Case Studies

Valuing Ecosystem Services in the Eastern Arc Mountains of Tanzania

Ruth D. Swetnam, Andrew R. Marshall and Neil D. Burgess

As ecologists we all value nature extremely highly. Although we hold it in high regard many of us would be reluctant to attach a monetary value. Some would perhaps even regard nature as priceless. However for governments who aim to develop sound conservation policies, subjective impressions of value are extremely complicated to juggle against other more tangible economic figures. For this reason there are growing efforts to value 'ecosystem services' or 'natural capital' in an attempt to provide decision-makers with a broader set of arguments for conserving the natural world.

Udzungwa red colobus monkey Procolobus gordonorum. *Photograph by A. Marshall*

'Valuing the Arc' (VtA) is a 5 year interdisciplinary research programme funded by the Leverhulme Trust and the Packard Foundation which is measuring, modelling and valuing ecosystem services produced and sustained by the Eastern Arc Mountains, a global biodiversity hotspot in eastern Tanzania and south-eastern Kenya (Burgess et al. 2009). One early, unpublished estimate from the Government of Tanzania placed the value of the Eastern Arc Mountains to the Tanzanian economy at $620M/yr. The aim of VtA is to improve on this estimate through the systematic assessment and modelling of a broader range of ecosystem services. The programme is addressing the following questions:

a. What services are provided by the Eastern Arc Mountains, and where exactly are they being produced?
b. Who benefits from the different ecosystem services provided by the Eastern Arc and where are these people located?
c. How much are these services worth?
d. How might these benefits change over space and time if different policy objectives are pursued?
e. How much does it cost to maintain these services and who is paying?
f. How can the costs of conserving these services (for example, by protecting catchment forests) be equitably shared between those (such as nearby farmers) whose behaviour will determine their future delivery, and those who are using them further downstream?

Our first task was to develop a conceptual framework for service valuation which clarified how we defined services and where and when they can be valued (Fisher et al., 2009; Turner et al., in press). This framework subsequently underpinned a programme of fieldwork that has been used to guide the development of models and methods of valuation across our study area (Figure 1).

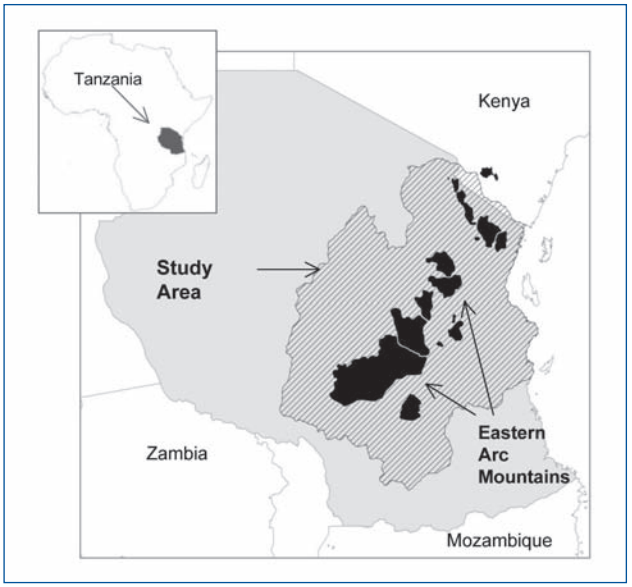

Figure 1: *Study region in eastern Tanzania with the Eastern Arc Mountains highlighted in black.*

Which ecosystem services are important in the EAM?

Our focal services are carbon storage and sequestration, the regulation of water flow, the provision of timber and non-timber forest products (including building poles, firewood,

Ecosystem Services and the Ecosystem Approach

Forest-agriculture mosaic in the Eastern Arc. Photograph by A. Marshall

charcoal, and foodstuffs such as mushrooms or tubers), nature-based tourism, and pollination. For each service we are building coupled biophysical and socioeconomic models to describe how the production, flow, use and value of that service are expressed across the Eastern Arc Mountains. These different services are linked within a common GIS database which now stores a range of spatial datasets both biophysical and socio-economic in nature. Many have been collated from existing studies, others have been newly collected for the project, while a third set have been derived or modelled from the other two.

