levels of deforestation beyond the road's right of way. Such deforestation would have negative consequences both for the environment and for local communities, including increased air pollution, soil erosion and soil nutrient loss, reduced water quality, and increased pressure on natural resources. Funding for road paving was therefore made conditional on spatial planning, institutional strengthening, and other mitigation measures implemented over more than 250,000 square kilometers that would reduce deforestation rates.

The landscape-level perspective and multi-sector approach adopted in the Acre Sustainable Development project were essential to the project's success at completing road paving with only a slight increase in deforestation rates[38]. Such an approach is especially relevant for road projects in areas with high levels of remaining natural vegetation, and for multi-sector planning processes. While ecosystem services such as erosion control and air quality regulation were considered in a general way in the Acre project, new approaches now make it possible for these benefits to be included in a more spatially explicit and quantitative manner. For example, those areas identified as most important for erosion control or flood regulation – both for the roads themselves and for local communities – could be specifically targeted for inclusion in sustainable management areas or development of resource management plans. Advance planning for the conservation and management of such places would mean not only that overall deforestation rates are lowered, as occurred in the case of BR-364, but that deforestation is avoided in the most critical areas, thereby maximizing the benefits from conservation activities.

Incorporating ecosystem services into project-level decisions: evaluating alternatives and dependencies

Once a project has been selected, ecosystem service information can continue to play a role in maximizing project sustainability. Two areas stand out as particularly useful opportunities for integrating ecosystem services information in project-level decisions:

1. *The analysis of alternatives, which are often part of a project's environmental assessment and economic assessment*
2. *Assessing and managing project dependencies on ecosystem services*

Approaches for addressing these two areas can equally be applied to the rehabilitation and repair of existing roads as to construction of new roads.

An ecosystem services framework can provide a useful tool for integrating social and environmental aspects when evaluating alternative routes or alternative road segments under consideration for a given project. By combining information on the magnitude of the impact with information on servicesheds that trace the distribution of impacts to beneficiaries, this approach can reveal how a particular option is likely to affect both the environment and surrounding populations, and allows for a comparison of how impacts and the equity of their distribution varies among alternatives (Figure 5).

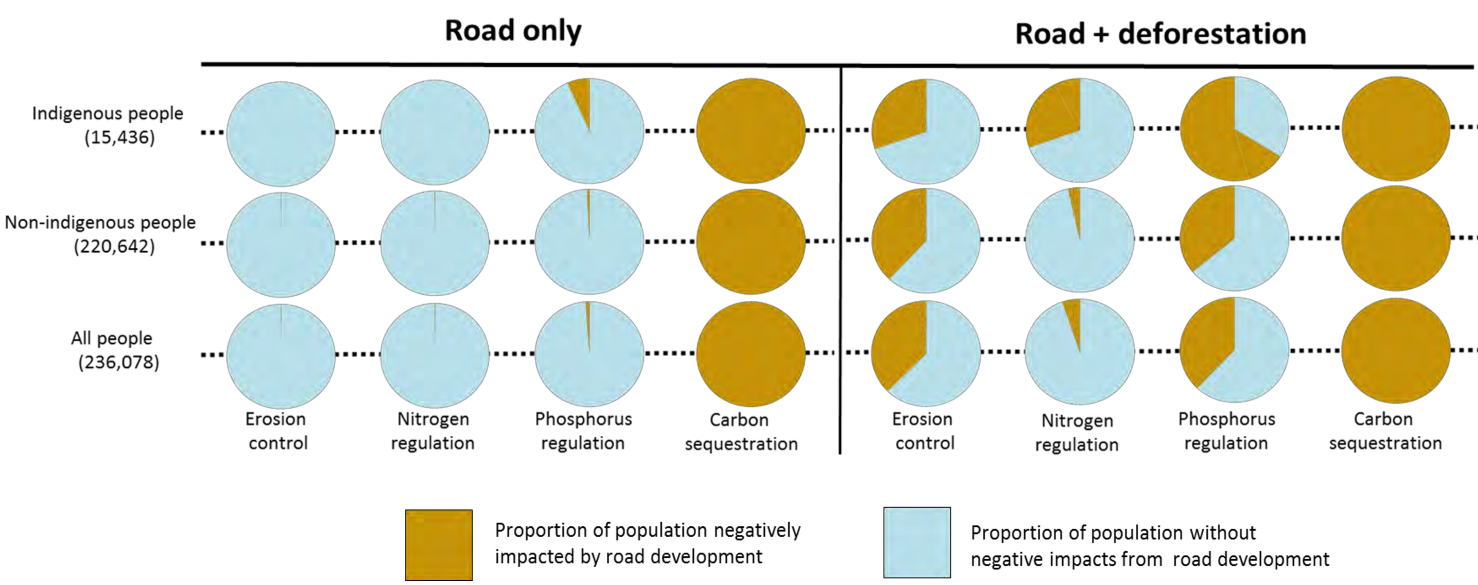


Figure 5. Projected impacts of development of the Pucallpa-Cruzeiro do Sul road on water quality and climate regulation services provided to local people in Peru[21]. Each pie represents the full population of a beneficiary group (indigenous, non-indigenous and all people). The "road only" scenario considers only the direct impacts of the road, while "road + deforestation" additionally accounts for likely road-facilitated conversion of forest to oil palm plantations and pasture.

