ESPA publications review

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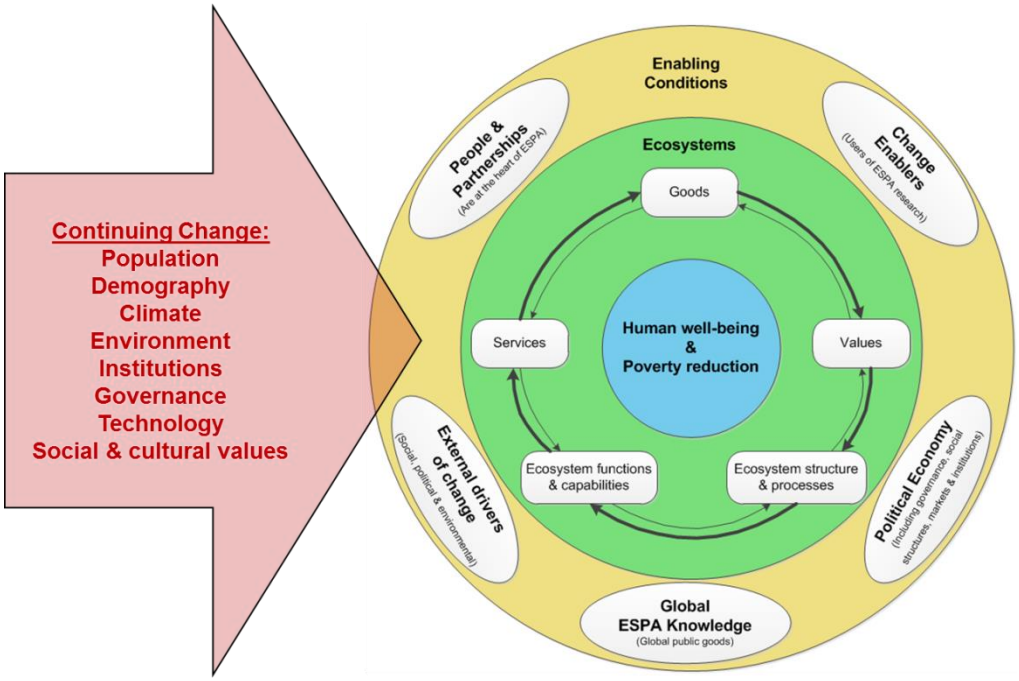
[1] Review conducted using a limited selection of papers made available during summer 2014.

1. Introduction

ESPA research covers a broad range of disciplines, includes many different approaches and methods, is applied across a range of scales of space and time, and is deployed in many geographical, environmental, political and social contexts. Hence it is a challenge to synthesise the findings from the many publications from the programme. The approach here is to broadly base the review on the original research framework[2], which was developed at the inception of the programme in 2010, and agreed to then by the funders and the IPAC. This framework reflects the broad disciplinary base and the interactions between the 'Enabling conditions' in knowledge, policy and decision-making, interfaced with the elements of 'Ecosystems', which are together anticipated to deliver 'Wellbeing and poverty alleviation'. There are two-way flows of influence and many feedbacks between these different elements. Overlaid on this framing is an understanding that all parts of this framework can play out at a range of spatial and temporal scales. The original research questions prioritised new knowledge to inform management of this system of many systems, in order to secure wellbeing, and alleviate and eliminate poverty everywhere.

A complicating factor is that every part of the system is subject to continuing change, indicated by 'External drivers of change' in the outer ring of the framework. In recent years the importance of these external drivers has become more strongly emphasised, especially environmental, demographic and economic drivers and their impacts on the way that people interact with the environment and its actual or potential benefits for them. Therefore, much research in ESPA has focussed on these drivers of change, their focus and intensity, and the positive and negative influences they have on ecosystem services.



The overall goal of ESPA is to ensure that, in developing countries, ecosystems are being sustainably managed in a way that contributes to poverty alleviation as well as to inclusive and sustainable growth. Therefore this review will start with the central objective of ESPA, concerning poverty alleviation and growth. Looking first at overall framings, and then examining research that addresses the delivery of sustainable benefits from the environment, the review moves on to findings about the direct effects of environmental and ecosystem condition, the indirect effects, and then to integrated studies considering governance and decision-making mechanisms.

[2] http://www.espa.ac.uk/our-work/knowledge

2. Poverty alleviation and sustainable growth

Frameworks and concepts

There have been proposals for many different conceptual frameworks concerning the relationship between the environment and poverty alleviation, including the well-established Millennium Ecosystem Assessment framing. Fisher *et.al.* (2013), in a comprehensive review, observe a broad but incomplete dichotomy between frameworks providing conceptual insight and frameworks designed to support data collection. They see these two as being roughly associated with natural versus social sciences, or qualitative versus quantitative and modelling traditions. Despite this they find much overlap in the nine leading frameworks they review and using the common framings conclude that ecosystem services are more likely to be associated with poverty prevention than reduction, and relate this to evidence that ecosystem services tend to provide 'safety nets' that people depend on for subsistence in lean times. The degradation or loss of ecosystem services can therefore perpetuate and/or lead to extreme poverty. Fisher *et al.*(2013) conclude that it is perhaps useful to think about ecosystem services as preventing absolute poverty. In a follow-up paper, Fisher *et.al.* (2014) note that such conceptual frameworks can be used either as tools for analysing situations (as in the development literature) or as devices from which numerical modelling approaches might develop (as in socio-ecological literature). The paper expands on the various components and pays particular attention to socially differentiated outcomes from ecosystem services, and variation among groups in access and decision-making. They identify certain applications for policy appraisal or project analysis which their framework could be used to support.

