Ecosystem Services and Resilience

Rising demand for food and upward trends in resource-intensive consumption are intensifying pressure on the world's food production systems (Garnett *et al.,* 2013; Bommarco *et al.,* 2013). Agriculture now accounts for 38% of the global land area (FAO 2011a) and provides employment for 31% of the world's employed people (World Bank 2014). Yet, an estimated 842 million people worldwide suffered from chronic hunger (FAO 2013), which means that they do not have enough food to lead an active life.

Industrial methods of agriculture have significantly increased crop yields per unit area (Bommarco *et al*., 2013). This has helped to meet the world's food needs, but has led to severe environmental impacts, including global biodiversity loss, and water and land degradation (Foley *et al*., 2011). As pressure on land, water and energy increases, the expansion of industrial agriculture becomes a less viable option. At the same time, less-intensive, smallholder agriculture alone cannot produce the yields that are needed to satisfy the world's growing demand for food. In order to feed the growing human population, changes are needed to the way in which we produce, distribute and consume food.

Sustainable intensification of agriculture has emerged as one promising response to these challenges, where discussions focus on increasing food production in ways that do not undermine the natural resource base upon which this production depends. There have been recent attempts to define, more precisely, what sustainable intensification means (see, for example, Garnett *et al.*, 2013) and understand how it might be achieved (Poppy *et al.*, 2014). It is also recognized that increasing production will not, on its own, be sufficient to increase food security (Loos *et al.*, 2014), and must be combined with efforts to achieve more equitable distribution of food and improve consumption patterns. Indeed, as much as one-third of the food produced may be lost or wasted, globally, through inefficient harvesting, storage and processing of food, as well as market and consumer behavior (FAO 2011b).

WLE proposes efforts to intensify agriculture shift to focus on increasing food and livelihood security through the creation of resilient socio-ecological systems that secure the sustainable provision and equitable distribution of ecosystem services. Our priority is to increase food and livelihood security for the world's poor by enhancing the sustainability and equity in the provision of ecosystem services – and securing the natural resource base that underpins these services – that flow to and from agriculture and provide monetary, health, and well-being benefits to people. There are potentially substantial benefits to people from the improved management of ecosystem service flows; as an indication, between 1997 and 2011, the losses to ecosystem services due to land-use change are estimated to be between USD 4.3 and USD 20.2 trillion per year (Costanza *et al.*, 2014). WLE seeks to understand how, when and where selected ecosystem services can be sustainably harnessed in agricultural systems and landscapes to unleash their potential and deliver positive outcomes for development. Our rationale for producing this ESR Framework is to specify the ESR core theme's research priorities and to provide a conceptual framework to WLE and its partners for applying ecosystem service and resilience science to achieve development outcomes.

Goals and objectives

The main goal of this ESR Framework is to help WLE achieve its Intermediate Development Outcomes (IDOs) and CGIAR's System-Level Outcomes (Table 1) by demonstrating how ecosystem services and resilience serve as key research for development themes.

The central hypothesis of this ESR Framework is that ecosystem service stocks and flows in agricultural landscapes can be managed to contribute to these development outcomes, and resilience concepts can help guide this process. While the concept of ecosystem services is in itself a topic of debate (Schröter *et al.*, 2014), in section 3 on Applying ecosystem services and resilience concepts to achieve development outcomes, we discuss the mounting evidence indicating that good management of ecosystem service flows to and from agriculture can improve human well-being in agricultural landscapes, increasing food and livelihood security. In this way, we seek to meet our objective of providing a conceptual framework and presenting the existing evidence base for applying ecosystem service and resilience science to achieve development outcomes.

Table 1. *CGIAR System-Level Outcomes (SLOs) and WLE Intermediate Development Outcomes (IDO).*

CGIAR System-Level Outcomes (SLO)	WLE Intermediate Development Outcomes (IDO)
A. Reducing rural poverty	1. **Productivity:** Improve land, water and energy productivity in rainfed and irrigated agroecosystems.
B. Increasing food security	2. **Income:** Generate increased and more equitable income from agricultural and natural resource management, and ecosystem services in rural and peri-urban areas.
C. Improving human nutrition and health	3. **Gender and equity:** Enhance the decision-making power of women and marginalized groups, and increase the benefits derived from agricultural and natural resources.
D. Sustainable management of natural resources	4. **Adaptation:** Increase the ability of low-income communities to adapt to environmental and economic variability, demographic shifts, shocks and long-term changes.
	5. **Environment:** Increase the resilience of communities through enhanced ecosystem services in agricultural landscapes.

Applying ecosystem service and resilience concepts to achieve development outcomes

The ESR core theme's vision is for ecosystem service management interventions that deliver multifunctional agricultural landscapes, where communities are supported by the multiple ecosystem services and associated benefits provided by natural and agricultural systems in these landscapes. To achieve this vision, we ask: how, when and where can ecosystem service management be used to create and sustain resilient socio-ecological systems and deliver positive impacts on food and livelihood security?