Projects can also benefit from an evaluation of the benefits a road receives, or depends on, from surrounding ecosystems. Ecosystem service models and decision support tools can help identify key areas that provide erosion control or flood mitigation services to infrastructure and local communities that rely on that infrastructure[29]. This approach can be used to identify both *where* protection or restoration of natural vegetation would benefit the road most, by reducing erosion onto the road or protecting the road from coastal storm surges, and *how much* vegetation is needed to ensure these benefits**. If protection or restoration of these critical service provision areas is incorporated into the project, this can help secure the sustainability of the road investment, potentially reducing maintenance costs, extending the productive lifespan of the road, and reducing risk from natural disasters.**

Such activities could take the form of restoring vegetation to prevent erosion into streams that would exacerbate bridge scour or protecting mangroves between the road and the coast that are important to averting road flooding during storms. For example, the city of Portland, Oregon, USA reduced flood risk to its Foster Road by one-third by restoring 63 acres of wetland and floodplain ecosystems around a nearby creek[30]. Previously, the road flooded every other year, making the road unusable and requiring businesses along it to close regularly. After restoration, the road is expected to flood only once every 6-8 years. Following a 2012 storm in which the creek reached more than two feet above flood stage, Foster Road remained dry and local businesses remained open thanks to the increased water storage capacity of the restored area.

This information can also be used alongside, or integrated with, economic analyses. As just one example, Conservation Strategy Fund and The Nature Conservancy-Panama used the Roads Economic Decision Model to assess the proposed Cerro Punta-Boquete road through Barú Volcano National Park in Panama and two alternative road investments under consideration in the region[31]. They also assessed the potential impacts of each possible route on ecosystem services including water for hydropower and irrigation and eco-tourism. In this case, the road that was the most viable from a standard economic perspective, the alternative southern route, was also the route with the fewest expected ecosystem service losses. In this example, the analysis did not need to quantify ecosystem service losses in monetary terms because it would not have affected conclusions about the best option. However, if desired, environmental costs could be calculated in monetary terms and integrated with the road economic analysis. This approach is likely to be especially useful in cases where there are trade-offs between the benefits to road users and the costs in terms of lost ecosystem services.

Incorporating ecosystem services into economic analyses

When planning for a new road or road maintenance, project assessments typically include a comprehensive engineering study and a detailed cost-benefit analysis to ensure appropriate design standards and that limited budgets are being spent appropriately. Many projects also include an environmental impact assessment (EIA) or similar environmental assessment to qualitatively assess the direct and indirect impacts roads have on the environment. However, a comprehensive cost benefit analysis of road projects requires that landscape-level environmental impacts and dependencies are assessed quantitatively in a common monetary metric. In this way, environmental considerations can be assessed as part of an integrated whole – rather than through an uncoupled cost benefit analysis and environmental assessment.

The functional relationship among roads, the surrounding environment, and people includes multiple pathways. As previously illustrated, roads both impact the surrounding landscape and depend on the integrity of surrounding ecosystems to ensure their continued function. For siting of roads and road design questions, representing landscape dependencies in monetary terms can allow for their explicit consideration in a cost benefit analysis alongside traditional engineering considerations.

Monetary values can be used to assess avoided damages, maintenance or engineering costs to roads, and increased benefits to road users provided by protection or restoration of ecosystems. For example, native shrub-steppe vegetation in the arid western region of the United States plays an important role in stabilizing soils and preventing erosion. When these ecosystems are converted to cropland, the loss of erosion control results in more severe dust storms, leading to increases in automobile accidents on roads from impaired visibility, closures, and increased maintenance costs to remove wind-blown soil from roads and ditches. An analysis by Scott and colleagues quantified the avoided costs from wind erosion provided by shrub-steppe at approximately $180 per hectare per year[33]. These values applied to rural roads with low levels of traffic and would increase with higher rates of use. Payments to land owners to maintain shrub-steppe vegetation on their property could be a cost-effective way to control road maintenance costs and prevent traffic accidents.

