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for Sustainable Development

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Landscape Connectivity
A call to action

syngenta

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Contents

Foreword 02

Summary 04

1 Introduction

The aim and scope of this paper 08

2 Habitat fragmentation and how landscape connectivity can counter it

The problem of habitat fragmentation 11
How landscape connectivity can help 11
Landscape connectivity in current biodiversity policies 14
Why we need a stronger focus on connectivity 14

3 Enabling landscape connectivity

Motivating the private sector 17
The policy perspective 18
Definitions, standards and certification schemes 18
Cross-sector collaboration in landscape design and governance 20
Incentives alignment 21
Addressing potential challenges 21

4 Call to action

Using marginal land in rural and industrial areas 24
Implementing, supporting and incentivizing spatial planning 25
Introducing green infrastructure in and around urban areas 26

5 Next steps

Landscape-level planning and implementation 29

6 Appendix

Examples of connectivity 30

7 References 32

Foreword

Peter Bakker
WBCSD

Connecting landscapes with vegetation buffers is actually about connecting people: landholders, community members, local governments, natural resource management experts and importantly, providers of finance and the private sector.

Climate change scenarios show there are many challenges ahead for our agricultural systems. As we face those challenges, we can take steps to manage some of the impact, by ensuring that we work together to create landscapes that are connected.

The vegetation buffers that link different parts of the landscape are critical. They provide valuable shelter and fodder for livestock. They reduce the speed of wind and the impact of accelerated erosion. They retain water in landscapes, as well as protecting waterways and bringing biodiversity benefits that are greatly needed.

Taking steps to connect landscapes - now - can provide the future adaptation pathways that many species will need to survive, thrive and be resilient to the effects of climate change.

There are clear economic and social rewards for business and government that create connected landscapes that support healthy, functioning ecosystems. These ecosystems provide benefits to people and nature, and can help governments move towards the achievement of their NDC targets under the Paris Agreement, while also contributing towards the Sustainable Development Goals (SDGs).

This report highlights the business case for landscape connectivity and seeks to close the gap between policy intent and real action. The outcomes of connectivity represent bankable returns for our production landscapes and they have an unrealized potential to spur the growth of new investment models to scale-up landscape connectivity.

Many organizations will need to work together to restore and connect landscapes at scale. This report will help those organizations take the steps towards collaboration and highlight the potential that connectivity provides to all of those who have a stake in our land.

Erik Fyrwald
Syngenta

In 1798 Thomas Robert Malthus thought that the increase in human population would outpace the growth in the food supply. Two hundred years and a six-fold jump in the population later, this famously pessimistic prophecy has not been fulfilled.

Since the first 'green revolution' 50 years ago, research has made valuable contributions to meeting the needs of a growing population with changing consumption patterns.

Nonetheless, producing more, better quality food, within the limits of what this small, fragile planet can supply and renew every day, has proven to be difficult. The decline in biodiversity, in fact, is already of great concern. Conservation efforts to date have concentrated on the protection of specific spaces and species. This alone will not be enough to turn around the current decline in biodiversity.

Businesses are in a position to contribute to the creation of additional landscape connectivity and wildlife corridors through the introduction of green infrastructure on marginal and less productive land. This intervention requires a collaborative, multi-stakeholder approach however and this paper is therefore a call to action.

I would like to thank our business colleagues and the many experts and contributors who worked so hard and skillfully to produce this report.

Monique Barbut
UNCCD

Up until 200 years ago, land use change and land degradation were localized and inconsequential when compared with contemporary changes in the Earth system. However, the capacity of land and soil to absorb the cumulative impacts of intensive human activities is now being severely tested. Worldwide, between 20-30% of our croplands are considered to be moderately or severely degraded mainly as a result of poor management practices. Each year about 12 million hectares of productive land are lost or abandoned due to soil erosion and land degradation processes.

Most modern land uses, such as industrial monocultures and surface mining, reduce biodiversity and limit the essential services we need for long-term economic growth and human security. Nature is good at connectivity.

This timely publication points to the progressive changes needed in the current model that account for linkages in the landscape and help business sharpen their focus on and commitment to the triple bottom line: people, planet and profit. Landscape connectivity can help rehabilitate degraded land and nurture the biological flows and structures needed to increase our resilience in the face of drought and other climate impacts. At the same time, adopting and scaling up SLM practices that increase landscape connectivity and deliver real land stewardship by the private sector offers the prospect of significant long-term returns. The business opportunities in creating a more sustainable world in which 9 billion people can live could be worth USD 3-10 trillion a year by 2050.

Everything is connected. Everything is linked. Business success and land stewardship are no exception.

Ann Tutwiler
Bioversity International

We need to address the complex and interconnected global challenges of improving global malnutrition and promoting sustainable agriculture. Scientific evidence demonstrates that using and safeguarding agricultural and tree biodiversity (the diversity of organisms used in agriculture and forestry) along with novel practices, can help achieve multiple Sustainable Development Goals with minimal tradeoffs. To guarantee productive, profitable farms today and tomorrow, we need agrobiodiversity at the ecosystem, agronomic and genomic level to work together.

Bioversity International's research mainstreams biodiversity in agricultural development, where studies are showing how both agricultural and wild biodiversity can boost productivity and livelihoods. Our research aims at better use of crop and tree biodiversity, and supporting systems that contribute to more diversity through: strategies, management and trait identification; information services and seed supplies; and policies, institutions and monitoring.

However, while agrobiodiversity holds solutions, global stakeholders, including the private sector are concerned that this diversity is shrinking, as many businesses rely on agrobiodiversity in the landscapes where they operate. Fragmentation and loss of habitats threaten agrobiodiversity, leading to smaller, more isolated populations of important species linked to agroecosystems. Connecting disparate agricultural landscapes is an effective approach to strengthening ecological integrity, preventing species loss and restoring healthy functioning ecosystems. While such 'landscape connectivity' has been promoted, there is a gap between policy intent and action on the ground. Bioversity International is therefore pleased to join with the private sector's efforts to mainstream landscape connectivity in its operations. Restoring healthy and productive agro-ecosystems will allow hundreds of millions of growers and their rural communities to benefit from improved productivity and livelihoods, where agricultural and forest systems more effectively nourish people and sustain the planet.

Summary

Creating landscapes with healthy, functioning ecosystems is not only key to making progress towards the environmental targets embedded in the Sustainable Development Goals, but also to addressing multiple social and economic targets that depend partly or wholly on the benefits that ecosystems provide to people.

Biodiversity is in decline globally and climate change looks set to further accelerate the process through its impact on habitat loss and fragmentation. Landscape connectivity, or the ability of species to move between areas of habitat via corridors and linkage zones, could help halt the decline by promoting improved foraging, breeding and migration routes. Species may better weather climate change if they are able to move to more suitable areas.

This is critical: creating landscapes with healthy, functioning ecosystems is not only key to making progress towards the environmental targets embedded in the Sustainable Development Goals, but also to addressing multiple social and economic targets that depend partly or wholly on the benefits that ecosystems provide to people.

Connectivity requires collaboration

Though increasing landscape connectivity is an intuitive and practical approach to countering habitat fragmentation and the associated decline in biodiversity, putting it into practice generally involves land owned, managed and used by many stakeholders. Efforts to improve connectivity in a given landscape therefore require coordination between many parties, including governments, local and international organizations and, critically, private industry: reducing the loss of biodiversity and ecosystem degradation is a responsibility shared by the public and private sectors.

Land connectivity initiatives are clearly in the interests of industry stakeholders directly affected by reduced biodiversity, but there are a number of factors that may also motivate others, including better reputation, improved relationships with local communities and stakeholders, and the creation of platforms for engaging with conservation organizations.

Incorporating the private sector voice into existing initiatives will not only have an impact on land use and management practices, but will also bring valuable knowledge and potential partnership opportunities, enhancing connectivity efforts. Businesses can benefit from being in a connected landscape and taking an active role in addressing landscape connectivity.

Connectivity supports existing efforts

Landscape connectivity is already referred to in several policies, conventions and initiatives on biodiversity and climate, and it is not the aim of this paper to propose a change to recognized and well-defined policy frameworks. There is however a gap between policy intent and action on the ground and so we suggest an improved framework for making landscape connectivity actions mainstream, even in the private sector. Better management of landscape connectivity can provide a complementary approach to current conservation efforts, help to strengthen ecological integrity and prevent species loss.