The ESR Framework is centered on the notion that people can manage ecosystem service flows through agricultural systems and landscapes in ways that achieve positive outcomes for human well-being, notably poverty reduction and increased food and livelihood security. WLE suggests that resilience be used as a guide for studying the stability of agricultural systems and the ecosystem services on which communities depend. In this document, we refer to this notion of ecosystem service management guided by resilience thinking as the ESR approach.

Ecosystem condition and the stock and flow of ecosystem services impact directly on human well-being. Scientists are working to better understand which factors determine the type and severity of these impacts, such as whether changes to the supply of one ecosystem service – notably food - has more significant impacts on human well-being than changes to another; whether timelags mask the impact of ecosystem service decline on human well-being; and whether technological and social advances can improve use efficiency and provide substitutes to ecosystem services to the extent that ecosystem degradation and human well-being are decoupled (Raudsepp-Hearne *et al.*, 2010).

To achieve positive impacts on human well-being, WLE scientists research the: (i) ecosystem structures and functions that underpin service provision; (ii) threats and critical thresholds affecting this ecosystem service supply; (iii) type and distribution of and trade-offs between ecosystem services across and between landscapes under different management regimes; (iv) the effect of different governance mechanisms and institutional structures on the availability of ecosystem services and their benefits to different beneficiary groups; (v) indicators and metrics for monitoring the impacts and outcomes of changes to ecosystem service flows on ecosystems and people.

WLE seeks to inform large-scale intervention decisions that have cross-scale and cross-level impacts on ecosystem service flows to and from agriculture. This includes large-scale decisions in planning (e.g. development allocations), energy (e.g. design and location of hydropower systems), agriculture (e.g. investment in irrigation infrastructure), conservation (e.g. habitat restoration and protection) and hazard mitigation (e.g. flood control). WLE engages with decision stakeholders to understand their information needs and the constraints to ecosystem service management, where decision-stakeholders typically include national and local governance institutes and their policy advisors, investors, community groups, farmer representatives, and conservation and development NGOs. Engaging these stakeholders is critical for ensuring ESR research is demand-driven and focused on closing knowledge and method gaps in all phases of decision-making.

Conceptual basis

CBD (1992) defines an ecosystem as "a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit." Biophysical structures and processes in an ecosystem can have functions that provide a service – something that is useful - to people (Haines-Young and Potschin, 2010). We use the definition of ecosystem services advanced by Walker and Salt (2006), with our additions shown in parenthesis: "the combined actions of the species [and physical processes] in an ecosystem that perform functions of value to society." This definition highlights that ecosystem services are about the benefits that ecosystems provide to people, and captures the notion that the biological and physical characteristics of a system underpin the delivery of ecosystem services. Similar to TEEB (2010), we classify ecosystem services as provisioning, regulating, habitat and cultural services, where:

- PROVISIONING services refer mainly to goods that can be directly consumed, and include food, water, raw materials, such as fibre and biofuel, and genetic, medicinal and ornamental resources.

- REGULATING services comprise regulation of climate, air quality, nutrient cycles and water flows; moderation of extreme events; treatment of waste – including water purification; preventing erosion; maintaining soil fertility; pollination; and biological controls, such as pests and diseases.

- HABITAT services are those that maintain the life cycles of species or maintain genetic diversity, through quality and quantity of suitable habitat, e.g., natural vegetation that enables the natural selection of species to maintain a diverse gene-pool or which service as a source of pollinator and pest control agents. These types of habitats benefit people primarily by maintaining stocks and flows of biodiversity, which underpin and ensure the resilience of many of the provisioning, regulating and cultural services provided by ecosystems.

- CULTURAL services refer to the aesthetic, recreational and tourism, inspirational, spiritual, cognitive development and mental health services provided by ecosystems. Figure 1 illustrates some of the ecosystem services provided by different landuse and management choices in an agricultural landscape.

