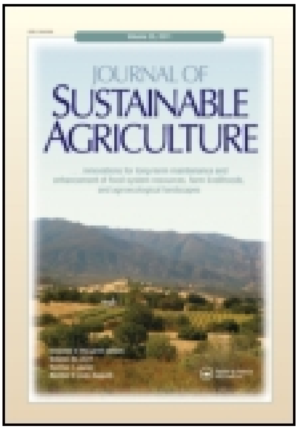

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Ecosystem-Based Agriculture Combining Production and Conservation—A Viable Way to Feed the World in the Long Term?

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Ecosystem-Based Agriculture Combining Production and Conservation—A Viable Way to Feed the World in the Long Term?

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This study analyzed examples of sustainable ecosystem-based agriculture where management methods supported livelihoods of smallholders while at the same time local ecosystem services were enhanced in Ethiopia, Brazil, and the Philippines. Participation by farmers and collective actions were found to be a crucial driving force, as local specific knowledge and "learning by doing" were main components of the development. Social cohesion, particularly through associations and cooperatives, and improved marketing opportunities were also important drivers. Furthermore, recognition by authorities at all levels was perceived as crucial. Effects of climate change, insecure property rights, and political instability were potential threats. The possibilities of such systems to be scaled up beyond self-sufficiency raised further questions.

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KEYWORDS agroecology, ecosystem services, livelihoods, mulit-functionality, participation, sustainable food production

INTRODUCTION

While global food demand is projected to increase, areas known as the world's granaries are being compromised by the global environmental crisis. Escalating global warming is predicted to lead to major changes in the Earth's climate and conditions for life, for example, melting ice, depleted fresh water, rising sea level, extinction of species, and increasing strength and frequency of natural disasters, such as droughts and floods (Intergovernmental Panel on Climate Change 2007). Global ecosystems and their functions are threatened. The UN-initiated Millennium Ecosystem Assessment (MA) found that about 60% of the ecosystem services assessed were being used faster than their rate of regeneration (Millennium Ecosystem Assessment 2005). Ecosystems services are commonly defined as ". . . conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" and the term was developed to make visible for humankind our intimate dependence on nature (Daily 1997, 3). Services that are fundamental for human wellbeing, not the least for food production, are now being compromised. Industrialized agriculture, which on the one hand has been highly successful in raising yields per unit area through the Green Revolution, is recognized as one of the main drivers in this serious alteration of natural ecosystems and reduced generation and maintenance of ecosystem services (Millennium Ecosystem Assessment 2005; Rockström et al. 2009). Human driven environmental failures include dropping water tables, loss of soil fertility, soil erosion, and massive extinction of crop varieties and wild species all over the world. These are obvious shortcomings in the current dominant food production system based on the provision of external inputs, principally seeds and agrochemicals (IAASTD 2009, Millennium Ecosystem Assessment 2005, Tilman et al. 2002).

Another aspect of the "Green revolution" has been a radical change in the distribution of land and resources, with large farms and plantations expanding at the expense of smallholder farmers and small family farms (International Assessment of Agricultural Knowledge, Science and Technology for Development [IAASTD] 2009; von Braun 2005). Socioeconomic conditions in developing countries tend to force poor smallholder farmers to deforest and exploit new land that is often unsuitable for agriculture just to survive (Clunies-Ross and Hildyard 1992; Buresh 1997). However, smallholders still dominate production in many developing countries (Food and Agriculture Organization of the United Nations [FAO] 2007, 2009).

As a response to these major problems the potential for agriculture to combine stable and high production with nature conservation and improvement of livelihoods for rural poor, is a growing issue in research today. The rapidly emerging field of agroecology is especially concerned with this (Altieri 2002; Gliessman 2007; Vandermeer 2009; Altieri et al. 2011). As a scientific discipline agroecology could be defined as transdisciplinary and integrative, including elements from agronomy, ecology, sociology, and economics (Dalgaard et al. 2003). The focus could be either on farming systems or on whole food systems (Francis et al. 2003; Mendéz 2010). Furthermore, work in agroecology has provided support for the potential for using participatory research approaches when working with complex questions with the aim of improving real situations (Altieri 2004; Scherr and McNeely 2008; Altieri et al. 2011).

The term "agroecology" has different meanings for different actors in different parts of the world, ranging from being a scientific discipline to an agricultural practice, or a political or social movement (Wezel et al. 2009; Amekawa 2011). Accordingly, agricultural concepts using ecological principles to guide the design and management of sustainable agricultural ecosystems are growing. The common threads in these concepts are the dual focus on production and conservation. "Sustainable agriculture" is a loosely defined umbrella for initiatives to produce food that is healthy for consumers, does not harm the environment, respects animals, provides decent living conditions and a fair wage for workers and farmers and enhances rural communities (Lefroy et al. 2000; Gould 2009). "Ecoagriculture" is a concept developed in the last decade, with a focus on recognizing sustainable, diverse and locally adapted management methods that rural communities have independently practiced for thousands of years (Scherr and McNeely 2008). The focus is on development of productive agricultural systems that have conservation of biodiversity and ecosystem services as a basis for improvements of rural livelihoods (Scherr and McNeely 2008.).

In contrast to initiatives focusing on the transition of conventional production systems, "natural systems agriculture" starts in a certain ecosystem and focus on how to mimic its structure and function (Jackson 1985; Ewel 1999). The Land Institute, in Kansas (United States), has been one of the leading centers of this focus, using the American prairie as a model for development of a more sustainable system than the monocultures that dominate the area. The work includes among other things improvement of yields of virgin prairie grass as well as efforts to make cereal crops perennial (Soule and Piper 1992). Different kinds of agroforestry systems mimicking the local forests in Latin America are also illustrative examples (Altieri 1999, 2002; Pretty et al. 2006).

The term *multifunctional agriculture* first appeared on the international arena at the Rio Earth Summit 1992 (Zander and Groot 2009).

Multifunctionality calls attention to the positive "goods" that agriculture can produce beyond food and fiber (Lankoski 2000). The benefits typically include contribution to the vitality of rural communities, biological diversity, recreation and tourism, as well as soil and water health (Lovell et al. 2010; Tscharntke et al. 2011). The concept has however rendered skepticism from developing countries suspecting multifunctionality to be just a new term for Europe and others to close their markets to agricultural imports, as it first gained popularity within countries which in international trade negotiations were under pressure to reduce subsidies and trade protections (Seehofer 2006).

