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A framework for measuring sustainability outcomes for landscape investments

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1 Introduction

Our contention is that aspirations towards global sustainable development are dependent on how the world's ecosystems and their components are managed predominantly at the landscape level. Challenges of global food supply, welfare and livelihoods for billions of people, carbon sequestration, conservation of biodiversity and provisions of renewable energy, water and soil fertility all need to be addressed at the landscape level. Recent studies indicate that sustainable use of many of our renewable resources is being exceeded on a global scale and that we should approach future use with great care (Tilman et al. 2001; Seppelt et al. 2014; Warman 2014). While increasing food, feed and fiber production per unit area can theoretically reduce pressure on land, the underlying effects of such yield increases on the landscape are uncertain (Tilman et al. 2001; Vandermeer and Perfecto 2007). Therefore, interest is increasing in investment in sustainable land use – i.e. combining long-term economic returns with the co-benefit of contributing to a sustainable future (Miller et al. 2010; Dewees et al. 2011). Scaling-up such investment requires that sustainability outcomes can be verified in cost-effective and convincing ways that satisfy investors and producers on the ground, as well as the wider public.

1.1 The sustainable development context

The concept of sustainability was first introduced in the context of forestry in Germany in the 18th century (Rubner 1992; Wiersum 1995). In recent years, the concept has evolved with increased focus on "sustainable development" (see Table 1 for definition of key terms used in this paper). The basic understanding of sustainable development has not changed since it was defined in the 1987 Brundtland Report *Our Common Future* (WCED 1987) which defined it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." That report was preceded by 15 years of intergovernmental deliberations, starting with the prominent International Conference on the Human Environment in Stockholm in 1972 (Sohn 1973), and followed by 28 years of international talks through a series of summits. Since the publication of the Brundtland Report, there has been strong political consensus that economic development must converge with social equity and environmental protection. However, implementing the three dimensions of sustainable development has seemingly been held back by financial constraints, national priority settings, social unrest, and the elusive specification and operationalization of the sustainable development concept.

A new, integrated sustainable development framework, known as the "Sustainable Development Goals" (SDGs) comprise 17 goals and 169 indicators that are mostly action oriented, global in nature and universally applicable. They build on the well-known Millennium Development Goals (MDGs, see UN 2012) and aim to build on MDGs achievements and to respond to new and emerging challenges. SDGs however, cannot be attained without practical implementation and monitoring strategies. There is a clear requirement to develop practical tools for the accomplishment of the new SDGs. Sustainable landscape development, incorporating, *inter alia,* agriculture, production forestry, rural energy, water production, restoration of degraded lands as well as a potential to enhance livelihoods for many poor people, has great potential as a framework for achieving most of the SDGs (Jones and Wolosin 2014; Mayers 2014). Sayer et al. (2013) claim that the landscape concept provides the setting to enable the unfolding of many difficult problems and associated solutions in relation to SDGs.

1.2 Landscapes and landscape approaches

Landscapes, if managed appropriately, yield a wide range of goods and services vital to humanity, including food, wood and other raw materials, as well as life support processes (e.g. climate regulation, water purification,), life fulfilling conditions (e.g. educational, aesthetic and recreation opportunities) and conservation options (e.g. genetic diversity for future use) (Gulickx et al. 2013; Baral et al. 2014; Ungaro et al. 2014). Many landscape products (e.g. timber, food) have commonly occurred in markets throughout human history and others (e.g. climate regulation) are emerging via various market-based instruments (e.g. payment for environmental services [Engel et al. 2008]). While investment in landscapes for production of forest goods can be profitable, such investment can often provide a number of environmental services critical to society at no additional cost (Dewees et al. 2011; Baral et al. 2014). We first discuss what we mean by 'landscapes' and then focus on providing robust and pragmatic means of measuring sustainability outcomes of landscape-level investments.

The term "landscape" has been increasingly used in fields ranging from the ecological to the socioeconomic and political sciences (see Tress and Tress 2001 and Wu 2012a, 2013 for various definitions and concepts of landscape ecology). Forman and Gordon (1986) defined landscape as "a kilometres-wide geographic area which corresponds to the human perceived landscape." Fundamentally, a landscape is a "spatially heterogeneous area" that can be large or small in size depending on the nature of its topographic or ecosystem heterogeneity or other parameters. Its definition then depends on the perspectives and objectives we apply to the landscape. For the purpose of this paper, we define landscape as "a place with governance in place" as suggested by Holmgren (2013). This relatively simple but practical definition covers two important characteristics: (i) scale – a geographical area that can be very small to very large; and (ii) governance – the existence of institutions (formal or informal) that consider options for the landscape and set management priorities (Holmgren 2013). In another words, landscapes are places where humans and natural ecosystem reside and interact with each other (Potschin and Haines-Young 2012; Wu 2013). A landscape is composed of patches with different characteristics that in turn contain smaller, spatially nested patches (Wu and Hobbs 2002; Wu 2012b). The sustainability of landscapes is influenced not only by the interactions among socioeconomic, environmental and institutional components but by their spatial configurations and management practices (Musacchio 2009; Turner et al. 2012). The focus of this paper is therefore "sustainable landscape" development by means of sustainable land-use practices, particularly agriculture and forestry or agroforestry systems. We see landscape approaches as a potential vehicle to achieve sustainable development.

Scientists, conservation organizations and governments have promoted a landscape approach for meeting the increasing demands for food and non-food products while minimizing the adverse impacts on natural environments (Sayer et al. 2013). A wide variety of landscape approaches have been applied in different settings and there is no universally accepted definition. They all provide a framework for integrating multiple objectives at landscape scale in an orderly manner for the 'best' possible outcomes for society. In many cases, landscape approaches are synonymous with spatial planning (Van Ittersum et al. 2008). For further discussion about landscape approaches see Milder et al. 2010; Sayer et al. 2013; Reed et al. 2014.

Ten key principles of a landscape approach as developed by a team from CIFOR and its partner researchers (see Sayer et al. 2013) are listed in Appendix 1. This list provides a summary explanation of the term "landscape approach", and how it seeks to address the challenges of enhancing productivity while minimizing negative impacts on the environment. In effect, a landscape approach seeks to provide practical tools for allocating and managing land to achieve desired socioeconomic and environmental outcomes where there is competition between land uses (Sayer et al. 2013). Proponents of landscape approaches claim these have the potential to enhance the provision of multiple ecosystem services that are vital to human survival and well-being. However, various trade-offs among these goods and services are inevitable at both spatial and temporal scales (Wiens 2013; Sayer et al. 2013; Baral et al. 2014). Sustainable landscape management often involves seeking ways to reduce trade-offs among multiple goods and services that are potential outputs from various components of land utilization within landscape. Table 1 provides brief definitions of several commonly used terms related to the field of landscape sustainability from recent literature.