The importance of a disaggregated analysis of outcomes is fully developed by Daw *et.al.* (2011). They focus on who derives which benefits from ecosystems, and show how these distributional aspects are critical to the well-being of the poor. Their analysis of four different aspects is illustrated with coastal ecosystem services in East Africa. First, different groups derive well-being benefits from different ecosystem services creating winners and losers as ecosystem services change. Second, dynamic mechanisms of access determine who can benefit. Third, individuals' contexts and needs determine how ecosystem services contribute to well-being. Fourth, aggregated analyses may neglect crucial poverty alleviation mechanisms, such as cash-based livelihoods. Securing ecosystem service delivery is therefore not enough, and can therefore still fail the poor unless the full socio-ecological system is considered.

ESPA projects are increasingly using socio-ecological systems as an overarching framework, at scales ranging from the local-scale to regional and even planetary (Mace *et al.* 2014). Dearing *et al.*(2014) develop the well-established planetary boundaries framework and apply it to two local case studies in China to explicitly include social wellbeing, and to define the safe and just space within environmental limits. They show how these ideas for a safe and just space can be implemented although there are complex dynamics related to interactions between pressures within and between such regions. Dorward's (2014) concept of 'livelisystems' takes livelihoods and ecosystems into a fully integrated framework where social, economic, agronomic, ecological, and environmental relationships are incorporated across multiple scales of analysis, with each livelisystem linked within and across the different scales, Within each livelisystem, analysis (and hence potential interventions) focus on asset property, attribute and function changes, and on livelisystems transitions (e.g., soil properties, input use, land productivity, fish populations, and stepping up or out of agriculture and/or fishing into other activities).

Debates continue about the extent to which the ecosystem services concept is a useful way to organize research on the nature-society relationship. Lele *et al.* (2013) trace the history of the concept from its origins in the 'life-support systems of the earth' through to recent links to valuation. While they welcome the greater interactions between economists and ecologists, the new literature on regulating services, and extensions made across scales from local to regional they also recognise some problems. In particular the continuing confusion in both terminology and uses of the terms, ecosystem services, ecosystem processes and functions, as well as about the relationships with biodiversity and biodiversity conservation. They suggest that bringing intrinsic

value within the category of cultural services could mean that, even if not traded-off in monetary terms, conservation goals would have to be negotiated with other societal goals. They recommend accepting that all values are anthropogenic as well as accepting *a priori* that disservices, trade-offs and synergies all exist, and therefore the focus should be on understanding their nature and extent in specific circumstances. The authors present initial steps of a framework developed specifically for an ongoing field study on tropical forest ecosystems.

Outcomes for wellbeing and poverty alleviation

ESPA recognises a broad range of poverty dimensions[3], but as in the general literature the focus tends to be biased towards income as an overarching metric, despite its incomplete contribution to overall wellbeing. (Suich *et.al.*, in review). Abunge *et.al.* (2013) address perceptions of wellbeing and the consequences of ecosystem service policies for local communities. They study ecosystem services and wellbeing using participatory approaches in local communities in a coastal area of Kenya where local restrictions on fishing have been enforced for fisheries protection and conservation. Four groups from the community including legal and illegal fishers and traders were asked in focus groups about their conceptions of wellbeing and its achievement now and in future. Jobs, money, health, children and education were all significant for wellbeing, as were some components of freedoms and choices (e.g. education, decision-making, knowledge and experience).

The health outcomes from ecosystems are widely discussed. The 'OneHealth' concept makes the case for investment in environmental and human health to simultaneously transform the management of neglected and emerging zoonoses that will safeguard people and the livestock that provide nourishment for many impoverished people (Grace 2014). The framework captures the costs of zoonoses and emerging disease to human, animal and ecosystem health in terms of cost of treatment, cost of prevention, health burden and intangible and opportunity costs (Grace *et al.* 2012). It is developed in several contexts including urban food security (Grace, Kang'ethe & Waltner-Toews 2012). As part of a review of modelling approaches, Leach and Scoones (2013) explore case studies concerning H5N1 in south-east Asia and Ebola in central Africa; they conclude that quantitative modelling the very complex and therefore poorly understood systems in zoonotic diseases outbreaks failed to reveal some significant information and options for interventions. They suggest that such contexts are inherently political and best approached using multiple approaches. Few (2013) similarly points to weaknesses in the ecosystem services framing for health and suggests that it can be too simplistic, linear and selective concerning where the costs and benefits lie, and points to examples in biodiversity conservation and carbon markets where there is evidence for this. Lassa fever is a disease associated with poor housing and the highest incidence in the world is consistently in the Kenema District of Sierra Leone. Kelly *et al.*(2013) discuss an architectural plan for low-cost houses specifically designed to limit rodent invasion, ideally using locally available materials in this very poor community.

ESPA continues to gather new ideas and approaches that can add to the lists of research questions and the tools for decision-makers. Adger & Adams (Adams; Adger & Adams) review migration as an adaptation strategy. Migration can be a good risk spreading strategy but may not be possible for people who are poor and vulnerable, and those least able to migrate to avoid environmental change who may also be those most vulnerable to it. Migration can also create new risks, for example currently affecting many in urban areas.
There is a complex relationship between environmental degradation, ecosystem services and rates of outmigration depending on the location, the form of environmental change and the social drivers of migration. Environmental factors act as both a trigger of migration decisions but there are also environmental consequences in both sending and receiving areas. They recommend more attention is paid to the links between vulnerability and migration.

[3] http://www.espa.ac.uk/files/espa/ESPA-Poverty-Framework.pdf

3. Ecosystem services providing benefits to people

Many ESPA projects concentrate on measuring, modelling or recording one or more ecosystem services in a particular context, illustrating trends over time and space, or the potential and actual consequences of environmental change or altered management.