Approach

For each of our target services, the same sequential approach is being taken with a data collation and collection phase designed to support the development of spatially explicit models of production, flow, use and value (Figure 2). Mapping production (i.e. where is a service produced) is relatively straightforward for most services and this stage of the work is supported by fieldwork observation, remotely sensed data and existing distribution maps. Mapping the flow of services from the point of production is more challenging, and takes a number of forms, from mechanistic hydrological models which predict water availability throughout a catchment, to econometric models which describe the movement of charcoal or timber from a source in woodland to urban markets such as Dar es Salaam. The subsequent valuation of these services is equally complex and has included market surveys, interviews with tourism operations, and questionnaire surveys of farmers. Accessibility of each resource is a key factor in its use and spatial models of forest disturbance which account for transport networks, population and markets are currently being refined to feed into this assessment.

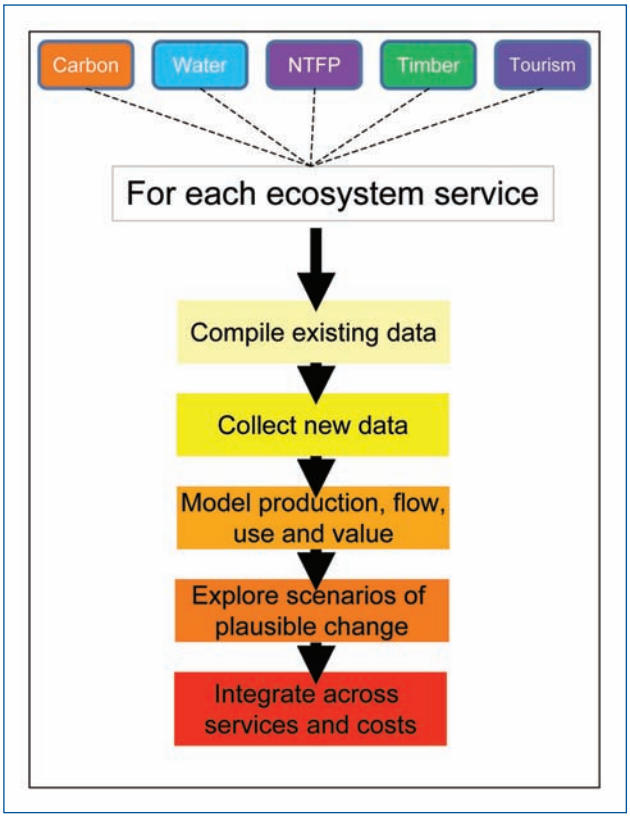

Figure 2: *Sequential approach to valuation for each target service in the Valuing the Arc project.*

Having an understanding of both the production and current value of ecosystem services is useful as a baseline, but policy-makers cannot make decisions based simply on gross estimates of service values: instead they need information about possible changes to these values arising from alternative policy decisions. To this end, VtA has undertaken a process of participatory scenario-building to develop two Tanzanian specific socio-economic scenarios of change which have been expressed spatially in the form of 'new' land-cover maps for 2025. Having created these outputs, they will now be used with our production and flow models to explore how service delivery may change in the future depending on the choices taken now.

Where does ecology fit in to the Valuing the Arc programme?

An understanding of ecosystem functioning is important to many aspects of the modelling we are undertaking. In particular, the structure of the forests and woodlands of the EAM are important determinants of carbon storage (how much is stored in above-ground, below-ground and in the soil). The amount of carbon depends on a complex

Ecosystem Services and the Ecosystem Approach

Pitsawing. Photograph by A. Marshall

interplay of environmental and human influences, which we are modelling to determine past and present trends and to predict future scenarios. The existence of the forest has a major impact on hydrology; the cloud-forest found in the mountains probably captures additional water as well as acting as a vegetative 'sponge', which regulates quality and flow of water, especially in the dry season. The biological diversity of the EAM is well recognised and its protected areas exist to try to maintain the many endemic species of flora and fauna of the region, which in themselves provide important services to the local population through the provision of supplementary food and medicinal plants.

Where next for VtA?

We are currently three years into our five year programme and the mapping of the production of our focal services should be completed by the end of 2009. Simple models of production are now in place for all of the services and these are currently being improved and refined to incorporate the effects of degradation, accessibility and climate. Valuation work is ongoing and will interact with different outputs throughout the final stages. Most recently, the preliminary outputs of the carbon module have already provided input to Tanzania's negotiations at the UNFCC Conference of Parties in Copenhagen. VtA is also playing an active role in the policy debate regarding the implementation of the REDD (Reduced Emissions from Deforestation and Degradation) process in Tanzania (Burgess et al, submitted).