Similar to the agroecology approaches, sustainable livelihoods studies investigate the situations of marginalized rural poor and their ability to make a living. The concept has diverse interpretations but shares the basic unit of analysis of households, including village studies, household economics, gender analyses, farming systems research and resilience studies (Amekawa 2011). The approach appeared in a working paper of Chambers and Conway (1992), where sustainable livelihoods were defined to include the ability to cope with and recover from stress, and to maintain and enhance capabilities, assets and activities required for means of living with out eroding the natural resource base (Chambers and Conway 1992).

The potential of agroecological management methods to increase production and conserve nature has been demonstrated in a growing number of research studies (Tomich et al. 2001). Altieri et al. (2011) present data from case studies in Cuba, Brazil, Philippines, and Africa showing that yield increases in polycultures range between 20% and 200% relative to monocultures and other conventional systems in the studied areas. Pretty et al. (2006), report 79% average increase in crop yields from 286 recent projects in 52 countries using local technologies and inputs. The production also showed to be more efficient in water use, improve the generation of ecosystems services, and demanding less pesticides than before or without the projects. The authors argue that conversion to such production systems might be the only possibility to feed an increasing global population given the scenarios of global warming, peak oil and an accompanying unstable global economy. They present results showing that such systems are both energy and labor efficient. The reasons that many traditional systems perform badly today might not be due to technical but to social problems according to the authors. Unclear land tenure systems, unsecure political situations and underdeveloped markets were among the identified constraints.

International bodies are now also recognizing that small-scale farming systems have potential to be highly water, nutrient and energy efficient, conserving natural resources, and biodiversity without sacrificing yield (Onǵwen and Wright 2007; IAASTD 2009; FAO 2009). Some bodies go even further, claiming that "underlying principles, processes and knowledge [used by smallholders] may be relevant and capable of extrapolation to larger scale farming systems, particularly in the face of climate change effects" (IAASTD 2009, 10). For this to happen national and international strategies for agricultural development must focus more support on smallholders, for example, by expanding projects to enhance farming systems based on agroecological principles, emphasizing among other things biodiversity and ecosystem services (IAASTD 2009; De Schutter 2010).

Scherr (2003) points to the interlinked problems of rural food insecurity, poverty, and biodiversity. She argues that food insecurity and poverty often are found in areas where biodiversity loss is especially pronounced. The reason is that wild foods are important for food security and livelihoods for rural poor, contributing substantially to the feeding of the families as well as to the income of the households. According to the author actions to support biodiversity are therefore paramount for reaching the Millennium Development Goals to halve the incidence of hunger and the rate of poverty, as well as to conserve biodiversity and environmental services (United Nations 2010).

In line with others, our study indicates that it is indeed possible to promote biodiversity and ecosystem services while increasing food production. Furthermore, it extends the understanding of the ecological and social interactions at the ecosystem level, so important for the development of sustainable and productive agricultural systems. We need to know a lot more about management methods that are applicable in practice, how they contribute to the generation of essential ecosystem services, and at the same time play a part in the livelihood of rural communities as well as for the society at large.

This study provides an analysis of three concrete, successful projects with smallholders as major stakeholders that are restoring and improving biodiversity and environmental services through ecosystem-based food production. It discusses situations where this is happening, and important drivers as well as threats and challenges to such development. The objective of the study was to choose projects that had managed to improve food security in the areas where they were working, using resources and services from local ecosystems. We explore in detail the methods employed and the ways the generation of local ecosystem services were affected using the categorization of the Millennium Assessment as a theoretical framework. We also wanted to identify reasons for the success of these projects.

We use the term ecosystem-based agriculture not with the intent to propose a new concept but to pronounce that production in the investigated projects was based on resources and services generated in the local ecosystem in contrast to industrialized agriculture's large dependence on external inputs. However, the research has an agroecological approach and the projects may well fit within either of the concepts included under the umbrella of sustainable agriculture.

Based on the work in these three innovative agricultural projects, located in Ethiopia, Brazil, and the Philippines, this article identifies key factors in and important aspects of sustainable agricultural systems that are resilient; meaning they include the capacity to deal with change while still providing vital functions in times of large global challenges. The overall aim was to contribute with new findings for other actors to learn from and have as a ground for further research and development. We think that it might provide important learning for the conversion of fossil fuel intensive industrialized production systems in the developed part of the world. Increasing energy prices and worries about global warming raise questions about the future of such agriculture. Depletion of non-renewable resources and unfavorable environmental effects, together with concerns for global equity, demand a rethinking about prevailing agricultural practices that has become even more urgent with the challenges of climate change.

MATERIALS AND METHODS

This is a exploratory study with the aim of understanding ways that ecosystem-based agriculture was used to combine production, and conservation and to discuss driving forces for this as well as threats and challenges. Thus, the purpose was not to represent the world but to examine certain functional elements common to all cases included in the study in order to identify factors and complexities suitable for further investigation (Stake 1998).

Qualitative methods have been used to explore three different cases in three countries. Data were collected by a) in-depth, open-ended, and thematic focus interviews with actors, 2) direct observations, and 3) written documents (Patton 2002).

Study Areas

Case studies were carried out on production units within projects run by: 1) The Institute for Sustainable Development (ISD) in the Tigray Region, northern Ethiopia; 2) Centro Ecológico (CE) in Rio Grande do Sul, southern Brazil; and 3) The Farmer-Scientist Partnership for Development (MASIPAG) in The Philippines. All these bodies are local NGOs. The cases were selected to show successes and challenges in combining production and conservation based on supporting local ecosystem services. We also wanted to explore the ways such systems were developed in different parts of the world.

Sustainable development and ecological land management by farming communities in Tigray, Ethiopia

In Tigray, people have been practicing agriculture for more than 5,000 years, developing a rich socio-biological wealth of indigenous and traditional knowledge and practices with inbuilt resilience for survival. However, over the last 150 years, the land and farming systems have become highly degraded (Abegaz 2005; Tewolde Berhan Gebre Egziabher 2006; Edwards et al. 2011). Heavy rainfall (500–700 mm within 2.5 months), free-range grazing in the mountainous areas and unsustainable cropping methods have resulted in severe soil erosion. Deep gullies destroy farmers' fields, carrying away thousands of tons of topsoil each rainy season (up to 30 tons/ha a year from crop land; FAO 1986), thus, diminishing the cropping area. Smallholders are experiencing recurring droughts and famines. Since 1996, ISD has used ecological principles to support farmers in recovering ecosystem services and increasing the productivity of their land. Today, the management methods employed in the project are used by farmers in all of the 165 cereal dominated districts in the country.