The complex relationship between ecological processes, functions and ecosystem service delivery is gradually becoming clearer, although research

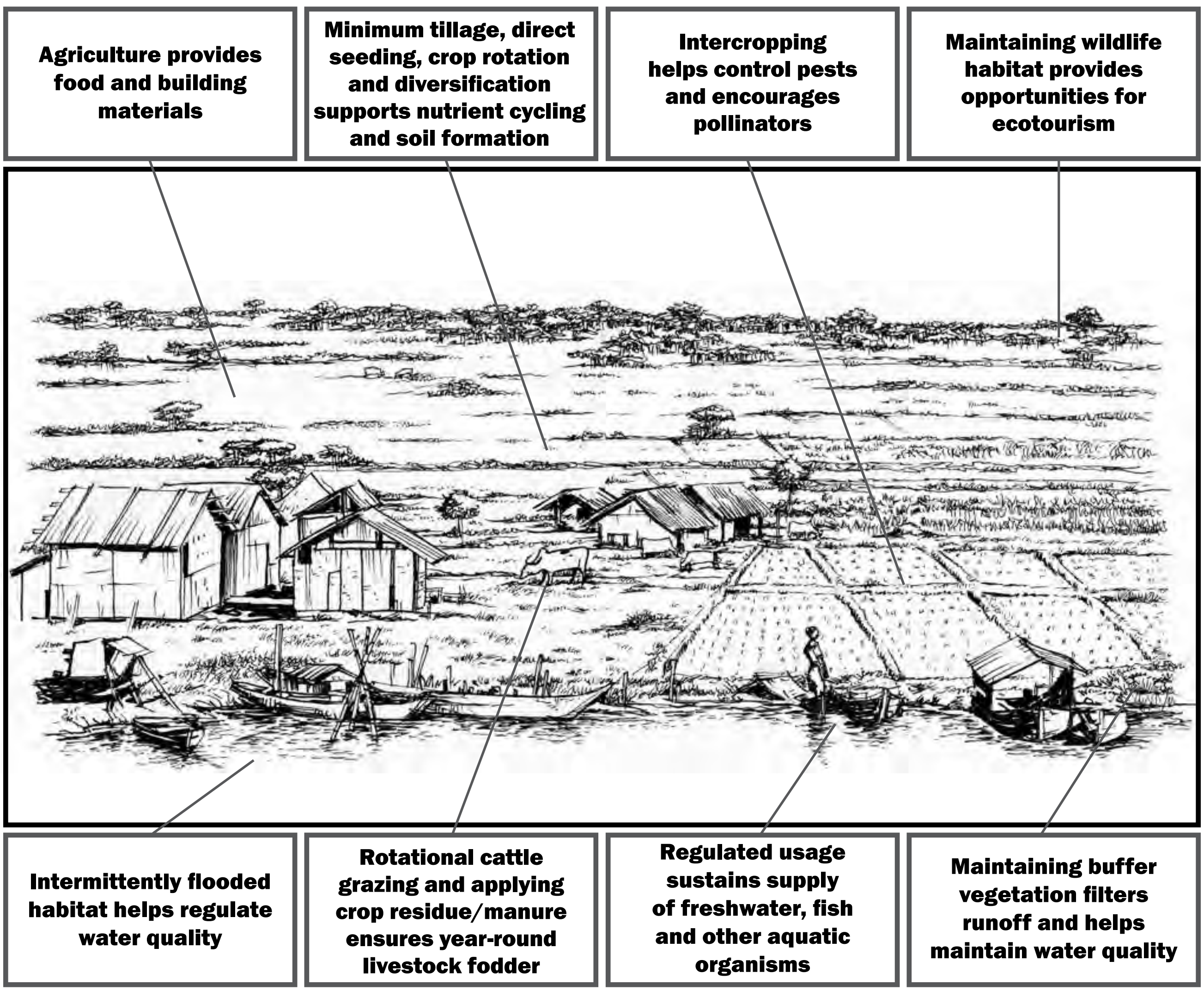

Fig. 1. Examples of ecosystem services that should be valued and bolstered in an agricultural landscape of Kampong Chhnang, Cambodia. WLE's vision for agricultural intensification include interventions that enhance these services to increase food quantity, quality and accessibility, and improve livelihood security. Source: WorldFish/E. Baran.

still needs to be carried out to strengthen this understanding. For example, soil biota in ecological systems are often disregarded, and yet they play fundamental roles in driving ecological processes that lead to ecosystem goods and services, upon which human civilization totally depends on (Lavelle *et al*., 2006). The array of ecosystem processes to which soil invertebrates make fundamental contributions include: i) increased soil porosity → water infiltration → water availability for agriculture; and ii) decomposition and humification → nutrient cycling → nutrient availability for crop and pasture growth (Lavelle *et al*., 2006; Bottinelli *et al*., 2014). However, while the linkages between soil biological diversity and ecosystem services are generally accepted, the task of attributing particular ecological functions to particular species, assemblages or even ecosystems remains a difficult one. In light of the ongoing work needed to disentangle the structures, processes and functions underpinning the provision of ecosystem services, mimicking the structure of natural ecosystems in managed agricultural systems seems likely to be the surest route to securing sustainable and resilient systems.