1.3 Investing in landscapes

Sustainable land uses may result in net positive benefits to society via the production of a wide range of market goods, such as food, timber, medicinal plants and non-market services such as clean water, fresh air and natural scenery. Some have shown that appropriate landscape investment can provide attractive rates of return to the investor and that risks can be minimized through diversification of crops, locations and end uses (Dewees et al. 2011).

Table 1. Definition of key concepts and terms used in this paper.

Key concepts	Brief definition	References
Ecosystem services	The benefits people obtain from ecosystems. These include: (i) provisioning services such as food, water, timber and fiber; (ii) regulating services that affect climate, floods, disease, wastes and water quality;(iii) cultural services that provide recreational, aesthetic and spiritual benefits; and (iv) supporting services such as soil formation, photosynthesis and nutrient cycling. They are often known as "landscape services." This paper deals mainly with regulating (Section 5.2) and provisioning (Section 5.4) services, because of their importance in providing basic materials for comfortable and safe living, human health and security.	MEA 2005
Landscape	A spatial context delineated by an actor where natural and socioeconomic systems intersect. It constitutes an arena in which entities, including humans, interact according to rules (physical, biological and social) that determine their relationships. In short, it is "a place with governance in place" (Holmgren 2013).	Gignoux et al. 2011; Sayer et al. 2013; Wu et al. 2013
Landscape approach	An integrated approach working across institutional boundaries that aims to reconcile competing land uses and to achieve both conservation and production outcomes, while recognizing and negotiating for inherent trade-offs.	Milder et al. 2010; Sayer et al. 2013
Landscape investments	The action or process of investing money in landscapes for profit or material results and sustainability outcomes.	Authors, this paper
Landscape services	The goods and services provided by a landscape to satisfy human needs, directly or indirectly. The term is used here interchangeably with "ecosystem services" (Gulickx et al. 2013; Ungaro et al. 2014).	Termorshuizen and Opdam 2009.
Livelihood	The capabilities, assets – both material and social resources – and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capability ties and assets, and provide net benefits to other livelihoods locally and more widely, both now and in the future, while not undermining the natural resource base.	Chambers and Conway 1991
Resource use efficiency	Use of the earth's limited resources in a manner that minimizes the impacts on the environment or resources. It often allows users to create more with less and to deliver greater value with less input.	EC 2015
Sustainability	The capacity to fulfill a set of goals, or the ability to continue making improvements over time under changing conditions: requires continued adjustment in response to changing conditions, knowledge and priorities.	Hansen 1996 Dale et al. 2013
Sustainable development	Development that meets the needs of the present society without compromising the ability of future generation to meet their own needs.	WCED 1987
Sustainable intensification	Where the yields of global agriculture are increased without adverse environmental impact and without the utilization of more land.	The Royal Society 2009
Sustainable land-use practices	Activities or practices at landscape level that are environmentally sound, economically profitable, and socially just. They can be either alone or a combination such as agriculture, forestry, agroforestry and wind energy farming.	Authors, this paper
Sustainable landscape	Landscape in which ecological integrity and basic human needs are concurrently maintained over generations.	Forman 1995
The landscape fund	A network-based system for financing sustainable land use. Its purpose is to transform agriculture and forestry at global scale by delivering capital in new ways that combine innovative approaches derived from science, finance and technology.	Authors, this paper

Combinations of crops with different end uses, harvest cycles and markets can be integrated within a landscape as a single investment product. Moreover, ethically designed investments in land use can also enhance landscape sustainability. However, changing existing practices to more sustainable land use over a landscape often requires considerable investment in capital, labor and technology, at least in the short term. Primarily, such investments have to come from the private or corporate sectors, especially where local land users are small-scale and resource poor.

There are a number of ongoing initiatives in sustainable land-use practices as investment products (UNEP 2014). There is evidence that many private individuals and institutions are interested in investing in sustainable land use (SLU) practices that provide risk-adjusted returns (Griffith-Jones et al. 2009). It has been estimated that over US$225 trillion dollars of private capital are currently being allocated through the world's financial markets (Burrows 2014). In addition, many investors specifically seek ethical investments in land use that will bring profit under sustainable conditions.

Burrows (2014) notes that strong indicators and measures of performance are a key prerequisite for attracting investment. A small number of high-performing indicators that are easy to measure and closely related to policy objectives can be more effective than a large set of indicators that are difficult to measure and require greater time and resources. Management solutions at a scale for small- and medium-sized producers in agriculture and forestry have generally not emerged because transaction and verification costs have been high. As a result, long-term and affordable capital has so far been largely unavailable to smallholder producers, regardless of the sustainability of their systems. While a number of measuring and monitoring mechanisms exist, many are not applicable for assessing the sustainability of landscape-level investments due to their high transaction costs and time requirements.

This paper reviews and analyses a set of indicators with a view to recommending sustainable landscape indicators that are consistent with emerging sustainable development goals (SDGs) and climate change policy objectives. These parameters and associated indicators are envisioned as a sound basis for measuring the performance of landscape investments. Apart from supporting investments in sustainable land use, such a set could be useful for monitoring and reporting purposes in development contexts. The target audience includes policy makers, business people including institutional and private investors, landowners and consumers.

In Section 2 of this paper, we review the main concepts and approaches and tools to assess landscape sustainability. In Section 3 we review a wide range of indicators and indices for measuring landscape sustainability and sustainable development. Section 4 discusses the key desirable properties of sustainable landscape parameters and indicators. In Section 5, we propose sustainable landscape parameters, and associated indicators. Section 6 discusses potential linkages between the SDG framework and landscape parameters followed by concluding comments outlined in Section 7.

2 Approaches and tools to assess landscape sustainability

2.1 Concepts/frameworks

Sustainability means different things to different people, depending on their contextual circumstances, (Gafsi et al. 2006; Sydorovych and Wossink 2008; Efroymson et al. 2013). Two schools of thought on sustainability are commonly reported in the environmental and sustainable development literature. First, sustainability is an "achievement" that can be defined and measured, using certain criteria and indicators (Dahl 2012; Moldan et al. 2012). A great deal of progress has been made in defining and assessing sustainability in this regard over the past decades.