ISD works in participatory partnerships with local farming communities and their agricultural professionals to train them in how to make and use compost (Edwards 2003). This increases crop yields through building up the fertility of the soil. The smallholders also rehabilitate degraded watersheds through physical and biological soil and water conservation treatments; they halt the free-range grazing of domestic animals to allow the local biodiversity to recover; and protect their interests through developing written bylaws for internal self-regulation, as well as recognition by higher authorities (Hailu Araya and Edwards 2006).

Organic agriculture and local markets in Rio Grande do Sul, Brazil

Only around 5% remains of the Atlantic rain forest that once covered the entire east coast of Brazil. This is the case also in Rio Grande do Sul, the southernmost of the coastal states (SOS Mata Atlântica 2010). Former forested lands were transformed into small farms growing bananas on steep hills, and sugar cane and paddy rice in the flat valleys, all based on high external inputs. In Brazil, and many other parts of Latin America, by the end of the 1980s the negative impacts of industrial agriculture, most obvious in ill health among farming families due to unregulated use of pesticides and in low prices for produce and increasing debts, resulted in many farming families abandoning their land for the cities (da Silva 1982; Chonchol 1994; Domingues 2002).

Centro Ecológico (CE) has been working directly with smallholders since 1985. The organization is one out of 30 that participate in an agroecological network of a total 3,000 farming families and 10 consumers cooperatives. Promotion of sustainable agricultural systems through the adoption of environmentally sound technologies, guided by social justice, is the strategic focus of CE. The aim is to work with the production system through marketing, that is, by organizing local farmer and consumer cooperatives to sell, process, and buy locally. Developing agroforestry by mimicking the natural forest and farming for self-subsistence while selling the surplus on the local markets are core strategies. A network with local nodes is the way in which the work is organized. CE has, together with other partners in the agroecological network, also developed a participatory guarantee system for organic food production, making certification economically feasible for smallholders by leaving the development of the standards in the hands of the local farmers and consumers.

Local rice breeding and increased self-sufficiency in the Philippines

In the Philippines large-scale production for export, liberalized trade, and technological, input-intensive agriculture have been unable to lift people out of poverty or even ensure basic food security. Seventy three percent of poor Filipinos live in rural areas, amounting to nearly 50% of the rural population (Bachmann et al. 2009). "Modern" farming focused on monoculture of rice as a commercial crop resulted in escalating debts from the purchase of seeds, fertilizers, and chemical pesticides, leaving farming families victims of oscillating incomes for buying food.

MASIPAG in the Philippines started in 1986 as a response to the adverse effects brought about by Green Revolution technology. It is a national network of smallholder farmers' organizations, with scientist and NGO partners. Its approach is farmer-led research and crop improvement involving conservation and management of rice biodiversity in farmer-managed research farms. They also work on diversification and integrated farming systems. Today, MASIPAG has a membership of more than 35,000 farmers organized in local organizations. The core of the work is the training of farmers as rice breeders to improve and develop new varieties and volunteer farmer-trainers to help in diffusion of these technologies. MASIPAG maintains three national back-up farms while farmers' organizations run local farmer-managed research farms for selection of locally adapted varieties, local rice breeding, technology development, and to serve as in situ gene banks.

Data Sources

Each of the organizations in the study was responsible for selecting cases and organizing field visits in their respective working areas. The criteria used for selection were that: a) the systems had empirically demonstrated their ability to improve agricultural production, income generation and environmental services; b) had been created and functioning using participatory principles; and c) were experienced in the direct marketing of their products.

Interviews with farmers and local advisory services and observations on farms

The main source of information in the study came from key informants among farmers, advisory officers and local decision makers and researchers. They were selected by convenience based on preknowledge within the research group (Bryman 2004). Interviews were performed using a thematic interview guide (Bryman 2004). Themes of the interviews focused on management methods, the reasons for including them and perceived outcome for the farming family, the community and the landscape. Questions focused on the history of farm and farming. Farmers' visions of the future were also included.

Observations of management practices and their effects were carried out in fields, on farms and in the communities, and documented by the research team. The focus was on identifying and estimating the role of individual ecosystem services and the impacts of the management methods used. The findings were analyzed and used as triangulation to control the quality of interviews (Kvale 1996).

Focus group interviews

A focus group discussion was also held at each study site with key informants and other actors in the communities based on themes from the main research question of the study (Krueger and Casey 2000; Patton 2002). As wide a group as possible of actors, both men and women, involved in the management and governance was included to give a broad perspective of the situations in the sites. However, both the composition and the size of the focus groups differed among the study areas. The groups included between 20 and 30 people. Themes of the focus groups were, for example, identification of the largest environmental and social problems affecting food production and ways in which they were best managed; perceived contribution of local environmental resources and services to the production, as well as the contribution of the management methods to support the resource base and these services; key factors for the development of sustainable agriculture; strengths, weaknesses, opportunities/options, and threats foreseen in the future; policy recommendations for local, national, and international policymakers to support ecosystem-based agriculture. In Tigray, the focus meeting also included mapping of watersheds (Pretty et al. 1995) to illustrate environmental and social changes brought about by the project. In the

Philippines, the focus group discussions were more informal and held with fewer persons and at separate times.

Review of written documents

Published and unpublished, scientific and popular reports, and other written documents related to the projects were reviewed. The objective was to gain a more in-depth understanding of specific issues, conditions and circumstances surrounding the interviews and observations, as well as historical backgrounds to and broader contexts of the projects.

Ecosystem Services

In the present study, the MA classification of ecosystem services (Millennium Ecosystem Assessment 2005) was adopted and sorted under three of the four main headings: Provisioning, Regulating, and Supporting services. The fourth category; Cultural services, was dealt with by a focus on livelihoods (see below). Each ecosystem service was listed according to the MA system, but, when appropriate due to the focus of the study, names were modified or services subdivided to be more specific.

Construction of management methods and ecosystem service matrix

A list of agroecologically based management methods used and ecosystem services assessed in the different case studies was set up based on the results from interviews, observations, and focus group discussions. A matrix assessing the relative importance of each agricultural management method for the generation of a certain ecosystem service in the different cases was made (Table 1). The assessment to which degree the practiced management methods contribute to the generation of certain ecosystem services were done on basis of analysis and evaluation by the research team during two separate workshops. Information from scientific reports from the different cases was used to complement and add to the analysis.