WLE considers agricultural systems to include the cultivation of crops and livestock production on land (agriculture) and in water (aquaculture), as well as fisheries and forestry. While the notion of ecosystems may conjure images of pristine natural landscapes, we explicitly include agricultural systems within the ecosystem concept as "novel", or human-modified, ecosystems (Hobbs *et al*., 2006). There is ample evidence that these managed ecosystems provide ecosystem services (Power 2010; Zhang *et al.,* 2007). Indeed, ecosystem services are very important in agricultural landscapes because of their critical role in achieving food security, human health and well-being. Farmers are generally considered 'providers' of provisioning ecosystem services, using inputs and practices to provide a range of goods on which we depend, such as food, fiber and biofuel. However, good agricultural management practices impact and can enhance the flow and provision of many other ecosystem services, such as pollination, biological pest control, maintenance of soil fertility and structure, supply of habitat for wildlife, sustaining the aesthetic value of a landscape and regulating water supply (Tscharntke *et al.,* 2005, Power 2010; Zhang *et al.,* 2007). Conversely, poorly planned or badly managed agricultural systems can negatively impact the flow and provision of ecosystem services due to nutrient runoff, unintentional pesticide poisoning of some species and habitat loss (Zhang *et al.,* 2007). This inclusion of agroecosystems within the ecosystem service concept has fuelled discussions around ecosystem service-based approaches to agriculture (Bommarco *et al.,* 2013; Kremen and Miles 2012) and generated a much more interdisciplinary view of agricultural systems. Notably, conservation biologists have given greater consideration to the benefits that humans derive from ecosystems, even though their more traditional focus is on the conservation of species (Kareiva and Marvier 2007); it has also been incorporated into environmental economics, creating a surge in discussions on the externalities involved in the consumption of services, and the complexities in equitably distributing economic costs and benefits of the use and management of ecosystem services. The role of economics in the valuation of ecosystem services has also conjured fierce debate on the commodification of nature (e.g., The Guardian 2012a, 2012b).

WLE defines an ecosystem service-based approach to sustainable intensification as deliberately harnessing or restoring ecosystem services for production goals (e.g., increased yields, higher crop-per-drop ratios) or in ways that support these goals (e.g., pest control, seed dispersal, protection from storm damage), while reducing the negative impacts on the natural resource base that underpins these ecosystem services. In essence, an ecosystem service-based approach aims to facilitate an overall net positive effect on the provision of ecosystem services, both to and from agriculture. In this way, it aims to manage natural resources sustainably while maintaining or increasing food production and other ecosystem services. This might include, for example, the conservation of habitat for predatory arthropods to facilitate natural pest control (Rusch *et al.,* 2013), landscape management of barriers to reduce the flow of agricultural pests (Avelino *et al.,* 2012) or coordinating and incentivizing collective soil conservation in agricultural landscapes to increase the efficiency of hydropower (Estrada-Carmona and DeClerck 2011). We note that an ecosystem service-based approach is not devoid of technology or solely based on biological processes; rather, the development of technologies, tools and management practices that complement and increase the efficiency and impact of ecosystem services remain a critical line of inquiry and development. In our view, human-dominated landscapes present better opportunities for ecosystem service management than natural systems or protected areas because of the greater feasibility to manage landscape composition and configuration in the function of priorities. Agricultural landscapes are particularly amenable to such management due to their tremendous dependence on, and capacity to provide, ecosystem services, as well as the potential to develop industrial approaches to agriculture to achieve desired production, landscape and development goals. For example, Garbach *et al.,* (In Review) found that, amongst five systems of agroecological intensification, precision agriculture showed the strongest potential to increase yields and ecosystem service provision).

Ecosystem services interact with, and are intrinsically linked to, social structures and processes. As described by Levin *et al.,* (2009), humans can be considered an "integral part of the ecosystem, since humans derive a portfolio of services from the ecosystem and also act as a driver influencing ecosystem processes." Consideration of the coupling between social and environmental systems has given rise to the notion of **socio-ecological systems**. There is a wealth of literature on the theory of socio-ecological systems (see, for example, Berkes *et al.,* 2003; Becker and Jahn 2006; Ostrom *et al.,* 1999; Ostrom 2009). WLE's understanding of socio-ecological systems is guided by Walker and Salt (2006), who highlight that: (1) social systems are embedded in and interlocked with ecological systems (dynamics in one system affect the other); (2) socio-ecological systems can change in unpredictable, non-linear and transformative ways; (3) they are complex adaptive systems; (4) socioecological systems have varying degrees of 'resilience', and biological, physical and social factors can enhance (or reduce) this resilience. Resilience, as we apply it here, means the ability of a socioecological system to undergo change and retain sufficient functionality to continue to support livelihoods through, for example, the sustained provision of ecosystem services, including the quantity, quality, access and utilization of food supply (Park *et al.,* 2010).

