Recognising the Complexities of Ecosystem Management and the Ecosystem Service Concept

According to the paradigm of ecosystem management, ecosystems provide essential services and goods for human well-being. Preserving those services – e. g., crop pollination – seems to justify nature conservation. Yet, are the assumptions underlying the ecosystem service concept well-founded?

Jaboury Ghazoul

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Abstract
Ecosystem management emphasises ecosystem service concepts in order to improve land management and to justify nature conservation. This approach rests on the assumption that conserving ecosystem services can deliver net benefits for human welfare in terms of economic development. To retain credibility, the advocates of ecosystem service concepts must acknowledge the constraints that may limit the reliability of this assumption, including trade-offs with other land-use benefits. The fact that ecosystem service concepts have not been well integrated into management implies that such initiatives have not been persuasive among land managers and agriculturalists. I argue that this is due to the combination of a failure by scientists, conservationists, and other advocates of the ecosystem management approach to account for the trade-offs and opportunity costs inherent in land management, and a lack of willingness to accept that managing for ecosystem services may place constraints on future management options. However, the ecosystem service concept has the opportunity to make substantial contributions toward more effective management by influencing thinking among policy makers, land managers, and the wider public.

Keywords
almonds, conservation, crop production, decision making, ecosystem services, ethics, integrated conservation and development projects, opportunity costs, pollination, trade-offs

Contact: *Prof. Dr. Jaboury Ghazoul* | Institute of Terrestrial Ecosystems | ETH Zurich | CHN G 74.1 | Universitätstr. 16 | 8092 Zurich | Switzerland | Tel.: +41 44 6328627 | Fax: +41 44 6321386 | E-Mail: jaboury.ghazoul@env.ethz.ch

The Fundamentals of Ecosystem Management

The Failing of "Integrated Conservation and Development Projects" (ICDPs)

Environmental degradation and land clearance continue unabated in many regions of the world. This is happening despite over two decades of efforts to reconcile nature conservation and economic objectives in the form of "integrated conservation and development projects" (ICDPs). Such projects have received the backing of international donors, national governments, the scientific community, and a variety of large and small non-governmental organisations (NGOs) engaged in nature conservancy, with perhaps billions spent on their promotion. These efforts implicitly recognise that, under most circumstances, conservation can be best achieved by taking account of the social and economic well-being of local actors, and by working with them to develop appropriate solutions.

Given the widespread support for ICDPs, it is surprising that the results have been mostly disappointing (Wells and McShane 2004), and that efforts to reverse environmental decline have made little progress. To a great extent, this has been due to the mismatch of conservation and development objectives and the failure of ICDPs to truly integrate these objectives in a coherent and equitable manner. I attribute the lack of success of ICDPs to unjustified assumptions: For instance, the economic benefits that protected areas can deliver to local communities have often been overestimated (Wells and McShane 2004).

Through nature conservation, the ICDP approach originally aimed at securing benefits to people living in and around officially protected areas. It now includes management of semi-natural systems in largely human-dominated landscapes. This follows recognition that many such landscapes retain a considerable amount of biodiversity worth conserving.

The Ecosystem Service Concept

The concept underlying the ICDP approach has recently been strengthened by the "ecosystem service" perspective of landscape >

management, which emphasises the environmental processes and functions that underlie human well-being. This is a central theme of the Millennium Ecosystem Assessment (MEA). New approaches to the management of complex environmental problems have been born out of the lessons of failed ICDPs, and these have been conceptualised within the MEA (MEA 2005). At the heart of this global initiative is the concept of ecosystem services: Ecosystems are seen as providers of essential goods and services for human well-being; linking ecosystem functions with human livelihood quality is therefore thought to justify nature conservation and environmentally sensitive management.

The Ecosystem Management Approach: Challenges

The concept of ecosystem services also underlies the ecosystem management approach to land use and planning that has become increasingly popular in recent years. Applying the ecosystem service concept to landscape management, however, risks repeating some of the errors of ICDPs. Specifically, it is not yet clear how the scientifically driven and informed ecosystem service concept should be presented to, or interpreted and used by, local actors and decision makers. Consequently, there has to date been very limited uptake of the ecosystem service concept by decision makers within policy and land management (Balvanera et al. 2001).

