Ecosystem Services and Environmental Change

From ecosystem accounting to environmental management

Prof. dr Lars Hein

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Rector Magnificus, ladies and gentlemen,

There is a long-standing recognition of the need to combine economic growth with maintaining the planet's natural resource base (e.g. WCED, 1989). This, however, is proving to be a major challenge. A first and important step in facing this challenge is understanding the way environmental change is taking place, from the local to the global scale, and how this is affecting people. This is the topic of my inaugural lecture.

In my lecture, I will focus on ecosystems, the benefits they supply to people, and how these benefits can be measured with ecosystem accounting. Ecosystem accounting is a type of natural capital accounting that aims to analyse changes in the capacity of ecosystems to support economic activities, in a way that is consistent with national accounts. Once operational, ecosystem accounting will allow monitoring changes in ecosystem capital and thereby monitoring the sustainability of ecosystem use, as well as the design of strategies for better management of ecosystems.

I will address a number of questions. First, what is driving the changes in ecosystem capital? Second, what exactly do we know about the status of, and changes in ecosystem capital? Third, what role can ecosystem accounting play in understanding environmental change? Fourth, how can ecosystem accounting support natural resource management? Hence, at the centre of this lecture is the relation between ecosystems and people.

Drivers for ecosystem change

A first set of questions pertains to why ecosystems change and to how we can measure changes in ecosystems and ecosystem capital. Ecosystems range from intensive croplands to pristine forests, and are characterised by their biotic and abiotic components, how these interact with one another, and how they are managed by people. Capital is the term I will use to denote those aspects of ecosystems that are valuable to people, because they support economic production or because they are consumed directly. The Millennium Ecosystem Assessment (2005) has taken stock of the state of the world's ecosystems, and distinguishes between indirect and direct drivers for ecosystem change. *Indirect* drivers include demographic change, economic drivers, socio-political drivers, cultural and religious drivers and science and technology. The *direct* drivers for ecosystem change include land use change, climate change, invasive species, overexploitation and pollution. Indirect drivers can also be seen as the causes behind the direct drivers, however the specific effects of indirect drivers are always a function of the environmental and resource management strategies that are pursued in society. The way ecosystems change, therefore, is a function of those direct drivers, human management of the ecosystem, and ecological processes such as predation or succession. The complexity of the system is in the multiple spatial and temporal scales at which drivers, management and ecosystem dynamics operate, ranging from short-term, local processes such as plant growth to long-term global processes such as climate change (e.g. Holling et al., 2002).

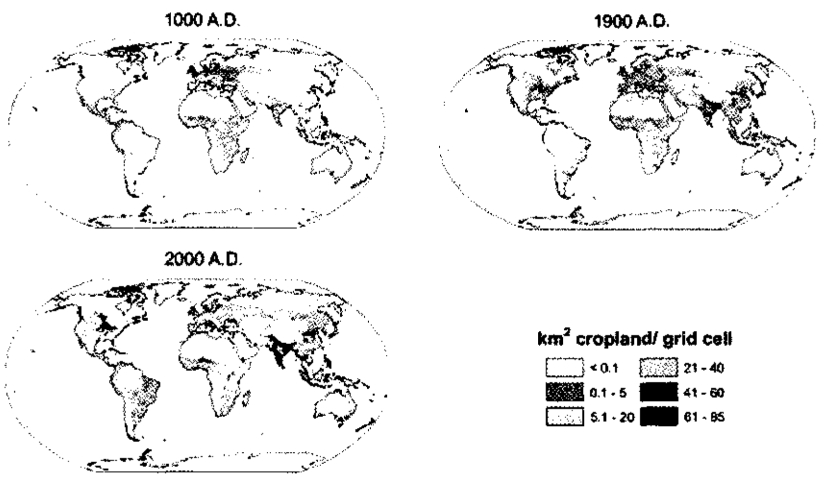

Figure 1. Increase in cropland in the last millennium and the last century, expressed as the share of cropland in overall land cover (Klein Goldewijk et al., 2011)