Livelihood

In the context of this study focusing on agriculture based on resources and services from local ecosystems we defined the concept of livelihood, following Chambers and Conway (1992) as*:* "a way of characterizing the resources and strategies individuals and households use to meet their needs and accomplish their goals. Livelihoods are often described in terms of

TABLE 1 Agricultural management methods used to various degrees by farmers in all of the three case studies and their support to the generation of local ecosystem services following the classification structure of the Millennium Ecosystem Assessment

	Agricultural Methods and Values											
	ECOSYSTEM-BASED/ORGANIC AGRICULTURE - AGROFORESTRY											
Ecosystem Service (Following MA structure)	Soil fertility improvement by using compost/ biofertilizer, vermiculture, animal manure & green manuring	Using local varieties of crops and animals, farmer led selection and breeding	Polyculture - promoting diversity in fields, among crops grown	Crop sequences in fields	Integrating legume crops in the agricultural system	Biological control of weeds & pest	Planting multi - purpose trees & bushes on field edges, or in plantations	Nurturing original trees & seedlings, cutting branches of trees, leaving leaves & under-growth as soil cover	Domestic animals doing work in the agricultural system	Feeding animals on crop residues & organic waste	Agroforestry – promoting biological, phytochemical & structural diversity	Combining biological & physical treatment - gully treatment & check dams, ditches & walls
Provisioning services												
Food	**B, E, P**	B, **E, P**	b, E, p	**B, E, P**	B, E, P	B, E, P	**E, P**	**B, P**	**B, E, P**	**B, E, P**	**B**	**E, P**
Fibre & biomass fuel		B, E					**E, P**	**B, E, P**			**B**	
Ornamental		B, E, P	b, e, p		B	B		**B**			**B**	
Biochemical, natural medicine & pharmaceuticals		B, E, P	B, **E**, P	B, E, P	B, P	b, e, P	B, E, P	B, e, P			**B**	

Maintenance and improvement of biological information	b	**B, E, P**	**B, E, P**	**P**	b, e, p	B, E	E, P	**B**			**B, E, P**	
Maintenance of genetic information	b	**B, E, P**	B, E, P	B, E, P	b, e	b, e, p		**B**	E		**B, E, P**	
Fresh water supply	b, **E**				B	B, E, P	e, p	B, P				**E**, P

(*Continued*)

TABLE 1 (Continued)

Ecosystem Service (Following MA structure)	Agricultural Methods and Values: ECOSYSTEM-BASED/ORGANIC AGRICULTURE - AGROFORESTRY											
	Soil fertility improvement by using compost/ biofertilizer, vermiculture, animal manure & green manuring	Using local varieties of crops and animals, farmer led selection and breeding	Polyculture - promoting diversity in fields, among crops grown	Crop sequences in fields	Integrating legume crops in the agricultural system	Biological control of weeds & pest	Planting multi - purpose trees & bushes on field edges, or in plantations	Nurturing original trees & seedlings, cutting branches of trees, leaving leaves & undergrowth as soil cover	Domestic animals doing work in the agricultural system	Feeding animals on crop residues & organic waste	Agroforestry – promoting biological, phytochemical & structural diversity	Combining biological & physical treatment - gully treatment & check dams, ditches & walls
Supporting services												
Photosynthesis/ Primary production	**B, E, P**	**B, E, P**	**B, E, P**	**B, E, P**	**B, E, P**	b, p	**E, P**	B, P			**B, P**	e, **P**
Soil formation	**B, E, P**	P	B, P	B, E, P	B, E, P		e, p	B, P			**B**	E, P
Improvement of water holding capacity	**B, E, P**	E, P	B, E	P	**B**		e, p	B			B	**E, P**
Improvement/ maintenance of soil structure	**B, E, P**		B	B, E, P	**B**		B, E	B			B	P

Nutrient cyclling	**B, E, P**	P	B	b, e, p	**B, E, P**		E	B, P	**E, P**	**E, P**	B	P
Biological nitrogen fixation	**B, E, P**		B	B, E, P	**B, E, P**		E, P	b			B, E	E
Water harvesting	B, E, P	E					E, P	b			B	**E, P**
Regulating services												
Pollination		B, E	**B, E, P**	B, E, P	**B, E**	**B, P**	E, P	b			**B**	
Weed and pest regulation	B, E, P	**B, E, P**	B, E, P	B, E, P	B	**B, E, P**	P	B, P			B	
Soil protection (erosion)	**B, E, P**		**B, E, P**	b, e, p	B		e, p	**B, P**			**B**	**E, P**

(*Continued*)

TABLE 1 (Continued)

Ecosystem Service (Following MA structure)	Agricultural Methods and Values – ECOSYSTEM-BASED/ORGANIC AGRICULTURE - AGROFORESTRY											
	Soil fertility improvement by using compost/ biofertilizer, vermiculture, animal manure & green manuring	Using local varieties of crops and animals, farmer led selection and breeding	Polyculture - promoting diversity in fields, among crops grown	Crop sequences in fields	Integrating legume crops in the agricultural system	Biological control of weeds & pest	Planting multi - purpose trees & bushes on field edges, or in plantations	Nurturing original trees & seedlings, cutting branches of trees, leaving leaves & undergrowth as soil cover	Domestic animals doing work in the agricultural system	Feeding animals on crop residues & organic waste	Agroforestry – promoting biological, phytochemical & structural diversity	Combining biological & physical treatment - gully treatment & check dams, ditches & walls
Adaptation & mitigation of natural hazards	B, **E, P**	**B, E, P**	b, e, p	E, P	B		e, p	b, p	**E, P**	**E, P**	**B**	**E**, P
Maintenance of favourable local climate	b, E, P	B, E, P	b, e, p	E, P	B	P	E, P	B			**B**	E, P
Carbon sequestration	**B, E, P**	B, E, P	B, E, P	E	**B**		e, p	**B, P**			**B**	

Notes. B = Brazil (Centro Ecológico); E = Ethiopia (Institute for Sustainable Development); P = Philippines (MASIPAG).
The size of the letter signifies the relative importance of the management method for generation of the particular ecosystem service in each specific case.

people, their capabilities and their means of living" (42). This definition is widely adopted and used among others by IAASTD, where livelihood is combined with human health and nutrition (IAASTD 2009; Amekawa 2011).

Construction of management methods and livelihood matrix

Following the procedure used when assessing the management-ecosystem service matrix a similar matrix was constructed to illustrate the effect of management methods on the improvement of livelihoods (Table 2).

The following five components of livelihood wellbeing were recognized and applied as a framework: basic materials for a good life; health; good social relations; security; and freedom of choice and action (Millennium Ecosystem Assessment 2005). However, in relation to the agricultural management methods, mainly, the first was considered (Table 2). Security was considered in relation to the provision of sufficient and healthy food throughout a year and between the years.