Resilience is emerging as an important concept for understanding the stability and trajectory of the complex socio-ecological systems where ecosystem services are provided and consumed (Gordon *et al.,* 2008, Scheffer *et al.,* 2001). Resilience is not a static notion, rather it is focused on temporal change and on the role of internal and external drivers in transforming societies for better or for worse. These include drivers such as extreme weather events, spread of invasive species, shifts or failure in economic markets, or the introduction of new governance structures. Within development and, specifically, the WLE context, the focus is on positive transformative change—improved conditions for the poor—when shocks occur. Resilience is not necessarily an inherent component of ecosystem service-based approaches; optimizing the delivery of a bundle of ecosystem services for a selected management goal may increase the vulnerability of other ecosystem service flows to changes in the future with potentially negative outcomes on system resilience. Consideration of resilience in the design of ecosystem service-based approaches adds another dimension to the consideration of trade-offs, whereby some amount of redundancy in service delivery and access is desirable (LaLiberte *et al.,* 2010). Principles of socioecological resilience (Biggs *et al.,* 2012) are largely derived from the natural sciences. However, we hypothesize that the complex adaptive nature of ecosystems and the services they provide inherently includes greater resilience than static technological fixes. This is a critical line of inquiry for WLE. The challenge lies in designing ecosystem service management approaches that build system resilience and prevent crossing undesirable change thresholds (TEEB 2010).

***Box 1.** Five Core Principles Underpinning WLE's ESR Framework.*

1. People: Meeting the needs of poor people is fundamental.
2. People and nature: People use, modify, and care for nature which provides material and immaterial benefits to their livelihoods.
3. Scale: Cross-scale and cross-level interactions of ecosystem services in agricultural landscapes can be managed to positively impact development outcomes.
4. Governance: Governance mechanisms are vital tools for achieving equitable access to, and provision of ecosystem services.
5. Resilience: Building resilience is about enhancing the capacity of communities to sustainably develop in an uncertain world.

Five core principles

The ESR Framework is grounded in five core principles (see Box 1) that we identify as being vital for the effective use of ecosystem service-based approaches and resilience thinking in the development context. These principles guide our ESR work in agricultural landscapes to help achieve development goals, including WLE's Intermediate Development Outcomes (IDOs).

WLE's ESR Framework

WLE's conceptual framework for using ecosystem service management to achieve development outcomes is presented in Figure 2.

WLE's work on ecosystem services and resilience is grounded in the idea that ecosystem services provide benefits to people that support livelihoods and human well-being, such as by generating income or providing nutritional diversity in diets (see Core principle 1). The quality and type of benefits received from ecosystem services depend on biological processes, creating tightly coupled socio-ecological systems (see Core principle 2), but also on whether the services and their benefits are equitably accessible and available for use.

As illustrated in Figure 2, ecosystem services in agricultural landscapes includes the following:

- services from agricultural systems, such as food (caloric, nutritional and cultural dimensions), water, fiber, biofuel and medicinal resources that flow directly to people;
- services to agricultural systems that support production, such as pollination, regulation of water supplies and genetic resources; and
- services that flow through, and are mediated by, agricultural systems to people in other ways, such as by moderating extreme climatic events, erosion control, regulation of air and water quality, and providing opportunities for recreation and ecotourism.

These service categories necessitate a matrix view of agricultural landscapes as including farmed fields, field margins, embedded semi-natural land uses, such as agro-forests, and natural land uses, such as wetlands and forests. Agriculture is frequently discussed in terms of its negative impacts on the environment, contributing to biodiversity loss, land degradation, water pollution and climate change (Foley *et al.,* 2011). Indeed, agricultural systems often negatively impact ecosystem service flows (and ultimately food production) in agricultural