The second school of thought assumes sustainability is aspirational rather than a state, which can only be defined in terms of the direction towards the goal, without the requirement to be measured in absolute terms (Bell and Morse 2008; Pollesch and Dale 2015). Interestingly, both schools of thought share a common conceptual definition of sustainability that is integrative in considering social, economic and environmental dimensions, or the "three pillar concept" (Hacking and Guthrie 2008; Mori and Christodoulou 2012). This paper builds on the latter perspective, because sustainability entails a combination of several biophysical and socioeconomic aspects that are not all readily measurable in quantitative ways (Bell and Morse 2008; Pollesch and Dale 2015).

We agree with Dale et al. (2013) who hold that assessing landscape sustainability involves comparing the relative merits of different options for land use and achieving sustainability requires continued adjustment in response to changing conditions, knowledge and societal priorities. Sustainability assessment requires an understanding of how dynamic processes interact under alternative trajectories and how interpretations depend on the priorities of stakeholders in a specific place and time (Dale et al. 2013). According to Hacking and Guthrie (2008) sustainability assessment is a process that "directs decision-making towards sustainability." Devuyst et al. (2001) define sustainability assessment as "a tool that can help decision-makers and policy-makers decide which actions they should or should not take in an attempt to make society more sustainable." Over the past three decades or more, there has been increasing recognition of the importance of assessing and reporting on sustainability and hundreds of assessments have been undertake at different levels of governance (IISD 2009; OECD 2009).

2.2 Existing tools

The purpose of sustainability assessment is to provide decision-makers with the means to evaluate integrated nature–society systems (at global to local scale) in the short and long term. Such evaluations would help to determine which actions should or should not be taken in an attempting to move towards more sustainable (natural and social) landscapes (see Ness et al. 2007). Further, sustainability assessment is becoming an important decision-making tool in anticipating the sustainability implications of proposed projects, plans or policies (Pope et al. 2004). A wide range of approaches and tools has been used to assess sustainability and the choice of tools usually depends on the context and scale of analysis (Acosta–Michlik et al. 2011). A variety of sustainability assessment approaches and tools are discussed by Buytaert et al. (2011) and US–EPA (2013) and a selection from various disciplines are summarized in Table 2.

In the context of sustainable landscape management, we propose to use an approach to assessment based on parameters and indicators because of its relative ease of use, flexibility and transparency. However, we propose that a limited number of parameters/indicators are applied, to avoid the complexity of previous approaches, which can lead to high costs, ambiguities and to context-specific results that cannot be generalized. The likely performance of identified parameters/indicators related to the SDGs framework is compared qualitatively in Section 6.

Table 2. Some common approaches and tools traditionally used in the assessment of sustainability.

Tools	Brief description	Use	Qualitative/ Quantitative	Reference
Sustainability criteria and indicators	Popular in policy and management of monitoring and assessing progress towards sustainable management goals in a given area (see Prabhu et al. 1998 for criteria and indicators associated to sustainable forest management).	Frequently used because of ease of use, flexibility and transparency	Qualitative and quantitative	IISD 2004, 2005; ITTO 2005;
Life cycle assessment	A practical tool to assess the environmental issues and impacts of production systems in a systematic way, from raw material acquisition to final disposal, in accordance with the stated goals and scope.	One of the most commonly used in carbon projects	Quantitative	Baelemans and Muys 1998; ISO 2006
Environmental impact assessment	A tool used to evaluate potential environmental impacts – considering the natural, social and economic issues – of a proposed project, with the aim of reducing the negative effects.	Well known and frequently used	Qualitative and quantitative	UNEP 2002
Cost benefit analysis	A method to estimate the total impact of a project on society by calculating social costs and benefits. Environmental impacts are evaluated and converted into monetary terms.	Well-established and utilized in economic decisions	Quantitative	EC 2008
Pressure-state-response framework	A framework proposed to evaluate how the pressures of human and economic activities lead to changes in the environmental states that prevail as a result of that pressure and may provoke responses by society to change the pressures and state of the environment.	Most commonly used and constantly evolved indicator framework to assess sustainability	Qualitative and quantitative	OECD 1999

Source: Adapted from Buytaert et al. (2011)

3 Indicators and indices for measuring sustainability and sustainable development

Scientists and various agencies have developed hundreds of indicators and indices to measure sustainable development (McRae et al. 2012; Singh et al. 2012). These have been used at various scales since the Rio Earth Summit in 1992 and some important indices are summarized in Table 3.

Sustainability indices such as those in Table 3 are mainly used for nationwide reporting of sustainable development outcomes and are not applicable in landscape investment. For example, many are political and they typically include absolute targets that are time and context-specific. Numerous authors have proposed indicators and indices for sustainable agriculture (e.g. Sands and Podmore 2000; Reganold et al. 2001; Stevenson and Lee 2001), forestry (Prabhu et al. 1998), and bioenergy production (Acosta-Michlik et al. 2011; Buytaert et al. 2011) that in principle are applicable to landscape investments. However, they are numerous, often difficult to measure and demanding of time and resources.

There is a clear need to identify a small set of efficient and generic parameters for determining sustainability outcomes in landscapes. This could potentially help in, *inter alia*, assessing performance of development projects or support finance initiatives designed to invest in sustainable land-use practices. In the following, we examine the required properties and possible construction of such parameters, as well as some potentially suitable measurable indicators.

Table 3. Some commonly used sustainability indices used in the assessment of sustainable development and landscape sustainability.

Sustainability indices	Description	Limitations	Reference
Gross domestic product (GDP)	Introduced in the late 1940s after World War II, GPD used to count government spending on services and war as a net positive for the economy at that time. With continuous revisions, GDP became the most influential index of the last century; it has been used as a composite index to gauge the health of a country's economy. It expresses the total monetary and market value of all final goods and services produced over a specific time period in a country.	Although GDP is the most popular means of measuring economic performance, it ignores social costs, environmental impacts and income inequality.	Van den Bergh 2009; Costanza et al. 2014
Green GDP	Green GDP was an alternative to GDP developed in the early 1990s in an attempt to take account of consequences for public goods and human well-being caused by environment and natural resource depletion.	Green GDP fails to accommodate aspects of psychological and physical well-being of citizens.	Talberth and Bohara 2006
Index of Sustainable Economic Welfare (ISEW) and Genuine Progress Indicator (GPI)	GPI is a modern version of the ISEW, first proposed in 1989. The GPI is aimed to measure economic welfare generated by economic activity, essentially counting the depreciation of community capital. It also includes the imputed values of non-market goods and services and adjusts for income distribution effects.	GPI uses inappropriate valuation methods without having a solid theoretical basis. It assumes that human-made capital and natural capital are substitutes.	Daly and Cobb 1989; Kubiszewski et al. 2013b; Costanza et al. 2014
Human development index (HDI)	HDI was used by the United Nations Development Programme (UNDP) in the 1990s through the *Human Development Report* to assess levels of human and social development. It is a composite statistic of life expectancy, education and *per capita* income indicators and is used to rank countries.	A major criticism of HDI is its abstraction from the environmental dimension of human welfare.	http://hdr.undp.org/en/content/human-development-index-hdi (Accessed 16 May 2015)