RESULTS

Improving Generation of Ecosystem Services by Sustainable Use

Based of information from stakeholders and observations from the research group, it could be affirmed that the introduction of agroecological management methods in all three case studies maintained and enhanced several of the ecosystem services identified by the MA (Table 1). This was also verified by quantitative data from published field studies in certain cases. The improved ecosystem services in turn were recognized to improved agricultural production and thereby also improved livelihoods (Tables 1 and 2).

Provisioning Services

Increased productivity of food, fiber, ornamental plants, and pharmaceuticals

Ecologically based agricultural methods used by farmers in the three study areas increased productivity in relation to conventional/modern methods in Brazil and Philippines, and unimproved/traditional methods in Ethiopia in one way or another, but to different degrees (Table 1).

A study of the impact of compost on grain yields of 5 crops from farmers' fields in Tigray, Ethiopia, showed that use of compost gave consistently higher yields (Figure 1) (Edwards et al. 2007) than the use of mineral fertilizer. These yields were generally twice the average yields from fields that had not received any inputs. Farming communities that had been using compost in amounts of 3.5 tons/ha or more for seven or more years were able to avoid dependency on mineral fertilizers and its associated debt

TABLE 2 Agricultural management methods used by farmers in the three case studies and their effects on livelihoods*

Ecosystem Service (Following MA structure) and Country of Case Study	Agricultural Methods and Values: ECOSYSTEM-BASED/ORGANIC AGRICULTURE - AGROFORESTRY											
	Soil fertility improvement by using compost/biofertilizer, vermiculture, animal manure & green manuring	Using local varieties of crops and animals, farmer led selecting/breeding	Polyculture - promoting diversity in fields, among crops grown	Crop sequences in fields	Planting legume crops	Biological control of weeds & pest	Planting multi-purpose trees & bushes on field edges and/or in fields, or in plantations	Nurturing original trees & seedlings, cutting branches of trees, leaving leaves & under-growth as soil cover	Domestic animals doing work in the agricultural system	Feeding animals on crop residues & organic waste	Agroforestry – promoting biological, chemical & structural diversity	Combining biological & physical treatment - gully treatment & check dams, ditches & walls
Cultural services: Effects on liveloods												
Brazil	High	Small	High	Medium	Medium	High	High	High	High	High	High	[not used]
Ethiopia	High	Medium	Medium	Medium	High	Medium	High	Small	High	High	Small	High
Philippines	High	High	High	High	Medium	High	Medium	Medium	High	High	Medium	Small

*The relative importance of the different management methods for improvement of the livelihood in each separate case was assessed and noted by the words; High, Medium, Small.

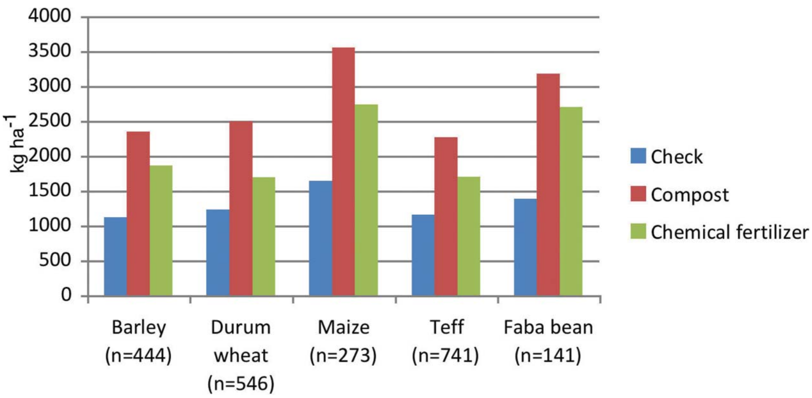

FIGURE 1 Average mean grain yields in kg/ha for four cereals and one pulse crop from Tigray, northern Ethiopia, 2000–2006 inclusive. Three samples of 1 m^2 of each treatment from all farm was harvested. The amount of compost used was on average 3,200 kg ha-1, which is an amount considered standard among the farmers in the area, and mineral fertilizers was applied in national recommended amounts in form of 100 kg DAP and 50 kg Urea, (Hailu Araya 2010). The nutrient content of the compost varied between sites and during years due to kind of organic wastes available (mainly, animal manure, plant litter, and household wastes). Check = without inputs, n = total number of plots from farmers' fields used in the analysis (Edwards et al. 2007) (color figure available online).

(Hailu Araya 2010). This was an amount of compost material that could be produced by organic wastes from the farming activities and households (Hailu Araya 2010).

The yield of rice varieties developed and selected by farmers and grown under organic conditions in the MASIPAG project areas in the Philippines was not significantly different from the rice yield of modern varieties grown using chemical fertilizers (Bachmann et al. 2009). However, the comparative yield, with less external chemical inputs, translated into a highly significant income advantage for organic farmers compared with conventional farmers (Bachmann et al. 2009). The interviewed Filippino farmers had on average observed a 25% increase in income from sold products.

Brazilian farmers employing agroforestry, directing the production first of all to satisfy the need in the household, instead of producing only one cash crop for the external market, perceived an increase in production. They express that much more from the system could be diverted into own use or sold at the local market. They now produce an ample amount of different edible products, fuels, construction materials, ornamentals and pharmaceuticals.

MAINTENANCE AND IMPROVEMENT OF BIOLOGICAL AND GENETIC INFORMATION

Agroforestry promoting biological, phytochemical and structural diversity, including local varieties of crops and animals, and replacing chemical pest control with locally produced bio-pesticides were observed to be ways to maintain and improve biological and genetic information in the project areas. The observed benefits of this diversity of species and varieties were increased adaptive capacity, enrichment in the food consumed on the farms, and improved possibilities for commercialization of food, medicines or ornamentals (Table 1).

In Rio Grande do Sul, Brazil, the development of agroforestry systems has been a means to bring back components of the Atlantic forest while also securing the provision of food according to the informants from Centro Ecológico. Production and conservation went hand in hand when indigenous self-seeded herbaceous plants, bushes and trees were nursed and restored, and indigenous and introduced plants were established. The farmer informants appreciated the increased self-sufficiency in food. They also perceived that the option of selling on local markets made the large variety of crops produced by the agroforestry system more favorable than only producing bananas or sugar cane for middlemen.

In Tigray and in the MASIPAG communities, the selection and improvement of local seeds by farmers had turned farm land into an important living gene bank, for example, sustainably storing the seeds of more than 1,000 local and improved varieties of barley in Tigray and of rice in the Philippines (Medina 2004; Fetien Abay 2008).

Based on interviews in all three projects, local varieties was preferred by the farmers for reasons that they tasted better, did not required expensive external inputs, were adapted to farmers' soils, more resistant to pests and diseases, and more resilient to changes in the local climate. Furthermore, they were perceived to yield better and strengthen the farmers' own control over the production.

