THE ROLE OF ECOLOGICAL RESTORATION AND REHABILITATION IN PRODUCTION LANDSCAPES:
An enhanced approach to sustainable development

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EXECUTIVE SUMMARY: KEY RECOMMENDATIONS

The annual costs of land degradation are thought to be in the order of 10-17% of global gross domestic product (GDP). The very high costs of land degradation makes large-scale ecological restoration a global imperative.

This paper documents the areas wherein, and manners whereby, large-scale ecological restoration has the potential to be an integral component of the sustainable management of natural capital within production systems. The paper reviews the main land management approaches that could drive large-scale uptake of ecological restoration in agricultural landscapes; in doing so, it also describes where and how some of the main barriers to widespread uptake can be found, and overcome. The approaches were selected for being integrated, and ecosystem-based, participatory in form, collaborative and involving multiple stakeholders. All approaches are equally applicable in low and high socioeconomic contexts because they aspire to collaborative, risk sharing implementation. The approaches focused on are:

- New integrated approaches
- Novel ecosystems and adapting to rapid global change
- Climate-smart agriculture and enhancing socio-ecological resilience
- Increasing the multi-functionality and productivity of agricultural landscapes
- Green infrastructure and nature-based solutions
- Rewilding abandoned agricultural lands
- Urban and peri-urban development
- Infrastructure development and biodiversity offsets

The paper also describes several case studies, in Africa and Asia, where ecological restoration is a key part of sustainable agricultural production.

Visionary approaches to integrate ecological restoration into sustainable land management

Visionary approaches that could drive widespread uptake of ecological restoration within production landscapes are identified:

- Conservation development: New urban developments at the urban fringe, which incorporate protected and restored greenspace, potentially forming networks with existing protected areas, and providing many human, social and psychological well-being benefits;
- Sustainable agricultural product certification: Expansion of the Sustainable Agriculture Network/Rainforest Alliance (SAN/RA) certification to include a requirement that producers restore farms to contain a minimum cover of native vegetation of 10-15%;
- Rewilding for green infrastructure: Planning and building green infrastructure networks that diversify landscapes, provide multiple benefits, and respect plural social values. For example, in Europe, an estimated 2.2% of agricultural land must be restored annually so as to maintain the supply of ecosystem services at 2010 levels, while a similar magnitude of agricultural land will simultaneously be abandoned;
- Multi-valued payment for ecosystem services: An incentive scheme which rewards ecological restoration, while respecting multiple social values. Payment schemes can motivate large-scale restoration, provided the shared cultural and plural values of local communities are understood and respected;
- Climate-smart ecological restoration: Ecological restoration that insures against future risks of climate change and other rapid global changes. The future of agricultural landscapes is increasingly uncertain; ecological restoration can mitigate damages from extreme and variable climates, shifts in commodity markets, and, especially, from future events which are currently unknown and/or only predicted.

Key recommendations to overcome hurdles to mainstream ecological restoration

Various challenges and barriers to the uptake of ecological restoration within sustainable land management approaches are summarized herein. The factors identified in the literature include: i) poor communication of technologies and benefits; ii) lack of capacity, networks and knowledge within farmer communities; iii) poor governance, legal, planning and tenure systems; iv) programme short-termism and fragmentation; and, v) a lack of shared understanding of the risks mitigated by, and benefits arising from, restoration. From our review of restoration projects and the scientific literature, there are several ways these barriers can be overcome.
These are our key recommendations for integrating restoration and rehabilitation projects and programmes within wider sustainable landscape approaches:

1. Make ecological restoration attuned to the multiple functions of landscapes, so that restoration targets satisfy the requirements of ecosystems and landscapes to supply multiple ecosystem services, including a wide range of cultural and social values.

2. Incorporate ecosystem services into greening projects and engage early with stakeholders. This empowers local citizens and is more likely to lead to successful implementation of large-scale green infrastructure and urban greening planning because of the realized ecosystem service benefits.

3. Communicate the benefits of restoration in an adequate manner, so as to ensure farmers’ comprehension. Farmers are, in general, more likely to plant trees to restore farmland if they benefit from larger households (i.e., more available labor) and are more literate and aware of the longer-term benefits of reducing degradation.

4. Ensure economic instruments to motivate and reward restoration (e.g., payments for ecosystem services); these must be consistent with the preferences and values of local communities, so efforts must be made to understand and respect shared cultural and plural social values.

5. Target sustainable land management policies toward different revegetation methods, socioeconomic incentives, habitat protection mechanisms, sustainable livelihoods, diversified funding and partnerships, technical support, and green infrastructure development. Doing so is more likely to have beneficial effects on the success of reforestation programmes.

6. Accept the legitimacy of multiple values and acknowledge the concerns of multiple stakeholders as a prerequisite for planning landscapes that contain a mix of intensive agricultural uses with low intervention re-wild habitat on abandoned land.

7. Calculate the full economic value of urban greenspaces (and green infrastructure) via ecosystem services valuation techniques to give credibility and increase public acceptance of urban greenspace.

8. Widen the scope and be open minded to the many different forms of ecological restoration in urban areas, and communicate the benefits of restoration to urban planners and stakeholders.

1. INTRODUCTION

Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration International Science and Policy Working Group, 2004). Ecological restoration is required when the degraded ecosystem is unable to self-repair. The main aim of ecological restoration is to reinstate ecological processes and functions that are resilient, adaptable to change, and deliver important ecosystem services.

Ecological restoration is especially important in agricultural and other intensive use landscapes where degradation and extensive modification is widespread. Recent estimates of the global extent of land degradation range from 991 million ha, mainly consisting of degraded and abandoned croplands (Cai et al., 2011), to over 6 billion ha of land (66% of the global land surface) affected by some form of land degradation (Bot et al., 2000). Significant economic costs arise from continued land degradation and land use change, estimated to be in the order of 10-17% of current global GDP, annually (ELD Initiative, 2015). Large-scale ecological restoration is needed to improve the condition of these vast tracts of degraded land; doing so can lead to increased crop yields (Branca et al., 2013), as well as to many other social, economic and ecosystem benefits, such as enhanced supply of regulation and cultural ecosystem services (ELD Initiative, 2015).

1.2 Why so much degradation?

There are several reasons for widespread degradation of ecosystems. Firstly, agriculture has adopted practices to maximize yield, which has typically required mechanization and heavy use of inputs, with minimal consideration for the environmental impacts thereof. Conversion of land from permanent forested cover to annual crop production and/or pasture for livestock is motivated by incentives which reward yield increases through greater income. Secondly, markets for food and other products derived from the land (e.g., minerals, water) do not adequately value the contribution of natural capital to the production of these goods. There are no market signals to sustainably manage the land and maintain the stock of natural capital because the prices paid for agricultural commodities do not adequately reflect the full costs incurred by commodity production. These externalities are now well recognized and governments in many countries are working to develop policies and regulations which internalize the externalities. Thirdly, the presence of perverse incentives across the globe encourage food production and infrastructure development for national and economic security reasons at the expense of environmental protection.
In recognition of the wide extent of land degradation and the many demonstrated benefits of ecological restoration, there is a need for an orders of magnitude increase in ecological restoration activities, globally; by some accounts this ought to be a hundred-fold increase (Alexander et al., 2016). Major international conventions (e.g., CBD, UNFCCC, UNCCD, Ramsar), programmes and platforms (e.g., IUCN, UNEP, UNDP, UNFF, FAO, IPBES), as well as the 2015 UN Sustainable Development Goals (SDGs) recognize the importance of large-scale restoration for achieving sustainable development goals and targets (Akhtar-Schuster et al., 2016). The UN SDGs include a target to achieve land degradation neutrality globally, by 2030, which will require extensive ecological restoration (UNCCD/Science-Policy Interface, 2016). Figure 2 shows that many other targets of the SDGs are relevant to the sustainable management of land systems, which puts increased emphasis on the importance of ecological restoration in degraded production landscapes. The 2015 UNFCCC Paris Agreement recognizes the importance of enhancing forest and soil carbon stock to mitigate climate change. There are also a number of regional and national policies and programmes promoting large-scale ecological restoration (Aronson and Alexander, 2013).

However, there are several implementation, financing and regulatory challenges to overcome before ecological restoration can be mainstreamed. Ecological restoration requires new capacity-building, knowledge-sharing and awareness-raising initiatives to become a large-scale and widespread activity (Aronson and Alexander, 2013). Perverse incentives which encourage intensive and unsustainable agriculture need to be removed, and appropriate market signals to protect and restore natural capital need to be established. Regulatory and planning instruments need to be expanded so that restoration becomes a requirement within land and water management regimes.