Even if stakeholders accept and understand the ecosystem service concept as it has been couched within the language of the MEA, they must still, in their local contexts, weigh the benefits of nature conservation (e. g., ecosystem services provided by maintaining natural elements on their land) against the opportunity costs, i. e., the potential benefits that could be received from other land use options that are forgone (Heal 2000). Local stakeholders at the farm or household scale usually do not refer to the same set of values as do conservationists or managers who seek to influence decision making at landscape or regional scales. In other words, it is by no means clear that win-win outcomes are realistic, and the sooner the trade-offs inherent in the ecosystem service concept are recognised, the easier it will be to engage all participants in an informed dialogue (IUCN 2006).

Additionally, management decisions are not based on the consideration of only one ecosystem service, even if most academic researchers restrict themselves in this way. Local decision makers have to weigh up a variety of cultural, regulating, and provisioning services. Undoubtedly, some of these services will feature more strongly than others in decision-making processes, either through perceived or actual relevance, personal outlooks, cultural biases, political and institutional influence, or lack of information. Thus a major challenge for the promotion of the ecosystem service concept to decision making at local and landscape scales is to capture its multiple dimensionality in an accessible format. Furthermore, a system is needed to conceptually explore the implications of decisions: By visualising trade-offs among ecosystem services and economic profits, it can serve as a basis of negotiation and discussion among stakeholders. One approach for mapping trade-offs among several ecosystem services has recently been presented for regional levels (Chan et al. 2006). This, however, fails to capture decision-making perspectives of individual actors to whom sub-landscape scales are more appropriate, and also fails to consider the opportunity costs of management for service provision.

Given the history of failed ICDPs, it is reasonable to question the likelihood of success of the ecosystem service concept in the context of ecosystem management. In other words: Can conservation and development objectives be mutually beneficial, or are trade-offs always inevitable? In this paper I seek to explore some of the conflicts in the current ecosystem management paradigm. By identifying these conflicts, inconsistencies, or paradoxes, we may begin to better understand, and therefore overcome, the barriers for uptake of effective management actions and interventions. We should seek to learn from the failures of ICDPs to ensure effective implementation of the ecosystem service concept to development and conservation. I focus on pollination services as these have received particular attention and media coverage in the past decade, and pollination is frequently cited as a service of crucial importance to human well-being, popularly associated with a third of the food we eat (Buchman and Nabhan 1997, McGregor 1976; see also Klein et al. 2007). However, the comments made in the following also apply to other ecosystem services.

Inconsistencies of the Ecosystem Management Approach

The MEA argues for the preservation of natural habitats and species based on their provision of ecosystem services that underlie human well-being, the assumption being that ecosystem service degradation will undermine economic stability and growth. Nevertheless, we cannot ignore the fact that great advancements in human welfare have been made at the cost of considerable environmental degradation, suggesting that the assumption of our dependency on ecosystem services may not be justified. If this is indeed the case, then this would undermine what has been described as a new environmental paradigm: the marriage of nature conservation and economic development through the ecosystem service concept. Thus some authors argue that human ingenuity and technological enterprise will always overcome environmental constraints as appears to be the case in the past (McCauley 2006), and that our capacity to adapt systems to our own purposes has been largely ignored by environmentalists who emphasise our environmental dependency. Consequently, I hypothesise that arguments for environmentally sensitive management based on ecosystem services may not, so far, have had much impact because they failed to consider the wider economic and social environments within which decision makers work, although more recently this is beginning to be addressed (Naidoo and Ricketts 2006, Chan et al. 2007).

Pollination Service: The Example of California Almonds

Pollination service for crop production provides an example where an apparently essential ecosystem service has been, and contin-

ues to be, degraded by intensive agriculture, but with little apparent impact on crop yields (productivity per unit area). Farmers therefore continue to discount the economic value of this service despite widespread publicity about its value in the scientific literature. The basic scientific argument is that pollinator variety and abundance is a function of the amount of natural habitat in a landscape, and that because the productivity of agricultural crops is dependent on pollinators, loss of natural habitat will lead to decline of agricultural productivity and economic well-being. For some crops, such as coffee, yields have been shown to be higher among plants growing close to natural habitats (Ricketts et al. 2004). Other studies link reduced crop pollination to loss of natural land cover, but fail to say whether yield is related to pollination (Greenleaf and Kremen 2006, Klein et al. 2003, Kremen et al. 2004). Despite this evidence, the adoption of improved farming practices to enhance pollination services has been remarkably slow and limited.