The farmers in the projects had an intricate system to improve the quality of seeds. They also combined the different varieties to achieve a high and stable production and at the same time fulfill multiple needs for cooking, animal feed, energy, and construction.

Since there are few if any commercial markets for local seeds in the areas, storage, and exchange of seeds were important parts of the common work in the communities, especially in Tigray and among the Philippine farmers. Seeds were distributed in ceremonial ways and exchanged for labor or other services. Skilled local breeders were also highly respected in the communities.

Observations by researchers from ISD in Ethiopia, from MASIPAG in the Philippines, and from Centro Ecológico in Brazil supported the perception of the farmers that the increase in crop diversity and the use and improvement of local varieties increased the total yield from the systems and made farmers less dependent on purchased seeds and thereby increased their economic resilience.

Fresh water supply

Combining biological and physical treatment for water harvesting was an important measure to increase the supply of fresh water. The Tigray study is an example (Table 1). In Tigray, the drive to reverse serious land degradation, mainly soil erosion, involved intensive methods of physical and biological soil and water conservation such as terraces, trench bunds, and check-dams enriched with fruit trees and plants that were used for animal feed. Such activities were reclaiming gullies and retaining soil and water, consequently improving the hydrology of watersheds. Interviewed farmers and researchers all confirmed an unexpected reappearance of springs and streams improving the fresh water supply, both by increasing the amount of water and by prolonging its availability throughout the year.

Supporting Services

Photosynthesis

No actual measure of effects on photosynthesis due to change in management methods has been performed in the projects. It would however be reasonable to assume that agricultural practices that increase fertility and water-holding capacity of soils as well as the inclusion of polycultures, which in numerous scientific research studies have proven to be more productive than monocultures (Altieri 1999; Tomich et al. 2001; Pretty 2006; Altieri 2011), would contribute to an the increased photosynthetic capacity. Higher yields and diversity in produce both measured and observed by farmers and researchers in the projects also add to this (Table 1).

On the MASIPAG farms in the Philippines, this multifunctional land use was exemplified by coconut (*Cocos nucifera)* as the canopy tree, and under it banana (*Musa* spp.), coffee *(Coffea* spp.), lanzones (*Lansium domesticum*), and papaya (*Carica papaya*) interspersed with fuel wood trees (e.g., *Gliricidia sepium*), which, in turn, acted as a trellis for black pepper (*Piper nigrum*) or yam (*Dioscorea alata*). On the ground there could be taro (*Colocasia esculenta*) or ginger (*Zingiber officinale*).

In Tigray, control of erosion in fields and former gullies has provided additional land for growing crops and other useful plants such as forages and fruit trees. Interviewed farmers all convey an impressive recovery of land with measures such as terracing and construction of trench bunds and check-dams, but also due to restrictions on free animal feeding on hillsides. Former gullies with only bare soil were turned into hectares of new agricultural land with photosynthetic capacity. Natural areas on the hillsides also recovered rapidly. The difference in vegetation on slopes in communities with bylaws restricting animal grazing compared to communities without was easily observed for any visitor in the landscape.

Soil formation and water harvesting

The Tigray region is generally regarded as the most degraded part of Ethiopia with some areas destroyed beyond restoration. Successfully halting erosion in such degraded and vulnerable ecosystems as found in the ISD project area are therefore useful examples of agricultural methods contributing to the ecosystem service of soil formation (Table 1; Hailu Araya and Edwards 2006).

The communities in the Tigray case have experienced a remarkable build-up of topsoil since 1996 when the project to rehabilitate the catchments started. The rate of soil erosion in the region has decreased by about 60% (Tigray Bureau of Agriculture and Rural Development, personal communication 2009) and farmland has started to build up again. Prolonged water through-flow in the landscape has resulted in higher water tables and, in some cases, also the reappearance of permanent springs, encouraging farmers to develop micro-irrigation to get a second or even third harvest each year. Horticultural production has become a new option for an increasing number of farming families (Hailu Araya et al. 2007).

Improvement of soil fertility, structure, and water-holding capacity

All three cases studied included modes of production that increase the input of organic matter to the soil (Table 1). As low soil organic matter tends to be a serious problem in tropical soils, means to increase this have clear and multiple effects, such as improvement of the soil structure, water-holding capacity and increase in nutrient deliverance, over all improving the fertility of the soil.

The Tigray case could serve as an illustrative example for other areas with declining production due to low soil fertility, for example, in sub-Saharan Africa (Smaling et al. 1993; Stoorvogel et al. 1993; Buresh 1997). Composting of weeds, straw, animal dung and urine in Tigray has led to improved structure and water-holding capacity in severely degraded soils.

Farmers in the project made individual or community composts next to the fields or near the residences. Interviewed farmers perceived that compost had improved the fertility resulting in higher yields and in increased infiltration capacity in waterlogged soils. The management methods and resulting effects have been described in detail by Hailu Araya and Edwards (2006) and Edwards (2003).

Another important means to increase the soil fertility perceived by the farmers in all cases was the introduction of multipurpose trees and bushes in the cropping systems or at the field edges. These trees or bushes were introduced for a multiple of purposes, for example for food or fodder and as fuel wood or construction material. Farmers in the Brazilian project observed that the trees protected vegetable plots from cold drying winds in the winter and maintained soil moisture.

Nutrient recycling and biological nitrogen fixation

Important functions of the multipurpose trees and bushes were to fix nitrogen and recycle nutrients in the system. Trees with deep roots accumulating nutrients from deep layers in the soil were also planted in the forested systems or in field edges on farms in all the cases (Table 1).

In the project in Rio Grande do Sul, Brazil, cutting tree branches, leaving banana stems after harvesting the bunches, and having fallen leaves and undergrowth as mulch were important production modes to recycle nutrients in the system. Interviewed farmers included indigenous and introduced multipurpose trees and were readily aware of the effects of trees in bringing up nutrients from lower levels and returning them to the soil through the leaf litter. They also expressed the importance of being aware of the different demands and effects on the system of different tree species.

Recirculation of nutrients and biological fixation of nitrogen were perceived by the farmers to be important for getting good yields. The inclusion of leguminous plants has led to a reduction in the use of mineral fertilizers observed by the researchers in all the projects.

A majority of farmers in the Philippines project also integrated animals into the production system. Ponds in corners of the rice fields where fish such as tilapia or catfish were grown and fed with rice bran was one example. To maximize the benefits from the ponds, a nitrogen fixating bacteria (Azolla) was introduced. Ducks were, furthermore, a common part of the systems; they fed on Azolla or grazed on the harvested rice fields, contributing with manure fertilizer to the soil.