continued on next page

Table 3. continued

Sustainability indices	Description	Limitations	Reference
Genuine Savings Index (GSI)	The GSI is a simple indicator that can be used to assess an economy's sustainability. It measures the level of saving after depreciation of produced capital and investments in human capital. It accounts for depletion of minerals, energy and forests and damage from local and global air pollutants.	GSI requires historical data and longer time horizons for better performance.	Lin and Hope 2004; Costanza et al. 2014
Inclusive Wealth Index (IWI)	The measurement of economic growth ignores the rapid irreversible depletion of natural resources that will cause serious detriment to future generations. Beyond the traditional economic and development yardsticks of GDP and the HDI, the IWI considers a full range of assets such as manufactured, human and natural capital. It also shows the actual state of a nation's wealth and the sustainability of its growth.	This framework is fraught with limitations associated with questionable theoretical assumptions and gaps in data availability.	UNU-IHDP and UNEP 2012; http://www.unep.org/newscentre/default.aspx?DocumentID=2688&ArticleID=9174#sthash.cYDc38ci.dpuf (Accessed 16 May 2015)
Ecological footprint (EF)	The EF is a measure of human impact on ecosystems. It reflects the human demand for natural capital that may be juxtaposed with the ecosystem's regenerative capacity. The EF of a country is the sum of land-use types required to produce the food, fiber and wood it consumes, to absorb the wastes emitted when it uses energy and to provide space for infrastructure.	Very limited in scope and limited role within a policy context.	Wiedmann and Barrett 2010
Environmental sustainability index (ESI) and environmental performance index (EPI)	The ESI was a composite index developed between 1999 and 2005. It measures environmental sustainability covering natural resource endowments, pollution levels, contributions to protection of the global commons, and a society's capacity to improve its environmental performance over time. It ranks how well countries perform on high-priority environmental issues in protecting human health and ecosystems.	The ESI does not cover a number of environmental issues such as quality of waste management, destruction of wetlands and exposure to heavy metals.	Esty et al. 2005; Hsu et al. 2014
Gross National Happiness (GNH) index	Coined in 1972 by the Fourth King of Bhutan, GNH indicates balanced development with preservation of traditions and nature. The concept implies that sustainable development should take a holistic approach towards notions of progress and give equal importance to non-economic aspects of well-being. GNH is a multidimensional development approach that seeks to achieve a harmonious balance between material well-being and the spiritual, emotional and cultural needs of a society.	It requires subjective analysis. Indicators may be different in the context of country and people.	Ura et al. 2012; Kubiszewski et al. 2013a; Wang et al. 2014
Happy Planet Index (HPI)	Invented by the New Economics Foundation in 2006, the HPI is a leading global measure of sustainable well-being. It is a new measure of progress that focuses on what matters: the extent to which countries deliver long, happy, sustainable lives for the people, i.e. sustainable well-being for all. The weighted index gives progressively higher scores to nations with lower ecological footprints.	Very subjective and controversial. It ignores issues such as political freedom, human rights and labor rights.	Johns and Ormerod 2007; Abdallah et al. 2012
Sustainable Society Index (SSI)	The SSI was developed in 2006 based upon the sustainability definition of the Brundtland Commission that explicitly including the social aspects of human life. The SSI integrates the most important aspects of sustainability and quality of life of a national society in a simple and transparent way.	Aggregation of all SSI indicators into one single figure for the SSI can be misleading.	Van De Kerk and Manuel 2008; Van De Kerk and Manuel 2014

Source: Adapted from: Wu and Wu (2011); Wu (2012)

4 Properties of sustainable landscape parameters

In the previous section, a wide range of sustainability indicators or indices proposed by various organizations and authors were mentioned. Drawing from the literature on those indicators, we identify key desirable properties for parameters and associated indicators that will be use to define the parameters and indicators for assessment of landscape sustainability. There is growing interest in concise and balanced sets of parameters that provide meaningful information on the key dimensions of sustainable landscape to policy makers, land managers and the general public. We propose a framework comprising a small number of key parameters of sustainable landscape development, each of which will have an associated standardized indicator (or measure). Although many previous studies and frameworks have used similar parameters and indicators, here we focus on parameters and indicators that serve the needs of investors seeking profitable returns from land-use investments while also satisfying sustainability requirements in an efficient and pragmatic manner. We have identified the key desirable properties of parameters and indicators as summarized in Table 4.

While some previous indicators or indices are claimed to have some of the properties listed in Table 4, they do not provide a level of precision that is required for scaling-up, including the integration between scales. Parameters and indicators with the properties shown in Table 4 can provide the general information required, if assessing whether a landscape is being managed in sustainable way or whether it is heading in the direction of greater sustainability.

Table 4. Desirable properties for sustainable landscape parameters and associated indicators.

Parameters should be
• forward looking and practical
• small in number (fewer than five)
• adequate in coverage or linkage to SDGs framework
• generally applicable to any landscape situation
• predictive of changes due to management choices
• sufficient when considered together
Indicators should
• be practical (easy to understand, cost-effective)
• be easily measurable (and compatible with changes in temporal and spatial scales)
• be readily understandable and policy-relevant
• fulfill statistical requirements concerning verification, reproduction; representativeness, and validity
• provide adequate information on spatio-temporal scales
• have high transparency of the derivation strategy
• provide information on long-term trends
• reflect local sustainability that enhances global sustainability

Source: Dale and Polasky (2007); Wu and Wu (2011); Dale et al. (2013); Holmgren (2013, 2014)

5 Establishing a set of parameters for landscape sustainability

Based on the desirable properties for sustainable landscape parameters (Table 4), we propose a set of four broad parameters derived from the literature that can be applied to assess the sustainability within any landscape – in terms of livelihood provisions, ecosystem services, efficient resource use and delivery of food, wood and raw materials (Figure 1). We acknowledge that this broad grouping does not provide a complete list of parameters to evaluate the sustainability of a landscape. Beyond these basic landscape parameters, there is a need to address aspects of governance (e.g. land tenure, existence/implementation of legal frameworks) and other aspects not within the scope of this paper. However, we consider that when indicators from each of these parameters/groups are used, they can together provide reasonable confidence in assessing landscape performance to stakeholders, including investors, land managers and policy makers. In addition, proposed parameter groups are not intended to measure sustainability in absolute terms, which is very difficult if not impossible to achieve. Nevertheless, they can provide an indication of whether a landscape is being managed in a sustainable direction (aspired to by land managers or government agencies) in terms of producing vital goods and services to the society. Furthermore, changes in sustainability may be considered for one landscape over time, but sustainability of different landscapes should not be compared by means of the indicators proposed here.