One unusually long term study, takes a multi-decadal perspective across multiple ecosystem services, and provides an important new analysis from the lower Yangtze basin, China for the period 1800-2006 (Dearing *et al.* 2012). The detailed data gathering of a wide range of both provisioning and regulating services, as well as social and economic trends, shows that rapid economic growth and population increases since the 1950s are strongly coupled to environmental degradation with conflicts between agricultural intensification since the 1980s which led to reductions in rural poverty, but has at the same time led to an increasing loss of regulating services. Trade-offs among ecosystem services are a recurring them. In a literature review Howe *et al.* (2014) found trade-offs recorded almost three times as often as synergies. There were three significant indicators for trade-offs being found: at least one of the stakeholders having a private interest in the ecosystem services, the inclusion of provisioning ecosystem services, and at least one of the stakeholders acting at the local scale.

Most studies are over shorter time periods, and many address one or two particular ecosystems or service types. Sustainable food production and its relationship to other ecosystem services lies at the core many ESPA projects. Poppy *et al.* (2014) suggest three crucial components are necessary for multiple benefits to result: to develop a spatial understanding of ecosystem service delivery, to understand distributional benefits, and to recognise and deal with trade-offs explicitly. They demonstrate these ideas using a case study of the forest-agriculture interface in Malawi. In a similar vein, but in a different context, Sjogerstein *et.al.* (2013) examine the recent land management of the Loess Plateau in northern China (the Grain for Green programme) where the focus has been to increase afforestation, and reduce grazing pressure and the use of marginal land in order to slow land degradation and flooding. The area is very diverse and this study sought to examine farmers' perceptions of climate change and the impact of these government-led interventions across this area where the circumstances of the farmers and the environmental conditions varied substantially. On the whole there was acceptance, if not understanding, of climate change and the benefits of the policy in terms of floods and soil erosion. But local contexts were not well dealt with and it was difficult to build local knowledge into the programme. Water availability was everywhere a continuing concern.

Too narrow a focus on a single land use can have unpredictable consequences. Zhou *et.al.* (2014) report on the effects of insecticide application on natural enemies in the North China Plain, a major cotton production region in China characterized by small farm sizes and high use of insecticides. Here, unlike in other agricultural areas that have been studied elsewhere, high land use diversity is not associated with high density of natural enemies, and differences seems to be due to both wider use of insecticides and some specific land use choices. The authors suggest that landscape-based ecosystem services here may require coordinated habitat management at the landscape scale including policies that encourage farmers to account for the human health and environmental costs of insecticides. There have been also been analyses of some intractable environmental problems. Bhagwhat *et al.* (2012), for example, consider *Lantana camara,* a shrub native to the American tropics, which has become one of the worst weeds in recorded history affecting ecosystems in Australia, India and South Africa. Over 200 years their study shows how multiple efforts to eradicate the species have been less than successful, and very costly.

Delivering pro-poor carbon storage and ecosystem service benefits in the semi-arid and dry sub-humid systems of sub-Saharan Africa, is an area of broad interest but there are key gaps in knowledge (Stringer *et al.* 2012). There is much interest in biofuels contributing to poverty reduction, but also to the potentially damaging impacts on agriculture and the environment. Gasparatos *et.al.* (2013), drawing on an earlier report (Gasparatos *et al.* 2012), use the ecosystem services framework to examine the development of biofuels, noting that different biofuel options can have significantly different environmental and socio-economic impacts, and that national

policies tend to be particularly weak on sustainable production. They show how an ecosystem services framework can be a basis for decision tools that can quantify trade-offs. Biofuel production and use affect rural development, energy security, food security, social conflicts, public health, air pollution, greenhouse gas emissions, soil erosion and biodiversity loss among others, but they conclude that possible risks can be avoided through a more inclusive ecosystem service analysis.

Several papers also focus on the conflicts over land use, especially between biomass crops grown for energy versus traditional agriculture for food. Biofuel development over recent decades has been controversial largely because of its potential impact on food prices and habitat conversion. Macqueen & Korhallier (2011) review the role that biomass energy has in national energy planning. It is locally accessible in even the poorest nations and communities and its development can ease balance of payments deficits and foster energy security. Gasparatos *et al.*(Gasparatos et al. 2012) provide an overall review while Black *et al.* (2012) focus more on how projected changes in climate may affect the relative costs and benefits. The quest for more sustainable biofuels has focussed attention on *Jatropha curcas* which it was hoped could be grown by poor, small-scale farmers on degraded and semi-arid land and van Maltitz *et al.* review the possible sustainability of *Jatropha*, based on diverse experiences (von Maltitz, Gasparatos & Fabricius 2014). However in most cases it has not proven successful although it has been successfully developed for soap in one village in Zambia (van der Horst, Chibwe & Vermeylen 2013). Agro-ecology includes a range of ecological principles that aim to support redesign of sustainable, agricultural systems and could be incorporated into a PES scheme (Farley *et al.* 2012).

Given dietary deficiencies in many poor communities, another potentially important intervention concerns micronutrient deficiencies that are addressable through enriched fertilisers. Hurst *et al.*(2013) show that Selenium deficiency is endemic in Malawi as well as common in other African countries and review the cost and benefits of interventions to alleviate it. In Malawi a study of food supply and food composition data with a new spatial survey of maize grain also revealed that average Calcium nutrition is likely to be inadequate for many individuals (Broadley *et al.* 2012), that sub-optimal diets also put people at risk of Selenium deficiency (Chilimba *et al.* 2011), and zinc deficiency is also a risk not likely be connected with Selenium (Siyame *et al.* 2013). In a broader cross Africa study the risk of dietary Mg deficiency in Africa is estimated to be low and unlikely to be a major problem, assuming access to sufficient food (Joy *et al.* 2013).