It is our hope that VtA will contribute to the development of best practice in ecosystem service analysis and valuation both in Africa and elsewhere, and will specifically inform the policy debate surrounding environmental protection and poverty alleviation in Tanzania.

See http://valuingthearc.org/ for further details.

Acknowledgements

VtA is a large, collaborative programme funded by The Leverhulme Trust and the Packard Foundation and involves the work of the following people: Antje Ahrends (York), Andrew Balmford (Cambridge), Brendan Fisher (UEA & Princeton), Jon Green (Cambridge), Rhys Green (Cambridge),Aloyce Hepelwa (Dar es Salaam), Kim Howell (Dar es Salaam), Jafari Kideghesho (Sokoine), George Kajembe (Sokoine), Kassim Kulindwa (Dar es Salaam), Simon Lewis (Leeds), Jon Lovett (York), Seif Madoffe (Sokoine), Rob Marchant (York), Joseph Makero (Sokoine),Rogers Malimbwi (Sokoine),Boniface Mbilinyi (Sokoine), Christina Mohammed (Sokoine), Felix Mtalo (Dar es Salaam), Pantaleo Munishi (Sokoine), Shadrack Mwakalila (Dar es Salaam), Sian Morse-Jones (UEA), Willirk Ngalason (Sokoine), Nasser Olwero (WWF US), Phil Platts (York),Taylor Ricketts (WWF, US), Mathieu Rouget (SANBI), Celina Smith (Cranfield), Kerry Turner (UEA), Doug Yu (UEA),Chacha Werema (Dar es Salaam), Sue White (Cranfield), Simon Willcock (Leeds).

REFERENCES

Burgess, N., Mwakalila, S., Madoffe, S., Ricketts, T., Olwero, N., Swetnam, R., Mbilinyi, B., Marchant, R., Mtalo, F., White, S., Munishi, P., Marshall, A., Malimbwi, R., Jambiya, G., Fisher, B., Kajembe, G., Morse-Jones, S., Kulindwa, K., Green, J., Balmford, A. (2009)	**Valuing the Arc – a Programme to Map and Value Ecosystem Services in Tanzania.** ***Mountain Research Initiative Newsletter*** **18(3) 18-21.**
Burgess, N. D., Clairs, T., Danielsen, F., Dalsgaard, S., Funder, M., Hagelberg, N., Haule, C., Kilahama, F., Kilawe, E., Lewis., S. L., Lyatuu, G., Marshall, A.R., Munishi, P. K. T., Nashanda, E., Sekhran, N., Shirima, D., Swetnam, R. D., Willcock, S., Williams, A., Zahabu, E., (submitted)	***Saving Forests to Reduce Global Warming: the United Nations "REDD" Programme in Tanzania.*** **Submitted to Oryx.**
Fisher, B., Turner, R.K., & Morling, P., (2009)	**Defining and classifying ecosystem services for decision making.** ***Ecological Economics,*** **68(3): 643-653.**
Turner, R.K., Morse-Jones, S. & Fisher, B., (in press)	**Ecosystem Valuation: A Sequential Decision Support System and Quality Assessment Issues** ***Ecological Economics Reviews 2010.***

Ecosystem Services and the Ecosystem Approach

Ruth Swetnam is a Research Associate in the Conservation Science Group at Cambridge University. She is a Chartered Geographer and GIS specialist and is leading the spatial modelling for the Valuing the Arc Programme. Her main research interests lie in the fields of landscape ecology, historical geography, land use change and environmental information.

Andrew Marshall is a Senior Research and Teaching Fellow in the University of York Environment Department, and Director of Conservation Science at Flamingo Land Theme Park and Zoo. He is a conservation biologist studying the ecology of rare species, carbon and forest management in the Eastern Arc Mountains since 1998 and now directs the Udzungwa Forest Project.

Neil Burgess is Professor of Conservation Biology at the University of Copenhagen and a Visiting Fellow of the University of Cambridge. He has previously worked in Tanzania, UK and Denmark on a variety of conservation and development projects. His main interests are on protected areas, biodiversity pattern and priorities, and the links between ecosystem services, biodiversity and human development.