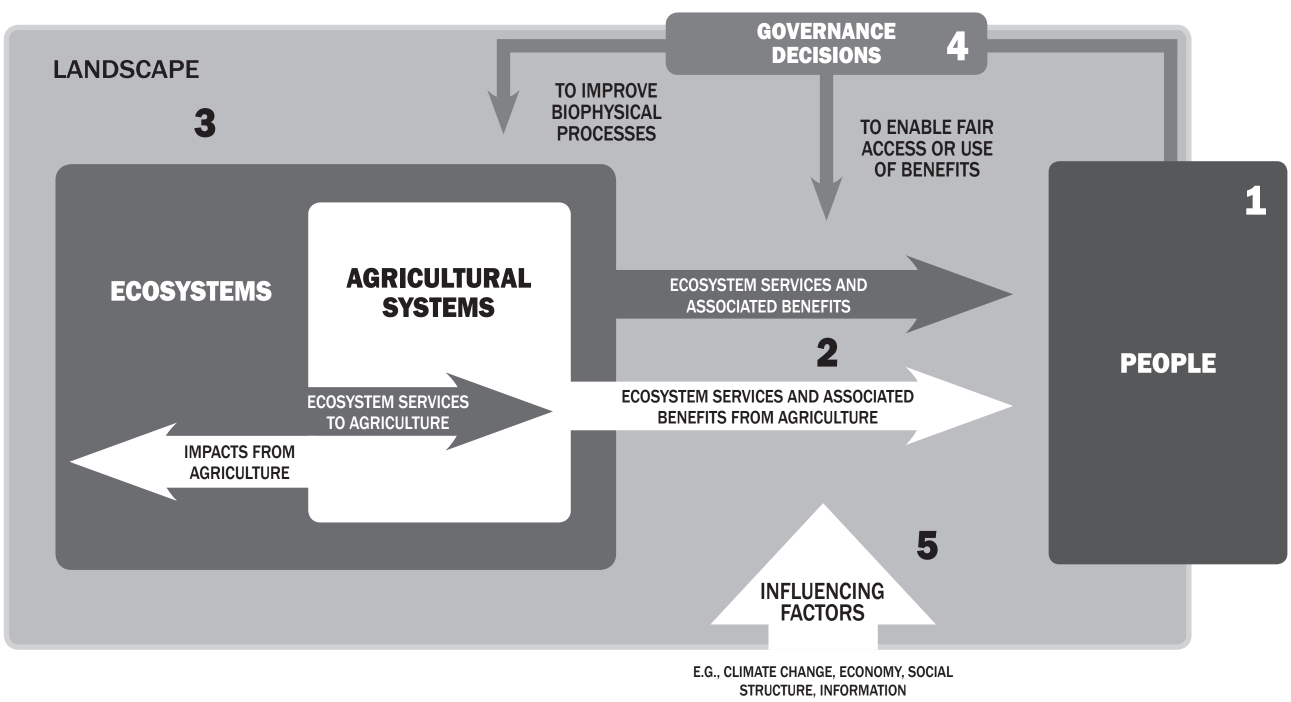

***Fig. 2.** WLE's ESR Framework showing how management of ecosystem service flowing through an agricultural landscape can improve the health, security and economic status of people.*

landscapes, for example, by polluting water and soil with nutrient runoff or by degrading natural habitat (Zhang *et al.,* 2007), increasing sedimentation in rivers and streams, and increasing greenhouse gas emissions (Power 2010). One of the important insights that arises from studying ecosystem services is the understanding that agricultural systems can be better managed across and within scales to lessen, reduce and even produce positive impacts on the environment, and improve the flow of ecosystem services to people (Core principle 3). For example, production is one component of agricultural systems, and is dependent on a plethora of regulating and supporting ecosystem services that are provided to agricultural systems and benefit people in other ways (Zhang *et al.,* 2007). Many of the ecosystem services that are critical to agricultural production can be enhanced on agricultural lands themselves, through in-field management and are included in agroecological fields of study. Others are best suited to landscape-level interventions, which consider the management, composition and configuration of agricultural, semi-natural and natural land uses within agricultural landscapes. However, it is vital to understanding the trade-offs at multiple management levels involved in increasing agricultural productivity (Fremier *et al.,* 2013); if increased yield is achieved at the expense of clean drinking water, productive fisheries or renewable energy generation then increasing agricultural productivity is unlikely to ultimately improve human well-being or alleviate poverty.

People (e.g., individuals, farmers, communities, institutions) can make conscious choices to improve the flow of ecosystem services and maximize benefits through better governance of ecosystem service flows (see Core principle 4). Our hypothesis is that selective ecosystem service use and management enhances the biophysical structures and processes that produce these services. These decisions can enable more equitable access to and use of benefits from these ecosystem services.

Ecosystem service flows are influenced, and constrained by, internal and external drivers, such as climate characteristics, social structures, including societal demand for different services (underpinned by social needs, norms, perceptions and values [Cowling *et al.,* 2008]), status of knowledge and information availability, and economic conditions. These factors can constrain governance options and create shocks that impact the flow of ecosystem services. Resilience thinking provides a foundation for securing resilience in socio-ecological systems (Core principle 5) and resilience of ecosystem service flows – providing increased security for livelihoods that depend on the benefits from ecosystem services and potentially increasing the capacity of communities to develop.

Conclusion

This summarized version of the ecosystem services and resilience framework presents an approach to agricultural intensification that we believe can contribute substantially to the challenge of meeting the food requirements of the world's growing population without irreversibly damaging the ecosystems on which this production depends.

Source

For a complete discussion of the ESR framework, please refer to the original complete source: *CGIAR Research Program on Water, Land and Ecosystems (WLE) Ecosystem services and resilience framework*. 2014. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and and Ecosystems (WLE). 46p. doi: 10.5337/2014.229

References

Avelino, J., Romero-Gurdián, A., Cruz-Cuellar, H.F., DeClerck, F.A.J. 2012. Landscape context and scale differentially impact coffee leaf rust, coffee berry borer, and coffee root-knot nematodes. Ecological Applications 22: 584-596.