Table 1:
Key benefits that are directly and/or indirectly supported through ecological infrastructures and landscape connectivity

Environmental	Economic	Social
Air quality	Additional income	Aesthetics and recreation
Carbon sequestration	Brand reputation	Culture and history
Conservation of species	Crop yields and quality	Ecotourism
Food, habitat and species mobility	Financial gains	Education
Gene flow	License to operate	Human health and wellbeing
Pest control	Property value increase	
Pollinator species	Recreational revenues	
Soil conservation		
Water regulation and protection		

Call to action regarding policies and practices

Policymakers can facilitate the involvement of private industry and other stakeholders by taking a number of steps in terms of standardizing definitions, guidelines and standards for implementing, maintaining and restoring connectivity. They can also promote collaboration among stakeholders by considering competition and interdependencies among land users, and help manage incentives including certification programs.

Indeed, creating multi-stakeholder platforms by calling on the involvement of a range of stakeholders and including expertise from all sectors in the planning, implementing and monitoring phases of multifunctional landscape creation is a necessary starting point. Collaborative, multi-stakeholder partnerships are essential to coordinating approaches to landscape connectivity, aligning stakeholder actions and providing economic value. Partners should include major land users, influencers and regulatory bodies, and planning should focus on a local scale.

Businesses and other stakeholders united in this way are then in a better position to contribute to the creation of additional landscape connectivity and wildlife corridors. This paper discusses a potential way of working together and three key approaches to doing so:

1. Using marginal land in rural and industrial areas
This is the biggest opportunity to enhance biodiversity in agricultural landscapes. Multifunctional field margins can significantly improve agricultural practices by supporting pollinators, pest management, soil and water conservation, and overall ecosystem resilience.

2. Implementing, supporting and developing incentives for spatial planning
Policies and plans for urban and rural development or restoration of degraded land need to integrate spatial planning.

3. Introducing green infrastructure in and around urban areas
This is an opportunity for manufacturers, retailers, and processors to benefit from 'green urban planning' and achieve lower operating costs, higher building value and lower lifetime costs. The creation of green buildings can provide long-term competitive advantage and improve brand image.

Next steps

Critical next steps involve raising awareness of the importance of landscape connectivity, spatial planning, green infrastructure, and promoting the use of this paper as a reference point for motivating joint work. The aim is to encourage more multi-stakeholder partnerships to implement and report on a variety of initiatives and to make their achievements more visible. The focus should be on the implementation of simple and workable solutions for landscape connectivity and its conservation on all scales.

The value of landscape connectivity

Landscape connectivity supports high levels of biodiversity and offers a range of environmental, economic and social benefits.

Habitats for pollinators

Corridors support populations of pollinators and natural predators for crop pests.

Ecotourism

Trails alongside corridors can provide significant value and support the conservation of local habitats alongside historical and cultural

Soil health and water regulation

Field margins and forested corridors alongside agricultural landscapes support soil conservation, reduce erosion and help protect water quality.

Carbon sequestration

Agroforestry and wooded corridors can contribute to increased carbon sequestration.

Farm income

Supporting pollinators, natural pests and in situ conservation of crop wild relatives can improve yields and agricultural resilience while agroforestry can provide a supplementary income.

1. **Introduction**

Improving landscape connectivity could help halt the loss of biodiversity and support key ecosystem services.

Measures such as the Living Planet Index, an indicator tracking 17,000 populations of vertebrate species around the world, suggest that biodiversity is in global decline[1]. Climate change and the resulting habitat fragmentation and ecosystem loss - two key factors driving the loss of biodiversity[2] - threaten to accelerate this trend.

Improving landscape connectivity, or the ability of species to move between areas of habitat via corridors and linkage zones, could help halt the decline by promoting improved foraging, breeding, and migration routes. Species may better weather climate change if they are able to move to more suitable areas.

Though increasing landscape connectivity is an intuitive and practical approach to countering habitat fragmentation and the associated decline in biodiversity, putting it into practice generally involves land owned, managed and used by many stakeholders. Efforts to improve connectivity in a given landscape therefore require coordination between everyone involved.

Among industrial stakeholders, those with large land footprints because of involvement in agricultural production, forestry or raw material extraction have a clear influence over ecological processes. Other companies have an effect on landscape connectivity too though, through land footprints of facilities and infrastructures, impact through the supply chain and in potential responses to customer and government requests for more sustainable products and practices.

While land connectivity initiatives are clearly in the interests of stakeholders directly affected by reduced biodiversity, there are a number of reasons that others should also be motivated. These include better reputation, improved relationships with local communities and stakeholders, and the creation of platforms for engaging with NGOs. Relevant projects have resulted in capital cost savings, reduced operation and maintenance costs and significant return on investment. Employee motivation and retention is enhanced by positive perception of company behaviour.

With measures improving landscape connectivity also supporting several Sustainable Development Goals[3], it is essential to involve industry in these efforts. Landscape connectivity can create significant benefits for nature, society, business and food production when managed effectively and in a collaborative way.

Some stakeholders such as conservationist organizations have made good inroads into landscape connectivity efforts and we do not propose a change to recognized and well-defined frameworks. The goal is rather to make the concept of landscape connectivity widely recognized among all stakeholders, including governments, local and international organizations and, particularly, private industry, and make it clear that the active participation of all groups is essential.

The aim and scope of this paper

This paper aims to raise awareness of landscape connectivity and initiate a call to action for implementing simple, workable solutions for promoting it. This paper is a reference for a large group of stakeholders, showing how it may be possible to work together in public-private partnerships.

The paper introduces landscape connectivity and its benefits, identifies policy gaps, and outlines the roles that stakeholders can play in promoting and implementing supporting measures. Also provided are recommendations for an inclusive approach that positions businesses to support the implementation of landscape connectivity, though all relevant stakeholders are called on to bring connectivity conservation to the core of decisions on the scale of the landscape.

60%

of ecosystem services that humans rely on are thought to be degraded or are being used unsustainably[4].

Sustainable Development Goals

[1] There is a fairly consistent downward trend in the Living Planet Index from the World Wildlife Foundation (WWF) and Zoological Society of London from 1970-2010, which suggests we are on track to further reduce vertebrate species population sizes by 2020. (WWF The Global Living Planet Index, 2014). [2] Fischer & Lindenmayer, 2007. [3] United Nations (UN), 2015. [4] Millennium Ecosystem Assessment, 2005

2. **Habitat fragmentation and how landscape connectivity can counter it**

Habitat fragmentation is threatening the key ecosystem processes and services that rely on connectivity. Going beyond habitat and species conservation, and promoting landscape connectivity, can offer a range of environmental, economic and social benefits.

The problem of habitat fragmentation

Habitat fragmentation involves the loss of original habitat, reduced habitat patch size, increased edges, increased isolation of patches and the modification of natural disturbance regimes[5]. Land use change, such as from agriculture, urbanization, or energy and transportation infrastructure[6], has been the most important proximate cause of habitat loss and fragmentation.

Habitat fragmentation is threatening the key ecosystem processes and services that rely on connectivity. Indeed, research in the Amazon suggests that once 70% of the rainforest has been lost in a landscape, the effects of fragmentation begin to outweigh the direct effects of habitat loss - the remaining 30% will not reach its full habitat potential[7]. The lack of connectivity between remaining habitat fragments can affect gene flow and thus changes the evolutionary development of populations, reduces species distribution[8] and increases extinction risks. Forest fragmentation can have other negative effects that can lead to carbon losses; this is particularly concerning in light of climate change[9] because this threatens to accelerate the process.

How landscape connectivity can help

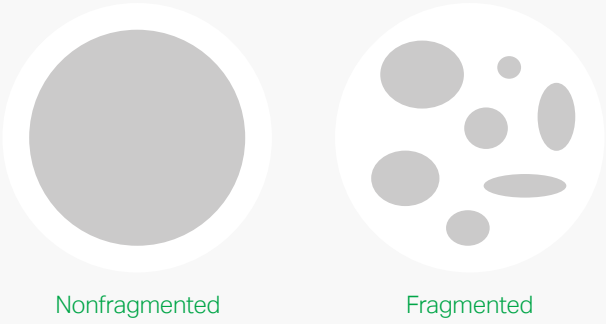
Connectivity or the 'degree to which the landscape facilitates or impedes movement among resource patches'[10] via complex and non-linear spatial distributions[11], enables species mobility and access to key ecological, ecosystem and evolutionary processes. It can complement the conservation of protected species by linking them to unprotected areas, natural and semi-natural landscapes and waterscapes[12].

Connectivity is therefore an important element of ecosystem health and biodiversity, particularly because it ensures that the species providing ecosystem services can move to the locations that need them. Connectivity can be managed in multiple systems including the terrestrial, aquatic or urban/peri-urban and on many levels, such as field, farm, landscape and region.