Wild pollinator services are only valuable if they are relevant to crop production. Most crops, however, do not require pollination services (Ghazoul 2005, Klein et al. 2007), including the most important staple crops wheat, maize, and rice, where pollination is effected by wind. In addition, a range of other important yield-limiting factors such as nutrient and water availability, pests, pathogens, and climatic disturbances moderate the relevance of pollination. In most agricultural systems, water and nutrient limitation are alleviated by irrigation and fertiliser application, while pests and pathogens are controlled by pesticides. This suggests that yield may become limited by pollination as all other constraints have been artificially alleviated. Yet even some of the most intensively managed and pollinator-demanding crops do not appear to be limited by pollination. Extensive monoculture coffee plantations in Brazil, for example, remain far more productive than less intensively managed coffee plantations (Campanha et al. 2005), implying that if pollination does limit productivity, it only does so at a level that far exceeds the productivity of comparatively environmentally benign crop systems.

The pollination inconsistency, or pollination paradox, is that plants require pollinators but pollination rarely limits production (Burd 1998, Burd and Callahan 2000, Sutherland 1986). Only in the most intensively managed cropping systems is it likely that pollinator-conserving measures benefit crop yields. But since productivity of intensive cropping systems is usually greater than that of less intensively managed systems, there is little economic incentive for environmentally friendly agricultural management.

The recent rapid decline of honeybees in California has given rise to considerable concern over the viability of almond production. Almonds are California's principal agricultural product, worth over one billion US dollars per year and expected to expand in order to meet growing demand. Yet almond farming has been cited as being very sensitive to pollinator decline owing to a necessary and immense demand for pollinators, almost exclusively honeybees (Traynor 1993). Honeybee colonies are rented from beekeepers during the short almond flowering period (mid-February to mid-March) to provide the necessary pollinating service. As early as 1996 concern has been raised about the decline of pollinating honeybees, largely due to the spread of new pests and diseases that weaken and destroy the colonies. Even so, while honeybee colonies have declined from around 3.4 million colonies in 1989 to about 2.5 million colonies in 2004 (USDA 2006), almond yields over this period have risen from around 1120 kilogrammes per hectare in 1996 to 1905 kilogrammes per hectare in 2006, an increase of 70 per cent (figures derived from data given in USDA 2006).

During this period the decline in honeybee colonies has raised colony rental fees such that these now account for 15 per cent of operating costs compared to only five per cent in 1996. Yet this is more than offset by increased almond productivity and high almond prices. This shows a sustainability conflict, with the decline in ecological sustainability of the pollination service seemingly at odds with the economic productivity of almonds. Although we should be careful not to overemphasise a single case, as Californian almonds certainly are, this example is nevertheless illustrative of the wider inconsistencies within the ecosystem service concept and the ecosystem management approach.

FIGURE 1: When using ecosystem services such as pollination to justify conservation of native vegetation, the economic realities of agroforestry systems should be recognised. This figure shows pepper plants growing up the stems of *Grevillea robusta* in a Southern Indian coffee plantation. *Grevillea* is a fast-growing exotic tree used for wood production, but has a low biodiversity value. Ecologically friendly management, i.e., promoting natural pollination services by retaining native trees, would preclude the substantial additional income from *Grevillea* and pepper, which is rain-pollinated.

Constrained Opportunities Constrain Management

Environmentally benign management of landscapes imposes constraints on future land use options. The opportunity costs of converting a small part of the crop land to semi-natural habitat may be marginal, yet other constraints may be more substantial. To ensure viable pollinator populations or other biodiversity values, farmers may have to constrain the use of pesticides and other agrichemicals that might impact wild populations directly or indirectly (e. g., by affecting their food resources). Effective environmental management – be it to secure natural services such as pollination, water flow and quality, or effective nutrient conservation – requires a range of integrated management interventions that may considerably limit future management options, as well as incur short-term costs. In view of these constraints and costs, promoting the benefits of natural services within an ecosystem approach to management is unlikely to be favoured by land managers unless all short-term and long-term costs are recognised, understood, and compensated (figure 1, p. 217).