Regulating Services

Weed and pest regulation

Farmers from all the cases witnessed that weeds demanded substantial labor. Pests and diseases were, however, not perceived as causing any serious problems. The main reasons expressed were the great variety in the system and the exclusion of pesticides. The farmers perceived an increase in the amount of natural enemies for pests since exclusion of pesticides. The damage was furthermore reduced by the many different species and varieties sown in a complex mix, diminishing the food available for each kind of pest. Farmers in the Philippine case had also observed that the local varieties were resistant to several common diseases.

Biological control of weeds and pests, such as the use of allelopathy between plants, cropping sequences, spraying bio-fertilizers (fermented liquid fertilizers prepared with, e.g., fresh manure, sugarcane juice, milk, and many kinds of leaves) and raising and releasing natural enemies to pests, were means used to different degrees in all three cases (Table 1).

The MASIPAG farmers developed an approach called alternative pest management relying on the natural ecological balance by redesigning the local agroecosystem (Bachmann et al. 2009). The approach aimed to deny the pests of their preferred conditions such as through wider spacing in rice planting, alternate irrigation and drying of rice fields, and replacing chemical nitrogen fertilizers with organic fertilizer all of which had been proven to be effective against planthoppers. The activity and efficacy of natural control agents were enhanced by intercropping, plant spacing and not spraying pesticides. Moreover, farmers develop local technologies such as using indigenous microorganisms, plant combinations with pest-repellent properties and the application of other botanical extracts.

Pollination

In the Ethiopian project area, an obvious result of the rehabilitation of hillsides by natural woodland was the reappearance of bee forage. Some farmers had started beekeeping, getting additional food and income. Honeybees and other wild bees need food in the landscape all year around in tropical regions. A deliberate increase in the managed biodiversity in the systems, as well as a ban on the use of pesticides, were perceived by the farmers and researchers in all cases to contribute to recolonization by wild bees. Brazilian farmers also kept hives of wild bees in their agroforestry systems (Table 1).

On the MASIPAG farms in the Philippines, an example of successful combination of pollination and pest regulation using ecological design was maize-peanut intercropping. During the flowering period of peanuts, parasitic wasps were attracted to feed on nectar and consequently perform the pollination while searching for pests on the maize to feed their larvae.

Adaptation to and mitigation of natural hazards

All the projects had among their main objectives to increase resilience to natural hazards using agroecological management methods to strengthen the health and integrity of the local ecosystem. This objective could be observed in expression from MASIPAG farmers in the Philippines that described their motives to diversify the production as "insurance." No actual measures of success were yet performed but observation by project researchers and information from interviewed farmers indicated a substantially increased ability to adapt to natural hazards such as unpredictability in rainfall and strong winds. The introduction of polycultures and the use of locally adapted crop varieties with large diversity in reaction to different hazards were perceived to be main reasons (Table 1).

Adaptation to natural hazards was a built-in component of the activities by farmers in the Philippine case. Crop diversification, planting windbreaks and trees to stabilize slopes, and breeding drought and salt tolerant rice varieties were among the coping strategies employed to resist typhoons, flooding, landslides, and droughts (Table 3).

In Tigray, digging shallow ponds and trench bunds on farmland to hold water, halt erosion and increase water-holding capacity enhanced the resilience to both drought and potentially erosive heavy rainfall. The physical and biological soil and water conservation activities supported by farmer innovations were important in retaining moisture and diverting flooding, while other crop management techniques, such as mixed cropping, were becoming local remedies for the unreliability of weather.

In addition to technological coping mechanisms, the farmers in Tigray, in Rio Grande do Sul and in the Philippines had strong social processes through their local farming organizations strengthening their capacity for buffering and adaptation. For example, seed exchanges among farmers were common. Work such as land preparation, planting, weeding or harvesting could also be done cooperatively, with the organization's members working as a group in a rotating schedule among their members. Use of local varieties with wide genetic adaptability was another important means to enhance resilience.

TABLE 3 Examples of the coping mechanisms used by MASIPAG farmers in the Philippines

Natural hazard	Coping mechanism or adaptation
Typhoons	• Breeding rice tolerant to lodging • Diversifying crops • Seed storage and seed exchange • Planting windbreaks plants (e.g., bamboo, *Gliricidia*, coconut, etc.) • Planting of tuber crops • Livestock integration
Flooding, landslides	• Planting of *Vetiver* grass and trees to stabilize slopes; hedgerows • Diversification of farms • Planting of tuber crops • Seed storage and seed exchange • Livestock integration
Drought	• Breeding rice tolerant to drought • Agroforestry • Diversifying crops • Livestock integration
Salt water intrusion	• Selection and use of rice varieties adopted to saline soils • Rehabilitation of mangrove areas • Maintenance of trial farm

Carbon sequestration

Soil fertility improvements performed in the three cases that included adding organic matter such as compost, animal manure, and green manure increased soil organic matter. This was used as an indirect indicator of the potential of an increase also of the sequestration of carbon (Table 1).

An exploratory study conducted in the Brazilian case showed that the agroforestry systems planted by farmers could accumulate between 22 and 47 tons of carbon per hectare over a period of 12 years. In a scenario of global warming, these numbers indicate the potential of such systems to mitigate greenhouse gas emissions (Gonçalves 2007).

The introduction of compost in Tigray has increased soil organic matter. This may also be a means to sequester carbon in soils with a "soil carbon gap" according to FAO (2007).

Improved livelihoods

One of the most striking characteristics of all the farmers and farming communities studied was their profound understanding of their surrounding ecologies, for example, the use of indigenous trees and herbs to provide nutrients for bananas and how to protect banana plantations from strong winds in the Brazilian case; how to interpret water and soil dynamics on the farms for water harvesting and good drainage in the Ethiopian case, and the many ingenious ways developed to cope with pests that challenged their rice crops in the Philippines case. This knowledge and the innovations derived from it provide the farming families and communities with ecological and social resilience to maintain and improve their livelihoods with low dependence on external inputs (Table 2). Overall, an extensive ecological knowledge of the local agroecosystems is seen in increasing diversity, such as the studied agroforestry system in Brazil as well as the diversified production systems in both Ethiopia and the Philippines. These will increase in importance as means to reduce risk and increase adaptability to expected large scale environmental changes, for example, local effects of global warming, for smallholder farming communities.