Smallholder agro-ecosystems in semi-arid Sahel are vulnerable to rainfall variability, and this is likely to become more uncertain in future, raising the question of whether environmental management could improve water retention. Barron *et al.* (2010) showed that a combined effort to enhance crop growth (through fertilizers) and through marginally increased tree cover could potentially shift the farming system domain to a more productive level in terms of both water use and absolute biomass production. Papyrus can also represent an important natural capital stock for poor communities around Lake Victoria (Morrison *et al.* 2012)

In a broader analysis, Hossain *et.al.* (2013) examine the use of an ecosystem services typology for SW Bangladesh, an area especially vulnerable to climate change effects because of the large scale vulnerability of its wetland areas that are important for food and livelihoods, yet facing sea level rise, salinization, and increasing population numbers. They find that different parts of the region vary in their relative exposure and sensitivity to climate change impacts but food production and water management are critical. In a comparable study in a geographically distant area, Kafumbata *et.al.* (2014) examine the small African wetlands of Chad, Chilwa and Naivasha which provide important services to many people, including food and water security, livelihoods and energy. They have led to many people moving in to these areas, and then to increasing pressures on these systems. They document how the growing pressures and the future changes expected under population growth and climate change may make current and recent practices unsustainable, and suggest that comprehensive, integrated planning in these areas, designed to include food security and all related ecosystem services, could significantly reduce risks. In general policies that seek to support resilience need to reflect the trade-offs that operate at different scales, also discussed further with reference to fisheries (Coulthard 2012).

Mangroves are another well-studied ecosystem with many services potentially benefitting the poor. Locatelli *et al.*(2014) provide a detailed review of the good potential for mangrove forests for PES schemes due their potential as carbon sinks especially because of the amount of carbon stored below ground, and their limited susceptibility to damage from biophysical hazards (except for sea level rise). Mangroves also support other ecosystem series such as nursery areas for fish, water purification, provision of wood products, and coastal protection. A study of mangrove loss in Kenya (Rideout *et al.* 2013) analysed drivers and risk factors and compared two different approaches to predicting risk. Risk factors tested included various possible predictors of anthropogenic deforestation related to population, suitability for land use change and accessibility. Local population density, soil type and proximity to roads were all found to be important predictors and two models were compared for predicting future losses based on this and on historical trends. Relatively simple models were found to have quite high predictive power. Baker *et al.* (2010) emphasise the role that ecological science should play in designing and monitoring carbon-based PES schemes, especially in tropical forests, ensuring outcomes are as intended and reflecting uncertainties and feedbacks effectively.

One widely supported scheme for maintaining ecosystem services of importance for the poor, Reduced Emissions from Deforestation and Forest Degradation (REDD+) has received widespread support as a major component of future global climate change policy. Payments for the ecosystem service of carbon sequestration in tropical forests are expected to create incentives for conservation of forest cover and condition, and potentially the benefits can flow to poor local communities. Rendón Thompson *et al.* (2013) assess the set-up, implementation, and monitoring costs, of six REDD+ projects in the Peruvian Amazon and compare them with established projects in Brazil and Bolivia. The costs of implementing REDD+ are shown to be highly uncertain because of issues such as inadequate project design and how additionality is determined. Their results suggest that the cost of preserving existing intact forests in the Peruvian Amazon may have been underestimated. Cohen *et.al.* (2013) present a detailed methodological approach that could support participation in REDD+ schemes which require estimates of carbon pools and accompanying estimates of uncertainty. Currently few methods are available for mangroves, and they establish a method based on stem diameter, tree height and density. They find that the model worked well and could be used for scaling estimates up and down from different sites. Trivedi *et.al.* (2009) propose an additional mechanism to REDD+ – PINC (Proactive Investment in Natural Capital) – that recognises and rewards the value of ecosystem services provided by standing tropical forests, especially from a climate change adaptation perspective.

Urban developments are increasing rapidly in many areas, and already fragile water supply systems are likely to come under increasing pressure from population growth, increasing demand and climate change affecting supply. In a geospatial modelling analysis of four major cities in the Andes that overall demographic pressures are shown to be the dominant factor but the distinctive topologies and geospatial arrangements of different cities mean it is important to analyse water supply within a broader ecosystem services framing (Buytaert & De Bièvre 2012).

4. Ecosystem service analysis: methods, tools and models

Novel methods of data gathering, especially those that link local observations, small and large scale models, cloud computing and visualisations, are likely to become central to many environmental projects in the coming decades, as both the local technology, computing capacity and cloud infrastructure grow. But there are a range of issues to be addressed in realising the huge benefits that could result, including some fundamental epistemological issues around concepts, processes and uncertainties (Beven, Buytaert & Smith 2012), as well as resolving the means to develop and deploy models that include people in a way that supports management of resources that address local livelihoods (Buytaert *et al.* 2012).

Villa *et.al.* (2014) provide a detailed description of the ARIES (ARtificial Intelligence for Ecosystem Services) model which is used in a number of ESPA projects. The methodology has been in development since 2007 and in use since 2010. This model is different from other available tools in being explicitly dynamic and spatially explicit, measuring actual ecosystem services as the benefits that people receive, and including probabilistic measures that reflect uncertainties. It has a modular

design and so it can be adapted for particular contexts. Simulations from ARIES provide outputs in the form of spatial flow density maps representing what ecosystem service benefits were actually received, and with both ecosystem sources and human beneficiaries identified. To deal with the complexity and specificity of ecosystem service modelling they report ecoinformatics innnovations in ARIES that may have implications for other applications in environmental sciences. Unlike many related tools, ARIES is a bottom-up model, parameterised locally using relevant knowledge and information, and is open source. It can use storylines, with machine learning tools dynamically involved in model outcomes. Models addressing eight ecosystem services – carbon sequestration and storage, riverine flood regulation, coastal flood regulation, aesthetic views and open space proximity, water supply, sediment regulation, subsistence fisheries, and recreation - have been developed so far using ARIES, based on literature reviews and expert inputs. Case studies are now being expanded via ESPA and are focused on several locations in the USA, Latin America, and Africa. They raise a fundamental question about the minimum level of detail that ecosystem services assessments need (Villa, Voigt & Erickson 2014). The ARIES model is presented as an innovation that can improve understanding of ES dynamics in data-scarce situations.