Land connectivity can be improved though a number of options, including linear strips of habitat connecting otherwise isolated patches, field margins, wooded areas adjacent to bodies of water, hedgerows and windbreaks[13] as well as connectivity networks serving multiple purposes such as coffee plants grown under a canopy of trees, providing connectivity for tropical forest species as well as a cash crop[14].

The benefits of landscape connectivity are extensive and some, supported by research and existing case studies[15], are listed below. Although placing specific values on such benefits is challenging, they should not be underestimated, especially when considered altogether, including both onsite and offsite benefits.

Habitat fragmentation



Habitat fragmentation reduces habitat patch size and interior habitat, while increasing the amount of edge. Nonfragmented habitat patches have a larger interior habitat. Fragmented habitats also become more isolated and movement between habitat patches is more restricted than in nonfragmented habitats.

[5] United States Department of Agriculture (USDA), 1999. [6] Reducing habitat fragmentation from transport infrastructure would counteract the following: spreading traffic noise and pollution, changing local climates, reducing the size and persistence of wildlife populations and deteriorating the scenic and recreational value of the landscape (Jaeger, 2007). [7] Andren, 1994. [8] e.g. small mammals in tropical forests are known to be unable to cross even narrow gaps caused by roads and powerlines in the forest (Goosem, 2000). [9] Doerr, *et al.*, 2010. [10] Merriam, 1984. [11] Waage *et al.*, 2005.
[12] Connectivity is highly relevant in waterscapes as well as in landscapes, however this paper focuses on terrestrial connectivity and does not include an analysis of seascapes. Companies involved in fisheries, offshore extraction, aquaculture, shipping and those with shoreline processing units are just some of those for whom marine connectivity will be relevant. (Worboys *et al.*, 2016).
[13] 'Linear strips of habitat connecting otherwise isolated patches' (Baum *et al.*, 2004), including multifunctional field margins, riparian forests, hedgerows and windbreaks. Landscape connectivity corridors can either be natural or result from anthropogenic changes. They can include vertical (i.e. different plant heights) and horizontal structures (i.e. habitat types and their spacing) with different physical and biological characteristics (USDA, 1999). [14] e.g. Rappole *et al.*, 2003; freeway under passes can both facilitate connectivity for vertebrate species (Canadian Parks and Wilderness Society, 2013; Clevenger, 2012; Atlas Obscura), and riparian corridors can both contribute to water quality, and serve as corridors (USDA, 1999). [15] More detail on these case studies in Appendix III.

Table 2:
Key benefits that are directly and/or indirectly supported through ecological infrastructures and landscape connectivity

Environmental	
Carbon sequestration	Agroforestry and wooded corridors (e.g. those near a watercourse, riparian) can contribute to increased carbon sequestration[16 17].
Conservation of species	On-site conservation of plant species (e.g. crop wild relatives)[18]. Wetlands support a number of endemic bird and plant species.
Food, habitat and species mobility	Connected landscapes can better encompass the natural range, food sources and migration routes[19]. Over- and underpasses, encourage species movement despite the barriers from road construction[20 21 22].
Gene flow	Supporting gene flow and genetic diversity for various specie[23 24].
Pollinator species and pest control	Over 70% of our fruit and vegetables rely on insects and other animals for pollination[25]. Corridors support populations of pollinators and natural predators for crop pests[26].
Soil conservation	Field margins and forested corridors alongside agricultural landscapes support soil conservation and can improve soil fertility[27]. Reduced soil erosion upstream can improve water quality downstream[28].
Water regulation and protection	Natural areas of vegetation can help reduce the difference in water flow between wet and dry seasons[29], improve water quality and lessen the impact of floods[30], reduce water temperature and slow the release of sedimentary phosphorus[31]. Recovery and restoration of water resources.
Air quality	Urban tree corridors can provide cost-effective pollution reduction strategies by removing air pollutants and subsequently improving air quality in urban areas[32].

Economic	
Additional income	Agroforestry can provide supplementary income that also offers a buffer against sources of economic difficulty[33]. When smallholders aggregate their resources, they can create more valuable products[34].
Brand reputation	Improvements in business reputation, positive relationships with local communities and platforms to engage with stakeholders.
Crop yields and quality	Average yield for wheat, oilseed rape and beans increased significantly with the creation of wildlife habitats on 3% of land[35]. Pollinators and pest resistant species provide agricultural value[36]. In situ crop wild relatives can improve agricultural resilience[37].
Employee gains	Employee motivation and retention is enhanced by positive perception of company behaviour, particularly amongst millennials.
Financial gains	Capital cost savings, operation and maintenance costs, significant return on investments and innovation and revenue creation[38].
License to operate	Supported compliance with effluent guidelines.
Property value increase	Land and properties adjacent to corridors are valued higher than if they were not close to them. All variables being equal, property next to greenbelts in Colorado would experience a property value increase of 32%[39].
Recreational value	Trails alongside corridors can provide significant value[40], often in rural and economically disadvantaged areas[41].

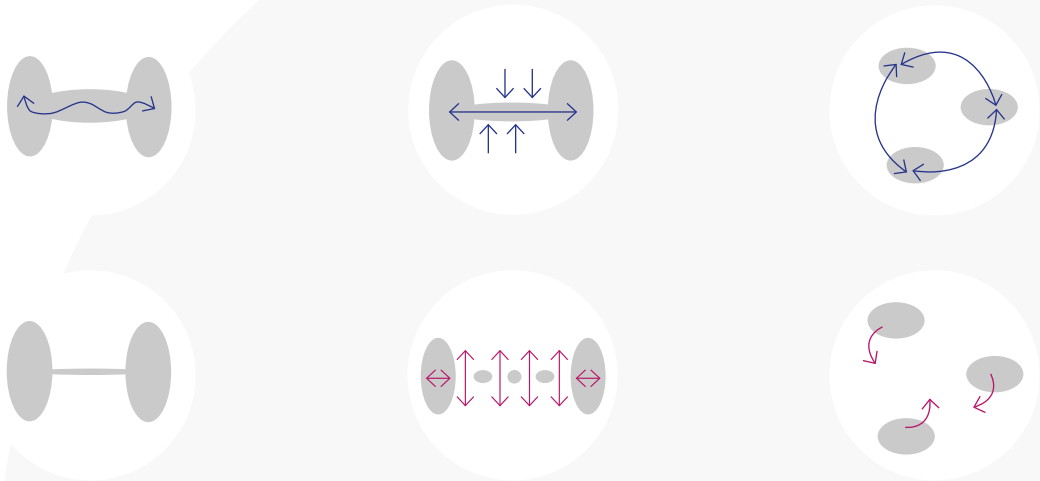
[16] Jose, 2009. [17] Chazdon, 2008. [18] Jarvis *et al.*, 2015. [19] Persey *et al.*, 2010. [20] Canadian Parks and Wilderness Society, 2013. [21] Clevenger, 2012. [22] Atlas Obscura. [23] Mech & Hallett, 2001.
[24] WWF, 2006. [25] Klein *et al.*, 2003. [26] Zhang *et al.*, 2007. [27] Harvey *et al.*, 2008. [28] Al-Kaisi & Tidman, 2001; Fremier *et al.*, 2013. [29] Houlahan & Findlay, 2004. [30] Houlahan & Findlay, 2004.
[31] USDA, 1999. [32] Dearborn & Kark, 2009. [33] Idol *et al.*, n.d. [34] Harvey *et al.*, 2008; Minang *et al.*, 2015. [35] Pywell *et al.*, 2014. [36] Mitchell *et al.*, 2013. [37] Dulloo *et al.*, 2015. [38] WBCSD, 2015. [39] USDA, 1999.
[40] Richardson & Loomis, 2008. [41] Macdonald, 2011

Social	
Aesthetics	Green corridors can beautify 'grey infrastructure'.[42].
Ecotourism	Ecotourism arising from connected landscapes can support conservation by protecting habitats and biodiversity[43]. Can help to conserve historical and cultural features. Threatened, endangered, and rare species have a social value[44].
Education	Partnerships with universities to drive research. Helping farmers with livestock husbandry improvements and working with local communities[45]. Increasing awareness to create sustainable ecosystems[46].
Human health and wellbeing	'Minimal amounts of nature' improved employees' satisfaction with their workspace by 30%[47]. Trees planted near buildings can filter out airborne particles[48]. Urban green areas, riparian corridors and forests can act as recreational areas[49 50 51].

How can landscape connectivity help?

Factors supporting or preventing movement between habitat patches

Wide and continuous corridors and near patches support connectivity.



Narrow and discontinuous corridors and distant patches prevent connectivity.

[42] i.e. green corridors under overhead electricity cables throughout wooded areas in Belgium and France (Life Elia). [43] Burger, 2000.
[44] Richardson & Loomis, 2008. [45] Panthera. [46] The Florida Wildlife Corridor. [47] Kaplan, 1983. [48] Fleming, 2016. [49] USDA, 1999. [50] Li *et al.*, 2005. [51] Mönkkönen, 1998.