The participatory approach in all three projects holds the promise of an increased self-confidence and empowerment both for individuals and in the communities, as observed in the interviews of farmers and researchers. Reduced reliance on external markets when cutting the need for external inputs in combination with increased focus on production for self-consumption, with the objective to sell the surplus on the local market, were expressed as reasons. Development of participatory guarantee systems in Rio Grande do Sul and in the Philippines as well as the development of "farmer-to-farmer" learning systems in all three cases were also mentioned in the interviews.

During focus group interviews in the project in Rio Grande do Sul farmers expressed that they felt happy because they saw that they were delivering healthy food to their customers. They also articulated an improved relationship with consumers and with nature. Another perceived advantage was that they now had direct control over the commercialization of their products and did not any longer have to go through a middleman. This was more profitable for them.

"It is a matter of philosophy, now we can produce food to sustain the family and that is enough, one feels safer without loans and we could help each other. That is better than quick and high, but insecure income, in conventional agriculture," concluded a Philippian MASIPAG farmer.

DISCUSSION

Management methods in the cases studied in Ethiopia, Brazil, and the Philippines had their base in nature conservation while the ecological resilience of the production systems was strengthened. Our own observations and statements from stakeholders in interviews in our study as well as other published reports (Edwards et al. 2011) from the project in Tigray reveal that restriction of free-grazing animals, the introduction of compost as well as the construction of terraces and trench bunds had halted soil erosion and restored watersheds so that the area of land, producing crops and other useful plants, actually increased. Moreover the introduced methods prolonged the water through-flow in the landscape and allowed local biodiversity to recover.

Key informants in the project described the progress to be even faster than expected. Soils on hillsides had recovered fast, trees and wild animals had appeared within only a couple of years after introduction of efficient methods to control erosion. Soil fertility also improved substantially within a few years, notable in increased yields, mainly, by the use of compost. Informants perceive that the conversion to agroecological management methods on farms had proceeded faster due to increased costs for fertilizers.

The introduction of agroforestry systems in the project in Rio Grande do Sul has been contributing to rehabilitation of the Atlantic rain forest (Goncalves 2007). The system of participatory plant breeding employed in the Philippines (Frossard 2002) and also, partly, in Tigray (Fetien Abay 2007) has the potential to be a resilient way to secure stable, high production in an environment with high ecological, economic and political variability. It empowered farmers and increased their "freedom of choice and action, identified by MA as an important prerequisite for wellbeing (Millennium Ecosystem Assessment 2005). Local economic and social factors, such as limited financial resources, pesticides affecting health, and poor infrastructure, have rendered agricultural production based on the sustainable use of local ecological resources more attractive than production heavily dependent on expensive external inputs. The increasing cost of mineral fertilizers has encouraged farmers to make compost using their own labor and the biomass and animal manure available to them. On steep slopes in climate regimes with unreliable rainfall and on poor soils, local crop varieties and production methods with addition of organic matter are producing higher yields than “improved” seeds and synthetic chemical fertilizers in Ethiopia, the Philippines and Brazil (Hailu Araya and Edwards 2006; Pretty 2006; Bachmann et al. 2009; Altieri 2011).

Our findings support the arguments that agriculture based on local ecosystems and services have a potential to feed the world in the long term. It also confirms the importance of maintained and enhanced agrobiodiversity, as well as provides examples of productive management methods.

To process, develop and implement agricultural approaches and solutions that fit specific agroecological conditions and socio-cultural situations, farmer involvement is crucial. Decisions on seed selections, soil fertility management, pest control, and crop diversification are forms of control by farmers over their production system that enhance the location-specific adaptability of particular agricultural technologies (Oram 2003). Farmers doing plant breeding themselves to improve the varieties that they grow based on criteria that they have identified is a social process that diversifies solutions to unique environmental and social conditions (Frossard 2002). Participation, cooperation, and collective action are, therefore, some of the important driving forces in developing sustainable agriculture that is based on local ecosystem characteristics. Flexible institutions at different levels that recognize and support local ecological and social processes are needed (Berkes and Folke 2002). It is a large challenge to build institutions based on adaptive management, which strengthen and interact with local communities and have a learning-by-doing approach (Ostrom 1999).

Effects on local climate and ecological functions of global warming are threats to the development of ecosystem-based agricultural systems as well as to all agricultural systems. Absence of rain, too heavy rains, delayed rainy seasons, or more unpredictable rainfalls were among the changes noticed by, and cause concern, for key informants in all three projects. Insecure property rights and political instability were also perceived as potential threats. The three cases have shown promises of improving the livelihoods of rural populations, which may increase the incentives to stay in the countryside and halt the migration to the cities. However, to feed a growing, both urban and rural, world population in a future with increasing prices of energy and other non-renewable resources and escalating stress on local and global ecosystems, agroecological management methods based on local resources and services needs to be implemented in all kinds of agricultural systems in both developing and developed countries. Infrastructure has to be built to enhance local food processing and local farmers’ markets.

Local decision making has to be respected so that the power to decide on local resources is in the hands of local communities. Fundamentally, farmers' access to land and tenure to use that land have to be secured.

CONCLUSIONS

This study analyzed successful examples of sustainable ecosystem-based agriculture with smallholders as the major stakeholders. In Tigray, Ethiopia, compost was used to improve structure and water-holding capacity of soils giving consistently higher yields than the use of mineral fertilizer. Furthermore, community-based erosion control led to reappearance of springs and streams. In Rio Grande do Sul, Brazil, agroforestry systems help to bring back components of the Atlantic forest while securing food and sequestering carbon. Yields of rice varieties developed and selected by farmers and grown under organic conditions in the Philippines have resulted in comparable yields but higher incomes compared with modern varieties and high external inputs of agrochemicals and in the same time increasing the genetic diversity among seeds used.

Based on these three case studies from three different continents and a number of recent global assessments and seminal studies, we conclude that it is indeed possible to increase production and enhance the resilience of livelihoods and agriculture through agroecological management methods based on conscious design and use of local ecosystem services and resources. Reliance on an increased diversity of managed and wild flora and fauna as well as multifunctionality were found to be of crucial importance.

Participation and collective action were identified as essential for success in developing sustainable agriculture. Our research adds to the increasing awareness among research bodies as well as among policymakers of the importance of participation of multiple stakeholders and the multifunctionality of agriculture (IAASTD 2009). Local decision-making needs therefore to be strengthened and policies to enforce and encourage ways to move responsibilities to local resource managers with their unique knowledge of the local ecological systems. Policies at all levels need to recognize the role of localized food production for food security and to promoting local food processing and local farmers' markets. However, more research on how eco-based farming systems can be scaled up to provide food for an increasing urban population is needed.

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