The following section outlines the rationale behind the selection of these parameters and associated indicators. Operational monitoring of these indicators, including the sampling design, accuracy and uncertainty is not within the scope of this paper.

5.1 Livelihood provisions

The sustainability of landscapes can be considered in terms of improvements to the livelihoods of people dependent on the landscape. For the purpose of this paper, a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living (Chambers and Conway 1991). A livelihood is considered sustainable when it can cope with and recover from stress and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base (Chambers and Conway 1991). Key livelihood assets and their associated indicators in rural settings are outlined in Table 5. Methods of measuring livelihood impacts can vary depending on available data, resources and time.

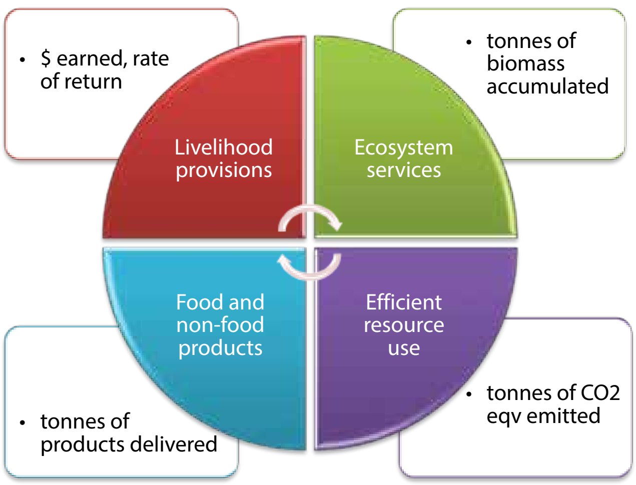

Figure 1. Key landscape parameters and indicators needed in the assessment of sustainability associated with investment in land use within landscapes.

Table 5. Rural livelihoods assets (or capitals) and their indicators.

Livelihood assets	Determining indicators
Natural	Level of production in agriculture, forestry, aquaculture or other production systems
Financial/ economic	Access to credit, financial services, income generating activities
Physical	Availability of infrastructure, communications, drinking water, irrigation, alternative energy
Social/ institutional	Participation, social inclusion, gender balance, empowerment, cultural values
Human	Access to health, education, skills development, awareness

Source: Ellis (2000)

Although all livelihood assets are important for human well-being, assessing a number of assets by associated indicators is an immense task. Thus income level is often taken as one of the most important indicators, because living standard is seldom uplifted without income being enhanced through economic activities within the landscape. Improved income is also directly linked with other livelihood assets such as access to health, education, infrastructure and communication. Livelihood status can be measured by tangible livelihood assets, such as cash savings, or intangibles such as opportunities for employment or education (see Table 7).

5.2 Ecosystem services

Both natural and modified ecosystems contained within a production landscape can provide a wide range of ecosystem services that are essential to human survival (MEA 2005; Balvanera et al. 2006) and economic prosperity (TEEB 2010). The UN Millennium Ecosystem Assessment (MEA) (2005) identified a strong link between ecosystem services and human well-being. Ecosystem services contribute substantially to comfortable and safe living, human health, harmonious relations, security and freedom of choice and action (MEA 2005, see Figure 2). Many definitions and classifications associated with ecosystem services include ecosystem goods under the category of provisioning services (MEA 2005, TEEB 2010). However, in the context of landscape investment, it is more useful for analysis to separate ecosystem goods and services to avoid double counting. Actual provisioning services (or ecosystem goods) are assessed under the category of food and non-food materials (Section 5.4). Here we focus mainly on regulating ecosystem services because of their importance in providing basic materials for comfortable and safe living, human health and security (see Figure 2, Table 6). Figure 2 shows the relationship between ecosystem services and human well-being and Table 6 provides key regulating services in production landscapes and possible indicators.