Ecosystems have changed very considerably in the past millennium, with the degree of change, when observed at the planetary scale, accelerating considerably in the past century. Ecosystem changes are manifested in several formats. Ecosystem change includes the conversion of land, often from natural or extensively used ecosystems to intensive croplands or plantations. In the last decades, land conversion has been particularly rapid in the tropics (see Figure 1). Figure 1 also shows that in many areas, there is very little room if any for further expansion of croplands. Ecosystem change can also be in the form of modifications within a given ecosystem type, for instance through degradation, recovery or natural processes. These changes can be either gradual or abrupt, and either reversible or irreversible (Scheffer et al., 2003).

The status of ecosystems and ecosystem capital

Because ecosystem change involves a modification of the ecosystem's components and ecological processes, it also changes the capacity of ecosystems to generate benefits for people. It is not always easy to pinpoint and compare the multiple effects of ecosystem change on people. To give an illustration, in my work at Wageningen University I have looked at the rapid expansion of oil palm plantations in Indonesia. Often - though not always - oil palm plantations replace forests, varying from heavily degraded forest up to pristine rainforest. Since oil palm is a highly profitable crop, under suitable agronomical conditions, this can bring important economic benefits. Yet the share speed and the way oil palm plantations have been established have caused a number of social and environmental concerns, which are, to a degree, addressed in several policy initiatives including the Roundtable on Sustainable Palm Oil. The example of oil palm shows very nicely the difficulties in understanding the societal implications of ecosystem change (e.g. Hein and Van der Meer, 2012; Sumarga and Hein, 2013). People appreciate both the availability of palm oil, and the presence of virgin rainforest, though not every person will necessarily obtain the same level of satisfaction from these resources. Clearly, the natural forest and the oil palm plantation provide very different types of benefits. A central question in understanding ecosystem change is therefore how we can analyse and compare the economic benefits of different types ecosystems, given that ecosystems provide such different sets of benefits. Against what yardstick can we measure degradation or improvement in ecosystem condition ?

It has been stated that ecosystem health, and its inverse, the degree of ecosystem degradation, can be interpreted as the degree of change compared to a natural ecosystem. From a nature conservationist point of view this statement is often correct, even though some managed systems can be very rich in biodiversity. As the example of oil palm versus natural forests demonstrates, however, nature conservation is not society's only interest, and naturalness is a poor yardstick.

Measuring the status of the planet's ecosystems therefore requires consideration of the aggregated set of services supplied by ecosystems to people, across the landscape or potentially even at scales exceeding the landscape scale. These services are very diverse, including (i) provisioning services, i.e. the products that can be harvested from ecosystems including crops grown on cropland; (ii) regulating services involving the regulation of hydrological, climate and ecological processes; and (iii) cultural services, the non-material benefits provided by ecosystems. Jointly, these various contributions of ecosystems to benefits for people have been labelled 'ecosystem services' (TEEB, 2010, Haines-Young and Potschin, 2013; EC et al., 2013). In the case of provisioning and cultural services, the services differ from the benefits, because ecosystem services need to be combined with human interventions for the benefit to materialise. For instance, trees standing in the forest (the resource provided by the ecosystem, i.e. the service) needs to be combined with labour and equipment (e.g. a saw) to result in harvested timber (the benefit). Regulating services (for instance carbon sequestration) do not always require human interventions to materialise, and the service will often equal the benefit.