The ARIES model is being applied in several ESPA projects and being tested against other models and in a range of settings. One case study, based on water security in the semi-arid landscape of the Great Ruaha river of Tanzania, shows the advantages that the model has for identifying ecosystem service flows, the different beneficiaries and the potential to review trade-offs and constraints quickly and efficiently for policy. The limitations are related to the number of ecosystem services currently modellable, and the difficulty of representing the fuller complexity of the socio-ecological system over large and longer scales of space and time. Bagstad *et al.*(2013a) describe an ARIES case study application to the San Pedro River watershed, Arizona, USA. They develop and test models for final ecosystem services such as carbon sequestration and storage, surface water supply, aesthetic views, open space proximity, and recreational values, and quantify changes in biophysical, abstract, and monetary values of services for three different land use scenarios for the region. The trial indicated areas for future model elaboration including how best to deal with interactions among ecosystem service values, how to represent uncertainty in model outputs, as well as challenges of valuation. Bagstad *et al.* (2013b) present the methodology for the agent-based models that are used to map ecosystem service flows, highlighting the spatial connections between source, sink, and use locations.

Another approach to socio-ecological systems modelling comes from bringing two models together (Forrester *et al.* 2014), one based in local stakeholder actions and another based on ecosystem wide dynamics, and concludes that this process creates a well-established overall model of the system that can be further refined for decision-making.

Souty *et.al.* (2012) present a new global model with a detailed representation of agricultural intensification in a structure accounting for the main types of demand for biomass at the global scale. The model is being tested for non-linear shifts in interactions between energy prices, crop yields and deforestation.

These large scale issues certainly require more work but several ESPA projects have shown how specific models can support research design and policy priorities. Many concern economic payments from ecosystem services, for example an Excel-based tool for analysing the potential effects of incentive payments to reduce emissions from deforestation (REDD) in Bolivia (Andersen *et al.* 2012) and a novel framework for the holistic and interdisciplinary investigation of zoonotic disease emergence and its drivers (Wood *et al.* 2012).

Data-gathering and monitoring can be demanding but there is a large potential for increasing involvement of citizens in data collection because of the increasing availability of inexpensive, robust and highly automated sensors, and the possibility to combine them with powerful environmental models to create rich and interactive visualization methods, for example in hydrological models (Buytaert *et al.* 2014).

Zulkafli *et.al.* (2013) show that hydrological predictions with the widely used Joint UK Land Environment Simulator earth system model (JULES-LSM) can be unreliable due to a large uncertainty in the driving data and poor simulation of the baseflow component in the upper Andean basins. In the peneplain, the model is unable to reproduce the well-regulated regime as it neglected the hydrological functions of the flood forest. Nevertheless, for a global model that is not purpose-built for hydrological modelling, JULES is capable of producing reasonable simulations of the flow regime at fine temporal scale.

A more general critique of environmental modelling is presented by Leach and Scoones (2013) who reject the traditional view of quantitative modelling as an objective approach that can be used to direct policy. They discuss three broad types of modelling: mathematical/process-based models of epidemiological and ecological relationships parameterised according to available data; pattern-based models which extract relationships from statistical analysis of empirical datasets, and 'participatory' modelling based on anthropological, ethnographic and participatory approaches. They draw on case studies to show that a limited modelling approach can miss key elements in systems characterised by complex social dynamics, including several zoonotic diseases.

5. Measuring and modelling environmental change

Environmental change is occurring at increasing rates, with disproportionate affects in developing countries and affecting the poor. Hence there is much interest in methods of recording and predicting areas of rapid and/or detrimental change. One project examines the trends in different ecosystem services and in biodiversity over time, based on the exceptional time series data from China (Dearing *et al.* 2012) including evidence for early-warning signals for linked social–ecological systems that are approaching "tipping points" (Wang *et al.* 2012). Using observational data from a lake system they show how rising variance coupled to decreasing autocorrelation and skewness started 10–30 years before the eutrophication transition. If generally applicable, this finding suggests that early warning signals of transitions may be stronger, and hence easier to identify, than previously thought.

A rapid review of the reported links between climate change, ecosystem services and poverty alleviation found that most studies focus on a very limited number of ecosystem services and rarely considered multiple dimensions of poverty or the full range of climate change effects(Howe *et al.* 2013). This study also emphasised the need for a more commonly understood terminology and conceptual basis in order to develop a stronger science base related to climate change impacts on poverty alleviation mediated by ecosystem services

Multiple ecosystem services and their drivers have been analysed in several contexts. Dearing (2013) notes that lake sediment records can provide highly resolved time-series of data that give essential long term perspectives for complex socio-ecological systems, especially at regional scales, and the case study in China shows that regulating services (e.g. water purification, soil stability, climate regulation) seem to have many potential proxy records in sediments and these are often the least well monitored, and show declining trends despite gains in provisioning services. Ogutu *et.al.* (2014) analyse the changes to wildlife and livestock within Kajiado County of Kenya, with a rapidly expanding human population, settlements, cultivation and other developments during 1977-2011. They find that wildlife species contracted, especially wildebeest, giraffe and impala. However, livestock distribution expanded to cover most of the county. Recurrent droughts, intensifying human population pressures, land use changes and other anthropogenic impacts, decades of ineffective or failed government policies, legislations, law enforcement, management institutions and strategies are cited as the causes of the declines and range compressions in wildlife. A detailed study of the impacts of land use change on the carbon assimilation and sequestration potential of tropical wetlands showed that increasing population densities, economic development and agricultural encroachment along the shoreline of Lake Victoria are reducing the optimal performance of these wetland ecosystems (Saunders, Kansiime & Jones 2012). Furthermore, increasing temperatures and a reduction in rainfall under climate change may further reduce wetland function. The conclusion is drawn that it is imperative that the multifunctional role of tropical wetlands forms an integral part of future wetland management strategies.