The Natural Capital Project

Heather Tallis, Wang Yukuan, Fu Bin, Zhu Bo, Zhu Wanze, Chen Min, Christine Tam and Gretchen Daily

After spending decades struggling to keep people out of nature, conservation is emerging on the global stage with a new vision for connecting people to nature. One of the largest efforts to date, the Millennium Ecosystem Assessment, proposed a vision of a world where people appreciate natural systems as vital assets, recognize these assets as critical for human well-being, and routinely include their values in decisions (MA 2003). This vision is starting to take hold in policy innovations worldwide. China, for instance, is investing over 700 billion yuan (£60 bn) in ecosystem service payments over 1998-2010 (Liu et al. 2008). Through pioneering local leaders to government bureaucracies, and through traditional cultures to new corporate initiatives, a tremendous variety of approaches is being deployed to incorporate natural capital into decisions (e.g. Kareiva and Marvier 2007; Ostrom 2007; Kleiner 2009). The big challenge is to replicate and scale these emerging models of success so they become part of everyday life (Daily and Ellison 2002; Goldman et al. 2008). The Natural Capital Project was designed to build on these innovative but highly site-specific efforts, and bring natural capital into the mainstream of everyday decisions around the world. This somewhat lofty goal requires rapidly advancing the science of ecosystem services, and turning the valuation of services into real, effective policy and finance mechanisms – a problem no one has solved on a large scale.

Launched in October 2006, the Natural Capital Project (NatCap) is a unique partnership between Stanford University, The Nature Conservancy, and World Wildlife Fund (www.naturalcapitalproject.org). In addition to these three core partners, we are working with others globally in the public, private and non-profit sectors. For example, our work in Tanzania is a collaboration with four Universities in the UK (Cambridge, East Anglia, York, Cranfield), two universities in Tanzania (Sokoine and Dar es Salaam), and a variety of local non-profit organizations.

As a group bringing academic research to a global laboratory of on-the-ground projects, we aim to make three major advances that together will transform how businesses, governments, and individuals interact with nature:

(1) Developing new knowledge & practical, credible tools. The new global focus on connections between people and nature suggests that investments in conservation will provide returns to people in the form of ecosystem services, or the benefits people receive from natural capital. While this idea is tantalizing, the research community needs to deliver knowledge and tools to show this connection is real and project how it will change in the future. NatCap has developed InVEST, a family of software-based tools for Integrated Valuation of Ecosystem Services and Tradeoffs. InVEST helps decision-makers quantify the importance of natural capital in biophysical, economic, and some social terms; generates maps of where and how benefits are delivered today; and assesses the tradeoffs associated with alternative scenarios or policy options for the future. NatCap is developing tools to accompany InVEST that help decision makers create scenarios and design policies.

(2) Moving from knowledge to action: demonstration projects. Through a suite of demonstration projects, we are developing cases that integrate natural capital into major

resource policies and decisions. These projects are designed to be sustained, replicated, and scaled, and thus to help embed natural capital approaches into formal business and government planning widely. InVEST tools are being used in resource decisions in China, Colombia, Ecuador, Indonesia, and the United States (California, Hawai'i). Early analyses are also being done to engage policy makers in Bolivia, Brazil, Canada, Mexico, Peru, Tanzania and other regions of the US (Oregon, Washington). The tools have proven useful with national governments, private landowners and corporations, and increasing demand for the tool indicates that the time is ripe for ecosystem service thinking to change the face of management across sectors and around the globe.

(3) Magnifying our impact: engaging leaders. This third area is new, and we will design a plan for achieving broader impact now that we have something new to offer in the tools realm. In the research arena, we are focused on building international, interdisciplinary science and outreach. We aim eventually to engage with global leaders in different arenas of society. The overall aim is to achieve a deep, lasting, and global transformation in how people think about and interact with nature.