Two major international efforts to analyse the status of global ecosystem and the ecosystem services they supply were conducted in the last decade: the Millennium Ecosystem Assessment (2005) and the 'The Economics of Ecosystems and Biodiversity' (TEEB) study (2010). These studies compiled and assessed a wide range of published and non-published studies dealing with ecosystem change and ecosystem services. Yet, in spite of the large amount of work carried out, these studies did not result in a full analysis of the societal impacts of ecosystem change. For instance, the statement that *"approximately 60% (15 out of 24) of the ecosystem services evaluated in this assessment are being degraded or used unsustainably"* (Millennium Ecosystem Assessment, 2005) raises more questions than answers. The oil palm example indicates that there are trade-offs in ecosystem management, where land conversion to a different type of productive ecosystem will inevitably lead to the loss of some ecosystems in exchange for enhancing the supply of other ecosystem services. Land conversion may, in some cases, lead to a reduction in the overall supply of a whole range of services that are of little value by society, and a gain of only one service (e.g. crop production) that is of very high value. This illustrates that it is not straightforward to examine if society is better or worse of as a result of land conversion. Hence the conclusion that a decline in the majority of ecosystem services, at the global level, points to a loss of ecosystem capital is premature.

It is difficult to compare present day natural capital to the natural capital of say a century ago. However, it is clear that, in addition to an expansion of croplands, many 'natural' ecosystems such as forests or wetlands are being affected, by either land conversion or degradation. A negative trend can be observed for many fish stocks (Pauly et al., 1998), tropical forests (Hansen et al., 2010), wetlands (Zedler and Kerchner, 2005) and coral reefs (Carpenter et al., 2008). In addition, in the course of the coming decades climate change will have major impacts on ecosystems, including such major issues as ocean acidification threatening coral reefs (Hoegh-Guldberg et al., 2007) and major changes in vegetation zones as a consequence of changing temperature and rainfall regimes (Leemand and Eickhout, 2004). The impacts of climate change and other drivers for ecosystem change are interlinked. For instance, degraded ecosystems may be more vulnerable to climate change (see e.g. Hein, 2006 for an example). The precise consequences of the changes in ecosystems for human welfare in the decades ahead are difficult to forecast. What is clear is that the impacts of ongoing ecosystem change will be significant, and that they will differ greatly between different parts of the planet. In general, tropical zones may be particularly vulnerable. They are subject to rapid ecosystem change, and are likely to be strongly affected by climate change, including changes in rainfall patterns, in the coming decades (IPCC, 2014). In addition, the capacity of many developing countries to adapt to ecosystem change, for example by ensuring alternative livelihood opportunities for people depending upon natural resources, is low. In order to design methods to adapt to and where feasible mitigate ecosystem change, there is a need for developing methods to better understand the relation between ecosystem capital and human well-being, and for monitoring changes in ecosystem capital.

The role and components of ecosystem accounting

However, it is not straightforward to develop a metric or a set of indicators that can consistently measure the capacity of ecosystems to support economic production and/or welfare. These complications arise from a number of factors. First, ecosystems and the services they generate are highly diverse, involving man-dominated to natural systems and such diverse services as the supply of products, the regulation of processes and the generation of non-material benefits. Second, ecosystem services operate across different spatial and temporal scales, from locally important nitrogen fixation to carbon sequestration important for global climate change. Third, services may be linked in a causal chain. For example, forests in upper watersheds may regulate water flows and thereby mitigate flood risks in lower watersheds, and this reduced flood risk may, in turn, facilitate crop production in lowland areas. Finally, ecosystem services analysis has a whole set of potential applications ranging from supporting management to monitoring change, and it has been difficult to define concepts and design classifications for ecosystem services in such a way that they are suitable for these various purposes (e.g. Haines-Young and Potschin, 2013).