The spread of environmentally benign farming practices in Europe is motivated primarily by the increasingly lucrative and growing market for organic products (and government subsidies), rather than by on-farm ecological considerations. European farmers are currently "compensated" for their opportunity costs by subsidies, new market opportunities, and higher prices for their products. This contrasts with the situation in the tropics, where lack of land tenure security, fluctuating market prices, high discount rates, and the already limited options for many poor farmers make ecosystem service approaches unattractive since they constrain future land use options.

A further difficulty is that pollinators and other ecosystem services are a common resource that cannot be easily defined in terms of private ownership. Hence the costs of conservation interventions must be borne by individuals, while the benefits go to all farmers in the region. This makes such systems highly vulnerable to cheating, which may undermine both individual and collaborative action. A challenge for ecosystem management is

FIGURE 2: The Asian giant honeybee *(Apis dorsata)* is one of a number of pollinators of coffee in Southern India. This bee may provide an important ecosystem service. However, this may not suffice to justify the conservation of native tree cover, as these bees, as well as other pollinators, also persist in anthropogenically highly altered landscapes.

therefore to promote institutions and social structures that support collaborative management and minimise opportunities or incentives for cheating by non-participation. Furthermore, land managers have to take action in anticipation of a problem that may never materialise. In other words: Ecosystem service decline has to be defined and recognised before recovery becomes too costly, although before this critical point there is often little indication that the service is under threat. Persuading farmers on a course of action that incurs short-term costs is therefore difficult in the absence of a clear statement of the problem.

Ecosystem Services versus Biodiversity Conservation

As mentioned above, the ecosystem service approach to land management risks repeating some of the errors associated with the failure of ICDPs. Principal among these is that what may be adequate in terms of land management for sustaining ecosystem services may not match expectations in terms of conservation (Chan et al. 2006): If only small patches of semi-natural habitat suffice to provide adequate ecosystem services, then how should we argue for additional land required for biodiversity conservation if our justification for conservation is entirely based on ecosystem service provision? Ecosystem services are an interesting and powerful argument for improved landscape management, but taken alone they are unlikely to be sufficient as an argument for conservation as long as there is a mismatch between area and management requirements for delivery of environmental functions as compared to biodiversity conservation (figure 2).

Discussion and Conclusions

Dealing with Complexity

In this paper, I use pollination service to illustrate some challenges for the ecosystem service concept, and Californian almonds as a specific example. This is, of course, but one example and one service, and it would be churlish to dismiss current market-based approaches to conservation and land management based on this single case. Indeed, it is not my intention to do so, nor do I pretend that the Californian example is representative of the wider situation. It is precisely because it is *not* representative that, in this case, it has value: Californian farmers are unusually well informed and wealthy, and have the knowledge and ability to change production systems to favour wild pollinators should they so choose. The fact that they have chosen instead to "buy" themselves out of the problem – by paying increasingly more for rented honeybees – suggests that this is more cost-effective than adopting practices that support wild pollinators.

Understanding decision-making processes requires that we recognise the complexity of such processes. The ICDP literature has taught us that land-use practices are influenced by markets, policies, incentives, social interactions, and personal outlooks. We should therefore not be surprised if decision makers resist or ignore ecosystem service concepts in management. Among the reasons for the failure of ICDPs were simplistic assumptions to reduce the inherent uncertainty of society-environment interactions (Sayer and Campbell 2003, Wells and McShane 2004). Similarly, extrapolating from pollination service studies to whole farm systems is fraught with complexities that may render evaluations meaningless and recommendations inappropriate. By evaluating bundles of services at several scales, scientists working with managers are beginning to overcome these problems. Nevertheless, we should be asking why farmers do not more readily change their agricultural practices to promote ecosystem services, particularly those with local and immediate benefits such as pollination. We also should aim to learn what motivates those farmers who do adopt environmentally benign strategies. Finally, we should consider that ecosystem service arguments may not appeal to many poor landowners who seek to maximise only short-term gains in the hope of securing alternative, non-agricultural livelihood options (Dorward et al. 2006, Ghazoul 2007).

Should Ecosystem Services Be Advocated?

Studies demonstrating the benefits of pollination services to crop productivity represent the objective reporting of empirical research conclusions. Nevertheless, such studies are also used to advocate biodiversity conservation using economic and ecosystem service arguments, and are widely reported as such in the news media. It is my view that as scientists we should be cautious with an association with advocacy, particularly when we are unable to appreciate the full suite of factors shaping the decisions of land managers. We should also be honest to ourselves in recognising that our motivation is often different from that of land managers.