The corridor systems involved in landscape connectivity can also serve other conservation purposes, such as the protection of crop wild relatives (CWR)—or wild plants closely related to domesticated plants. Their conservation is important because of their potential to address growing challenges such as food security[52]. Indeed, CWRs[53] deserve more focus because of their potential to contribute to ecosystem services through their value for conservation and agricultural research and development[54 55 56].

Restoring landscape connectivity through various means is an intuitive and practical approach to addressing habitat fragmentation[57] and in turn supports high levels of biodiversity, offering a range of other environmental, economic and social benefits, including agricultural value. It also helps meet the need to continuously improve productivity of agricultural lands, control urbanization and reduce human land requirements and revert lands no longer needed for human use to host more stable ecosystems.

Landscape connectivity in current biodiversity policies

The benefits offered have already been acknowledged by a number of groups and the concept is already an important component in key international conventions, initiatives and unions on biodiversity, ecosystems and climate change (Table 3).

Coherent approaches to describing landscape connectivity and a more explicit emphasis on its importance together with appropriate incentives would speed up systematic implementation.

Why we need a stronger focus on connectivity

Any efforts to promote landscape connectivity must consider existing conservation policies[58] and we do not aim to change recognised and well-defined frameworks, but rather to make landscape connectivity a well understood and mainstream concept.

While ambitious conservation goals such as the Aichi Targets are being set[59] at the global level, and policies and initiatives listed in table 3 promote landscape connectivity, in most cases the focus is on protecting spaces and species[60].That is, most conservation efforts concentrate on preventing ecosystem loss by creating protected areas and focussing on particular species.

Though creating protected areas and not just targeting charismatic and (critically) endangered species has the potential to conserve additional species and diversity, existing isolated reserves will not be enough to turn around the current decline in biodiversity in the face of climate change. Landscape connectivity must be increased.

While reserves and protected areas play an important role in maintaining natural ecosystems and biodiversity[61], most biodiversity exists outside of such lands and areas themselves are often isolated fragments of remnant habitat[62]. Furthermore, protected areas cannot address rapid biodiversity decline[63] alone and are also unlikely able to incorporate large-scale or long-term ecosystem ecological and evolutionary dynamics[64].

What's more, climate change is threatening ecosystem viability and structure, and will require species to move across the landscape, making landscape connectivity even more critical. Climate models examined in a recent study revealed that temperature-sensitive species in 45-65% of protected areas in the Amazon will have to disperse beyond the boundaries of their protected areas to survive by the 2050s. In contrast, well-connected protected areas enable the dispersal of species to temperature-equivalent habitats. As a result, species in only 20-35% of these connected protected areas will have to move beyond the boundaries of protected areas as the climate changes[65].

Connectivity may also buffer negative environmental impacts of human intervention. In short, there are many reasons for promoting landscape connectivity and going beyond current habitat and species conservation approaches. Assessing ecoregions[66] and the levels of connectivity between protected areas within them shows that this will be a challenge: 40% of the world's ecoregions have relatively low or fair levels of connectivity between protected areas and 35% of ecoregions have very low connectivity or no protected areas[67]: Connecting ecoregions is also a great opportunity.

[52] Jarvis *et al.*, 2015 [53] Wild plant species that are more or less closely related to domesticated species, including crop progenitors, and are a potential source of traits beneficial to our crops (Maxted *et al.*, 2012). [54] Ford-Lloyd *et al.*, 2014 [55] Dulloo *et al.*, 2015 [56] Thormann *et al.*, 2013. [57] Meir et al., 2004. [58] e.g. the Brazilian Forest Code that requires all landowners to put 20-80% of their land aside as a legal reserve could have an increased conservation impact if connectivity is considered when identifying/restoring these legal reserves (WWF, 2015). [59] Target 5: 'By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.' Target 11: 'By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascapes.' (CBD, 2011a). [60] Global Biodiversity Outlook 4, 2014. [61] Protected areas include 15% of terrestrial and freshwater environments (Juffe-Bignoli *et al.*, 2014). [62] Franklin & Lindenmayer, 2009. [63] e.g. even some of the largest existing reserves in North America and East Africa are too small to contain the local ranges or migration routes of many large mammals (Crooks & Sanjayanm, 2006). [64] Bergsten, 2012. [65] Feeley & Silman, 2016. [66] "large areas with characteristic combinations of habitats, species, soils and landforms" (Olson *et al.*, 2001). [67] Woodley *et al.*, 2012.

Table 3:
Key conventions, initiatives and unions that support landscape connectivity

Aichi Biodiversity Targets[68]	Support the overall aims of the Convention on Biological Diversity by aiming to reduce degradation and fragmentation, and integrating well connected systems of protected areas across landscapes.
Bonn Convention[69]	Convention on the Conservation of Migratory Species of Wild Animals: Connectivity conservation is key for the 'maintenance of a network of suitable habitats' for the migratory routes of species.
Convention on Biological Diversity (CBD)[70]	Connectivity conservation links to several Articles of the Convention. The CBD Program of Work on Protected Areas specifically supports the achievement on in situ conservation.
EU Biodiversity Strategy[71]	The EU has an overall goal to reduce biodiversity loss through the Birds and Habitats Directive, the Natura 2000 ecological network across the EU[72] and the EU Strategy on Green Infrastructure[73].
European Landscape Convention[74]	Dedicated to protecting, managing and planning European landscapes through a people-centred and forward-looking way.
Intergovernmental Panel on Climate Change (IPCC)[75]	Recognizes that connectivity supports the ability of ecosystems to adapt to climate change and recommends measures to restore connectivity.
Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[76]	Assesses the state of biodiversity and ecosystem services. Aims to 'strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development'.
International Union for Conservation of Nature (IUCN)[77]	Acknowledge the global significance of conserving flora and fauna from the effects of natural habitat loss and fragmentation. Convened a working group on connectivity that has produced draft guidelines for defining 'Areas of Connectivity Conservation'.
Land Degradation Neutrality Target[78]	The goal calls for the restoration of degraded land and soil. The restoration of these areas can support landscape connectivity.
Ramsar Convention[79]	A specific focus on the migratory needs of waterfowl and therefore the connectivity of wetland habitats across national borders.
Sustainable Development Goals (SDGs)[80]	While connectivity is not formalized as a specific goal, it is important for supporting several of the SDGs.

[68] Convention on Biological Diversity (CBD), 2011b. [69] Convention on the Conservation of Migratory Species of Wild Animals, 1979. [70] CBD, n.d. [71] European Commission, 2016a. [72] European Commission, 2016b. [73] European Commission, 2016c. [74] Landscape Institute. [75] Intergovernmental Panel on Climate Change (IPCC), 2014. [76] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). [77] Worboys *et al.*, 2016. [78] Global Mechanism of the United Nations Convention to Combat Desertification (UNCCD), 2016: Demonstrated by the recent momentum around the Natural Capital Protocol for business, Zero Deforestation Commitments and the Land Degradation Neutrality target which aims to restore degraded land and soil and strive to achieve a land degradation-neutral world by 2030. [79] The Ramsar Convention Secretariat. [80] UN, 2015.

3. **Enabling landscape connectivity**

Coherent approaches to landscape connectivity and a more explicit emphasis on its importance would speed up systematic implementation.

Exploiting the connectivity potential requires coordinated efforts and goals across existing governance boundaries and between different stakeholders in a given landscape. That is, landscape approaches require collaboration among stakeholders to gain momentum[81].

Public institutions are needed to lead the push for biodiversity-enhancing measures. They must fix objectives that are both relevant to the local socio-economic context and shared by businesses which are in a better position to support implementation.

Businesses must accept that halting biodiversity loss and reducing ecosystem and land degradation is a responsibility shared by both the public and the private sectors. All parties must understand that successful collaboration could represent a significant opportunity to improve policy making and implementation.

Motivating the private sector

Companies with large land footprints for agricultural production, forestry or raw material extraction clearly influence ecological processes in the landscapes in which they operate. However, other companies also impact landscape connectivity through the land footprints of their facilities and infrastructure, impact through their supply chain and ability to respond to customer and government requests for more sustainable products and practices.

While many leading businesses are mobilizing to help protect and restore biodiversity and ecosystem services[82], further action is needed. Aside from their direct influence over land use and sustainable practices, incorporating the private sector into existing initiatives will bring valuable knowledge and potential partnership opportunities.

One way of convincing private industry of the value of the approach is to point to established successes. Many companies, for example, opt to construct wetlands for their tertiary water treatment instead of installing equivalent 'grey' infrastructures.