The research conducted in the Environmental Systems Analysis group on ecosystem accounting has shown that a consistent measurement system for ecosystem capital needs to comprise three fundamental aspects, see Figure 2. These are: (i) ecosystem condition; (ii) ecosystem capacity to supply services; and (iii) the flow of ecosystem services per time unit. First of all, it is important to distinguish the capacity of ecosystems to generate services and the annual flow of ecosystem services. Trends in the flow of services may or may not provide any understanding of the development of the ecosystem's capacity to generate the service. For instance, fish harvests may well increase because of an expansion of the fishing fleet, and not because of a growth in the fish stock. Hence, even when the actual flow increases (e.g. the fish harvest), there may at the same time still be a decrease in ecosystem capital (e.g. the fish stock). Note that a decrease in ecosystem capital may increase investments required to use the ecosystem service (e.g. to harvest the fish) and that there may be abrupt changes in ecosystem capital (e.g. in fish stocks) when ecological thresholds governing ecosystem dynamics are exceeded (see for an example Hutchings and Myers, 1994). Ecosystem condition determines the capacity of the ecosystem to generate services. This may pertain to such factors as the nutrient status of the soil or the water body, or the species composition of the ecosystem. Hence, the three elements of service flows, capacity and condition are crucial to understanding how ecosystems change and how these changes affect the benefits people obtain from ecosystems.

Flows and capacity (but not condition) have both a physical and a monetary connotation and can be expressed both in physical units and in monetary units (Edens and Hein 2012). Monetary valuation enables weighing and comparing different types of ecosystem services, aggregating benefits across spatial areas and, eventually, integrating ecosystem services in national accounts. The latter will require much further work in order to enhance the rigour and reliability of valuation approaches. In ecosystem accounting, monetary valuation needs to be conducted in a manner that is aligned with the System of National Accounts, which means that the focus of the valuation is on measuring production, which differs from measuring welfare. A key difference is that consumer surpluses as an element of economic value are not considered in the national accounts (contrary to a welfare accounting approach).

Unfortunately, in spite of a large amount of research in the field of ecosystem services, there are very few comprehensive analyses to date that show how the factors condition, capacity and service flow are mutually interdependent, and how they are affected by ecosystem management – in particular at aggregated scales. In addition, compared to the diversity of ecosystems and the services they provide,

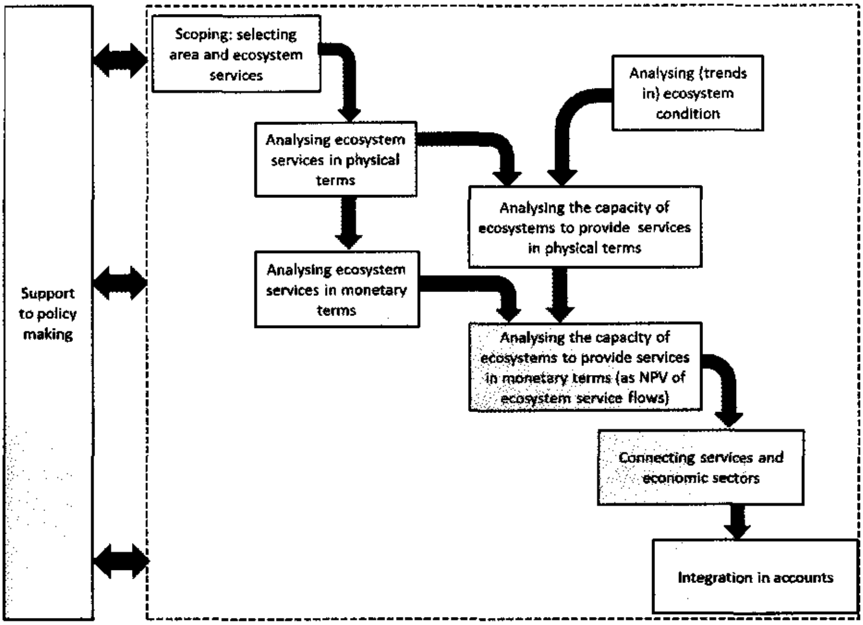

Figure 2. Framework for Ecosystem Accounting.

there is as yet a scarcity of well-conducted ecosystem valuation studies that provide the basis for accounting for ecosystem services flow and capacity at an aggregated scale.