Ecosystem service arguments are often motivated by scientists' desire to protect and conserve wild species and semi-natural habitats (evidenced by many such papers being published in scientific journals with a conservation focus), and we justify this by promoting arguments that make the link to economic well-being. While this is reasonable, it is also susceptible to the criticism that the well-being of farmers is not foremost in our priorities, a criticism which may erode trust in our outputs and recommendations. This is likely to be particularly so in developing countries where the history of failed ICDPs has already undermined the confidence in scientists' perspectives (a common criticism of ICDPs is that they were rarely truly integrated, but instead prioritised either conservation or development (Sayer and Campbell 2003, Wells and McShane 2004). This trust may be eroded further if economic returns from agriculture are not seen to be closely associated with ecosystem services. Therefore, while in favour of arguments and practices that seek to promote both conservation of wild species and economic well-being, I express concern that promoting such approaches without due regard to the full complexities of decision making may undermine trust in scientists, and risks repeating some of the fundamental errors of ICDP approaches.

Ecosystem service arguments suggesting that trade-offs between productivity and environmental values do not necessarily exist may be valid at the regional scale, but are difficult to comprehend and implement at the farm scale. The true test of win-win scenarios, which ecosystem service approaches effectively are, is >

whether farmers adopt such strategies. Perhaps it is too soon to tell, and perhaps what limits adoption is insufficient transfer of scientific information and concepts to farmers in appropriate forms. This again would reflect some of the errors of the ICDP approach, which was often undermined by a communication failure between scientists and land managers (Sayer and Campbell 2003, Wells and McShane 2004). As decisions are made at the farm scale this is an important issue that needs to be recognised and addressed by both scientists and policy makers. Overemphasising the economic benefits of ecosystem services without due recognition of trade-offs and opportunity costs or of other forms of valuation may risk undermining conservation efforts, as well as the credibility of conservationists, if economic outcomes turn out to be less than favourable (Chan et al. 2007, Ghazoul 2005).

Further Research Needs

A difficulty for the ecosystem service approach to environmentally benign landscape management is that the marginal benefits of increased landscape heterogeneity are comparatively low. Many ecosystem services, including pollination, are insensitive to large changes in landscape conditions, though thresholds may exist beyond which services begin to degrade rapidly. Thus gradual landscape degradation may not be reflected in a decline in service quality until the threshold is exceeded, and the reverse also applies, i. e., investment in land preservation or environmentally sound management is not likely to show major gains in service quality. This is less problematic if the investment in sound land management could be reflected in terms of distance from critical thresholds, as the marginal benefits could then be represented in terms of risk reduction. An important area of future research is to identify the patterns of responses of ecosystem services to environmental stress allowing the prediction of thresholds to be avoided. Overcoming this challenge requires considerable knowledge of system processes in order to identify, among other things, the location and severity of thresholds in service responses. Such knowledge is largely lacking, and where it exists it is highly context-specific.

Another necessary area of research is to integrate ecosystem services, economic aspects, and ethical values within a single decision framework that is readily applicable to complex environmental scenarios. Such a framework should merge current knowledge and perceptions with empirical information to provide a basis for negotiation and planning despite uncertainty. It needs to consider that each landscape is unique, by virtue of its anthropogenic and biogeographic history, as well as its contemporary ecological, economic, political, and social make-up. Any framework should be able to accommodate discussion and negotiation and allow visualisation of the trade-offs of ecosystem services and economic values in a sufficiently flexible manner to be applied to different contexts.

Research has traditionally offered two opportunities to farmers and land managers, one of technological innovation to achieve specific outcomes, and the second of improved understanding of the functioning of agro-ecosystems, by which such systems may be more effectively managed. The former option presupposes the capacity for uptake and a facilitating policy and social structure that allow the innovations to be readily adopted and incorporated into current management systems, with the debate over genetically modified crops being one highly publicised example of the difficulties that this can present. The latter option has mostly failed to substantially improve rural livelihoods in developing countries as it has not been effectively communicated to local decision makers, and has generally failed to take account of local social and economic realities. It has become paradigmatic to em-