Beyond accounting for ecosystem benefits to roads, a comprehensive cost-benefit analysis would also allow for monetary valuation of benefits from ecosystems to society as well as the impact of the road on these benefits. In addition to contributing benefits in terms of reduced accidents and maintenance costs, shrub-steppe vegetation also provides recreational value, reduces house maintenance costs from dust storm damage, and improves water and air quality. If protection or restoration of natural vegetation is incorporated into road projects, the value of these additional benefits to society could be factored into the cost-benefit analysis. In the case analyzed by Scott and colleagues[32], shrub-steppe ecosystems provide another $180 per hectare per year in value to recreational game hunters, on par with the wind erosion prevention benefits.

Many of the services relevant to roads have multiple options for estimating monetary and non-monetary values that range from simple to complex. The most appropriate approach for a given context depends on the question of interest, data availability, and compatibility with other approaches or models being used. The following section describes the range of tools available for evaluating ecosystem services and provides a starting point for selecting a tool to answer a specific question in the road-planning process.

Integrating Road Development with Conservation and Payment for Ecosystem Service Programs in Honduras

The road sector in Honduras supports 80% of overland freight and passenger travel, but Honduras' road network is substantially under-developed. As of 2008, only 20% of the country's roads were paved, and the road service index (kilometers per thousand population) and road density index (kilometers per thousand square kilometers area) were well below Central American averages[39]. Like many LAC countries, Honduras also supports high levels of biodiversity and many endemic species found nowhere else in the world. As a consequence, several key roads that would benefit from paving or other improvements pass near or through critical habitat for endangered species. In the case of the globally endangered Emerald Hummingbird, which exists only in four remaining areas, both the World Bank and the IDB have linked road pavement projects to payment for ecosystem services (PES) schemes to enable protection of remaining humming bird habitat. The PES schemes compensate landowners who maintain or restore hummingbird habitat on their lands.

The San Lorenzo-Olanchito road is part of a road corridor connecting central Honduras to the Caribbean port of Trujillo. A 2008 World Bank loan provided funding for road improvement conditional on protection of 1400 ha of hummingbird habitat. This led to the creation of a PES schem which, by 2011, protected 835 ha of habitat on private lands, with funding to enroll an additional 600 ha and funds for 10 years[40]. However, this program faces challenges of financial sustainability and the ability to maintain payments to landowners to secure conservation of habitat over the long term.

The IDB is financing a road-paving project in the nearby Agalta Valley in northeast Honduras. Twenty remaining hummingbird habitat fragments exist within the project's area of influence; all but one are on private land. Building on the World Bank's experiences with the San Lorenzo-Olanchito project, the IDB is supporting the development of a similar PES scheme. Design of the PES scheme will bring together stakeholders from local government, landholders, and environmental NGOs to ensure effective conservation measures supported by appropriate levels of compensation[41]. This PES-based approach could be used in other road projects to conserve areas, providing erosion control, flood regulation, or coastal protection services to roads directly.

Honduran Emerald Hummingbird image courtesy of Magnus Manske, Flikr

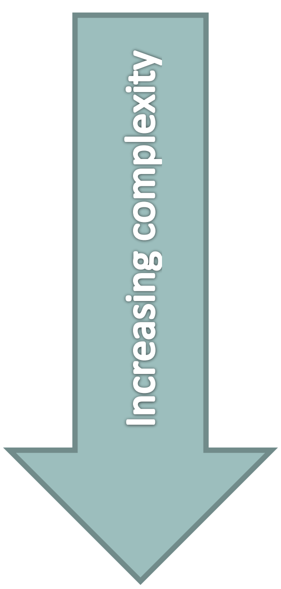
VI. Tools for Incorporating Ecosystem Services Information into Road Planning

The number of decision-support tools available to assess ecosystem services is growing rapidly. The most appropriate tool for a particular project and question depends on the issue being evaluated, the level of precision needed in the results, and the amount of time, data, and expertise available. Screening tools tend to be simpler, requiring less technical or scientific expertise, and provide results in ranked or relative terms. Tools for mapping, quantifying, and valuing ecosystem services generally require more data, time, and technical capacity, produce quantitative outputs that show the location and amount of services provided, and can be directly linked to economic valuation.

The following list provides some examples of freely available tools that can be useful for assessing road impacts to, and dependence on, ecosystem services. This list is meant to be illustrative rather than comprehensive. See the "Additional Resources" section of this document for a link to Business for Social Responsibility's 2014 report *Making the Invisible Visible: Analytical Tools for Assessing Business Impacts & Dependencies Upon Ecosystem Services*, which provides information on approximately 50 useful tools for ecosystem service analysis.

Tools for screening

Simpler tools, qualitative or relative results



Roads Filter

Conservation Strategy Fund

The Roads Filter compares the relative risks and benefits of roads, integrating measures of economic, environmental, socio-political, and cultural risk. Quantitative and qualitative indicator variables are weighted by their importance and combined into a risk index. The Roads Filter can be used to prioritize road projects that have lower risk.