A further complication in reaching a comprehensive understanding of ecosystem capital pertains to the complexity of ecosystem dynamics. Ecosystems may be subject to sudden and sometimes unexpected changes in their species composition and/or in the ecological processes that govern their functioning (e.g. Scheffer et al., 2003). At threshold levels for ecosystem change, small perturbations, or small increases in stress exerted on an ecosystem may cause very rapid and significant changes in both the condition of ecosystems and in the service they generate. The propensity to maintain ecosystem structure and functioning in the face of such perturbations is called resilience. Ecosystem resilience is an aspect of ecosystem capital, since it determines to what degree the ecosystem will be able to generate services in the future. However, there are still few studies that have analysed ecosystem resilience in relation to ecosystem capital (but see e.g. Walker et al., 2009 for an example), and for many ecosystems there is still a relatively poor understanding of which factors determine ecosystem resilience.

Ecosystem accounting in the context of natural resource management

Through the research in the ESA group, we contribute to the development of methods for ecosystem accounting. Ecosystem accounts (i) present a comprehensive overview of ecosystem capital including the different services provided by different land use and administrative units; (ii) indicate interdependencies between

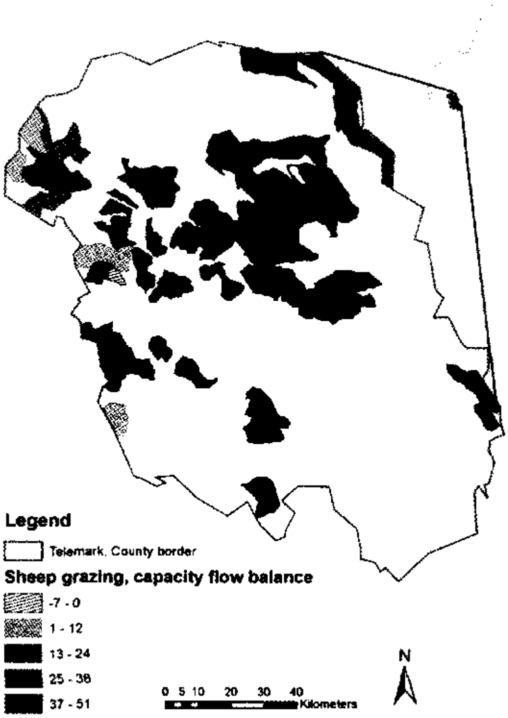

Figure 3. Differences between actual sheep grazing pressure and the capacity of the ecosystem to sustain sheep grazing, expressed in number of animals per km2, in Telemark, Norway (Schröter et al., 2014). Positive values indicate a pressure lower than the capacity.

ecosystems and economic activities; (iii) allow measuring changes in ecosystem capital over time; and (iv) have a number of other potential applications that can support environmental management. For example, ecosystem accounting allows analysing in which part of the landscape extraction rates exceed the capacity of the ecosystem to supply the resource. This is illustrated in Figure 3, which shows that free-range sheep consume only a small part of the available pasture resource in

Telemark County, Norway (Schröter et al., 2014) and that this activity is sustainable in most of the county, in the sense that extraction rates are considerably lower than the regenerative capacity of the ecosystem. Of course, this ratio differs strongly between different ecosystems and ecosystem services, for instance the ratio is quite different in the Sahel (Hein et al. 2011).

Fundamental for ecosystem accounting is the spatial approach taken. In ecosystem accounting, ecosystem condition, capacity and services flows are all analysed in a spatially explicit approach (EC et al., 2013). This is essential in order to allow integration of scarce data on multiple ecosystem services at aggregation levels relevant for accounting, such as the province or the country. The spatial approach supports additional applications, such as land use planning. For instance, ecosystem accounts can indicate which parts of the landscape should be maintained and protected in a (semi-)natural state in order to sustain the supply of regulating services that are critical to the supply of other ecosystem services such as crop production.