Figure 1: The links from natural capital to human well-being, and back.
Ecological and socioeconomic sustainability is achieved through recognizing and accounting for the links in this pyramid. The restoration of natural capital generates many benefits to society.
Source: Alexander et al. (2016).
1.3 Purpose of this working paper

The aim of this paper is to document the areas wherein, and manners whereby, ecological restoration has been, or has the potential to be, an integral component of the sustainable management of natural capital within production systems. This paper reviews the main land management approaches that could drive large-scale uptake of ecological restoration in agricultural landscapes; in doing so, it also describes where and how some of the main barriers to the widespread uptake of restoration can be found, and overcome. The approaches were selected for being integrated, ecosystem-based, participatory in form, collaborative and involving multiple stakeholders. All approaches are equally applicable in low and high socioeconomic contexts because they aspire to collaborative, risk sharing implementation.

The approaches focused on are:
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2. NEW APPROACHES FOR LARGE-SCALE ECOLOGICAL RESTORATION

2.1 New integrated approaches

New and emerging integrated landscape approaches to conservation and restoration of land and water resources provide opportunities for wider uptake of ecological restoration. These approaches aim to deliver multiple benefits by way of enhanced land and water management, minimizing trade-offs and taking advantage of synergies between: food and timber production; water supply; biodiversity conservation; supply of other ecosystem services; and poverty alleviation (Estrada-Carmona et al., 2014). These integrated approaches lead to more sustainable resource use; their implementation involves: planning and designing landscapes at multiple scales; identifying and respecting the needs and perspectives of multiple stakeholders; improving coordination between multiple sectors; enhancing human and institutional knowledge and capacity for decision making; and implementing policies and incentives that encourage sustainable outcomes (Estrada-Carmona et al., 2014; Faizi and Ravichandran, 2016).

Three landscape-scale integrated planning approaches, tailored toward agricultural land, forestry and water management sectors, respectively, are Sustainable Land Management (SLM), Sustainable Forestry Management (SFM), and Integrated Water Resources Management (IWRM). Each of these approaches holds much promise for widespread adoption of ecological restoration.

Sustainable land management (SLM) is also known as multi-functional agriculture (Jordan and Warner, 2010), eco-agriculture (Scherr and McNeely, 2008), whole landscapes management (DeFries and Rosenzweig, 2010), multifunctional landscapes (Sayer et al., 2013; García-Martín et al., 2016), integrated landscape management (Estrada-Carmona et al., 2014), agroecology (Altieri, 2002), and about eighty other lesser-known or lesser-used terms (Scherr et al., 2013). The diverse terminology has arisen due to nuanced differences between approaches, but common across all SLM is the holistic and interconnected management of land for the multiple objectives of food production, biodiversity conservation, sustainable rural livelihoods, and other ecosystem service benefits derived from sustainable stewardship. SLM approaches applied in developing countries also have poverty alleviation and rural empowerment as prominent goals (Mganga et al., 2015; Adimassu et al., 2016). Most recently, SLM has been broadened to incorporate climate change adaptation and resilience (Cowie et al., 2011; Schwilch et al., 2014), in particular, through the design of multi-use land systems providing diverse income sources, including biomass for alternative energy production (Cushman et al., 2015).

Sustainable Forestry Management (SFM) is the use and conservation of forests ensuring that their multiple economic, social and environmental values are maintained and enhanced for the benefit of present and future generations (MacDicken et al., 2015). SFM recognizes that forests can simultaneously perform many functions and deliver many different types of goods and services, depending on national and local conditions (Miura et al., 2015). Sustainable forestry, in the traditional sense, aims to ensure timber production can continue indefinitely for a continued income stream. SFM additionally requires that broader social, cultural and environmental values are maintained in perpetuity. Because SFM can apply to all types of natural, modified and plantation forests, ecological restoration is able to play an important role in returning their multiple original benefits and values to degraded forests. Restoration of forests by reducing the impact of logging has shown to provide benefits, such as climate change mitigation (West et al. 2014). Ecological restoration using forestry species is an important component of integrated landscape planning, and – if managed using SFM principles – can reinstate the multiple functions and services provided by forests (Tesfaye et al., 2015). Box 1 provides a case study in which SFM principles were introduced so as to restore degraded habitat in Tanzania, with multiple economic and environmental benefits.

Integrated Water Resource Management (IWRM), also known as integrated catchment or watershed management (Cobourn, 1999), is the coordinated development and management of water, land, and related resources, in order to maximize economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems (Global Water Partnership, 2016). IWRM recognizes the important contribution of land and watershed management to water yields, water quality, flow regimes and flood risks (de Vries, 2003). Poor land management, which increases the risk of water and wind erosion of soils, impacts on the quality of water entering streams and reservoirs. Similarly, the excessive use of crop inputs (e.g., fertilizers and pesticides), along with poor livestock waste management, also degrade water quality (Bryan et al., 2009; Sutton et al., 2011; Jones et al., 2016). Water yields can be impacted by land cover, with a heavily forested landscape potentially reducing the amount of run-off entering streams and underground aquifers (Zhang et al., 2001). Implementing IWRM in degraded landscapes by excluding stock, and planting perennials – preferably native species – can reduce soil erosion and soil loss to waterways (Haregeweyn et al., 2012), as well as improving biodiversity (Gibson-Roy et al., 2010).
Water management and water supply authorities are important beneficiaries of ecological restoration of degraded landscapes because functioning ecosystems can improve water quality for little cost.

Design of landscapes, using integrated approaches, typically respects the following principles: i) using crop, grass and tree combinations to mimic the ecological structure and functions of natural habitats; ii) minimizing or reversing conversion of natural areas; iii) protecting and expanding larger patches of high-quality natural habitat; and, iv) developing effective ecological networks and corridors (Scherr and McNeely, 2008). Applying these principles provides significant opportunity for widespread ecological restoration, especially in areas where there is extensive degradation.

Integrated approaches take the impacts of land and water resource management decisions into consideration, weighing them against multiple objectives and stakeholder needs, at both the landscape and regional scales. There is considerable scope to mainstream ecological restoration within integrated approaches because its benefits, costs and trade-offs are not confined to a few individual private actors. Ecological restoration within integrated planning approaches enhances the supply of many ecosystem goods and services; this substantially widens the beneficiary pool, and, in so doing, provides non-monetary and monetary economic values that are not otherwise recognized by traditional site-based perspectives of land management (de Groot et al., 2013; Schwilch et al., 2014).

New environmental markets, removal of perverse policies and incentives, and significant technological training and capacity-building are needed so as to encourage the widespread adoption of ecological restoration within integrated planning approaches.

Box 1: Engaging smallholder farmers in forest restoration through market supply chains and technology, Miombo woodlands, Zambia.

Felix Kalaba, Copperbelt University, Kitwe, Zambia

This participatory project is implemented in the Luanshya district, a mining town in the Copperbelt province of Zambia. The project supports farmers in protecting Miombo woodlots on their farms and trains farmers in sustainable forest management and sustainable livelihood improvement. Farmers invited to the project have smallholder farmers with farms of between 4–200 hectares. Their farms contain degraded forests and farmers voluntarily participate in the project. Farmers have varied age, gender and occupation and different social groups. The Luanshya district was selected due to the high deforestation rate of the region, a high dependence on forest products in the mining town, and current economic challenges experienced by the mining sector leading to job losses. The main incentive for farmers to participate is the knowledge gained through training in silviculture, conservation farming practices and permaculture techniques. Importantly the smallholder farmers retain the rights to the benefits from the tree and tree products from the restored woodlands.

The restored forest trees provide farmers with additional ecosystem services and removes pressure from native forests. The Miombo woodlands, like many woodlands in tropical zones, are an important source of foods, medicines, fodder and construction material to local people (Chirwa et al. 2008, Kalaba et al. 2013). Additionally, these woodlands are an important carbon store, and are biologically diverse, providing climate change adaptation and mitigation benefits through increasing carbon sequestration and strengthening capacity of farmers to build resilient livelihoods and ensure more long-term food security.

In this project the local people participate in selecting trees to retain on their farmlands. This is mainly driven by local needs. Farmers are given an opportunity to choose the trees to protect as well as tree species to plant. Many farmers prefer planting fruit trees and trees with medicinal values. Tree planting provides farmers with additional expertise in sustainable forest management. It also contributes to UN Sustainable Development Goal #12 which seeks to ensure sustainable consumption and production patterns. The project also contributes to UN Sustainable Development Goal #15 through promoting restoration, reversing land degradation and halting biodiversity loss in the biologically diverse Miombo woodlands.

Restoration is achieved through assisted natural regeneration involving protection of saplings from fire and nurturing tree saplings, which is done by farmers. The incentives provided to farmers include establishing market linkages for farmers through protecting markets for timber and non-timber forest products. Local farmers are introduced to supply chains through local private sector companies. Sustainably extracted biomass is purchased from the farm cooperative and processed into wood chips to fuel low polluting cooking stoves.
2.2 Novel ecosystems and adapting to rapid global change

Ecosystems are dynamic and undergo continual change in structure, composition and function because of complex interactions between species, climate change and climate variability. Over evolutionary time scales, species respond to climatic changes and niche shifts by dispersing in line with shifting climatic suitability, declining in abundance toward potential extinction, or evolving new mechanisms to adapt to new climates.