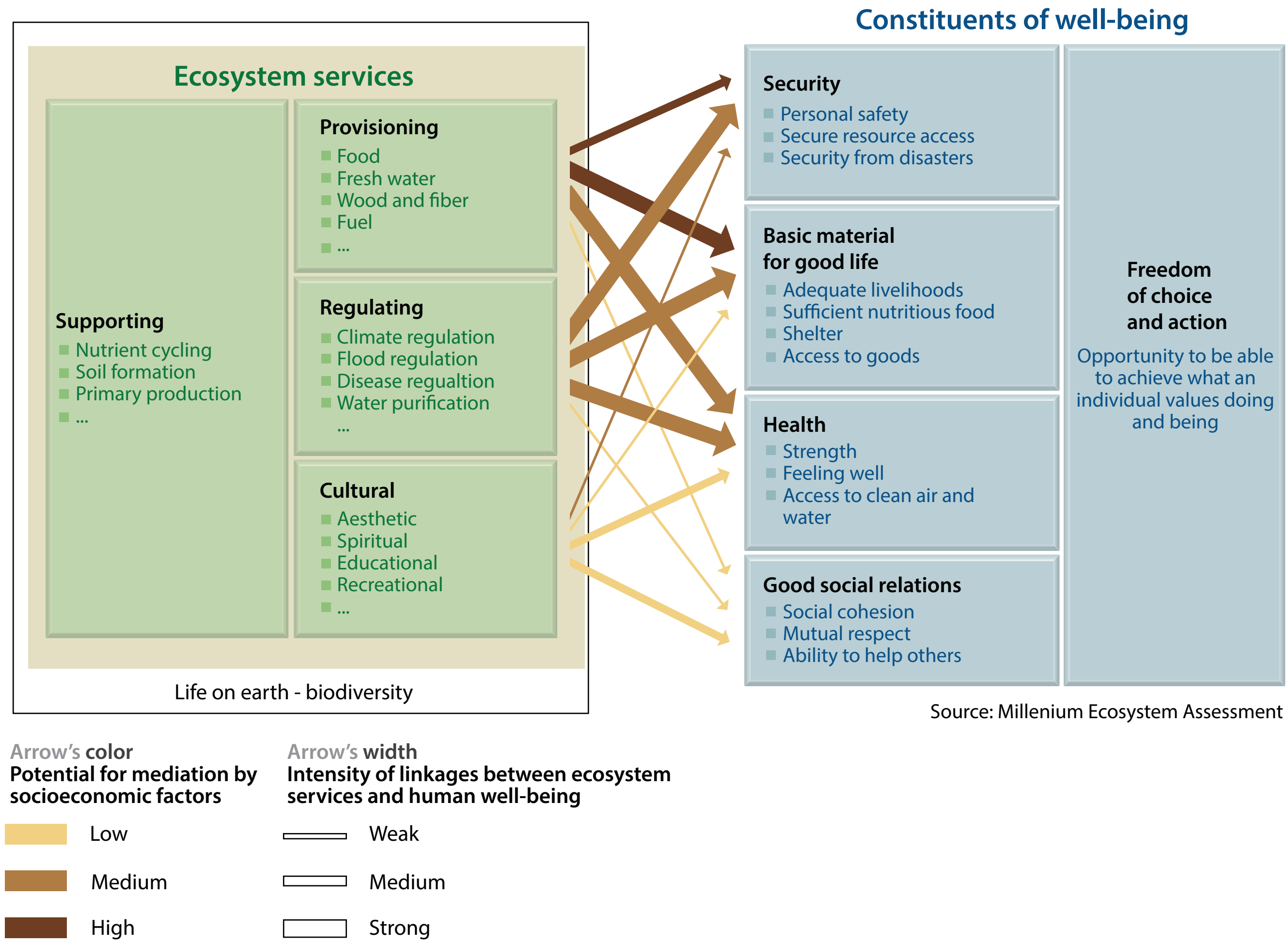

Figure 2. Relationships between ecosystem services and human well-being.

Source: MEA (2005)

A wide range of indicators for assessing ecosystem services has been proposed by various authors (De Groot et al. 2010; TEEB 2010) and it would be very difficult and time-consuming to assess all of the indicators. For the sake of brevity, practicality and simplicity, we adopt only one key indicator here, i.e. mean annual biomass dry matter (DM) retained from annual production per hectare. We understand that there are many other important indicators (such as biodiversity, water and soil health) but biomass is a key indicator that underpins many other regulating and provisioning ecosystem services (Cardinale et al. 2007, 2012). It can best be expressed as mean annual DM retained in the landscape on a long-term basis.

The literature on ecosystem services shows that primary production can be a good indicator for assessing landscape-specific ecosystem services. Net primary productivity is commonly measured by total plant biomass produced/ha/year (after losses from respiration, predation and decomposition). Total mean standing biomass held/ha/annum is a good proxy for a number of ecosystem services such as carbon sequestration, pollution filtration or fauna habitat (Tilman et al. 2005; Fitter et al. 2010). International climate change policy has also recognized the paramount role of primary production in climate change mitigation through its function in sequestration of atmospheric carbon dioxide as well

Table 6. Important regulating ecosystem services in production landscapes, brief description, beneficiary type and potential indicators.

Ecosystem services	Description	Beneficiary/ Use	Indicators/Unit of measurement
Air quality regulation	Capturing/filtering of dust, chemicals and gases	Public	Leaf area index; air quality amplitude
Global climate regulation	Sequestration and storage of greenhouse gases in ecosystems	Public	Sink of carbon dioxide, methane and water vapor, Mg ha^{-1} yr^{-1}
Local climate regulation	Changes in local climate components such as wind, precipitation, temperature and radiation due to ecosystem properties	Public	Temperature (°C); albedo (%); precipitation (mm); shaded areas (ha, % of landscape)
Nutrient regulation	Internal cycling, processing and acquisition of nutrients by vegetation and microorganisms	Private	kg ha^{-1} yr^{-1}
Pollination	Pollination of wild plant species and harvested crops	Private/ Public	Numbers of or impact of pollinating species
Water purification	Capacity of an ecosystem to purify water, e.g. from sediments, pesticides etc.	Public	Water quality indicators; sediment load (g l^{-1})
Water flow regulation	Role of land cover in regulating hydrological flows by vegetation	Public / Private	Groundwater recharge rate (m^3 ha^{-1})
Erosion regulation	Soil retention and the capacity to prevent and mitigate soil erosion and landslides	Private/ Public	Vegetation cover (%); loss of soil particles by water and wind (kg ha^{-1} yr^{-1})
Natural hazard protection	Protection from and mitigation of effects of floods, storms and avalanches	Private/ Public	Number of prevented hazards (No/ yr^{-1})
Pest and disease control	Capacity of an ecosystem to control pests and diseases through genetic variations of plants and animals making them less disease-prone and by the actions of predators and parasites	Private/ Public	Populations of biological disease and pest control agents (No. ha^{-1})
Biodiversity	Landscape capacity to hold naturally functioning ecosystems and support a diversity of plant and animal life	Public/ Private	Species richness (No. ha^{-1}); Shannon index
Regulation of waste	The capacity of an ecosystem to filter and decompose organic material in water and soils	Public/ Private	Amount and number of decomposers (No. ha^{-1}); decomposition rate (kg ha^{-1} yr^{-1})

Units of measurement: 'm^3' cubic meter, 'ML' megaliter, 'Mg' megagram, 'kg' kilogram 'g' gram, 'l' litre.

Source: Kandziora et al. (2013); Baral et al. (2013)

as the long-term carbon storage potential in tree and root biomass in terrestrial ecosystems (Searchinger et al. 2008). Primary production is likely to be negatively impacted by unsustainable land use and land-use change, land degradation, climate change and loss of biodiversity in both quality and quantity (Fitter et al. 2010). For these reasons, in assessing the long-term capacity of a landscape to provide ecosystem services, we can use biomass held (as DM) per unit area as an appropriate indicator of ecosystem (and landscape) health.

5.3 Efficient resource use

Improvement in resource-use efficiency implies achieving 'more with less' resources and/or with less damaging impact (EC 2015). Planners and policy makers commonly see this as the path along which both economic development and livelihood outcomes can progress, i.e. lower resource use and minimal impacts on the environment (Foley et al. 2011). UNEP (2012) defines efficient use of resources from a life-cycle and value-chain perspective that means reducing the overall environmental impact while producing and consuming ecosystem goods and services, from extraction of raw materials to final use and disposal. A generic example showing a comparison of average *per capita* wealth and resource use for various countries around the world is depicted in Figure 3.