InVEST: A Set of Tools

NatCap is developing the InVEST software system for quantifying ecosystem service values across land- and seascapes. This tool informs managers and policy makers about the impacts of alternative resource management choices on the economy, human well-being and the environment. InVEST can help answer tricky questions such as 'How would a new forestry plantation affect timber yields, biodiversity, water quality and recreation?', or 'How would expanding biofuels change a downstream city's drinking water supply?'. In the coming year, InVEST will also answer questions about the marine environment like 'Where should we put fishing zones, alternative (wave) energy farms, and aquaculture to reduce conflicts and provide the greatest benefits for biodiversity and coastal communities?' Climate change and population growth effects can be added to these questions as well.

InVEST is designed for use as part of an active decision-making process. The first phase involves working with decision makers and other stakeholders to identify critical management decisions and to develop scenarios of how an area might look under future management options, climate change or population growth. Based on these scenarios, a modular set of models quantifies and maps ecosystem services in a flexible way. The outputs of these models provide decision makers with maps and other information about costs, benefits, tradeoffs, and synergies of alternative investments in land- (e.g., Nelson et al. 2009) and seascapes.

Demonstration Projects

We have several projects underway around the globe where we are learning how useful these tools can be in the real world. In China, the government has recognized how valuable the natural environment is in providing public benefits, and is investing in natural capital through the design, and eventual implementation of a national system of 'Ecological Function Conservation Areas' (EFCAs). Our focus is on supporting the design of this system of priority areas that will inform conservation and development planning (Fig. 1, 2). At one of our key pilot sites, our local team is working with county-level government on master planning to improve zoning for development -- a major issue in China right now -- by integrating EFCAs into the zoning plan. We are also conducting socio-economic studies to understand the economic and social impacts of ecosystem service payments at the household level, especially for poverty alleviation (e.g., Li et al., in review; Liang et al., in review; Tai et al., in review). The results of these projects will be used by the government at several levels to refine policy and finance mechanisms, with the goals of achieving greater social benefit and avoiding unintended negative consequences.

In Colombia, planners are embracing ecosystem services from the local to the national level as well. We are working with the agriculture industry and local government to manage new water funds that direct payments from downstream water consumers to inhabitants of upstream watersheds, in exchange for changes in land management that are expected to improve water quality. This program is one of the first to consider the impacts climate change will likely have on water supply in the region. They are designing investments to target areas where water supply will likely be robust to climate change, setting the water fund up to act as a climate adaptation strategy. At the national level, the government is remaking their resource licensing and mitigation policy for all major infrastructure development in the country, including agriculture, energy, mining, and transportation. With help from our local partners, we are developing the framework they will use and applying InVEST to assess ecosystem service impacts and find places to target mitigation in a demonstration case for the mining sector.

Ecosystem Services and the Ecosystem Approach

Success

There are many global efforts underway now to achieve the vision of the MA: DIVERSITAS, IPBES, PECS, and TEEB, to name a few. Though they make up an alphabet soup of inter-governmental, multi-lateral efforts, they hold real promise for changing the way people and institutions take resource decisions. We are working to tie NatCap efforts to these global initiatives to help drive changes in the way everyday projects are designed and policies are made at all levels of government and in the private sector. The main goal is to get people thinking regularly about ecosystem services as part of the direct cost or benefit of every decision. It is our hope that this will be as routine and easy to understand as our daily weather forecasts. Nations will be building infrastructure, catching fish, developing energy, growing food, and harvesting timber in ways that minimally impact biodiversity and ecosystem services. When there are impacts, people will provide offset payments for conservation of natural capital elsewhere. In response to feedback from policy leaders, new basic research will be launched to address some of their critical concerns, such as in the soil fertility, water quality, health and poverty arenas. Mistakes will still be made, but in general the connections between nature and human well-being will be explicitly represented in a wide variety of decision support tools, web-based tradeoff calculators, and government and business practices. In the world we are working towards, decisions will likely still be all about the bottom line, but pursuing the bottom line will no longer be a race to the bottom.