The possibility of large-scale loss of Amazonian rainforest under some future climate scenarios predicted by some general circulation models is a cause for concern, especially to understand the relative importance of different environmental drivers (precipitation, temperature, humidity and CO2). Model comparisons show that temperature is more important than precipitation in most models and that rising CO2 can mitigate much of the climate-driven biomass losses in the models (Galbraith *et al.* 2010). Meir & Woodward (2010) introduce modelling studies on the response and vulnerability of Amazonian rain forests to drought while Meir & Pennington (2011) review climate change impacts on the seasonally dry tropical forests. Climate change may affect rain forest causing it to change to savannah or to seasonally dry tropical forests, and they find that soil fertility is very significant for determining the transition. Embedding a regional climate model within the global GCM, testing predictions against observations with particular regard to precipitation and temperature anomalies can improve predictions (Chou *et al.* 2012).

Use of the PRECIS regional climate modelling system suggests that South America could experience significant and often different changes in rainfall and temperature extremes by late 21C (Marengo *et al.* 2009); the occurrence of warm nights is projected to be more frequent in the entire tropical South America while the occurrence of cold night events is likely to decrease. Significant changes in rainfall extremes and dry spells are also projected. A regional climate modelling study examining the Amazon, So Francisco and the Parana River basins indicated future large rainfall reductions in Amazonia and Northeast Brazil, and rainfall increases around the northern coast of Peru and Ecuador and in southeastern South America, with changes becoming more intense after 2040 (Marengo *et al.* 2012). Soares & Marengo (2009), using GCM modelling for the Andes, suggest increased moisture transport from north to south east of the Andes as compared to the present.

The information from monitoring land and water bodies using remote sensing is improving all the time, and offers a new way to track critical changes in ecosystems and their services. Ometto *et.al.* (2011) review and synthesize the global effects Amazon deforestation in Brazil, as well as drivers and challenges related to this process, and emphasise the role of remote sensing for monitoring ongoing changes. Kirui *et.al.* (2011) illustrate the use of LANDSAT satellite images to measure the loss of mangroves over the 25 years between 1985 and 2010; the method indicated rates of decline in Kenya similar to (although slower than) global estimates. Loiselle *et al.* (2014) undertook a systematic comparison of the dynamics of the bio-optical and thermal properties of thirteen of the largest African lakes between 2002 and 2011 using aquaMODIS satellite data. Lake surface temperatures were mostly increasing though phytoplankton dynamics varied considerably between lakes as well as within lakes. Satellite based measure of thermal dynamics provides can new insights into the response of these ecosystems to global and regional drivers.

6. Biodiversity, ecosystem processes, functions and services

The widely cited study on the Economics of Ecosystems and Biodiversity TEEB (Kumar 2011) pointed to the importance of biodiversity underpinning many ecosystem services, but there are many different conceptualisations about the role that biodiversity actually plays. While many people equate ecosystem services with biodiversity, and see nature conservation as complementary to poverty alleviation, others see conflicts. For example, one comparison of attitudes to biodiversity contrasts the indigenous and local communities who depend directly on it for cultural and spiritual value with its usefulness to humans, as in the ecosystem services framework, and suggests that these differences require more nuanced analysis (Stephens 2012).

Cardinale *et al.* (2012) review of the evidence using a more specific, ecological definition of biodiversity that measures the diversity of genes, species and biological traits. At local scales more diverse systems are more efficient for ecosystem processes such as production and decomposition, and these relationships intensify in a changing environment where diversity represents a store of adaptability. However, in terms of ecosystem services there is a more variable and context-dependent relationship between diversity and efficiency. Some services show mixed relationships with diversity while others are stronger with reduced diversity (e.g. food

production and pest resistance). However, they conclude that the trade-offs between efficiency and resilience are not well understood.

There is already a large literature on biodiversity links to ecosystem services and to poverty alleviation. In a series of recent publications Roe and colleagues have been reviewing links between biodiversity conservation and poverty. They have edited a book on the subject (Roe *et al.* 2012), as well as a technical report for the Convention on Biological Diversity. However, more relevant to ESPA, is the systematic literature review by Roe *et.al.* (2014) based on the systematic review described in an earlier paper (Roe *et al.* 2013). The study addressed the question, "Which components or attributes of biodiversity influence which dimensions of poverty?" The review included 284 studies that addressed this question specifically in non OECD countries. While they focussed on wild biodiversity the results showed that the most common positive linkages reported were between direct uses (often consumptive) and limited dimensions of poverty (income, assets and food security) even though wider aspects of poverty and indeed of governance were often part of the study. They found the importance of the diversity components of biodiversity were much less strongly emphasised than the extent or distribution, which is at odds with the CBD definition of biodiversity that emphasises variability. Rather worryingly there were few papers where sustainability was explicitly considered. The authors suggest that many relevant studies may have been ruled out by the specific criteria for inclusion and exclusion that were necessary for such a broad question. More detailed understanding of the linkages may require a number of more focussed reviews, including for example on underpinning biodiversity, on dryland systems, on biodiversity-poverty trade-offs and the biodiversity contributions to ecosystem services.

Mace *et al.*(2012) consider the relationship between biodiversity and ecosystem services and document how different aspects of biodiversity has key roles at all levels of the ecosystem service hierarchy: as a regulator of underpinning ecosystem processes, as a final ecosystem service and as a good that is subject to valuation, whether economic or otherwise. Howard (Howard 2013) reviews the literature on 'tipping points' in biodiversity and the impacts that these may have on people's wellbeing, at scales ranging from households to biomes and identifies the importance of early-warning systems that need to be developed at the interface of human and natural systems.