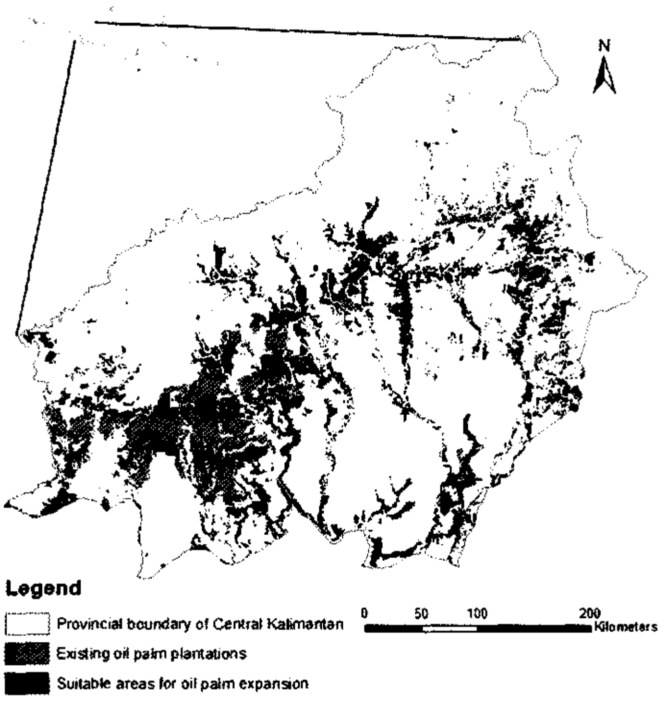

Figure 4. Central Kalimantan: Areas where oil palm expansion would lead to low impacts on ecosystem services, based on criteria of local stakeholders (Sumarga and Hein, 2014)

Figure 4 provides an example involving the identification of areas potentially suitable for oil palm expansion in Central Kalimantan, Indonesia. Based on inputs obtained from local stakeholders, we identified areas that should not be converted in order to maintain ecosystem services supply (carbon sequestration, rice production, tourism, biodiversity habitat, etc.), see Sumarga and Hein, 2014. Ecosystem accounting can also indicate the local opportunity costs of preserving ecosystems and the potential compensation required through 'Payment for Ecosystem Services' mechanisms.

Finally, by linking ecosystem services to beneficiaries and economic sectors, ecosystem accounting can indicate potential winners and losers of ecosystem change, and assist in designing compensation mechanisms.

However, as with any scientific development and environmental management tool, ecosystem accounting has clear and important limitations. A first, obvious, one is that it is complex to set up a full account including condition, capacity and service flows, in both physical and monetary units, and that there are still important data shortages in most parts of the world. Also, not all aspects of ecosystem use (e.g. cultural and spiritual aspects) can be meaningfully integrated in an accounting framework. A second is that the national accounts and therefore ecosystem accounts measure production not welfare. Hence, the accounts will always provide a partial indication of the economic value of ecosystems, which will often be an underestimate. Unfortunately, methods such as Comprehensive Wealth Accounting (e.g. Ferreira et al., 2008) and Inclusive Wealth Accounting (Duraiappaha and Muñoz, 2012) which do aim to measure welfare at aggregated scales have a number of limitations as well, in particular the misconnect between data required for such methods and datasets that can in practice be measured or modelled. Third, ecosystem accounting does not provide a tool to understand and design measures to deal with long-term effects and risks resulting from ecosystem and climate change. Risks are not made explicit in accounts and, through discounting, long-term effects only have a small effect on current values of ecosystem capital.

Finally, of course, having more information on the status of and trends in ecosystem capital by no means implies that this information will necessarily lead to improved governance of ecosystems. Better ecosystem management is hampered not only by a lack of information on ecosystem change and ecosystem capital, but also by a whole range of other aspects, related to the economic and institutional structures governing resource use. These include a propensity to cater to short-term interests rather than long-term sustainability, as witnessed by decision making in the private sector, in politics and in our day-to-day decisions as consumers. Further, clearly, interests of private actors do not always coincide with the interests of society at large, and it is in a complex and globalising world difficult to set up regulations and incentives that fully align public and private interests. Fortunately, both awareness of the urgency of using natural capital in a more sustainable way and the technologies required to do so are still progressing.