These decisions usually result in lower environmental impacts across a broad range of indicators, support a number of endemic bird and plant species, and provide savings over a project's lifetime, particularly linked to reduced operation and maintenance costs.

Other compelling business case studies—such as the restoration of freshwater ecosystems—are described in the Appendix. These case studies aim to inspire businesses across all sectors to follow and become a part of joint landscape connectivity effort. Nonetheless, it is clear that policy initiatives will also be needed to support the effort.

Importance of pollinators

Declining biodiversity is threatening pollination, an economically significant ecosystem service. The global benefits provided by pollination services range between US$235 billion and US$577 billion per year (Breeze *et al.*, 2016).

Forest fragmentation

Forest fragmentation may have been responsible for the loss of 599 million tonnes of carbon from the Amazon over the last 10 years due to edge effects (Pütz et al., 2014).

[81] Multi-stakeholder groups define aligned conservation objectives and work towards integrated management of their shared landscape (WBCSD, 2016). [82] Global Mechanism of the UNCCD, 2016.

Sustainable Land Management Plan

Votorantim Cimentos in partnership with the Atlantic Forest Biosphere Reserve and the Brazilian Society of Speleology created the Sustainable Land Management Plan – a voluntary action that identify and rank the environmental and social assets in Votorantim Cimentos lands and propose measures for its conservation and sustainable use. This plan subsidize the environmental management strategy, conservation and responsible use of the natural and cultural resources and contribute to the company's compliance in Brazil where it is required to protect 20-80% of its lands as legal reserves.

The Harmony Charter

Mondalēz has a tool known as the 'Harmony Charter' that includes a principle focused on biodiversity-enhancing agricultural practices. They dedicate 3% of their fields to growing flowers that support pollinator species.

The policy perspective

From a policy perspective, there are a few key elements that can affect actions promoting landscape connectivity and as such demand special attention from policymakers. These include the establishment of definitions, standards and certifications; cross-sector collaboration in landscape design and governance, and incentives alignment. It is clear that any policy developed will also need to address potential challenges.

Combining these elements with current policies and initiatives will bring landscape connectivity to the forefront of conservation approaches and may close the gap between the intent of policy and what is happening on the ground. In the end, large scale landscape management will be the result of decisions made by many players.

Definitions, standards and certification schemes

Companies developing new areas for infrastructure, forestry, agriculture or extraction are faced with a myriad of environmental, economic and social factors to consider. And while there are many definitions, standards and certification schemes relevant to landscape connectivity, they are not aligned and this complicates the task—these need to be made clear[83].

Similarly, a growing awareness of the impact of biodiversity loss and ecosystem degradation on business has led some companies to measure and manage the associated risks through sustainable approaches[84]. However, business standards (some examples are shown in the table) need to be fully developed and refined to ensure their relevance at the landscape-level and consider connectivity, including when and how to maintain and restore it.

In addition to clarifying and refining definitions and standards, the development of certification schemes may also promote interest in improving landscape connectivity. Such schemes, which would award a certification to products that support landscape connectivity and promote biodiversity, can motivate businesses by giving them the opportunity to differentiate themselves as a 'better' product to consumers.

One successful example is the Rainforest Alliance, which works with farmers, foresters and tourism entrepreneurs to address the three industries with a significant landscape footprint. It currently has more than 42,000,000 hectares of land under sustainable management[85] and awards certifications after carrying out training and guidelines on minimizing environmental impacts and maintaining stable incomes[86].

A collaborative, systematic, large-scale effort to monitor and manage certification schemes would establish a feedback loop for continuous improvement and increased effectiveness of these private instruments for environmental governance. Certification schemes can also be a positive force for improving rural livelihoods and meeting biodiversity conservation goals as a component of broader scale conservation planning and natural resource management strategies.

[83] The continuing developments in the field of landscape connectivity lead to a variety of terminology, i.e. conservation corridors (USDA, 1999), areas of connectivity conservation (Worboys *et al.*, 2016), that relate to the same concept. [84] e.g. as is already the case within the EU for best practice in agriculture (European Commission, n.d.). [85] Rainforest Alliance. [86] Certifications can either be through the Sustainable Agriculture Network standard, the Forest Stewardship Council standard or the Rainforest Alliance's UN-accredited tourism standard (Rainforest Alliance).

Table 4:
Existing standards that consider connectivity

Global Standard for the Identification of Key Biodiversity Areas[87]	The Global Standard for the Identification of Key Biodiversity Areas was approved at the IUCN Council in September 2016 in order to systematically identify important areas for biodiversity beyond just protected areas. Landscape connectivity has already been incorporated as one of the defining criteria.
High Carbon Stock Approach[88]	The High Carbon Stock Approach for the implementation of zero-deforestation commitments includes a measure on connectivity/fragmentation.
High Conservation Value Approach[89]	Defines critical values at a local and landscape scale and supports a landscape approach to maintaining or enhancing target values. It is also included in many commodity certification schemes.
IFC Performance[90]	Standard 6 provides a broad definition of 'critical habitats'. The IFC's clients are expected to adhere to this standard in order to receive project and corporate finance. The IFC's standards are also recognized more broadly as a benchmark in the industry.
ISEAL Alliance[91]	Provide a useful overview on how standards are beginning to support landscape approaches[92]. Aims to improve the impact and effectiveness of standards, define credibility for sustainable standards and increase their uptake.
IUCN[93]	The IUCN is in the process of developing criteria for the identification of 'Areas for Connectivity Conservation', the delineation of which could be recognized alongside the existing list of protected areas.
Roundtable on Sustainable Biomaterials[94]	One of the only certification standards to specifically incorporate criteria on connectivity. The standards are designed to verify that biomaterials are ethically, sustainably and credibly-sourced. There is still a need for clear guidance on how companies can meet these criteria.

[86] International Union for Conservation of Nature (IUCN), 2016. [87] High Carbon Stock (HCS) Approach Steering Group, 2015. [88] High Conservation Value Approach. [89] "Habitats supporting globally significant concentrations of migratory species and/or congregatory species and areas associated with key evolutionary processes" (International Finance Corporation (IFC), 2012). [90] ISEAL Alliance. [91] Mallet *et al.*, 2016. [92] Worboys *et al.*, 2016. [93] Feeley & Silman, 2016.

Collaborating to recover rainforest

Collaboration between Syngenta, The Nature Conservancy, and other public and private sector partners empowered farmers to recover rainforest in agricultural landscapes through the Soja + Verde project. The 2016 results of the project reflect the great success of Syngenta's partnerships with a range of stakeholders where the project alone contributed 2.8 million hectares.

Cross-sector collaboration in landscape design and governance

While private business has a critical role to play, connectivity is relevant at such different scales, from hedgerows and field boundaries to the drainage areas of bodies for water, and even to large continental networks involving multiple countries, that successful initiatives strongly rely on the voluntary participation and cooperation of all relevant stakeholders[96].

Research has also found that continuous stakeholder engagement, the exchange of knowledge and the development of partnerships are essential for initiatives to thrive[97]. Engaging local communities during corridor design and implementation supports connectivity, local ownership, socio-economic resilience, rural livelihood and local biodiversity[98 99]. Additionally, policies that favor the spread of traditional land management practices and agro-ecological knowledge allow for multifunctional landscapes to prosper[100].

Landscape connectivity should have a social dimension[101] and an inclusive approach in order to achieve effective ways of accommodating and managing the competition and interdependencies of natural resources, cultural heritage values and ecosystem services among land users[102].

Land devoted to connectivity does not have to exclude human use and can help protect important cultural, spiritual or historic sites[103]. If managed correctly, and if property rights permit, increasing connectivity in a landscape can increase the ecosystem services available to stakeholders. It can also maintain or enhance community access to ecosystem services.

'Landscape thinking'[104] has started to gain momentum and is not defined by geographical scale, but rather by the management of different land uses[105]. It includes a cross-sectoral approach, which will also help avoid fragmented policies that do not bring together various stakeholders[106]. Developing methods for landscape-level planning, implementation and assessments requires the participation of all.