Extensive ecosystem modification, in combination with rapid global change – principally from anthropogenic climate change, but also from human demographic, social and economic shifts, as well as due to invasive species introductions – will lead to novel and hybrid ecosystems (Hobbs et al., 2009; Hobbs et al., 2014). Novel ecosystems arise because of extensive biotic and abiotic modification that creates barriers prohibiting species from adapting and shifting in response to the competition from invasive species and ecosystem changes (Western, 2001; Ito et al., 2013). The appearance of novel ecosystems will be especially prevalent in ecosystems and landscapes that suffer from higher degrees of degradation, and are therefore less resilient to rapid change (Hobbs et al., 2009).

A consequence of widespread land degradation and ecosystem modification and fragmentation, compounded by the pressure of climate change, is that it may be unrealistic to restore landscape to a desired pre-disturbance state (Seabrook et al., 2011). There may be no current or historic analogue (i.e., reference ecosystem) to guide ecological restoration. Restoration will need to be forward-looking, focusing on future trajectories of climate, land use, demographic and socio-economic change, as well as species range shifts. Restoration will need to be guided by future ecosystem trajectories in combination with current or historic analogues (Hobbs et al., 2009). For example, seeds sourced for restoration should be drawn from species suitable to modeled future climates in the restoration site, combined with seeds of local provenance (Breed et al., 2013). Furthermore, ecological restoration will need to be more attuned to the multiple functions of landscapes (Shackelford et al., 2013), so that ecological restoration targets satisfy the requirements of ecosystems and landscapes to supply multiple ecosystem services (Bullock et al., 2011; Seabrook et al., 2011; Sayer et al., 2013; Hobbs et al., 2014); this includes a wide range of cultural and social values (Bryan et al., 2010; Petursdottir et al., 2013; Shackelford et al., 2013).

Figure 3 summarizes the decisions that need to be made when considering restoration interventions in novel ecosystems, guiding policy-makers, planners and land managers toward whether restoration should be based on historic, novel or hybrid ecosystems. It is evident from Figure 3 that, in a rapidly changing world, technical, financial and scientific capacity constraints and barriers exist with regard to the feasibility of ecological restoration.

Figure 3: Flowchart to guide major decisions regarding management and restoration interventions in historical, hybrid and novel ecosystems. Source: Hobbs et al. (2014)
2.3 Climate-smart agriculture and enhancing socio-ecological resilience

There are many opportunities within production landscapes for ecological restoration, given the importance for it to be forward-looking and to consider landscapes as a whole (Hobbs et al., 2014). The forecast impacts of climate change in many agricultural landscapes includes increased frequency of droughts, floods and heatwaves, which will have significant negative impacts on agricultural yields, threatening global food security (Kang et al., 2009; Wheeler and Kay, 2010; Niang et al., 2014; Porter et al., 2014). For example, Knox et al. (2012) predict climate change to result in an 8% decline in overall crop productivity in Africa and South Asia by the 2050s. Drylands, semi-arid regions, and areas of high rural poverty are especially vulnerable to climate change impacts because agriculture is already occurring at the margins in such places, and adaption is constrained by financial and technological barriers (Reynolds et al., 2007; Müller et al., 2011; Menz et al., 2013; Niang et al., 2014).

Identifying, monitoring and mitigating threats and vulnerabilities to agricultural production will increase system resilience. Resilience can be enhanced by increasing the capacity of the landscape to avoid, deflect, absorb or recover from threats (Sayer et al., 2013). In the case of climate change resilience, landscape capacity is enhanced by implementing strategies which mitigate the impacts of increased climatic extremes and increase the system’s ability to recover from disturbances (Shackelford et al., 2013). While each landscape and ecosystem is different, and the factors that enhance capacity are unique to each one, resilience can be improved by strengthening the capacity of local stakeholders to mitigate and/or adapt to climate change, and by learning from the experiences of others (Sayer et al. 2013, Shames et al. 2016).

Some strategies requiring large-scale ecological restoration can be commonly adopted to increase ecological and socioeconomic resilience. An important goal as regards enhancing ecological resilience is to improve connectivity, and remove dispersal barriers, in production landscapes, so as to make it easier for species to migrate following rapidly shifting climatic niches. In heavily modified and degraded landscapes, where remnant habitat is highly fragmented, extensive recreation of habitat is required so as to link remnant patches and create new habitat. Another goal is to incorporate functional redundancy into landscapes so that the supply of multiple ecosystem functions and services can be maintained despite the collapse of one, or a few, functions following major disturbances (Yachi and Loreau, 1999; Elmqvist et al., 2003). Restoration of forest habitat to connect remnant patches has been shown to improve functional diversity and redundancy (Craven et al., 2016).

An important goal for enhancing socioeconomic resilience to climate change in degraded landscapes is to diversify crop production and adopt new technologies which increase crop yields and crop production efficiency. This strategy is part of an emerging agricultural policy shift toward designing incentives that make production landscapes more resilient to pending climate change. Termed ‘climate-smart agriculture’ (FAO, 2010; Lipper et al., 2014), the emphasis is on encouraging farming techniques which increase yields, reduce vulnerability to climate change, and reduce greenhouse gas emissions. Two forms of ecological restoration have a significant role to play: i) conservation agriculture; and, ii) agroforestry. Conservation agriculture involves minimizing soil disturbance, maintaining permanent soil cover using stubble retention and/or permanent perennials, and introducing crop rotations (Lal, 2009). These activities restore degraded land by increasing soil biodiversity and carbon stocks, regulating oxygen and nutrient cycles, and therefore making soil and crops more resilient to heat and drying extremes, as well as reducing greenhouse gas emissions (Lal, 2004; Lipper et al., 2014). Agroforestry involves introducing tree species into the farming enterprise, as inter-row plantings and/or larger scale patches. The benefits of agroforestry include: diversification of farm income streams; favorable micro-climatic conditions for crop growth; habitat for pollinators and other important species, such as crop pest predators; and enhancement of soil nutrients.

There are many studies of the direct economic benefits of increased yields and lower input costs following the adoption of conservation agriculture and agroforestry (Knowler and Bradshaw, 2007; Lalani et al., 2016). For example, in Malawi, agroforestry increased maize yields by around 50% when nitrogen-fixing trees were planted among croplands (Denier, 2015). Similarly, the planting of nitrogen-fixing shrubs among croplands in Senegal improved concentrations of soil organic matter, nitrogen and phosphorous. These tree and shrub plantings also provide habitat for wildlife, improve water filtration into the soil, and sequester carbon. Adoption of conservation agriculture in Zambia, meanwhile, lifted maize yields by around 50% compared to conventionally tilled maize, as well as reducing chemical and energy inputs and soil erosion (Denier, 2015). In the vein, the economic returns from maize grown in central Mexico were 75% greater following the adoption of conservation agriculture (Hobbs et al., 2008). Equally, the adoption of no-till rice-wheat systems in south Asia led to higher yields at lower costs, which increased smallholder farm incomes and freed up time for farmers to dedicate to other productive uses, thereby generating off-farm income (Hobbs et al., 2008).
There are other values and benefits that arise from implementing climate-smart agriculture. One emerging concept is that of insurance value. Baumgärtner and Strunz (2014) viewed resilience’s insurance value as its ability to reduce an ecosystem user’s income risk in the event of changes in available ecosystem services due to unpredictable future disturbances. Implementing climate-smart agricultural practices, such as conservation agriculture and agroforestry – via the restoration of habitat connectivity and permeability, improvement of soil composition, structure and filtration capacity, reduced soils exposure, and crop diversification – potentially have high insurance value by reducing the risks to future extreme climatic events and disturbances. A recent example articulated by Pascual et al. (2015) is of the insurance value to a farmer of maintaining and restoring soil biodiversity. The authors describe how a high and diverse soil microbial biomass can reduce the likelihood and severity of crop losses caused by soil borne diseases and pathogens triggered by disturbances. Land management that restores soil microbial biomass mitigates the risk of crop failure under climate change, the economic value of which can be ascertained through measures of insurance value (Pascual et al., 2015).

Some caution, however, is needed. For example, from a review of 87 integrated landscape management programmes, across 33 African countries, Milder et al. (2014) argued that long-term climate change adaptation benefits are unlikely to be realized via projects which are only funded on a short-term basis. Short-term sustainable development programmes, funded externally by donors and other groups, such as non-governmental organizations (NGOs), development banks and aid agencies, will need to be complemented or superseded by new policies, regulations and governance arrangements. The new arrangements must embed sustainable management and restoration within policy frameworks in order for benefits from climate change adaptation to be fully achieved over the long term. The integrated landscape management programmes will also need to be aligned with existing national and regional level development planning processes, preferably within a spatial land use planning framework (Metternicht, 2016).