REFERENCES

Daily GC and Ellison K. 2002. ***The New Economy of Nature: The Quest to Make Conservation Profitable.*** **Washington, D.C.: Island Press.**

Goldman RL, Tallis H, Kareiva P, and Daily GC. 2008. **Field evidence that ecosystem service projects support biodiversity and diversify options.** ***Proceedings of the National Academy of Sciences USA*** **105: 9445-9448.**

Kareiva P and Marvier M. 2007. **Conservation for the people.** ***Scientific American*** **297: 50-57.**

Kleiner, A. 2009. **Thought Leader Interveiw: Gretchen Daily.** ***Strategy + Business*** **57: 1-9.**

Li, C, S Li, M Feldman, GC Daily, J Li. *In review.* **Labor out-migration and rural household's livelihood capital in western rural China: An empirical analysis in the Qinling Mountain Area.**

Liang, Y, MW Feldman, S Li, GC Daily, J Li. *In review.* **Asset endowments, non-farm participation, and local separability in rural China.**

Liu J, Li S, Ouyang Z, *et al.* 2008. **Ecological and socioeconomic effects of China's policies for ecosystem services.** ***Proceedings of the National Academy of Sciences USA*** **105: 9489-9494.**

MA (Millennium Ecosystem Assessment). 2003. ***Ecosystems and Human Well-being: A Framework for Assessment.*** **Washington, D.C.: Island Press.**

Nelson, E, G Mendoza, J Regetz, S Polasky, H Tallis, DR Cameron, KMA Chan, GC Daily, J Goldstein, PM Kareiva, E Lonsdorf, R Naidoo, TH Ricketts, and MR Shaw. 2009. **Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales.** ***Frontiers in Ecology and the Environment*** **7: 4-11.**

Ostrom E, Janssen MA, and Anderies JM. 2007. **Going Beyond Panaceas: Special Feature.** ***Proceedings of the National Academy of Sciences USA*** **104: 15176-15223.**

Tai, X, S Li, M Feldman, GC Daily, J Li. *In review.* **Rural households' risk management strategies and vulnerability to poverty in western rural China.**

Heather Tallis is at The Natural Capital Project, Woods Institute for the Environment, Stanford University, Stanford, CA 94305-5020 USA

Wang Yukuan, Fu Bin, Zhu Bo and Zhu Wanze work at the Key Lab of Mountain Hazards and Earth Surface Process, Institute of Mountain Hazards and Environment, Chinese Academy of Science, No.9 fourth section of South Renming Road,Chengdu, China 610041

Chen Min is at The Natural Capital Project China Demonstration Site, B4-2 Qijiayuan Diplomatic Compound, 9# of Jianwai Dajie, Beijing, China 100600

Christine Tam WWF- DRC Programme Office, 14 Avenue Sergent Moke,Commune de Ngaliema, Kinshasa, Democratic Republic of Congo (DRC)

Gretchen Daily is at the Center for Conservation Biology, Dept. of Biology, and Woods Institute for the Environment, 371 Serra Mall, Stanford University, Stanford, CA 94305-5020 USA