[96] e.g. policymakers, land owners, famers, academic institutions, government and non-government organizations, conservation biologists, landscape ecologists, financial institutions, value chain partners, and other specialists (USDA, 1999). [97] Reed *et al.*, 2014; de Vente *et al.*, 2016. [98] Shadie & Moore, 2012. [99] Rosset, 1999. [100] Castillo & Toledo, 2000. [101] e.g. adaptive governance (Folke *et al.*, 2005). [102] e.g. Within Europe, policy-makers have integrated the concept of 'Nature-Based Solutions' (NBS) into their new framework programme for research and innovation, 'Horizon 2020', providing a new narrative involving biodiversity and ecosystem services aligned with goals of innovation for growth and job creation ("Nature Based Solutions", European Commission). [103] e.g. the Mesoamerican Biological Corridor (MBC) incorporates 600 protected areas that often include original indigenous inhabitants and all the major Mayan archaeological sites. The MBC project also plays an important role in promoting peace and cooperation (Graham, the World Bank). [104] 'Landscape thinking' strives to establish coordinated thinking across existing governance boundaries and between different stakeholders in a landscape (Minang *et al.*, 2015). [105] e.g. the IUCN World Commission on Protected Areas has developed a Connectivity Conservation Management Framework that considers spatially and environmentally diverse habitats, and the range of stakeholders involved (Worboys *et al.*, 2010). [106] Rueff *et al.*, 2015.

The Hercules Project

The HERCULES project understood landscapes as spatial representations of complex interactions between human activities and ideas, social structures, and physical features. The project has underlined the importance of having a landscape approach at the centre of policy and governance models.

Incentives alignment

Governments and regulatory bodies should also prioritize the creation of new incentives and ensure that those already relevant to conservation[107] promote landscape connectivity. Large-scale initiatives for developing corridors are often expensive and complex[108] and so incentives, financial support and insurance schemes should reflect the resources required for these kinds of projects. Incentives should be directed and easily accessible to those bearing the costs.

Incentives that do not directly focus on sustainability, should, at the very least, not impair connectivity. In the EU, the Common Agricultural Policy directly promotes the restoration and maintenance of Ecological Focus Areas and this can be conducive to connectivity[109]. It is however limited because it is possible to receive green payments without a specific effort to enable connectivity. Incentives should encourage the creation of corridors, as well as their sustainable management for wider landscape connectivity.

Policymakers should also be aware that motivation will likely vary between stakeholders and monetary incentives will not always be the most important consideration[110].

It can also be difficult to place a monetary value on initiatives—recreational opportunities provided by corridors shared by humans and wild animals are highly valued, for example, but it is difficult to put a value on their benefits[111]—and so creating appropriate incentives is not always straight-forward. Incentives are also specific to the location and study site and depend on who is providing conservation services[112]. The idea is to create new incentives, align existing ones, remove disincentives and subsidies that encourage further fragmentation.

Addressing potential challenges

Finally, policymakers need to address potential challenges facing the promotion of landscape connectivity. Projects need to consider issues such as species demography and genetics to avoid population losses or reduced local adaptations. Connectivity should not act as a conduit for unwanted species or increase competition for resources[113] or pollination services[114]. Appropriate management is also critical to successful conservation and preventing problems associated with greater connectivity[115]. More research is required to identify how to avoid and mitigate these challenges.

Creating successful partnerships also requires careful consideration as it can be a complex process. Satisfying all stakeholders is not always possible and can result in potential tradeoffs.

"We are promoting and enabling action to protect and enhance biodiversity, primarily by managing marginal and less productive farmland alongside fields and waterways to create rich, connected wildlife habitats. Working in partnerships with others – farmers, academic institutions, NGOs, governments, and other organizations – is an essential part of our approach."

Romano De Vivo
Syngenta

[107] e.g. Payments for Ecosystem Services (Naeem *et al.*, 2015). [108] Pulsford *et al.*, 2015. [109] To be eligible for these incentives, farmers have to apply one of the following three practices: maintaining permanent grassland, crop diversification or maintaining an Ecological Focus Area of at least 5%, later increasing to 7%, of the arable area of the holding (Massot, 2016). [110] The highest motivation factor for landowners in the River Raisin watershed to adopt conservation practices was related to their intrinsic motivation and attachment to their land, and the lowest motivational factor was receiving payments for the conservation efforts (Ryan *et al.*, 2003). [111] USDA, 1999. [112] Narloch *et al.*, 2013. [113] Stroller *et al.*, 1997. [114] Free, 1993. [115] e.g. spread of pathogens and invasive species (Park *et al.*, 2003; Thies *et al.*, 2005; Avelino *et al.*, 2012)

4. **Call to action**

Multistakeholder platforms are essential for successful landscape connectivity. Identifying sector responsibility gives an indication of how groups can best work together.

With such a policy framework in place, stakeholders, including businesses, are in a better position to improve connectivity. The first step in doing so must involve the creation of multi stakeholder platforms.

Multifunctional landscapes can restore ecological integrity, improve human well-being and support businesses, but doing so must involve partnerships. Supporting existing multistakeholder platforms and creating new ones is essential to successful landscape connectivity.

The Bonn Challenge, for example, is a practical way of bringing together existing international commitments, with a pledge of almost 150 million hectares[116]. Involving a range of stakeholders means that expertise from all sectors is included in the planning, implementation and monitoring phases. The table below shows what different stakeholders are often best able to contribute to such efforts.

Identifying sector responsibility will benefit landscape connectivity actions and gives an indication of how groups can best work together.

Such cross-sector collaboration is often more applicable to landscapes with relatively large, uniform landholdings. However, landscapes can consist of a complex mosaic of smallholders that would benefit from similar, inclusive models[117]. Addressing intra-governmental tensions in developing economies can further harmonize land-use-management strategies.

Businesses and other stakeholders united in this way are then in a better position to contribute to the creation of additional landscape connectivity and wildlife corridors through three key approaches: using marginal land in rural and industrial areas; implementing, supporting and encouraging spatial planning and, finally, introducing green infrastructure in and around urban areas.

Connectivity opportunities across all landscapes

An elaboration of FAO data by Syngenta indicates that 41.3 % of global land cover is agricultural land, 34.6 % is dedicated to conservation, 24.2 % is intact land, 3.1 % is marginal agricultural land and 0.2 % consists of buildings.

Table 5:
Examples of stakeholders and how their involvement can support landscape connectivity platforms

Stakeholder examples		Expertise
International organizations	WBSCD	Access to businesses, experience in creating working groups and bringing partners together.
	Bioversity International	Research focused and can provide sound scientific advice for developing and monitoring protocols
UN Conventions	UNCCD	Access to governments, committed to a collaborative and bottom-up approach.
Local institutions	Universities	Knowledge on specific characteristics of local landscapes.

Table 6:
Defining sector interventions and other contributors for landscape connectivity actions

Actions	Sector intervention	Other contributors
Use marginal land in rural and industrial areas	Private	Enabling policies from the public sector
Implement spatial planning	Mainly public	Businesses can play a supportive role
Introduce green infrastructure in urban areas	Private	Governments need to allow greening infrastructure

[116] Bonn Challenge. [117] e.g. Grow Asia.

Restoring wetland areas

Mondi partnered with WWF to restore wetland areas by businesses in water-stressed landscapes across South Africa to create a connected ecological network that now accounts for 25% of its production land (>0.5 million hectares). Restoring freshwater ecosystems significantly improved their reputation and has provided Mondi with long-term ecosystem service benefits securing the ongoing productivity of its land.

Enhancing biodiversity

Syngenta is committed to enhancing biodiversity on 5 million hectares of farmland by 2020, primarily by managing marginal and less productive farmland alongside fields and waterways to create rich, connected wildlife habitats. In the last three years, they have engaged in programs contributing 4.9 million hectares by working together with farmers, NGOs and local stakeholders.

Using marginal land in rural and industrial areas

The biggest opportunity for enhancing biodiversity in agricultural landscapes via inter-connected ecological corridors is to create rich habitats in field margins and riparian zones by rivers. Off-season management such as the winter flooding of rice fields in temperate regions to create a comprehensive water network can also contribute to connectivity[118]. Better crop production systems, including tree crops and shade crops, can help farming contribute to a healthy matrix.

Achieving connectivity involves working across all different types of land in a landscape. Restoring uncropped and abandoned areas (alongside sustainable management practices on cropped areas) can provide the backbone for a topographically and hydrologically defined ecological network capable of delivering multiple benefits[119]. Ongoing management of these conserved or restored areas is critical to their continued function[120] and establishing corridors with uncropped, abandoned or marginal land can provide substantial landscape connectivity benefits[121].

Introducing multifunctional field margins is an excellent solution for increasing landscape connectivity while also significantly improving agricultural practices by supporting pollinators, pest management, soil and water conservation and overall ecosystem resilience[122].

These factors can play an important role in improving socio-economic outcomes, such as increased yield or higher market value and demand as a result of implementing biodiversity measures. Best management practice for marginal land is to take it out of production and use it for connectivity purposes.

At a landscape level, silvopastoral[123] systems, an agroforestry practice that integrates livestock, forage production, and forestry on the same land, can integrate connectivity corridors so that they provide more ecosystem services, remain productive for longer and reduce pressures to clear more forest compared to conventional pasturelands[124]. Agroforestry works across a range of landscapes to enhance connectivity and provide farmers with additional products and income[125].