7. Consequences of ecosystem services policies for fairness and justice

The wider adoption of the ecosystem services framework has had some major consequences for environmental policy where financial incentives can start to play a significant role, and therefore involve a new set of stakeholders and decision-makers. Muradian *et.al.* (2013) published a widely read commentary aimed at raising awareness among policy makers of some of the potential drawbacks of PES and why such schemes might not represent the win-win options that they are often perceived to be. Ecosystem services do not operate as true market commodities and the incentives that PES provides will not necessarily create functional markets. This is further complicated by the fact that most ecosystem services are either public goods or common pool resources, and that the outcomes of payments depend to a large extent on political forces. They conclude that PES cannot be considered *a priori* a cost-effective policy option to achieve environmental goals or development benefits. Mahanty & McDermott (2013) examine how the principles of free, prior and informed consent (FPIC) enshrined in international conventions actually affect indigenous people when activities impact their lands, cultural, intellectual, religious and spiritual property. They examine national laws and policies concerning land, mining and forestry that influence FPIC in case studies in Brazil, Canada and PNG and conclude that FPIC is not a universal panacea and that failures in equity and distribution result when specific contextual factors are not fully taken into account. This is of great importance for REDD+ implementation. Ituarte-Lima & Subramanian (2013) similarly address biodiversity and climate debates in the international legal arena, especially considering specific legal instruments that will likely accompany implementations of REDD+ in areas of tropical forestry in Peru and Indonesia. They highlight the equity dimensions of the debate especially as these relate to definitions and use of terms relating to technology and the cultural contexts of forest people. They conclude that equitable environment-related legal negotiations and policies need to be actively fostered in policy mechanisms such as

ABS and REDD+ especially ensuring that mechanisms overcome power imbalances in negotiations and the difficulties that forest dependent people have in complying with legal requirements.

Sikor's edited book on "The Justices and Injustices of Ecosystem Services" includes chapters from several ESPA project authors (Sikor 2013b). They take the concepts of ecosystem services as originally outlined in the Millennium Ecosystem Assessment, and develop various aspects of this relationship that bear upon justices and injustices, especially as the consequences of applications of the ecosystem services framework unfold in practice. Sikor (2013a) lays out the approach to defining environmental justice that is used through most of the rest of the book. Drawing on an empirical approach, justice has three dimensions: distribution, participation and recognition. Distribution refers the fair distribution of ecosystem goods and services (as well as their damaging effects), participation refers to the ability of all people affected by decisions to be able to play a role in the discussions and negotiations leading to decisions. Recognition is more nuanced and requires that the differing needs, wishes and cultural norms that people hold for the environment are respected and decisions do not simply follow dominant norms. Recognition has proved to have a significant role in ecosystem services because of the different conceptions of 'nature' that are held by different cultures, and has been a lively area of debate in the formulations underpinning IPBES for example. Despite all the best efforts to reflect these concerns about environmental justice in the commitments to international agreements, such as the UNFCCC, there are a number of further considerations as processes such as REDD+ are implemented (Sikor 2013c; Sikor *et al.* 2014). These will alter the way that decisions are made with substantial bearing on governance arrangements, and on the values that different groups of people have for environmental services. In addition, and perhaps most significantly, the methodologies introduced for measuring and managing ecosystem services may not reflect the values systems of local communities, and therefore alter the human-nature interactions of some groups of people, especially with technical and professional scientific approaches starting to overwhelm local perceptions, experiences and knowledge systems. The immediate losers here are likely to be the local community, but the implications may be broader.

Martin *et.al.* (2013) take up the topic of fairness and justice in the context of biodiversity conservation. They start by noting the awkward realities that (1) many areas of high biodiversity value are located in countries that are relatively poor, (2) there tends to be geographical overlap between areas of high cultural and high species diversity, and (3) that the favoured conservation approach of protected areas has often disadvantaged the local poor. In fact none of these observed patterns make an approach to fair and just sharing of benefits impossible, it is just that in practice there have been many cases where this has not happened. Using the example of tourist revenues in the Bwindi Impenetrable National Park in Uganda, they show that one the one hand asymmetries of power and competition for resources exclude certain kinds of benefits from poor, local people. But equally important is participation in framing the nature of a problem and its solutions, in effect the participation and recognition dimensions of environmental justice. Zeitoun & McLaughlin (2013) consider conflicts between uses and users of water in river basin systems in Yunnan, China and the Upper Jordan River. In both cases, despite various formal and informal means to deal with conflicts and trade-offs they conclude that economic incentives tend to win out over both environmental sustainability and equity, although again this is not inevitable. It requires more attention to governance and decision-making systems. Few (2013) discusses how in an ecosystem services context, health is used to mean more than narrow absence of disease, and is used to mean a generally good and fulfilling life. But the links with ecosystem services are sometimes selective and only work at aggregate levels. For example, there is often an assumption that more natural and intact ecosystems underpin better health. This may not always be true, especially where intact ecosystems harbour pathogens or dangerous species. Many costs of broader goods are felt by local people who may lose the options for growing food or other livelihood options. Similarly, in PES, McDermott *et al.* (2012) present a framework for analysis of based on three dimensions. The first, distributive equity, addresses the distribution of benefits and costs. The second, procedural equity, refers to decision-making. These are linked by the third dimension, contextual equity, which incorporates the pre-existing conditions that limit or facilitate people's access to decision-making procedures, resources and, thereby, benefits.

A comprehensive equity framework to compare the priorities and trade-offs of different environmental and social certification schemes (McDermott 2012), considering the primary decision-makers and intended beneficiaries assessed across the dimensions of procedural, contextual and distributive equity. Van der Horst & Vermeylen (2011) consider moral and local rights in carbon debates and then take a more holistic approach to the energy landscape (van der Horst & Vermeylen 2012), by examining claims of ownership and notions and measures of value inherent in different claims and value systems which can influence decision-making.