Becker, E., Jahn, T. (eds.) 2006. Soziale Ökologie. Grundzüge einer Wissenschaft von den gesellschaftlichen Naturverhältnissen. Frankfurt/New York: Campus.

Berkes, F., Colding, J., Folke, C. 2003. Navigating social-ecological systems: Building resilience for complexity and change. Cambridge, UK: Cambridge University Press.

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E.L., BurnSilver, S., Cundill, G., Dakos, V., Daw, T.M., Evans, L.S., Kotschy, K., Leitch, A.M., Meek, C., Quinlan, A., Raudsepp-Hearne, C., Robards, M.D., Schoon, M.L., Schultz, L., West, P.C. 2012. Toward principles for enhancing the resilience of ecosystem services. Annual Review of Environment and Resources 37: 421-448.

Bommarco, R., Kleijn, D., Potts, S.G. 2013. Ecological intensification: Harnessing ecosystem services for food security. Trends in Ecology & Evolution 28(4): 230-238.
Bottinelli, N., Jouquet, P., Capowiez, Y., Podwojewski, P., Grimaldi, M., Peng, X. 2014. Why is the influence of soil macrofauna on soil structure only considered by soil ecologists? Soil and Tillage Research. DoI: 10.1016/j. still.2014.01.007
CBD (Convention on Biological Diversity). 1992. Convention on Biological Diversity. United Nations.
Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., Turner, R.K. 2014. Changes in the global value of ecosystem services. Global Environmental Change 26: 152- 158.
Cowling, R.M., Egoh, B., Knight, A.T., O'Farrell, P.J., Reyers, B., Rouget, M., Roux, D.J., Welz, A., Wilhelm-Rechman, A. 2008. An operational model for mainstreaming ecosystem services for implementation. Proceedings of the National Academy of Sciences of the United States of America 105(28): 9483-9488.
Estrada-Carmona, N., DeClerck, F.A.J. 2011. Payment for ecosystem services for energy, biodiversity conservation and poverty alleviation. In: Integrating ecology and poverty alleviation and international development efforts: A practical guide, eds., Ingram, J.C., DeClerck, F.A.J., Rumbaitis del Rio, C. New York: Springer.
FAO (Food and Agriculture Organization of the United Nations). 2011a. FAOSTAT database. Available at http://faostat3. fao.org/faostat-gateway/go/to/download/R/RL/E, Last accessed 17 July 2014 (accessed on September 3, 2014).
FAO. 2011b. Global food losses and food waste: Extent, causes and prevention. Rome: Food and Agriculture Organization of the United Nations (FAO).
FAO. 2013. The state of food security in the world. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).
Foley, J.A., Ramankutty, N., Brauman, K., Cassidy, E.S., Gerber, J.S., Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Shehan, J., Siebert, S., Tilman, D., Zaks, D.P.M. 2011. Solutions for a cultivated planet. Nature 478: 337-342.
Fremier, A.K., DeClerck F.A.J., BosquePérez, N.A., Estrada-Carmona, N., Hill, R., Joyal, T., Keesecker, L., Zion Klos, P., Martínez-Salinas, A., Niemeyer, A.S., Welsh, K., Wulfhorst, J.D. 2013. Understanding spatiotemporal lags in ecosystem services to improve incentives. BioScience 63(6): 472-482.
Garbach, K., Milder, J.C., DeClerck, F.A.J., Driscoll, L., Montenegro, M., Herren, B. In Review. Close yield and nature gaps: Multi-functionality in five systems of agroecological intensification.
Garnett, T., Appleby, M.C., Balmford, A., Bateman, I.J., Benton, T.G., Bloomer, P., Burlingame, B., Dawkins, M., Dolan, L., Fraser, D., Herrero, M., Hoffmann, I., Smith, P., Thornton, P.K., Toulmin, C., Vermeulen, S.J., Godfray, H.C.J. 2013. Sustainable Intensification in Agriculture: Premises and Policies. Science 341: 33-34.
Gordon, L., Peterson, G.D., Bennett, E.M. 2008. Agricultural modifications of hydrological flows create ecological surprises. Trends in Ecology & Evolution 23(4): 211-219.
Haines-Young, R., Potschin, M. 2010. The links between biodiversity, ecosystem services and human well-being. In: Ecosystem ecology: A new synthesis, eds., Raffaelli, D.G., Frid, C.L.J. Cambridge, UK: Cambridge University Press.
Hobbs, R. J., Arico, S., Aronson, J., Baron, J.S., Bridgewater, P., Cramer, V.A., Epstein, P.R., Ewel, J.J., Klink, C.A., Lugo, A.E., Norton, D., Ojima, D., Richardson, D.M., Sanderson, E.W., Valladares, F., Vilà, M., Zamora, R., Zobel, M. 2006. Novel ecosystems: Theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography 15: 1-7.
Kareiva, P. and Marvier, M. 2007. Conservation for the People. Scientific American 50- 57.
Kremen, C., Miles, A. 2012. Ecosystem services in biologically diversified versus conventional farming systems: Benefits, externalities and trade-offs. Ecology and Society 17(4): 40.
Laliberté, E., Wells, J., DeClerck, F., Metcalfe, D., Catterall, C., Queiroz, C., Aubin, I., Bonser, S., Ding, Y., Fraterrigo, J., McNamara, S., Morgan, J., Sánchez Merlos, D., Vesk, F., Mayfield, M. 2010. Land use intensification reduces functional redundancy and response diversity in plant communities. Ecology Letters 13: 76-86.
Lavelle, P., Decaens, T., Aubert, M., Barot, S., Blouin, M., Bureau, F., Margerie, P., Mora, P., Rossi, J.P. 2006. Soil invertebrates and ecosystem services. European Journal of Soil Biology 42: 3-15.
Levin P.S., Fogarty, M.J., Murawski, S.A., Fluharty, D. 2009. Integrated ecosystem assessments: Developing the scientific basis for ecosystem-based management of the ocean. PLoS Biol 7(1): e1000014.
Ostrom, E. 2009. A general framework for analyzing sustainability of socialecological systems. Science 325: 419- 422.
Ostrom, E., Burger, J., Field, C.B., Norgaard, R.B., Policansky, D. 1999. Revisiting the commons: Local lessons, global challenges. Science 284(5412): 278-282.
Park, S.E., Howden, S.M., Crimp, S.J., Gaydon, D.S., Attwood, S.J., Kokic P.N. 2010. More than eco-efficiency is required to improve food security. Crop science 50(1): 132-141.
Poppy, G.M., Jepson, P.C., Pickett, J.A., Birkett, M.A. 2014. Achieving food and environmental security: New approaches to close the gap. Philosophical Transactions of the Royal Society B 369(1639): 20120272.
Power, A. 2010. Ecosystem services and agriculture: Trade-offs and synergies. Philosophical Transactions of the Royal Society B 365: 2959-2971.