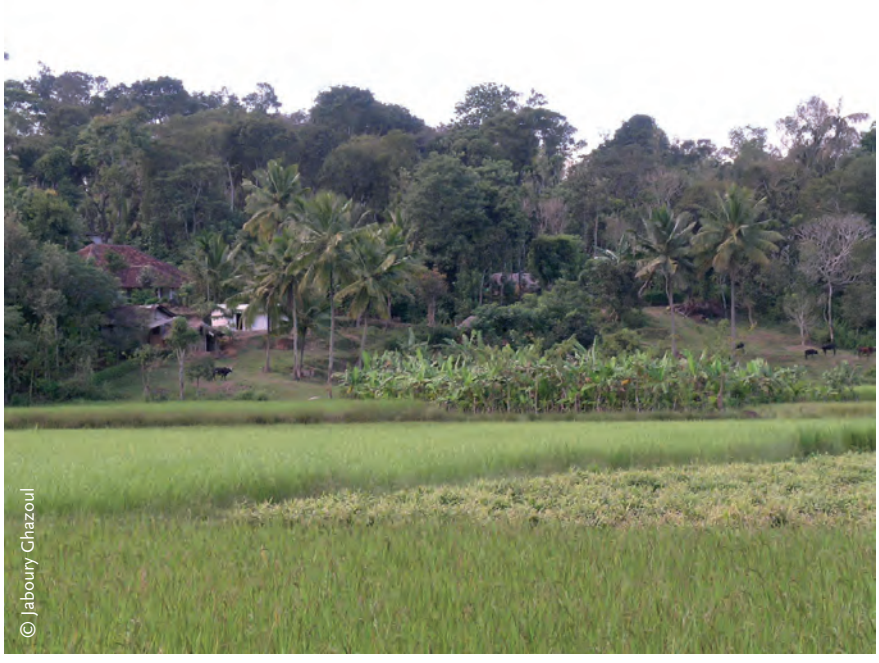

FIGURE 3: Paradigms such as the ecosystem service concept must be locally appropriate or adaptable to local conditions. This is exemplified by complex agroforestry systems in Southern India: Rice is grown for subsistence use (in the foreground), with bananas, palms, and livestock around the houses, while income-generating coffee is cultivated under native and mostly fruit-producing trees (in the background).

phasise the need for research that integrates ecological, social, economic, and political disciplines, and yet the history of ICDPs has proven how difficult such integration is.

Research should therefore develop analytical methods by which interdisciplinary knowledge can be effectively integrated to provide information that is adaptable to, and adoptable within, local land management systems (figure 3). Research programmes of this nature must work closely with local stakeholders, e. g., by making use of simple simulation models developed collaboratively by local actors and researchers to more effectively evaluate how ecosystem services can deliver benefits within locally relevant scenarios. Scientists should thereby seek to deliver better – not more – information to land and resource managers, information that can be readily incorporated within current management systems. Thus I do not propose that we necessarily need new research, but rather a new way of doing research, by which innovative technological development and ecosystem knowledge can be "married" into a single land-manager-controlled knowledge system.

Life's reality is that the opportunity costs of conserving nature are well recognised, but the economic benefits nature provides are not. Thus improving awareness of ecosystem services and their value among all stakeholders allows for a more balanced consideration of environmental impacts. An improvement in ecosystem-related knowledge empowers people to make decisions based on a more intimate understanding of the trade-offs with environmental benefits. These decisions may not always be favourable to nature conservation, but they are at least more likely to be so. Human ingenuity may, eventually, develop cheaper technological alternatives to natural services, but this misses the point: Ecosystem service concepts raise awareness of new visions for management that are more likely to favour environmental conservation. But in seeking to influence management decisions by raising awareness of ecosystem services, we should also promote full recognition of the societal and economic costs and benefits of doing so. Only in this way can we achieve a meaningful dialogue with agents of change, and secure our own credibility as scientists, conservationists, and advisors.

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Jaboury Ghazoul

Born 1967 in Baghdad, Iraq. In 1989 he graduated in marine and environmental science and in 1993 completed his PhD in evolutionary ecology, both at the University of St Andrews, Scotland. After spending a year surveying the biodiversity of newly designated forest reserves in Vietnam, he worked at the Natural History Museum in London on impacts of logging on dipterocarp tree reproduction in Thailand. From 1998 to 2005 he was a lecturer, then senior lecturer, in ecology at Imperial College London. Since 2005 professor of ecosystem management at ETH Zurich. Main research interests: pollination biology and plant reproduction.