8. Governance and decision-making

Sandbrook (2013) considers the different kinds of evidence that are available for evidence-based policy, and the processes used to gather this evidence with special reference to biodiversity conservation and poverty alleviation. In medical and conservation systematic review methodologies there is a focus on quantitative, experimental and controlled studies, which are regarded as providing 'good' evidence compared to qualitative, uncontrolled studies or case studies. However there is not a single hierarchy of evidence quality and some questions are better answered by qualitative methods (e.g. a study on political incentives) rather than via a controlled experiment (e.g. an ecological process). Another option is to base the evidence on structured analyses of agreement among experts, which can be useful where complex and interdisciplinary questions require an answer. Here multiple sources of information may be required because the questions are broad and he suggests that rejecting more informal information sources may exclude significant information.

Liu *et al.*(2010) study the 'Priority Forest Programs' developed from the late 1990s in China and examine the evidence that these have enhanced rural households' income, one of the original objectives. To date, of the 6 programs studied, three have had positive effects, two have had no effect and one has had a negative effect. A 40 year history of ecological events and management issues of ecological importance in Lake Naivasha, Kenya together is presented with commentary on governances and management with implications for the future (Harper 2011).

There are several studies illustrating how a focus on one or two significant ecosystem services can have detrimental outcomes over the longer term or for the poorest people. The exploitation of the Bolivian Chaco for gas has led to dominance of one ecosystem service with inequitable outcomes that are especially detrimental for indigenous communities. Building on this case study, Bebbington (2013) argues that any effort to reduce inequality of outcomes produced by the governance of ecosystem services should first recognize and address asymmetric relationships and inequities in access to economic and political opportunity. An eco-hydrological model developed for the Pongola floodplain, South Africa was developed to support decisions about where water is best used in terms of poverty alleviation. Poor households on the floodplain currently have a diversity of income and food sources, but a trend towards intensive agriculture which may deliver higher returns but with greater costs and increased vulnerability to the poor. Use of the model identifies the timing of flood releases, and consideration of regulating and cultural services to be key to better overall governance of the system with benefits for the poor (Lankford *et al.* 2011).

Considering the implementation of PES schemes, Balana *et.al.* (2011) researched landholder preferences for alternative land-management schemes aimed at enhancing the provision of watershed services in the River Kapingazi catchment in central Kenya. Results indicated that shortage of water for both domestic use and irrigation was perceived as the most acute environmental problem in the area and that the three principal attributes influencing landholder's ratings and probability of adopting the proposed land management options were 'size of land area to be committed', 'length of contract period', and 'granting or prohibiting rights to harvest environmental products from the committed land'. Thus, they conclude that these attributes should be the focal points in designing land-management contract for watershed services in the study area.

Protected areas have complex consequences for local communities, and their effectiveness will improve with local support that comes from clear governance. Bavink & Vivekanden (2011), investigated the implementation of a Marine Protected Area in the Gulf of Mannar, India revealing areas of social conflict that are related to the diversity of the MPA, as well as to its societal embedding. The importance of nesting a MPA in wider societal processes and structures that will lead to more balanced decision making, and to a greater appreciation of the 'fairness' of MPA policy is illustrated by this study. Based on a comparative study of water basin management in Tanzania and Nigeria, Franks *et.al.* (2011) emphasise a continuing need to develop processes of water governance that operates at all scales from the local to the basin scale , and to move from bureaucratic technology-led approaches to water resources management and more open flexible ad hoc responses to specific and localized situations. The emergence of ecosystems-services discourse calls out for the active engagement informed by cybersystemic understandings (Ison) that, in the hands of theoretically aware practitioners, based on case studies in South Africa, Australia and the UK provide offer opportunities to move towards more systemic and adaptive water governance (Ison *et al.* 2011).

9. Natural resource management and the political economy

An understanding of the political economy of negotiations and trade-offs can assist policymakers and users in making more informed choices over ecosystem services and poverty alleviation with particular relevance to India (Vira *et al.* 2012). Traditional approaches to natural resource management, based on local agreements need to evolve to be sustainable but are in many areas being put under extreme pressure from both internal growth in demand and extrinsic competitors and pressures, Coulthard (2011) analyses the factors limiting adaptation of the widespread 'padu' system of South Asia, and examines the complex relationships between adaptability and wellbeing that emerge as communities strive to develop resilience in the face of such changes (Coulthard 2012).

Recognising the policy challenge of reconciling poverty and environmental objectives for development policy makers Coulthard *et al.* (2011) conclude that there has to be a social wellbeing approach for fisheries governance. This does not mean that hard choices are made easier, in fact the approach highlights profound nature of some of the challenges, but they contend that better informed governance systems and processes that are able to focus on the wellbeing of fishers may have the capacity to produce more effective policy decisions for achieving fisheries sustainability. Collins *et al.*(2009) draw on European and SA experiences to demonstrate that it is possible to invest in social learning as a governance mechanism for water managing, but overcoming key constraints related to context and learning is key to success.

There is much interest in financial mechanisms that allow both costs and benefits of alternative ecosystem management to be represented. Wei *et.al.* (2010) investigated an approach for estimating the physical dimensions of the environmental externalities from a maize cropping system in oasis farming of the arid north-west of China, and show how the monetary valuation of these environmental externalities could maintain both the social and farmers' benefit–cost ratios although there were large costs associated with recharging groundwater. Nevertheless a method that reframes water catchment management in the form of social learning has the potential to realise more systemic and adaptive forms of water governance (Wei *et al.* 2012).

Using the case study of the mechanism known as the Yasuní-ITT Initiative, by which Ecuador would be compensated for not exploiting the reserves of heavy crude lying underneath the Yasuní National Park (a Biosphere Reserve located in the Amazon Region), Rival (2010) shows how an anthropological perspective may complement ecological economics and various political and economic approaches in development policy. Rival (2009) summarises the benefits of an anthropological approach generally, including for the specific challenges posed by the design of economic instruments for the protection of ecological wealth in Latin American countries poor in financial capital, but rich in biological diversity (Rival 2012).

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