Now let us look briefly at the future, at the research domain and it's scientific and societal context. What is becoming clear is that in both the domain of climate change and associated ocean acidification (IPCC, 2014), and in the domain of land and ecosystem management, the time for moving to sustainable resource use is running out. First because many changes in ecosystems and climatic cycles are irreversible at human time scales, second because the number of people is still growing, and third because a shrinking natural resource base reduces our options and is making it increasingly harder to move to sustainable use levels.

A critical element in the management of the planet's ecosystem capital is the relation between regulating and provisioning services. Some regulating services directly provide benefits to people, for instance by removing air pollutants from our ambient environment. Other regulating services are required to sustain the production in other ecosystems, for example the forest vegetation of upper watersheds is often critically important to regulate downstream water supply. These regulating services are often provided more effectively by (semi-) natural ecosystems – for example forests are much better in regulating water flows than degraded, barren lands or croplands (TEEB, 2010). One of the main challenges of today is therefore to identify which regulating services are critical for human welfare, from the local to the global scale, and how they can be best preserved. Ecosystem accounting provides a framework for such analysis, but further work is required in this domain, both in terms of identifying such zones, and in terms of developing the governance structures required to preserve them. As an important co-benefit, sustainable use of these ecosystems in their present state also provides additional opportunities for biodiversity conservation in natural ecosystems.

To conclude, I see the following important steps ahead in the broader research domain. First there is a need to further develop and standardise ecosystem accounting, under the mandate of the UN Statistics Commission and involving a collaboration between statistical agencies, the various UN agencies working on environmental and accounting themes and the research community. Second, there is a need for technical capacity building in the field of ecosystem accounting, a process that has already started with recent World Bank, UN-DESA and UNEP/TEEB initiatives. Third, there is a need for further research on how earth observation systems, and in particular the new Sentinel satellites, can support the development of ecosystem accounts. Fourth, there is a need to further test how ecosystem accounting can support environmental and resource management. As mentioned, in addition to accounting for changes in ecosystem capital, there are several other potential applications of ecosystem accounts such as land use planning. It should also be examined how ecosystem accounting can be applied in conjunction with other types of information, for instance on long-term effects and risks resulting from environmental and climate change, or with consideration of values that cannot be (or not fully be) captured in ecosystem accounts.

And finally, there is a need to design new approaches to support governments with the sustainable use of zones critical for locally and globally essential regulating services. Ecosystem accounts can be instrumental in delineating these zones. Promoting their sustainable use may also require the design of new funding mechanisms. One of the main current global funding mechanisms in the environmental domain, the Global Environment Facility, does not yet offer sufficient financing opportunities for long-term conservation of zones critical for biodiversity and/or for securing regulating services (Hein et al., 2012). As for maintaining carbon stocks, there is a need to continue the development of the REDD+ mechanism, both by promoting demand for REDD+ credits in OECD countries and by supporting the development of on-the-ground REDD+ projects in developing countries.

Working with friends, colleagues and students I look forward to making a contribution to the further development and implementation of ecosystem accounting and to the broader field of ecosystem services and environmental change.

Word of thanks

I am grateful to many people that supported me over the past many years. Professionally, there are many people that inspired and supported me at Wageningen University including in particular Rik Leemans, Leen Hordijk and Ekko van Ierland. There are many other colleagues in the ESA group and other parts of WUR that I have really come to appreciate including the PhD students that I have (had) the pleasure of supervising: thank you for the collaboration. I would like to thank Bram Edens and Carl Obst for the many fruitful discussions on ecosystem accounting. From '97 to 2002 I worked at the FAO Investment Centre and I still look back at that period as a fantastic professional experience. I particularly enjoyed working for two people, Daud Khan and Andrew MacMillan. Thanks are also due to my friends for the many nice evenings, to Paul Westerman for the tai chi lessons and to Hans Harthoorn for his karate lessons in the past 25 years. I want to thank my parents,

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