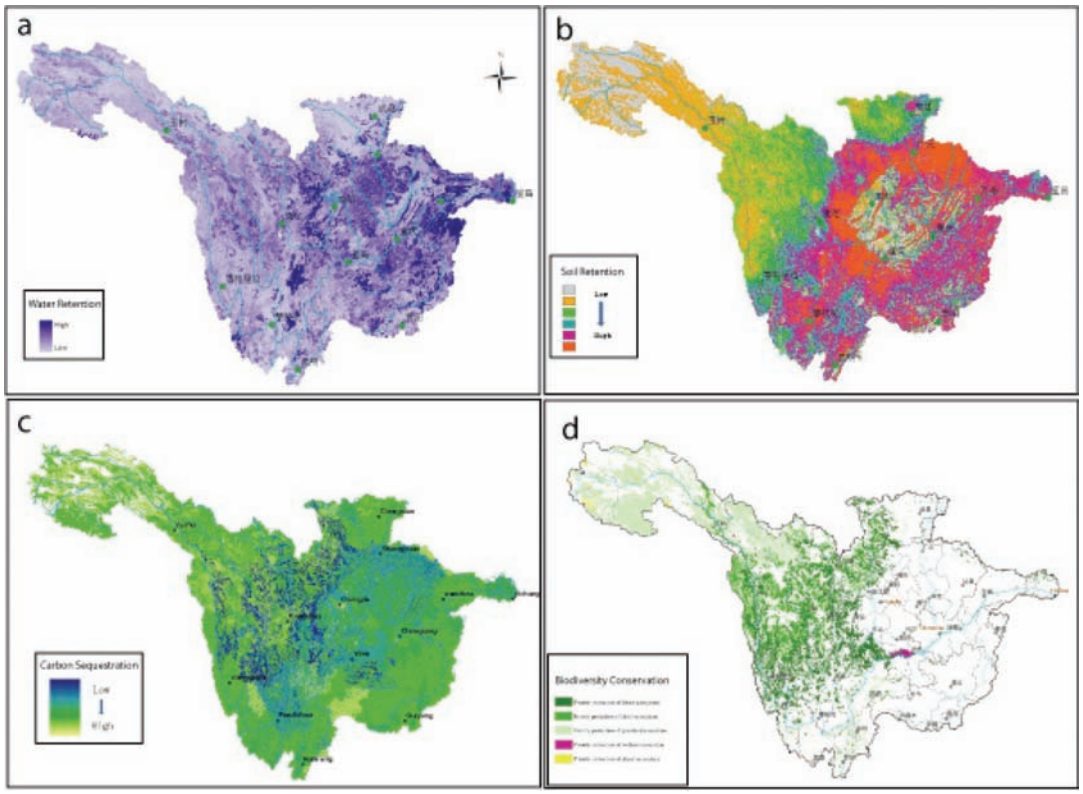

Figure 1 (Tallis et al). *Application of InVEST to the Upper Yangtze River Basin (UYRB) in China. The upper basin of about 1 million km² feeds water into one of China's major agricultural regions that produces 35% of the nation's grain. This upper region is undergoing rapid change as a result of the rapidly growing Chinese economy (10% per year for the last 20 yrs), affecting the 400 million people in the Yangtze River Basin as a whole. We are using InVEST to map critical ecosystem services, including (a) water retention and (b) soil stabilization to overlay with (c) carbon sequestration and (d) biodiversity priorities developed with other tools for the region.*

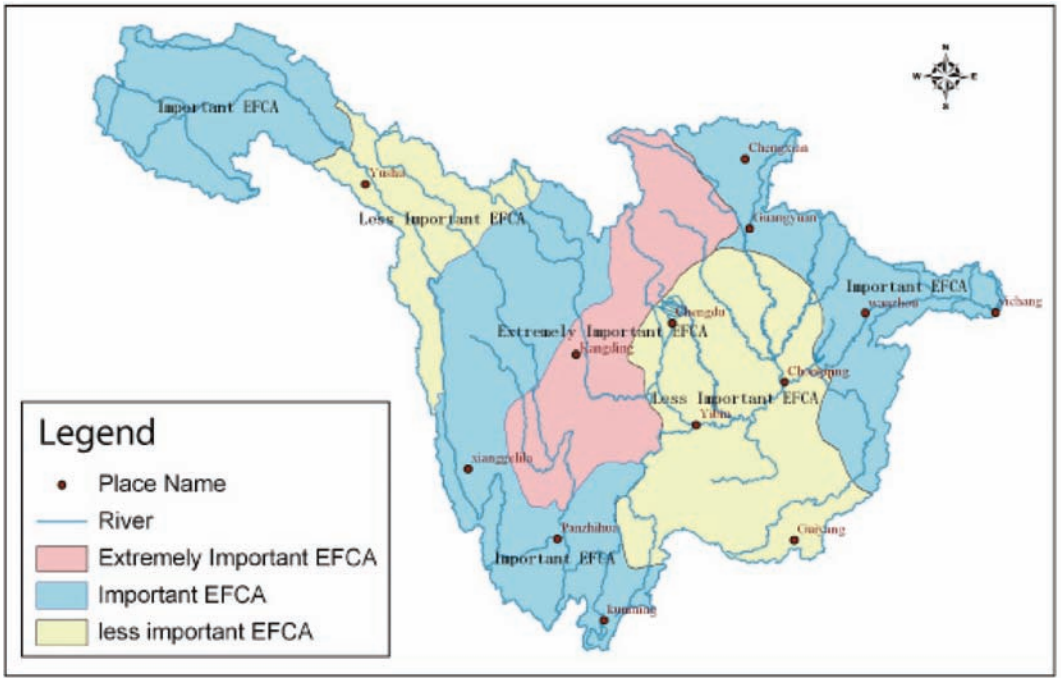

Figure 2 (Tallis et al). *Map of the priority Ecosystem Function Conservation Areas for the Upper Yangtze River Basin, China, based on an integrated assessment of ecosystem service provision and value.*