Figure 4: Flows of knowledge of agricultural technologies. Knowledge flows are represented by arrows and arrow width represents the perceived level of knowledge transmission, with a thicker arrow representing a higher amount of knowledge transfer. The X represents barriers to flows of knowledge.

Source: Eidt et al. (2012)

Further barriers exist to the uptake of integrated land management and climate-smart technologies and practices that enhance resilience in production landscapes. Dissemination and communication of the advantages of new land management practices, tools and techniques for ecosystem restoration can be hampered by the excessive use of scientific jargon, and by a lack of understanding of farmers’ specific circumstances (Long et al., 2016). Knowledge and information flows can also be hampered by: insufficient efforts to build capacity and train farmers; poor or absent communication of economic benefits of new techniques; and absent or limited presence of farmers’ initiatives, participation and interaction (Eidt et al., 2012). An elegant and comprehensive summary of barriers to the adoption of new agriculture technologies that increase resilience in agro-ecosystems is shown in Figure 4. A survey of Kenyan farmers by Eidt et al. (2012) concluded that farmers’ levels of community organization and trust will influence the level of adoption of new technologies. Better documentation and packaging of material explaining the benefits of the new techniques and tools will likely increase adoption, as will the building of farmer networks and capacity.
2.4 Increasing the multi-functionality and productivity of agricultural landscapes

Aside from enhanced resilience to the future shocks and changes, expected under rapid global change, ecological restoration can also foster many other benefits, when included as part of broader sustainable land management initiatives in production landscapes.

The direct financial and economic benefits to landholders, which arise from the implementation of sustainable land management practices, are well established. For example, increased soil organic carbon in cropping systems consistently leads to increased yields, although the magnitude of the increase varies with specific practice and agro-climatic conditions. Yields tend to be higher in areas of low and variable rainfall, as demonstrated by Branca et al. (2013) in a global review of 160 studies reporting field data on the yield effects of sustainable land management. In livestock systems, high grazing pressure will have negative impacts on soil function – defined as the stability, nutrient-cycling and infiltration-capacity of soils, and its ability to support pasture (Read et al., 2016). Soil function can be successfully restored using native trees of mixed species and shrubs (Read et al., 2016); this illustrates that the introduction of agroforestry can be a restoration strategy for grazing systems as well as for cropping systems. In livestock-grazed grassland systems, restoration of diverse grassland of conservation value was shown, by Bullock et al. (2007), to benefit farm income over the long term, by increasing hay yields. Further study by Bullock et al. (2011) showed that the potential economic returns from other ecosystem services can far exceed, by a ratio of 7:1, the returns from intensive grazing (Figure 5).

Nevertheless, direct financial benefits are not the only motivators of ecological restoration. Gessesse et al. (2016) surveyed smallholder farmers in a degraded temperate/tropical highland catchment of central Ethiopia to determine what motivated them to plant trees for land restoration. The authors concluded that farmers were more likely to plant trees to restore farmland if they had larger households (i.e., more available labor), were more literate and aware of the longer-term benefits of reducing degradation, and had security over land tenure (Gessesse et al., 2016). In Europe, García-Martín et al. (2016) concluded that integrated landscape management approaches (including restoration) are driven by civil society, and are most salient and relevant when the programmes have multiple objectives, involve and coordinate different sectors and stakeholders at many levels, and have a significant awareness-raising element. Similarly, in a French Pyrenees case study, Couix and Gonzalo-Turpin (2015) reported that wider stakeholder participation, and a collective effort to understand the benefits of restoration at the landscape scale, were more conducive to ecological restoration. Box 2 provides a case study of three examples of non-financial incentives to motivate forest restoration in less developed and transitioning economies.
The landscape approach has also become the main approach for Peru’s national strategy to address climate change. As per Global Land Outlook (2014), REDD+ in productive forest landscapes of the Amazon is recognized as complementary mitigation strategies to REDD+. ICRAF delivered capacity building and technical advisory to key ministries (e.g. Ministry of Environment (MINAM), Ministry of Agriculture (MINAGRI)) at the national level to prove the evidence for integrated landscape approaches through explicit engagement in mitigation. ICRAF also worked with the Ministry of Agriculture (MINAGRI) to hold a side event at COP 20, the REDD+ debate in Peru was focusing on policies and interventions internal to the forest and conservation sector and on land governance, leaving out the agricultural sector. 

For instance, highlighted, when examining south Asia, that misaligned and competing agricultural promotion and environmental protection policies impede forest protection and restoration. They noted that efforts to halt both forest clearing and steep slope agricultural conversion are undermined by government promotion of investments in nearby ethanol plants with large feedstock demands. There are novel and emerging instruments to motivate ecological restoration by providing financial rewards for multiple direct and indirect benefits. Payment for ecosystem services (PES) is cited as an efficient, adaptive and equitable market-based economic instrument to reward landholders for restoring degraded lands by enhancing natural capital and improving the flow of ecosystem services (Wunder et al., 2008; Bullock et al., 2011; Wunder, 2013). PES typically involves performance-based payments from the public sector to a private landowner, and encourages alternative livelihoods which are more environmentally sustainable (Lambin et al., 2014). Box 3 provides a case study of the use of PES to reward farmers in South Korea for undertaking forest restoration activities on their lands.

### Box 2: Non-financial incentives achieve forest restoration and multiple benefits in Indonesia, Vietnam and Peru.

Florence Bernard, World Agroforestry Centre (ICRAF), Indonesia.

Developing and promoting the adoption of functional incentives schemes, specifically non-financial incentives, targeting drivers of deforestation and increased sustainable benefits to promote sustainable multifunctional landscapes is a key objective within the NORAD-funded SECURED Landscape (Securing Ecosystems and Carbon benefits by Unlocking Reversal of Emissions Drivers in Landscapes) project. The SECURED Landscape project, operating from 2013–2015, was led by the World Agroforestry Centre (ICRAF) in 5 countries namely Cameroon, Indonesia, DRC, Peru and Vietnam.

A key project lesson is that non-financial incentives emerge as better “nudges” of change in landscapes with sustainable benefits. In TanJaBar province in Indonesia, remaining peat swamp forests is threatened by illegal logging, land clearing for agricultural development and land conflicts. Efforts to rehabilitate the area initiated in 2009–2010 through a replanting program and seedling provision of endemic latex-producing tree species led by the district forestry office were challenged by resistance and reluctance of the newly settled people. ICRAF tested a community forestry (CF) management scheme that would work as an incentive by providing conditional land rights to communities while supporting protection of peatland areas. For approximately 3 years, ICRAF and the forestry office facilitated and built capacity to increase awareness on the importance of peat swamp forest protection and robust governance systems. These processes were positively received by farmers who enthusiastically participated and left with a better understanding of the importance of not occupying state forest land. The “Makmur Jaya” Farmer Group Association was formed in 2014 which was the first ever milestone indicating community’s willingness and readiness for further processes in proposing the CF license for part of the remaining peat forest in TanJaBar province. The CF license has been submitted to the Ministry of Environment and Forestry and if granted, it will be the first CF license for Peatland Protection Forest area in Indonesia.

In Bac Kan province in Vietnam, the development and implementation of a “bundle of incentives” including long term land use right certificates (LURC) for “encroaching” communities and community forest management on previously “unmanaged” forest, financial support through the Payment for Forest Environmental Services and technical support for agroforestry development on sloping land to replace maize mono-cropping have proven to be effective in restoring encroached forests. The LURC was obtained for 85 ha of community forest allowing and directing the forest user groups to sustainably manage the forest areas, establish fair benefit distribution mechanisms and be recognized as carbon and other resource right owners to benefit from future carbon markets and PES. Key drivers for up-scaling restoration within production landscapes is to have landscape approaches that become part of the national policy dialogues in dealing with land use planning and particularly emission reduction and development. For instance, despite the recognition of the role of agricultural expansion in driving deforestation in the Amazon (the 36% of national GHG emissions are LULUCF), before the COP 20, the REDD+ debate in Peru was focusing on policies and interventions internal to the forest and conservation sector and on land governance, leaving out the agricultural sector and the Ministry of Agriculture (MINAGRI) from any explicit engagement in mitigation. ICRAF delivered capacity building and technical advisory to key ministries (e.g. Ministry of Environment (MINAM), MINAGRI) at the national level to prove the evidence for integrated landscape approaches through real case pilots. Because of these processes, agricultural NAMAs for commodity crops (coffee, livestock, cocoa, oil palm) driving deforestation and degradation in the Amazon have become an integral part of the national mitigation strategy and are recognized as complementary mitigation strategies to REDD+ in productive forest landscapes of the Amazon.