Raudsepp-Hearne, C., Peterson, G.D., Tengo, M., Bennett, E.M., Holland, T., Benessaiah, K., MacDonald, G.K., Pfeifer, L. 2010. Untangling the environmentalist's paradox: Why is human well-being increasing as ecosystem services degrade? BioScience 60(8): 576-589.
Rusch, A., Bommarco, R., Jonsson, M., Smith, H.G., Ekbom, B. 2013. Flow and stability of natural pest control services depend on complexity and crop rotation at the landscape scale. Journal of Applied Ecology 50(2): 345-354.
Scheffer, M., Carpenter, S., Foley, J.A., Folke, C., Walker, B. 2001. Catastrophic shifts in ecosystems. Nature 413(11): 591- 596.
Schröter, M., van der Zanden, E.H., van Oudenhoven, A.P.E., Remme, R.P., Serna-Chavez, H.M., de Groot, R.S., Opdam, P. 2014. Ecosystem services as a contested concept: A synthesis of critique and counter-arguments. Conservation Letters. doi: 10.1111/conl.12091.
TEEB (The Economics of Ecosystems and Biodiversity). 2010. Ecological and economic foundations. London, UK: Earthscan.
The Guardian. 2012a. Putting a price on the rivers and rain diminishes us all: Payments for 'ecosystem services' look like the prelude to the greatest privatisation since enclosure. Available at http://www. theguardian.com/commentisfree/2012/ aug/06/price-rivers-rain-greatestprivatisation?guni=Article:in%20 body%20link (accessed on June 18, 2014).
The Guardian. 2012b. We must put a price on nature if we are going to save it: Campaigning against economic valuations could inadvertently strengthen the hand of those who believe nature has little or no worth. Available at http://www. theguardian.com/environment/2012/ aug/10/nature-economic-valuecampaign (accessed on June 18, 2014).
Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I., Thies, C. 2005. Landscape perspectives on agricultural intensification and biodiversity: Ecosystem service management. Ecology Letters 8: 857-874.
Walker, B., Salt, D. 2006. Resilience thinking: Sustaining ecosystems and people in a changing world. Washington, DC: Island Press
World Bank. 2014. World Development Indicators: Agricultural inputs. Available at http://wdi.worldbank.org/table/3.2 (accessed on June 10, 2014).
Zhang, W., Ricketts, T.H., Kremen, C., Carney, K.M., Swinton, S.M. 2007. Ecosystem services and dis-services to agriculture. Ecological Economics 64(2): 253-260.