ESR for IA – Ecosystem Services Review for Impact Assessment

World Resources Institute

ESR for IA is a six-step approach with spreadsheet-based tools for assessing and prioritizing project impacts and dependencies on ecosystem services. It can be used to identify options to manage road dependencies on ecosystems and to mitigate road impacts on the benefits from ecosystems.

Tools for mapping, quantifying, and valuing ecosystem services

More complex tools, quantitative and detailed

RIOS – Resource Investment Optimization System

Natural Capital Project

RIOS combines biophysical, social, and economic data to identify where watershed management activities would provide the greatest ecosystem service benefits. It can be used, for example, to determine where restoration or protection of ecosystems would be most effective at reducing erosion that could damage bridges or roads, or improving water quality for users affected by road development.

InVEST – Integrated Valuation of Ecosystem Services & Tradeoffs

Natural Capital Project

InVEST uses spatially-explicit environmental and economic data to map, quantify, and value ecosystem service provision. It can be used to evaluate, for example, which coastal roads depend most on mangroves for protection from flooding, or to quantify and value the change in erosion expected from agricultural expansion from road paving.

SWAT – Soil and Water Assessment Tool

Texas A&M University and the USDA Agricultural Research Service

SWAT simulates the quality and quantity of surface and ground water and predicts the environmental impact of land use, land management practices, and climate change. SWAT can be used to assess soil erosion prevention and control measures and watershed management activities. It can provide results with high temporal resolution (e.g., daily estimates) but requires more data and expertise to run than simpler tools.

ARIES – ARtificial Intelligence for Ecosystem Services

University of Vermont's Gund Institute for Ecological Economics

ARIES models and maps ecosystem service provision, using spatial dynamics based on the location and demands of beneficiaries. ARIES is very flexible and will eventually allow users to automatically select the most appropriate models and data for the areas and services of interest. ARIES remains under development, so at this time, it requires a high level of expertise to run and/or close collaboration with its developers.

Conclusions

Applying an ecosystem services approach to planning, preparation, and implementation of road projects can improve returns on investment by producing more reliable and durable roads that contribute to sustainable and equitable economic benefits. This report has highlighted a number of practical ways in which the benefits of ecosystem services can be accounted for and put to use in the context of road investments. There is great opportunity to invest in Latin America and the Caribbean's natural capital – its wealth of ecosystems and biodiversity – towards achieving inclusive and sustainable economic development. The region's ecosystems prevent flooding and erosion, protect infrastructure and people from coastal storms, and provide clean water for drinking and energy production alongside numerous other benefits that form the foundation of current and future economic growth and well-being. Consideration of these vital ecosystem services provides a useful lens for understanding the connections among nature, infrastructure investments, and development. The Latin America and Caribbean region and the Inter-American Development Bank are poised to lead the way, demonstrating the benefits of this approach to the global community.

FOR MORE INFORMATION:

IDB's Biodiversity and Ecosystem Services Program: www.iadb.org/biodiversity
Natural Capital Project: www.naturalcapitalproject.org
The Nature Conservancy: www.nature.org

ADDITIONAL RESOURCES:

Business for Social Responsibility (BSR): Making the Invisible Visible: Analytical Tools for Assessing Business Impacts and Dependencies upon Ecosystem Services
http://www.bsr.org/reports/BSR_Analytical_Tools_for_Ecosystem_Services_2014.pdf

Gore, Leoniak et al.: Best Management Practices: A Guide for Reducing Erosion in the British Virgin Islands
http://issuu.com/alookingglass/docs/best_erosion_practices-alookingglas

Transportation Research Board: Evaluation of Best Management Practices for Highway Runoff Control
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_565.pdf

United States Environmental Protection Agency: Runoff control for roads, highways and bridges
http://water.epa.gov/polwaste/nps/roadshwys.cfm

USAID: Low-Volume Roads Engineering – Best Management Practices and Field Guide
http://pdf.usaid.gov/pdf_docs/PNADB595.pdf

World Bank: Road Maintenance and the Environment
http://siteresources.worldbank.org/EXTROADSHIGHWAYS/Resources/td-rd17.pdf

World Bank: Roads and the Environment – A Handbook
http://siteresources.worldbank.org/INTTRANSPORT/Resources/336291-1107880869673/covertoc.pdf

World Bank: Watershed Management Approaches, Policies, and Operations
http://www.unwater.org/downloads/442220NWP0dp111Box0327398B01PUBLIC1.pdf

World Resources Institute: Weaving Ecosystem Services into Impact Assessment
http://www.wri.org/publication/weaving-ecosystem-services-into-impact-assessment

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This document provides guidance on how to include ecosystem services into road design and development. It is intended to help readers identify, prioritize, and proactively manage the impacts the environment has on roads as well as the impacts roads have on the environment.

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