The landscape approach has also become the main approach for Peru’s national strategy to address climate change.
The effectiveness of PES is context-dependent. As such, the instrument’s successful usage may be constrained by the fact that, to properly function, it requires a number of surrounding factors, such as: robust legal and governance institutions; a culture of payments; well organized service users; a trustful negotiation climate; and well-defined land tenure regimes for providers of ecosystem services (Wunder, 2013; Lambin et al., 2014). Additionally, the perceived value of the ecological restoration motivated by the PES will need to be greater than the perceived value of the opportunity and transaction costs associated with the PES (Lambin et al., 2014). Concerns also exist about fairness, equity and land access issues, as well as regarding the commodification and monetization of ecosystems by economic instruments (Bullock et al., 2011; van Noordwijk et al., 2012). Some consider that this practice may favor ecosystem services which have markets (e.g., carbon sequestration and water supply) at the expense of other services where ready markets do not exist (e.g., cultural, wildlife habitat). This being said, it has nonetheless been demonstrated that PES is able to motivate landscape-scale change consistent with the preferences and values of local communities, provided their shared cultural and plural values are understood and respected; this was illustrated by Reed et al. (2015) in a study of rangeland restoration in the Kalahari rangelands of Botswana. Reed et al. (2015) further argue that PES (and other types of market-based instruments) must be carefully regulated and should form one of several policy approaches to restoring degraded lands.

Another type of market-based instrument that could drive substantial uptake of ecological restoration is the adoption of product certification of agricultural commodities to meet sustainable land management standards. Agricultural production that meets a set of sustainability and social responsibility criteria can be certified as having goods and services which are environmentally and ethically produced, which can, in turn, attract a market price premium. The process is voluntary and offers an alternative to regulatory-based instruments of sustainable production, which is particularly important in lower income countries where governments lack capacity and resources to effectively regulate agricultural production (Barrett et al., 2001). The uptake of sustainability certification by agricultural producers is growing fast; Tayleur et al. (2016) estimated that global certified crop area has increased by 11% annually, from 2000 to 2012, although covering only 1.1% of total crop area in 2012. The crops with the highest level of certification are coffee, cocoa, tea, and palm oil, with more than 10% each of their total global production area being certified (Tayleur et al., 2016). Boxes 4 and 5 provide case studies of large-scale restoration in South Africa illustrating its multiple benefits to the private sector, including employment and branding.
Box 3: Designing an agri-environment scheme for restoration in Chungnam Province, South Korea.

Namue Lee, Ecosystem Services Partnership Asian Regional Office, South Korea

The Chungnam Provincial government in the Republic of Korea started a two-year agri-environment pilot project in 2016. Almost for 14 years since 2002 existing farming practices in the Chungnam province have resulted in salt accumulation in soil, increasing crop diseases, and decreasing rice price due to perverse governmental subsidies encouraging overuse of chemical fertilizers. The Chungnam initiative is a new trial to transform the former agricultural payment into an innovative financial scheme to encourage agricultural ecosystem services through conservation and ecological restoration. The provincial government program aims change local perceptions of the values of agriculture from food production to ecological services and subsequently support the formulation of “new” local governance based on participation and benefit-sharing. Local villagers are encouraged to join the local decision-making process and are given support to better manage natural capital.

In 2014 the Chungnam provincial government initiated six major policies for local development including PES and the introduction of agri-environment payments for public benefits. The province has also supported research for implementation of these policies. Chungnam’s agri-environment programs are led by local communities to improve ecological conditions and to achieve sustainable development. According to the implementation plan, contracted farmers will receive payments for ecological landscape management. In 2015, Jang-hyun and Hwa-am villages surrounded by mountains and rivers, were selected as pilot project sites through an open contest. The Jang-hyun village is relatively well-known for its organic farming practices with a younger demographic composition and its villagers are more interested new trials for local development. Local governments organized public hearings, provided program-consulting services, and set up work plans based on agreements with local stakeholders. In April, 2016, governments and farmers made a commitment on the new “agri-environment implementation agreement”. The program consists of three components:

1) increase of food self-sufficiency by crop diversification and environmentally friendly farming;
2) ecological restoration of farmland by diversified farming practices reflecting local conditions, and;
3) improvement of agricultural landscape by managing village forests and cultural heritage.

The total program budget of 1.2 billion KRW was jointly provided by the provincial government and the municipal government. There is a ceiling for each farm household of up to 3million KRW per year. Through interviews and media reports, farmers expressed their changed perceptions on the values of ecosystems and improved self-esteem. After analyzing the participants’ satisfaction and program effectiveness, in 2017 the Chungnam provincial government will further develop the agri-environment schemes and apply in other locations. Local legislations will soon be introduced to underpin these new agri-environment schemes, and the provincial government will consult with the Ministry of Agriculture, Food and Rural Affairs (MAFRA) with the goal of changing legislation at the National Assembly.
Although the many different sets of standards for commodity certification all share the same broad goals for biodiversity (12 reviewed by Tayleur et al., 2016), only a very few encourage restoration of degraded landscapes; when it is encouraged, restoration mostly entails increasing the density and diversity of shade trees which also provide habitat for species. In 2017, however, the criteria for the globally popular Sustainable Agriculture Network/Rainforest Alliance (SAN/RA) certification will be expanded to include a requirement that producers plan to restore farms to contain a minimum cover of native vegetation of 15%, if growing shade-tolerant crops, or 10%, if growing shade intolerant crops (Sustainable Agriculture Network, 2017b). The SAN/RA standards operate in more than 40 countries and across more than 100 crops, making this set of restoration criteria a significant driver for the widespread adoption of ecological restoration. The new 2017 SAN/RA standards also promote climate-smart agricultural practices (Sustainable Agriculture Network, 2017a), which function as additional drivers for restoring degraded landscapes in order to increase resilience to climate change (as reviewed above).

**Box 4: Baviaanskloof Development Company: how to include farmers in integrated landscape management and restoration, South Africa.**

*Simon Moolenaar, Commonland, The Netherlands*

The Baviaanskloof Development Company (BDC) is a newly established commercial entity set up for the purposes of producing, processing, marketing and distributing aromatic oils in the Baviaanskloof Hartland. The “Hartland” consists of 46,000 ha privately owned farmland, which is surrounded by a nature reserve and part of a UNESCO World Heritage Site. Over the past decades, intensive grazing of goats on the hillsides has led to the severe degradation of the natural vegetation. The BDC is a joint initiative of Baviaanskloof farmers and Four Returns (the South African subsidiary of Dutch NGO Commonland), which provides a new sustainable income source for farmers and appropriate financial returns for external investors. This will enable farmers to exit from the ecologically degrading practice of farming goats on the hillsides of their farms and thereby make those hillsides available for large-scale landscape restoration.

**Project’s environmental and social benefits**
- Conversion of 100 ha of traditional fields into organic fields (ambition to scale to 500 ha)
- Farmers signing up to holistic management contracts, which put 28,000 ha under improved management. Active restoration (planting Spekboom trees) on severely degraded sites (Coca Cola Africa Foundation has funded 2,000 ha to start with and the goal is to restore approx. 5,000 ha)
- Creation of at least 50 jobs in the farming and restoration activities
- Increased income for farmers (potential to double profitability per ha)
- Bringing inspiration back to rural areas

**Bottom-up, participatory approach**
- Strong collaboration with South African NGO Living Lands, using intensive stakeholder engagement: strong focus on co-creating solutions, and listening to farmers, rather than telling them what to do.
- Farmers involved in all decision-making (including shaping the company as it is now)
- The company is co-owned and co-managed by the farmers, and they make the restoration plans for their farms together with ecologists.

**Clear path/options for upscaling the project**
- Strong interest from other farmers in the area to join; potential to bring 500 ha under cultivated aromatic oils, which will bring the entire area (46,000 ha) under improved management.
Box 5: South Africa, taking the lead in large-scale ecological restoration.

Benis Egoh, CSIR, Stellenbosch, South Africa.

South Africa as a country is one of the leading examples in Africa in promoting restoration of degraded land within its boundaries. A very popular working for water program (WfW), which aims at removing invasive alien species to restore water flows, provide jobs and improves biodiversity, was one of the first and remains one of the largest restoration programs in the country. Following the success of this program, there has been several restoration programs around the country, including Banvianskloof reforestation program (www.livinglands.co.za) and Bufflesdraai community reforestation project (http://www.durban.gov.za/).

Recently, the city of Durban in South Africa implemented ecological restoration programmes for two mega-events: the Durban 2010 FIFA™ World Cup and the United Nations Framework Convention on Climate Change COP17/CMP7 in 2011 (Witt and Loots 2010, Diederichs and Roberts 2016). The combination of hosting these two events led to the city initiating a reforestation project that involves the planting of trees to store carbon, improve biodiversity and enhance the livelihood of local communities living around the project site. The site (Buffelsdraai) is a landfill site with an 800-hectare buffer zone under sugar cane cultivation. The eThekwini municipality, the legal owners of the land, contracted Wildlands Conservation Trust (WCT) to restore at least half of the sugarcane fields into scarp forest. Currently, about 500 ha of former sugarcane land is restored.