[118] Bouman *et al.*, 2006; Elphick & Oring, 2003. [119] e.g. to successfully create windbreaks to manage wind soil erosion, both the horizontal structure (i.e. proper spacing of windbreaks and rows within the windbreak) and vertical structure (i.e. include plant sizes from ground level upwards) should be introduced (USDA, 1999). [120] Management of an ecological network can be 2-5 times more influential than the design (Bazelet & Samways, 2011). [121] A biodiversity 'spillover' effect occurs when species biodiversity is increased within target patches and corridors allow surrounding non-target habitats to benefit. A largescale corridor experiment showed that increased richness can extend for approximately 30% of the width of 1-ha connected patches (Brudvig *et al.*, 2008).
[122] The restoration and creation of field margins is considered to be part of agri-environment schemes (initiatives that support environmental improvements in farming) as a biodiversity, soil, and water conservation measure, alongside providing resilience against climate change (Donald & Evans, 2006). [123] USDA, 2008. [124] Increased milk and meat production with no evidence of decreasing grazing potential can be achieved by creating a system of high density fodder shrubs, improved and productive pasture lands and planted timber tree corridors (Murgueitio *et al.*, 2010).
[125] Agroforestry in pasture lands can provide marketable wood products and non-timber products (Murgueitio *et al.*, 2010).

Four main agroforestry ecosystem services and environmental benefits

Increased carbon sequestration, biodiversity conservation, soil enrichment and improved air and water quality (Jose, 2009).

Agricultural landscapes that include such field-based and farm-based sustainable land management practices additionally work towards creating 'climate-smart landscapes' that help address food security needs[126]. Such integrated landscape management is emerging with the focus on supporting food production, ecosystem conservation and rural livelihoods[126].

The use of marginal land, especially on farmland, is particularly important for crop wild relatives as they act as a source of genes for enriching the genetic pool of adjoining cultivated plants. Conservation interests of CWR often occur in areas not considered as conservation priorities[127] according to site-based conservation measures.

Implementing, supporting and incentivizing spatial planning

Incorporating landscape connectivity concepts into spatial planning can be an effective means of integrating it into policy frameworks. Some countries have successfully achieved this by creating regulations covering spatial planning. For example, Denmark's Consolidated Planning Act requires corridors to be included in municipal land use plans[128]. Such policies also need to represent urban and rural development plans that consider new land developments or restoration of degraded lands[129].

Stakeholders should consider the full set of environmental impact assessment tools at their disposal for new land development. The High Carbon Stock Approach has developed a methodology for companies to distinguish between forest that needs protection and degraded land that can be converted. The resulting decision tree includes basic guidelines for assessing the level of fragmentation and connectivity in an area[130].

Connectivity features across landscapes

Olam's commitment to growing responsibly involves creating new palm oil plantations, preserving land and integrating riparian corridors, ecosystem blocks and conservation corridors at a landscape scale.

"Olam used a landscape analysis combined with site level HCV assessments to embed landscape connectivity into the design of its Gabon oil palm plantations. The spatial plan incorporates large blocks of core habitat, linked by corridors and riparian buffer zones, to preserve sufficient habitat for viable populations of priority species, and to ensure easy movement of animals across the plantations and beyond their boundaries. A key aspect was to incorporate the hydrological system in the design, protecting the health of seasonal wetlands and streams."

Christopher Stewart
Olam

[126] Scherr *et al.*, 2012. [127] i.e. disturbed habitats and landscape features, grassland habitats, cropped and weedy areas, fertile grassland and lowland woodland (Jarvis *et al.*, 2015). [128] e.g. Shadie & Moore, 2012; Barcelona has created a tool, SITxell, for its municipalities that provides decision-makers and land planners in the Province with knowledge about the ecological and socioeconomic values of natural areas and to support spatial planning (Castell, n.d.); the Streamside Protection Regulation (SPR) in British Columbia, Canada mandates riparian buffers of given widths in several key municipalities (The Pacific Streamkeepers Federation, 2001). [129] e.g. the EU Strategy on Green Infrastructure. [130] HCS Approach Steering Group, 2015.

Improving the working environment

By improving the working environment (e.g. increasing daylight), productivity can increase by up to 16%. Effects on brand image are harder to quantify but their value should not be underestimated or disregarded (Johnson, 2000).

Creating green infrastructure

Choosing to construct 45 hectares of wetlands for tertiary water treatment instead of installing the equivalent 'grey' infrastructure at its Union Carbide Corporation site in Texas saved The Dow Chemical Company about $282 million over the project's lifetime and provided an estimated net worth of $20 million. The Dow Chemical Company lowered its environmental impact and supported compliance to environmental protection guidelines.

Companies involved in resource extraction, oil and gas, agriculture and construction can play a role by incorporating fragmentation prevention and mitigation strategies into decision making. Certification schemes that include conservation principles can also contribute to better spatial thinking in planning and design.

A healthy landscape matrix should focus on maintaining sufficient habitat and connectivity for wild and functional species. Having such a matrix is very important for facilitating movement[131], and can provide an important source of food, seasonal cover and temporary refuges when disturbances occur[132]. Therefore, matrix management can also have a big impact on the connectivity value of surrounding ecosystems[133] and should be considered in spatial planning. Many animals and plants will not restrict their movement or dispersal to the specific corridors provided[134], but rather show behaviour that responds to the whole mosaic in the landscape[135]. Spatial planning can drive successful sustainable land management approaches to deliver benefits[136].

Introducing green infrastructure in and around urban areas

Manufacturers, retailers and processors can contribute to connectivity by integrating their infrastructure into a green network system. The EU Strategy on Green Infrastructure[137] and the Urban Infrastructure Initiative communicate the benefits of 'green urban planning'[138]. The highest ranked business reasons for creating green infrastructure are lower operation costs, higher building value and lower lifetime costs[139]. However, despite these benefits, there is still the perception that green buildings generate extra upfront costs, discouraging the private sector[140].

Businesses will become a leading example of how lowering environmental impact can lead to additional social and economic gains when introducing elements of green infrastructure into operational facilities. The creation of green buildings is starting to increase as the business case becomes more compelling[141]. They provide a long-term competitive advantage that can reduce costs, increase productivity and improve brand image.

[131] Improving the quality of the matrix may lead to better conservation returns than changing the size or configuration of the remaining patches of natural habitat (Prugh *et al.*, 2008). [132] Species are more likely to go extinct in patches of habitat where there are no foraging opportunities in the surrounding matrix (Driscoll *et al.*, 2013). [133] e.g. increased agricultural development in the Southern High Plains in the USA was found to increase levels of sedimentation, decreasing the length of time that the surrounding wetlands supported water, which reduced the habitat connectivity for two species of spadefoot frogs (Gray *et al.*, 2004). [134] Haddad *et al.*, 2003. [135] Bennett, 2003. [136] Persey *et al.*, 2011. [137] European Commission, 2016a. [138] WBCSD, 2014. [139] Chan *et al.*, 2009. [140] Johnson, 2000. [141] Hamilton, 2014.

Currently many green buildings focus on savings from energy and water efficiency. Principles of landscape connectivity are an innovative addition to the design of green buildings, or as a way of converting grey buildings, to enhance the environmental, economic and social benefits. Green urban infrastructure can also help form alternate routes between disconnected natural ecosystems. Abandoned or unused pieces of land can be transformed into urban gardens and farming opportunities.

Urban agriculture can improve the environment, allow communities to grow, create aesthetic places, and increase food security and residence health[142]. Knowledge about agricultural production is brought closer to urban areas and the public is educated about where fruits and vegetables come from[143]. The concept of urban agriculture also has a business potential and does not have to be limited to being an individual, family, community or non-profit venture.

Sustainable distribution centres

Nike is introducing sustainable innovation in its distribution centres to improve company growth and customer service, while also taking into consideration its environmental impact (Zhang, 2016).

Big City Farms

Big City Farms in Indiana is a business that uses vacant, residential lots and other urban areas for urban agriculture to grow vegetables sustainably. They operate a Community Supported Agricultural Program, work together with local chefs and have partnered with a youth and empowerment program (Big City Farms).

"The Dow Chemical Company champions the idea that dependencies and impacts on ecosystem services should be considered in business decisions. When solving infrastructure problems, we strongly consider green infrastructure solutions and mixes of green and grey."

Mark Weick
The Dow Chemical Company

[142] Bernstein, 2014. [143] Christiane, 2013.