Figure 3 indicates that at national level, higher prosperity is often associated with greater consumption of resources. However, landscape investments aim to maximize food and non-food

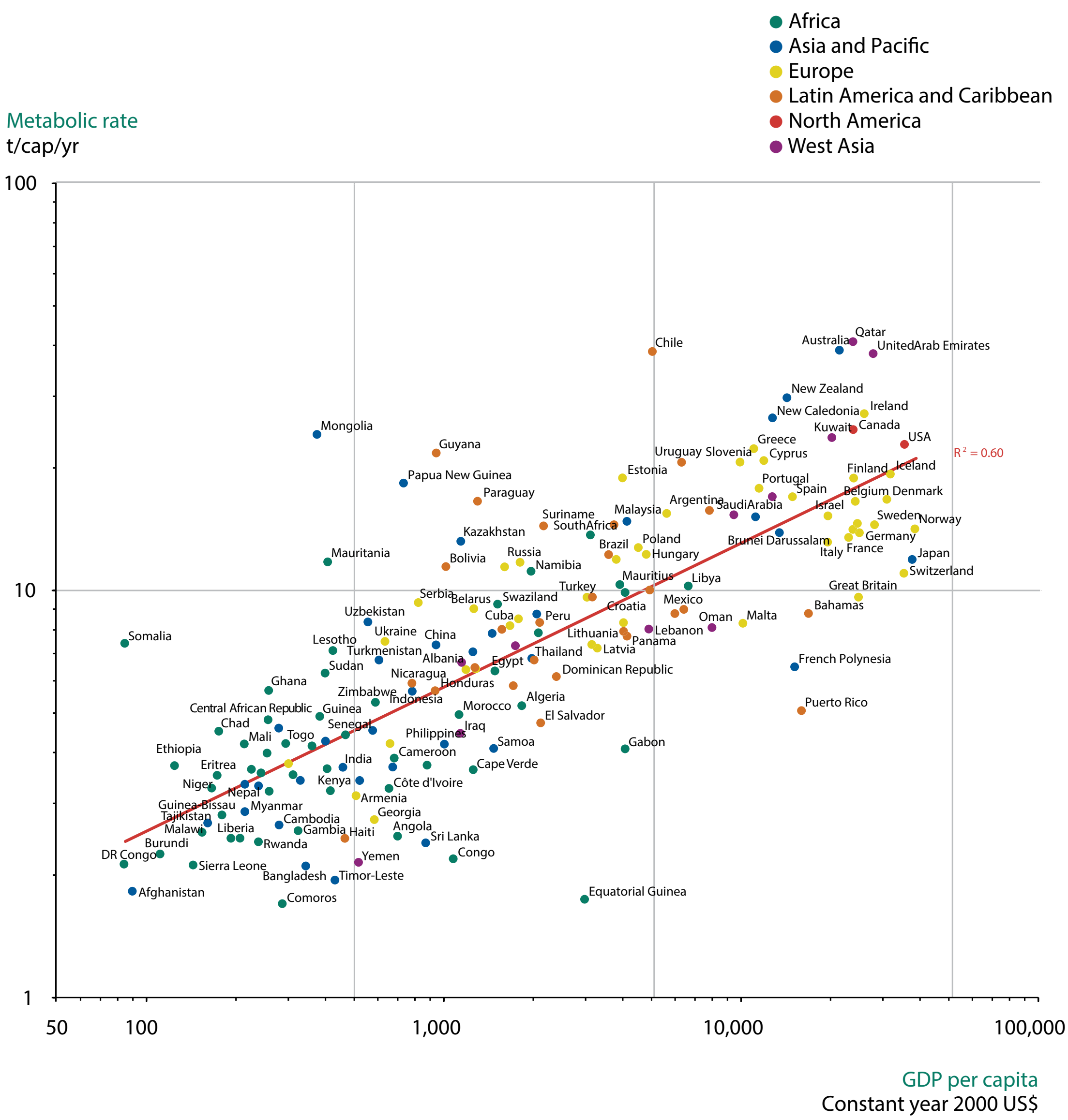

Figure 3. Comparison of *per capita* wealth and resource use in 175 countries in 2000.

Source: UNEP (2011)

production with the minimum possible use of resources and limited use of chemicals. In order to know whether or not proposed land-use practices are on a path towards resource-use efficiency, we need robust indicators that can be measured with reasonable confidence. Improved resource efficiency in land use can be measured as net greenhouse gas emissions (CO_2-eqivalent) from land-use practices because this is directly linked to energy efficiency (West et al. 2010; Foley et al. 2011). It is also the cornerstone in sustainable development that we are striving for today (Chu and Majumdar 2012).

5.4 Food, wood or raw material production

As human population numbers and quality of living are rising rapidly in many regions, so too is the demand for food, wood, energy and raw materials, and this places increased pressure on landscapes. Various population scenarios suggest that 70% more food will be needed by 2050 (FAO 2009), and energy supply will need to be doubled by 2050 (WEC 2007). Similarly, the demand for timber will triple by 2050 (WWF 2014). However, the expansion of agriculture or production forestry in natural forest areas is not a sustainable solution and is banned in many parts of the world (FAO 2012). Therefore the increasing demand for resources and products will have to come from sustainable "intensification of landscapes". It is clear that along with other parameters the actual production of food, wood and raw materials from landscapes is an important parameter for assessing and monitoring landscape sustainability. The amount of food and raw materials produced per unit area can be measured in tonnes (t) (of food) per hectare (ha) per year or cubic meter (of wood) per ha per year. However, as different products (e.g. livestock or cheese) have different dollar value per unit of DM to others (e.g. wheat or timber), units of measurement must take these differences into account. Table 7 summarizes the key parameters and measures proposed for measuring sustainability associated to landscape investments.

Table 7. Summary of key parameter categories for assessing sustainability outcomes in landscape, and associated measures/indicators.

Key parameters	Measures	Unit of measurement
Livelihood provisions	Total income or return from landscape	ROI, NPV
Ecosystem services	Total biomass stock in the landscape	t of biomass (DM) per unit area
Resource use efficiency	Total greenhouse gas emissions from the landscape	Net greenhouse gas emissions (CO_2-eqivalent)
Food and non-food products (productivity)	Amount of food production	t of food produced
	Wood and/or material production	Cubic meters of wood or raw materials produced

* ROI – return on investment, NPV – Net present value

6 The SDGs framework as it applies to the four parameters

Sustainable land-use practices for forestry and agriculture in particular will need to play crucial roles in achieving several of the UN's SDGs – since the outcomes from sustainable landscape development are closely connected with a large number of the SDGs and targets (Jones and Wolosin 2014; Mayers 2014; Table 8). Although agriculture and forestry are only explicitly mentioned in three of the SDG targets (2.3, 2.4 and 15.2, see UN 2015 for SDGs and targets) the importance of the land-use sector beyond food security and sustainable forest management is evident from their contributions to at least eight other SDGs (see Table 8).