The WCT sources seedling from the surrounding local community members (coined tree-preneurs) in exchange for vouchers which they can use in a variety of ways including buying groceries or paying for school fees (eThekwini municipality and Wildlands Conservation Trust 2015). In addition to supplying seedlings to WCT, many locals are employed as field workers who do a variety of tasks including field preparation for planting, digging of holes, planting seedlings, invasive alien plant management, and fire control. Since initiation, the project has created more than 400 jobs, improved schooling for children, increased disposable income for additional needs of households and increased access to adequate food supply to project participants (Douwes et al. 2015). In addition to the social benefits, tree species have increased from 0 to 51 while birds species have increased from 91 to 145 since project initiation in 2008 (Douwes et al. 2015).

Despite several emerging novel drivers for restoration, there are impediments to success and widespread uptake. For example, the difficulty of monitoring and evaluating outcomes makes investors and governments reluctant to adopt long-term policies and plans in which restoration is embedded. Monitoring and evaluation are not impossible, however. For instance, Chaves et al. (2015) described how, in the State of São Paulo in Brazil, the government introduced a legal instrument to support planning and to assess whether the outcomes of mandatory ecological restoration are being achieved. Investment in ecological restoration in São Paulo requires the collection of three indicators describing native vegetation ground cover, and number and density of spontaneously regenerating native plant species (Chaves et al., 2015).

Technologies such as high spatial and temporal resolution remote-sensing offer a cost-effective method for collecting indicators for planning and monitoring the outcomes of restoration (Cordell et al., 2016). Others have identified factors of success in reforestation policies of degraded tropical landscapes. For example, Le et al. (2014), in a case study of the Philippines, conclude that policies targeting revegetation methods, socioeconomic incentives, forest protection mechanisms, sustainable livelihoods, diversification of funding and partnerships, technical support, and infrastructure development are likely to have a broad systemic and beneficial effect on the success of reforestation programmes in tropical developing countries (Le et al., 2014).
2.5 Green infrastructure and nature-based solutions

Green infrastructure, synonymous with nature-based solutions, is the interconnected network of natural and semi-natural areas, features and green spaces in rural and urban, terrestrial, freshwater, coastal and marine ecosystems, which conserve natural ecosystem values, contribute to biodiversity conservation, and benefit humans through provision of ecosystem services (Weber et al., 2006; Naumann et al., 2011). The concept of green infrastructure is more often applied to the spatial planning and design of open and green spaces in urban areas, especially in Europe (Tzoulas et al., 2007; Lafortezza et al., 2013; Kopperoinen et al., 2014; Emmanuel and Loconsole, 2015; Maes et al., 2015), but also in the US (Weber et al., 2006; Wickham et al., 2010). The green infrastructure concept has recently been extended to include mitigation and adaptation to climate change impacts (Matthews et al., 2015; Van Teeffelen et al., 2015). In urban areas, green infrastructure can contribute to ameliorating the enhanced heat-island effect, and to lowering the flood risk anticipated under climate change by regulating ambient temperatures and reducing storm-water runoff (Matthews et al., 2015). The same functions can be performed by green infrastructure in regional areas.

Central to green infrastructure planning is the goal to protect and enhance ecosystem services provided in intensively used and modified landscapes (Lovell and Taylor, 2013; Maes et al., 2015). By planning and constructing a connected and permeable network of natural and semi-natural habitats, the green infrastructure approach aims to design and engineer landscapes, via habitat protection and restoration, which meet multiple ecological and human well-being benefits. The focus on ecosystem services makes the benefits of green infrastructure more salient and tangible to people in modified landscapes. Lovell and Taylor (2013) argue that an approach which combines ecosystem service benefits, which arise from incorporating ecosystem services into greening projects, and early stakeholder engagement, which empowers local citizens, is more likely to lead to the successful implementation of large-scale green infrastructure planning.

Robust policy, tenure, governance and legal arrangements are required for implementing green infrastructure plans and strategies. For example, McWilliam et al. (2015) show that many urban planning policies in Ontario, Canada, designed to protect green infrastructure ecosystem services from urban expansion are ineffective because they lack relevant long-term goals, objectives or tools, particularly regarding adaptive management. It is worth recalling that maintaining a long-term focus when it comes to green infrastructure spatial planning is especially pertinent in the face of climate change.

There are cases in which green infrastructure policies have been drawn out with a long-term view. In Europe, the biodiversity strategy to 2020 aims to maintain and enhance ecosystems and their services by establishing green infrastructure and restoring at least 15% of degraded ecosystems (European Commission, 2011). The adoption and implementation of this policy has motivated many programmes and initiatives to quantify ecosystem services, and identify locations in European landscapes for large-scale restoration. For example, Liquete et al. (2015) identified about 16% of the European Union to target for ecological restoration with a view to building a spatially connected network of green infrastructure for increasing ecological and social resilience (Figure 6). A further analysis by Maes et al. (2015) concluded that under current trends of land use and climate change, about 20,000 km² of Europe’s agricultural land would need to be restored and added to the existing green infrastructure network by 2050 merely in order to maintain the supply of ecosystem services at 2010 levels.

Maes et al. (2015) identify a requirement in Europe’s Common Agricultural Policy (CAP) that will be potentially transformational for restoration of landscapes and green infrastructure. The 2014–2020 CAP requires that at least 5% of the arable area of farms with an arable area larger than 15 ha must be allocated to new Ecological Focal Areas (Maes et al., 2015). These Ecological Focal Areas are defined as those parts of agricultural land covered by field margins, hedges, trees, fallow land, landscape features, biotopes, buffer strips, and afforested areas. This requirement in the CAP will motivate extensive restoration across Europe.
Figure 6: Proposed green infrastructure (GI) for Europe.
The core GI network comprises the best functioning ecosystems crucial to maintain biodiversity and natural capital. 
Source: Liquete et al. (2015)
2.6 Rewilding abandoned agricultural lands

A growing feature of landscapes is the abandonment of less productive and marginal agricultural land. Estimated to cover 60% of arable land globally (Queiroz et al., 2014), the low productivity marginal agricultural lands are characterized by low input of pesticides and artificial fertilizers, low levels of mechanization, and high dependence on manual labor. The drivers for abandonment are aging and declining rural populations, mechanization of agriculture, and the increased productivity of agriculture in more fertile areas (MacDonald et al., 2000; Navarro and Pereira, 2012; Aide et al., 2013; Queiroz et al., 2014). Across Europe, rural populations have declined by 17% since 1961, with some mountainous rural areas in the Mediterranean region declining by more than 50% (Navarro and Pereira, 2012). The declining rural population has encouraged landscape multi-functionality to the partial benefit of biodiversity. Modeled reconstruction of European land use changes between 1950-2010 suggest that cropland has declined by almost 19%, and that pastures and semi-natural grasslands have decreased by 6% (Fuchs et al., 2013). In some transition economies, such as Latin America, the abandonment of less productive and more inaccessible agricultural lands due to the mechanization of agriculture, and the migration of rural populations to cities, is occurring with speed (Aide et al., 2013). A new idea, reviewed by Navarro and Pereira (2012), is to allow these abandoned lands to ‘rewild’ by passively assisting the natural regeneration of forests and other natural habitats.

The aim with rewilding is to remove human control and influence on the land, and thereby to allow natural ecological processes to reestablish themselves, with forest succession naturally occurring on land previously deforested for agricultural purposes (Corlett, 2016). While a number of more nuanced definitions of rewilding exist (for an overview, see Corlett, 2016), in its most passive form, rewilding involves no or very minimal human intervention to restore former agricultural lands to wild landscapes. The original expectation was that rewild habitat would return to ecosystems resembling those present before extensive modification. But now the reference state, or baseline, for rewilding is more appropriately aligned to novel ecosystems, relative to future modeled scenarios, (as discussed above) since the environmental changes of the Anthropocene have made historical baselines unachievable (Corlett 2015, Wiens and Hobbs 2015).

**Figure 7:** Qualitative assessment of the ecosystem services provided by rewilding, extensive agriculture, intensive agriculture and afforestation in Europe.

Source: Navarro and Pereira (2012)
Rewilding is not without controversy. European agricultural landscapes hold important cultural and historical values (Linnell et al., 2015) and the Common Agricultural Policy provides financial incentives to farmers to maintain traditional agricultural practices (European Environment Agency, 2004). A substantial change in the design of these incentives is the requirement to encourage more rewilding and restoration of abandoned land. There is also a degree of concern about the return of wild places, as people are often fearful of wild, unmanaged habitat.

Since the mid-20th Century there have been large increases in population of European carnivores, which prosper in modified landscapes, but pose threats to livestock (Chapron et al., 2014). Another issue is that the biodiversity benefits of rewilding abandoned lands are not always positive. For example, cases exist in which low-intensity heterogeneous agricultural landscapes that support high biological diversity were rewilded, yet this resulted in the homogenization of biodiversity (Katoh et al., 2009; Queiroz et al., 2014). Acceptance of the legitimacy of multiple social values, and acknowledgement of rewilding concerns, are a prerequisite for planning landscapes that contain a mixture of intensive agricultural uses with low intervention rewild habitat on abandoned land (Linnell et al., 2015). A balanced approach to landscape planning, which includes rewilded land as a part of multi-functional agricultural landscapes, will ensure the supply of multiple ecosystem services (Figure 7), in a manner more likely to be accepted by society.