5. **Next steps**

To raise awareness of the importance of increasing landscape connectivity and closing the gap between policy intent and what is happening on the ground. We encourage stakeholders to incorporate connectivity into their planning and practices and to establish public-private-community partnerships.

In order to help all stakeholders proceed with the steps identified above, WBCSD, its member companies and partners will be working to raise awareness of the importance of increasing landscape connectivity and closing the gap between policy intent and what is happening on the ground. We will, among other things, encourage and support member companies and partners to use this paper as a reference point for incorporating connectivity into their planning and practices and for establishing public-private-community partnerships. We will also encourage member companies and partners to collaborate with research and policy-making institutions to support landscape connectivity.

Landscape-level planning and implementation

Businesses and other stakeholders should not only maintain and monitor areas that have already been dedicated to landscape connectivity, but also work to expand dedicated terrain.

Successfully developing methods for landscape-level planning and implementation will require collaboration between many stakeholders and the focus will need to be on local community needs. Stakeholders must be aware of differing motivation factors and design incentives accordingly while considering all available means, including impact assessment and spatial planning tools. Stakeholders should focus on simple and workable solutions for landscape connectivity at all scales.

Though all stakeholders should work together, businesses in particular can help enhance landscape connectivity through better management practices such as restoring marginal, better matrix management and improving managed green areas. They should incorporate spatial planning in development options and use a mitigation hierarchy for new developments to prevent fragmentation of natural ecosystems.

Finally, the private sector should look to introduce green urban infrastructure, adhere to standards and follow effective implementation and monitoring strategies.

Looking ahead, all stakeholders should focus on collecting and distributing robust research based evidence confirming that corridors and ecological networks provide effective connectivity as well as acting as habitats in their own right.

"By creating partnerships with stakeholders across the supply chain, we encourage private industry to commit to sustainability goals that benefit both their business and local communities. Our active involvement in landscape connectivity is the result of its role in addressing the needs of smallholder communities to produce more and better quality crops, reduce environmental impacts and increase market access. The smallholder productions of sustainable coffee in Peru and of cocoa in Ghana are examples of the successful alliance of forest use and connectivity in the landscape."

Jeroen Douglas
Solidaridad

Appendix Examples of connectivity

Private sector	
The Sustainable Land Management Plan Votorantim Cimentos Brazil	During the execution of the Sustainable Land Management Plan, carried out in the Technical Cooperation between Votorantim Cimentos - Brazilian Speleological Society - Biosphere reserve of Atlantic Forest , an unused area of land was identified that encompasses important natural landscape attributes (i.e. the mangrove and Atlantic Forest remnants), historical and cultural buildings (i.e. Casarão house). In order to merge all these assets into a single landscape and assuring its conservation, the Company is creating a natural trail open for the local community and serving as a new attraction (recreational and educational demands).
Palm oil plantation Olam Gabon	Planting 50,000 hectares new palm oil plantations and setting aside 61,000 hectares (>50% of its total concession areas). Connectivity features were designed including riparian corridors, ecosystem blocks and conservation corridors as a part of Olam's commitment to growing responsibly. Conservation of key species, i.e. elephants, chimpanzees, gorillas and other rare/endemics species, through the land set aside. Provided access to market, license to operate in the country of origin and motivational factors for Olam's staff. Reduced scope for conflict with local populations, a collaborative spirit with local NGOs and a positive platform for engagement with critical international NGOs. Contributes to the national strategy for sustainable development and international climate change commitments.
Restoration program for the freshwater ecosystems Mondi South Africa	Initiated a strategic partnership with Stellenbosch University to drive the scientific research in its area. A programme initiated by WWF and Mondi catalysed the restoration of wetland areas (restored riparian zones of 30m either side of waterways were restored) by businesses in water-stressed landscapes across South Africa. Mondi has created an extensive and connected ecological network that now accounts for 25% of its production land (>0.5 million ha). Helped establish Mondi's reputation as a responsible business in the landscape. The restoration of freshwater ecosystems will provide Mondi with long-term ecosystem service benefits, securing the ongoing productivity of its land.
Valuing Nature The Dow Chemical Company US	Co-sponsor of the Natural Infrastructure for Business Initiative at the WBCSD. Launched seven strategic 2025 Sustainability Goals in 2015; the Valuing Nature Goals commits The Dow Chemical Company to incorporate the value of nature into its decision making processes. In one project, the company opted to construct 45 hectares of wetlands for its tertiary water treatment instead of installing the equivalent 'grey' infrastructure at its Union Carbide Corporation site. Lower environmental impacts across a broad range of indicators and wetlands are supporting a number of endemic bird and plant species. This project generated net present value savings of $282 million over the project's lifetime without having to commit a larger area of land that would have been required for the 'grey' infrastructure option, reducing operation and maintenance costs of the site, while supporting compliance with the U.S. Environmental Protection Agency effluent guidelines.
The Good Growth Plan Syngenta 30 countries	Involved in restoring and enhancing biodiversity across agricultural landscapes (www.goodgrowthplan.com). Importance is placed on increasing the quality and amount of marginal land to improve crop yield and quality. • Create ecological networks to reintroduce local plant species, increase pollinator species and biodiversity, and increase organism food resources. • Improve water, fertilizer and pesticide management. • Prevent soil erosion and improve soil management. • Improve partnerships with local stakeholders.

Public sector	
Latin America	More than 100 corridors have been created with more than 20 crossing two or more national borders. Bolivia, Brazil and Venezuela even have national legislation enabling corridors[144]. Panthera[145] has launched the Jaguar Corridor initiative, which aims to link core jaguar populations within the human landscape from northern Argentina to Mexico. The jaguar is currently threatened throughout its range due to habitat loss and fragmentation, hunting, and a lack of natural prey. Efforts to create and maintain biological corridors in Mesoamerica[146] and in Costa Rica[147].
Africa	Efforts in Africa have been directed towards transboundary protected areas, or 'peace parks', to incorporate the ranges of large vertebrates and enable political stability. However, none of the countries in Africa are known to have legislation specifically enabling connectivity or corridors[148]. The Great Green Wall for the Sahara and the Sahel Initiative is a pan-African programme to reverse land degradation and desertification, improve food security and boost local communities and their resilience to climate change[149].
North America	The Yellowstone to Yukon Conservation Initiative covers 3,200km of the northern Rocky Mountains[150] to reduce the major impacts building roads has on connectivity. As part of the initiative, 44 overpasses and underpasses have been constructed to enable the movement of animals across roads. In 2012, the Wildlife Conservation Board funded a project to map wildlife connectivity areas in the northern Sierra Nevada[151]. Scientists identified climate change refugia and connectivity between meadows across the Sierra Nevada. The TransCanada Highway cuts across the Banff National Park in Alberta, Canada, fragmenting critical habitat and creating a large barrier to wildlife movement[152]. To facilitate movement, Man-made overpasses and underpasses were constructed to span the highway to facilitate movement, provide a critical connection between fragmented forests and allow for continued gene flow between populations. There is a state-wide project with the goal of linking existing patches of natural land, water, farms and ranches throughout the Florida Peninsula[153]. Corridors are created to enable the movement of large mammals, allow continued flow of natural watersheds and protect existing agricultural land.
Oceania	Australia has seen a rapid growth in the establishment of networks of lands managed for connectivity conservation across tenures, at landscape and sub-continental scales. Their establishment has varied from state government-led initiatives to those initiated by non-government organizations and interested landholders[154]. The Great Eastern Ranges Initiative is a landscape-scale conservation corridor that stretches along the eastern coast of Australia from Victoria to far north Queensland[155]. The Initiative is a strategic response to mitigate the potential impacts of climate change, invasive species, land clearing and other environmental stresses on an area that contains high biodiversity.
Europe	Green and blue infrastructure: it is an ecological network for biodiversity conservation whose purpose is to incorporate the issues of maintaining and strengthening the functionality of natural environments into planning tools and development projects[156]. The Netherlands contains over 600 man-made ecological corridors, including overpasses and underpasses along busy highways. The longest of these, the Natuurbrug Zanderij Crailo, is an overpass that is part of larger protected area that provides forest and other natural habitats for a range of species[157]. Life Elia creates green corridors under overhead electricity cables throughout wooded areas in Belgium and France[158].
Asia	A three-level urban greening system is introduced in Beijing at a regional, city and neighborhood level[159]. Great Green Wall: planted wind-breaking forest strips designed to hold back the expansion of the Gobi Desert and now supposed to further expand alongside the Silk Road route[160]. The Terai Arc[161] is a large region encompassing the border of Nepal and India, covering 11 protected areas in India and Nepal and large non-protected areas between them. Among the non-protected areas are corridors and bottlenecks that are critical for wildlife species, movement between protected areas and for maintaining sufficient gene flow.

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