While our rapid coverage rankings between the SDGs and outcomes of sustainable landscape parameters showed good linkage with at least 11 SDGs, various authors argue that land-use sectors have the potential to contribute to 15 SDGs (Brandon 2014; Seymour and Busch 2014; Farming First 2015). For example, there is an indirect linkage to Goal 4 (e.g. forestry and agriculture education), Goal 5 (e.g. gender landscape and climate change, women's perspectives in forest management), Goal 9 (e.g. agriculture and forest industry, timber trade), Goal 11 (e.g. role of urban forests to city residents), and Goal 14 (e.g. role of mangrove forest to support costal protection and marine resources).

Table 8. Linkages between SDGs and parameters/outcomes from sustainable landscapes.

No.	Sustainable development goals (SDGs)	Outcomes of sustainable landscape development				Direct linkage	Indicative performance of the 4 selected landscape parameters
		Improved livelihoods	Sustained ecosystem services	Efficient resource use	Enhanced food & non-food products		
1.	No poverty	H			M	✓	Strong
2.	Zero hunger	H	M		M	✓	Strong
3.	Good health and well-being	M			M	✓	Some
4.	Quality education						No obvious link
5.	Gender equity						No obvious link
6.	Clean water and sanitation		M			✓	Low
7.	Affordable clean energy			L	M	✓	Strong
8.	Decent work and economic growth	H			M	✓	Strong
9.	Industry innovation and infrastructure						No obvious link
10.	Reduced inequalities	M				✓	Some
11.	Sustainable cities and communities						No obvious link

continued on next page

Table 8. continued

No.	Sustainable development goals (SDGs)	Outcomes of sustainable landscape development				Direct linkage	Indicative performance of the 4 selected landscape parameters
		Improved livelihoods	Sustained ecosystem services	Efficient resource use	Enhanced food & non-food products		
12.	Responsible consumption and production				L		Some
13.	Climate action		H	H		✓	Strong
14.	Life under water						No obvious link
15.	Life on land		H	H	M	✓	Strong
16.	Peace, justice and strong institutions	M				✓	Some
17.	Partnership for the goals						No obvious link

'H' indicates high relevance, 'M' medium relevance and 'L' low relevance.
Coverage rankings are indicative only, based on literature and authors' informal discussions with experts.

7 Concluding comments

We have developed and presented a framework that aims to assist in measuring sustainability outcomes in landscapes and designed to apply to any landscape setting around the world.

We have identified that sustainable development aspirations must be met to a large extent through better land use and landscape management. Moving from current and often unsustainable land-use practices to sustainable land use may defer profit or reduce production in the short term, but this loss is offset by future longer term gains (Dale et al. 2012). In many cases, change to more sustainable and productive practices by rural land managers may not be feasible without improved access to technology and initial capital. We note that increasing interest in landscape investment may offer potential for removing such constraints, particularly because many investors seek returns on capital in addition to “ethical investment” and (sustainability) outcomes.

We argue that one limiting factor for scaling up of investments in sustainable landscapes has been the lack of a limited set of cost-effective, high-performing, scalable, communicable and standardized performance metrics. As a way forward, we suggest here four parameters, each with one indicator metric, as an appropriate set to serve as a proxy for sustainability in land use. The potential of each of these parameters/indicators is reviewed and its likely performance related to the SDGs framework. We found that outcomes of sustainable landscape development are closely connected with at least 11 SDGs and that there is potential indirect linkage to an additional five SDGs.

We acknowledge some limitations of our generic framework, such as the obvious omissions of direct indicators for some important ecosystem services, for example biodiversity, water and soil health. The main reason for this is a lack of commonly agreed, cost-effective and standardized metrics to measure these services. As a proxy for such services, we suggest the use of mean standing biomass in a landscape. Various authors have found that higher biomass usually means higher biodiversity (Cardinale et al. 2007; Ravenek et al. 2014), better soil health (Mueller et al. 2013) and better water regulation capacity (Ilstedt et al. 2007; Vanclay 2009). Monitoring specific ecosystem services can only be effectively done at the local level where the site-specific circumstances are best known.

In conclusion, we suggest that a limited set of performance metrics for assessing sustainability in landscape development, such as the one proposed in this paper, could be used to serve the needs of development and investment communities, in their efforts to arrive at appropriate solutions to some of the largest and most urgent challenges for humanity.

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Appendix I

The 10 key principles of a landscape approach (Sayer et al. 2013):

1. Continual learning and adaptive management
2. Common concern entry point
3. Multiple scale
4. Multifunctionality
5. Multiple stakeholder
6. Negotiated and transparent change logic
7. Clarification of rights and responsibilities
8. Participatory and user-friendly monitoring
9. Resilience
10. Strengthened stakeholder capacity

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Rapidly increasing demand for food and agricultural non-food products to meet the demands of rising populations with new consumption patterns have worrying implications for sustainability of many ecosystems globally. Landscape approaches are often promoted as a win-win solution to reducing harmful impacts of development – a means to balance social needs and economic performance, while maintaining ecological function. In this respect, landscape approaches that address multiple sector needs, including agriculture, production forestry and conservation, are identified as a significant opportunity to contribute to the United Nations new Sustainable Development Goals (SDGs). However, assessing and verifying sustainability outcomes across broad, diverse and dynamic landscapes is challenging, mainly because of the lack of pragmatic and standardized means of assessment and measurement in cost-effective ways. This paper aims to advance the concept of sustainable landscape development, including ways to assess sustainability performance and to leverage the scaling-up of investment in sustainable development, as a means of achieving SDGs and other goals.

Tools and indicators used to measure sustainability outcomes are reviewed in the context of landscape investments, to identify high performing and pragmatic parameters and associated measurable indicators. Considerations include seeking parameters that are applicable to any type or size of landscape, and standardized indicators that are measurable within short time-scale and resource constraints. Based on these requirements, we develop and present a framework associated with four universally important parameters: (i) livelihoods; (ii) ecosystem services; (iii) efficient resource use; and (iv) food and non-food products. This framework will be useful to assist in measuring sustainability outcomes in landscapes and is designed to be applicable to any landscape setting. We elaborate on readily measurable indicators for each parameter group. Linkages between sustainability outcomes in landscapes and SDGs are discussed.

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