There is substantial scope for rewilding abandoned agricultural lands to drive large-scale ecological restoration. Modeled forecasts of future land use changes across Europe suggest that over 15% of agricultural land will be abandoned between 2000–2040 under a scenario of rising nation state power and a roll-back of international trade (Ceausu et al., 2015). Verburg and Overmars (2009) concluded that under the opposite scenario of a strong global economy, more than 20% of agricultural land might be abandoned between 2000–2030 in several regions in Europe, notably in northern Spain, southern France, and southern Germany. Rewilding abandoned lands could be part of Europe’s green infrastructure network. Under current trends in land use change toward non-natural habitat (e.g., urbanization), an estimated 2.2% of agricultural land in Europe must be restored annually to maintain the supply of ecosystem services at 2010 levels (Maes et al., 2015). The need to build and restore green infrastructure merely in order to maintain a supply of ecosystem services can be a key driver for ecological restoration via, inter alia, a strategy of re-wilding abandoned land.

In Latin America and the Caribbean, governments generally view reforestation of abandoned land as a positive, and it is often promoted in conservation plans. Aide et al. (2013) estimated that over 360,000 km² of abandoned lands in Latin America and the Caribbean were naturally reforested between 2001 and 2010; the largest proportion of this reforestation having occurred in Mexico. Similarly, in south western Australia, a large-scale conservation programme, named the Gondwana Link, aims to restore and rehabilitate extensive tracts of low productivity and abandoned farmlands. The area is identified as one of thirty-five global biodiversity hotspots, but has a 60-year history of extensive modification and degradation to support agriculture. The goal of Gondwana Link is to reconnect fragmented woodlands and forests along a 1000km tract of land, focusing on the least productive abandoned agricultural lands.

2.7 Urban and peri-urban development

Urban and peri-urban landscapes suffer intensive and continuous pressure from rapid urbanization and infill; about 4 billion people were living in cities in 2014, with an additional 2.5 billion expected by 2050 (United Nations Department of Economic and Social Affairs: Population Division, 2014). The pressure placed on land by rapidly expanding cities will typically target land in the peri-urban zone, currently used for agricultural or natural habitats. Existing open greenspaces in developed urban areas are also under threat from densification and infill (Haaland and van den Bosch, 2015).

Smart planning and policy can drive forms of urban development which are ecologically sustainable and beneficial for human well-being. Many studies demonstrate the benefits and values provided to people by the presence of urban greenspaces. The quality and biological diversity of the urban greenspace is also important. Hope et al. (2003) identified positive relationships between plant diversity and human wealth in urban areas in Phoenix, US. A recent area of investigation is the link between biodiversity, and human health and well-being. In a review of studies exploring links between biodiversity and health, Sandifer et al. (2015) reported that many examples exist of positive relationships between nature exposure and health, although the mechanisms through which this relationship function are not well-understood. One of the better-known effects of exposure to biodiversity, reviewed by Sandifer et al. (2015), is that microbial biodiversity can improve health, specifically by reducing certain allergic and respiratory diseases. Urban parks also offer opportunity for physical activities, such as running and hiking, which have direct health benefits (Wolf and Wohlfart, 2014). There is also rigorous evidence, through brain scans, that nature experience has positive effects on psychological well-being (Bratman et al., 2015). In addition to the health benefits of urban greening, are the improvements as regards climate change resilience. One of the primary threats urban residents face from climate change is that of the increased dangers from more frequent and intense heat waves.

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1 See http://www.gondwanalink.org/index.aspx
Urban greenspace offers climate change resilience and adaptation benefits by reducing the heat island effect of built-up urban areas, which gives urban greenspace high insurance value against future extreme events (Green et al., 2016).

There are, moreover, many economic arguments for maintaining and expanding/restoring urban greenspaces. Such spaces provide many other ecosystem services, such as noise reduction, air filtering, flood mitigation, and recreational and cultural values, all of which have potentially high economic value (Capotorti et al., 2015; Elmqvist et al., 2015). Vandermeulen et al. (2011) argued that calculating the full economic value of urban greenspaces (and green infrastructure) via ecosystem service valuation techniques would give credibility and increase public acceptance of urban greenspace. In an analysis of urban greenspace ecosystem service values in twenty-five urban areas across China, the US, and Canada, Elmqvist et al. (2015) concluded that ecological restoration and rehabilitation of rivers, lakes and woodlands in urban areas provides many economic benefits, in addition to the ecological and social benefits.

The many economic, climate change resilience related, and human health and well-being benefits of urban greenspaces provide significant drivers for maintaining and restoring green areas (McDonnell and MacGregor-Fors, 2016). Evidence suggests that green spaces with higher ecological and biodiversity values are of greater benefit than others; this adds further weight to the driver for ecological restoration in urban and peri-urban areas. This said, there are nonetheless equity and social justice concerns regarding urban greenspace. The more affluent parts of cities tend to have more greenspace (Wolch et al., 2014), and restoration of urban greenspace can have marked negative effects on land affordability, thus unfairly penalizing marginalized people (Foster, 2010). Moreover, urban greenspaces of higher ecological value will be experienced by people with a nature ethos who are willing (and able) to travel further distances in order to enjoy them (Shanahan et al., 2015). However, these equity and justice concerns can be countered by prioritizing greenspace restoration in less affluent areas. Urban brownfields, common in industrial and less affluent parts of cities, have high restoration potential, being then able to provide multiple ecosystem services (Mathey et al., 2015).

The form that ecological restoration takes in urban and peri-urban areas will be highly varied, according to local circumstances, and the history of development and human environment modification. It is, as such, unrealistic to expect restoration in heavily developed urban areas to resemble a pre-development reference state. More likely, is the management and restoration of novel ecosystems, such as urban grasslands (Klaus, 2013), and iconic species in urban gardens (Standish et al., 2013). At the peri-urban fringe, it may be possible to protect and restore green areas in a form closer to natural habitats as they were in their pre-development state (Standish et al., 2013). A new form of urban development at the urban fringe, which incorporates protected greenspace – labeled Conservation Development – has emerged as a tool that can accommodate development and, simultaneously, achieve land protection, potentially forming networks with existing protected areas (Mockrin et al., 2017). Widening the scope and being open minded to the many different forms of ecological restoration in urban areas, and communicating the benefits of restoration to urban planners and stakeholders, are important elements for success of restoration (Klaus, 2013; Standish et al., 2013).

2.8 Infrastructure development and biodiversity offsets. A relatively recent development in sustainability and biodiversity policy, at both public and private sector levels, is that of biodiversity offsets to mitigate damage caused by infrastructure development. The offset can comprise either protection of an existing area of equivalent habitat, or ecological restoration of a habitat matching that which is damaged. Several principles apply to the design of biodiversity offsets: i) the offset must be like-for-like; ii) offsets should be near the degraded area; iii) the protection or restoration must be additional to what would have occurred at the site in the absence of the offset; and, iv) the biodiversity outcomes of the offset must be equivalent to, or better than, what is lost. The requirement for biodiversity damage to be offset creates a market demand for protection and restoration, but needs to be supported by robust rules and institutions, especially enforcement, and monitoring and evaluation of outcomes. Corporate sustainability goals of Net Positive Impact (NPI) and No Net Loss (NNL) drive biodiversity offsets and ecological restoration. The mining industry is a leader in implementing NPI and NNL goals because of their greater participation in best practice bodies, high-profile impacts, and higher profit margins per area of impact (Rainey et al., 2015).

So far, however, there are only a few examples where ecological restoration for biodiversity offsetting has achieved good ecological outcomes – overwhelmingly, restoration offset expectations have not been achieved. For example, examining a case study of a new railway corridor in Austria, Pöll et al. (2016) concluded that ecological restoration, implemented to meet biodiversity offset requirements, although reducing some threats from intensive agriculture – by increasing connectivity and providing habitat for Red Listed species – was nonetheless not fully positive, since species and habitat diversity was lower relative to reference conditions.
Rainey et al. (2015), in a review of NPI/NNL goals in the corporate sector, concluded that the quality of biodiversity outcomes is highly varied, and thus that greater focus ought to be put on outcomes in corporate biodiversity initiatives. Similarly, Maron et al. (2012) reviewed biodiversity offset driven restoration and concluded that the outcomes of restoration rarely meet the expectations of offset policies. The problems identified by Maron et al. (2012) are that offsets do not achieve NNL because of time lags in achieving restoration outcomes, uncertainty, and difficulties regarding measurability of the biodiversity values being offset. These problems are surmountable, although the opportunity for restoration to achieve NNL offsets is small. Restoration science and offset policy need to work closer together in order to reduce the gap between offset policy expectations and biodiversity outcomes (Maron et al., 2012).

3. CONCLUSION AND RECOMMENDATIONS

3.1 Ecological restoration as an integral component of production landscapes

The annual costs of land degradation are thought to be in the order of 10–17% of global GDP (ELD Initiative, 2015). The very high costs of land degradation in production landscapes makes ecological restoration a global imperative. Restoration is one of the three components of the response hierarchy (the others being avoid and reduce) for achieving land degradation neutrality in the context of the UN Sustainable Development Goals, i.e., the aspiration to achieve land degradation neutrality by 2030 (UNCCD/Science-Policy Interface, 2016). While it is most cost effective to avoid degradation in the first place and reduce ongoing pressure on land to prevent further degradation, the significant costs and wide extent of degradation can make ecological restoration cost effective. Ecological restoration is an essential intervention if land degradation neutrality is to be achieved (Figure 8).

Figure 8: Framework for achieving Land Degradation Neutrality. Ecological restoration is part of the response hierarchy to reverse degradation.
Source: UNCCD/Science-Policy Interface (2016)
The economic value of restoration is further enhanced when the full economic benefits are considered. The investment in ecological restoration – if the monetary value of the enhanced supply of ecosystem services is calculated – has been shown to return a benefit cost ratio of 35:1 in grassland ecosystems (de Groot et al., 2013). There are, additionally, other less easily monetized cultural and regulating ecosystem services, plus intrinsic social values, which are enhanced by restoration, further strengthening the case for investment in ecological restoration in production landscapes. This paper documents where ecological restoration is, or has potential to be, an integral component of the sustainable management of natural capital. Several sustainable land management activities that are, or could, drive large-scale uptake of ecological restoration in agricultural landscapes were reviewed. The role of restoration within the integrated land and water management approaches of Sustainable Land Management (SLM), Sustainable Forestry Management (SFM), and Integrated Water Resource Management (IWRM) were first examined. Although these approaches are tailored to specific resource management sectors, they share the common goal of ensuring holistic, equitable, inclusive, and transparent planning of land for the sustainable management of natural capital. Along with these social goals is the central landscape design principal of protecting and restoring ecosystems. There is considerable scope to mainstream ecological restoration within integrated approaches because the benefits, costs and trade-offs of restoration are not confined to a few individual private actors; the beneficiary pool is much wider.

This paper further highlights that adapting to rapid global changes within production systems will require new approaches to agriculture, including diversifying land uses away from intensive cropping and livestock systems, toward multi-functional landscapes, which contain a variety of land uses and land covers. Ecological restoration techniques within intensive agricultural systems will be required to mitigate pressures from rapid global change. The short-term economic rewards of ecological restoration for adapting to global change can be large, but so too can the long-term rewards via the insurance values of restoring land to reduce risks from rapid change.

The traditional approach of ecological restoration will also need to be revised because of the growing absence of historical analogues to inform restoration. In many locations, especially heavily modified and fragmented landscapes, hybrid and novel ecosystems will be expected, and it is therefore these which should inform ecological restoration planning. Several inter-related landscape-scale sustainable land management approaches which have potential to motivate large amounts of ecological restoration are also analyzed herein. This paper purports to show that ecological restoration is a central intervention for increasing the multi-functionality and productivity of agricultural landscapes; this occurs in a number of manners: building green infrastructure as an alternative or complement to grey infrastructure; rewilding abandoned agricultural lands; making greenspace a part of urban and peri-urban development; and offsetting impacts on biodiversity from infrastructure development.

### 3.2 Evidence of success and benefits of ecological restoration

This paper has provided much evidence of the success and benefits of ecological restoration. For example, restoration of soil microbial biomass mitigates the risk of crop failure under climate change (Pascual et al., 2015), providing high insurance value. Many examples of the direct yield benefits of restoration in production landscapes are also provided (Hobbs et al., 2008; Denier, 2015). Several socioeconomic and human well-being benefits of restoration, particularly in urban areas, were also discussed (Standish et al., 2013; Elmqvist et al., 2015), as were those relative to the reduced risks and increased adaptation to climate change (Cowie et al., 2011; Matthews et al., 2015). The many environmental and ecological benefits of ecological restoration were analyzed; these include the increased connectivity and permeability in production landscapes, making it easier for species to migrate, so as to follow rapidly shifting climatic niches, and the improvements to water, soil and air quality, and many other ecosystem services.

Ecological restoration enhances the supply of many ecosystem goods and services, substantially widening the beneficiary pool beyond traditional site-based perspectives of land management. Notwithstanding ecological restoration’s many benefits, the practice will not up-scale and become mainstream simply by demonstrating them; there are several hurdles to overcome (Menz et al., 2013). Policies and initiatives are required so as to create incentives and enable widespread uptake of ecological restoration in production landscapes.
3.3 Incentives and enablers to mainstream ecological restoration

While many international programmes, platforms and conventions already exist (e.g., UN SDGs, UNCCD, UNFCCC, IPBES), as well as a number of national, regional and local programmes, both promoting large-scale ecological restoration, there are still a fair few visionary approaches which, if implemented, could drive widespread uptake of ecological restoration. These are:

- Conservation development: New urban developments at the urban fringe which incorporate protected and restored greenspace, potentially forming networks with existing protected areas (Mockrin et al., 2017), and providing many social and psychological well-being benefits;
- Sustainable agricultural product certification: Expansion of the Sustainable Agriculture Network/Rainforest Alliance (SAN/RA) certification to include a requirement that producers restore farms to contain a minimum cover of native vegetation of 10-15%;
- Rewilding for green infrastructure: Planning and building green infrastructure networks that diversify landscapes, provide multiple benefits and respect plural social values. For example, in Europe, an estimated 2.2% of agricultural land must be restored annually so as to maintain the supply of ecosystem services at 2010 levels (Maes et al. 2015), while a similar magnitude of agricultural land will simultaneously be abandoned;
- Multi-valued payment for ecosystem services: An incentive scheme which rewards ecological restoration, while respecting multiple social values. Reed et al. (2015) show that payment schemes can motivate large-scale restoration, provided the shared cultural and plural values of local communities are understood and respected;
- Climate-smart ecological restoration: Ecological restoration that insures against future risks of climate change and other rapid global changes. The future of agricultural landscapes is increasingly uncertain; ecological restoration can mitigate damages from extreme and variable climates, shifts in commodity markets, and, especially from future events which are currently unknown and/or only predicted.

3.4 Key recommendations: overcoming hurdles to mainstream ecological restoration

In this paper, various challenges and barriers to the uptake of ecological restoration within approaches for sustainable land management were identified. A series of other researchers, such as Chaves et al. (2015), Eidt et al. (2012), Long et al. (2016), Menz et al. (2013), Milder et al. (2014), have identified many common impediments to implementing sustainable land management approaches, including ecological restoration. The factors identified by these authors include: i) poor communication of technologies and benefits; ii) lack of capacity, networks and knowledge within farmer communities; iii) poor governance, legal, planning and tenure systems; iv) programme short-termism and fragmentation; and, v) a lack of shared understanding of the risks mitigated by, and benefits arising from, restoration. From our review of restoration projects and the scientific literature, there are several ways these barriers can be overcome. These are our key recommendations for integrating restoration and rehabilitation projects and programmes within wider sustainable landscape approaches:

1. Make ecological restoration attuned to the multiple functions of landscapes, so that restoration targets satisfy the requirements of ecosystems and landscapes to supply multiple ecosystem services, including a wide range of cultural and social values.

2. Incorporate ecosystem services into greening projects and engage early with stakeholders. This empowers local citizens and is more likely to lead to successful implementation of large-scale green infrastructure and urban greening planning because of the realized ecosystem service benefits.

3. Communicate the benefits of restoration in an adequate manner, so as to ensure farmers’ comprehension. Farmers are, in general, more likely to plant trees to restore farmland if they benefit from larger households (i.e., more available labor) and are more literate and aware of the longer-term benefits of reducing degradation.

4. Ensure economic instruments to motivate and reward restoration (e.g., payments for ecosystem services); these must be consistent with the preferences and values of local communities, so efforts must be made to understand and respect shared cultural and plural social values.

5. Target sustainable land management policies toward different revegetation methods, socioeconomic incentives, habitat protection mechanisms, sustainable livelihoods, diversified funding and partnerships, technical support, and green infrastructure development. Doing so is more likely to have beneficial effects on the success of reforestation programmes.

6. Accept the legitimacy of multiple values and acknowledge the concerns of multiple stakeholders as a prerequisite for planning landscapes that contain a mix of intensive agricultural uses with low intervention re-wild habitat on abandoned land.
7. Calculate the full economic value of urban greenspaces (and green infrastructure) via ecosystem services valuation techniques to give credibility and increase public acceptance of urban greenspace.

8. Widen the scope and be open minded to the many different forms of ecological restoration in urban areas, and communicate the benefits of restoration to urban planners and stakeholders.

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