# 14 Ecosystem Benefits of 'Bright' Spots

**Deborah Bossio,[1]* Andrew Noble,[2]** Noel Aloysius,[3]*** Jules Pretty[4]**** and Frits Penning De Vries[5]*****

[1]*International Water Management Institute, PO Box 2075, Colombo, Sri Lanka;* [2]*International Water Management Institute, c/o Worldfish Center, Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas, Penang, Malaysia;* [3]*International Water Management Institute, PO Box 2075, Colombo, Sri Lanka and Yale School of Forestry and Environmental Studies, 210 Prospect St, New Haven, CT 06511, USA;* [4]*Department of Biological Sciences, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, UK;* [5]*Nude 39, 6702 DK Wageningen, The Netherlands;*
*e-mails: *d.bossio@cgiar.org; **a.noble@cgiar.org; ***n.aloysius@cgiar.org; ****jpretty@essex.ac.uk; *****frits.penningdevries@gmail.com*

## Introduction

'Bright' spots of resource-conserving agriculture do occur in developing countries (Noble *et al*., Chapter 13, this volume; Pretty *et al*., 2006; Bossio *et al*., 2007). They provide optimism that, simultaneously, food production can be increased, food security can be improved and resource degradation addressed. This is in contrast to the conventional or 'green revolution' model of agricultural intensification, in which increased production has often been accompanied by degradation. The bright spots database[1] demonstrates significant food productivity gains in a range of smallholder agricultural systems. This indicates that poverty and inequity can also be addressed with these methods, since the vast majority of undernourished people are smallholder farmers and others that depend on the land directly for their livelihoods (Bossio *et al*., 2007). Thus, these methods, which emphasize a more ecological approach to farming, can contribute towards reducing rural poverty in developing countries and sustaining the natural resources and ecosystems upon which continued production depends.

Conventional 'green revolution' production systems have managed to reduce global hunger during a period of massive population growth, but in many cases, this approach has resulted in the degradation of natural resources. Since the technologies associated with these production systems are capital intensive and rely heavily on external resources, they are often out of reach of many disadvantaged populations. Consequently, they have been unable to eliminate the rural poverty, inequality and hunger entrenched in many areas of Asia and Africa (cf. Lipton and Longhurst, 1989), and many smallholder farmers, particularly in sub-Saharan Africa, have suffered as a result (Evenson and Gollin, 2003). Environmental implications include salinization, nutrient depletion and chemical pollution (Shiva, 1991), which have resulted from the intensive, high-input system model. Negative human health impacts in particular often result from the degradation of water quality (see Boxes 14.1 and 14.2). Off-site impacts are exemplified by the negative effects of water withdrawals for intensive

 *Conserving Land, Protecting Water* (eds D. Bossio and K. Geheb)

**Box 14.1.** Human health suffers from high-input conventional farming practices: the Yaqui Valley of Mexico

In the 1940s, farmers in the lowland areas of Mexico's Yaqui valley adopted irrigation agriculture that relied on the heavy use of chemical fertilizers and pesticides. In 1990, high levels of multiple pesticides were found in the cord blood of newborns and in breast milk. The children of this agrarian region also demonstrated decreases in stamina, gross and fine eye–hand coordination, 30-minute memory, and the ability to draw a person (Guillette *et al.*, 1998). Environmental contamination associated with irrigated agriculture can lead to long-term harm to children that not only inhibits their development but, when widespread in the human population, can undermine the ability of communities to cope with future change, because of a reduction in learning capacity.

**Box 14.2.** Human health impacts of salinization/sodicity

*Fluoride in groundwater, fluorosis and sodic soils*: 30 years ago Krishnamachari (1976) noted increased dental and skeletal fluorosis approximately 15 years after the introduction of two large irrigation schemes in India. Fluorosis depends on the development of sodicity, mobilizing fluoride. The extent of sodic soils in India has increased from 0.6 million ha in 1979 to 3.4 million in 2008. Sodicity has developed very rapidly in the command area of the Indira Gandhi canal in Rajasthan (Jaglan and Qureshi, 1996). About 65 million people are exposed to excessive fluoride content in their drinking water in India. The relationship between sodicity of soils and fluoride concentration in groundwater has been verified recently (Jacks *et al.*, 2005). The increasing rate of fluorosis paralleling the development of sodicity is noticed in Pakistan and around the Aral Sea. The extent of sodic soils in Pakistan is almost of the same extent as in India.

*Selenium and selenosis in alkaline soils*: paralleling the behaviour of fluoride is selenium, which is mobilized under alkaline conditions. Selenium toxicity in alkaline soils occurs in Punjab (Dhillon and Dhillon, 2000), and toxicity is observed in both animals and humans (Hira *et al.*, 2004). The selenium reaches the animals predominantly via the fodder, but groundwater concentrations are also elevated. Similar selenium mobilization occurs in California, in agricultural areas like the San Joaquin Valley (Herbel *et al.*, 2002).

irrigated agriculture that now affect 60% of freshwater habitats, an impact extensively assessed by the Millennium Ecosystem Assessment (MEA, 2005). The most extreme examples of the impact of these production systems may be observed in surface water resources in important river basins such as the Colorado, Huang-He (Yellow), Indus, Nile, SyrDarya and Amu Darya, which are 100% exploited, degrading aquatic ecosystems (WRI, 2000) with negative impacts on human well-being. Equally important are trends in unsustainable groundwater exploitation, particularly in South Asia (Morris *et al.*, 2003; Shah, *et al.*, 2007).

In addition, and not specific to 'green revolution' systems, land clearing for all forms of agriculture has made a huge contribution to global climate change through the release of $CO_2$ from biomass and soils (Lal *et al.*, 1997). Soil carbon loss, and its myriad consequences in terms of lost productive potential, is ubiquitous in both extensive and intensive agricultural systems. In many fragile soils in the tropics, soil carbon loss results in depressed productivity after only a few years of tillage, as soil nutrient and water-holding capacities are compromised (Stocking, 2003). A dramatic example of the massive impacts of land clearing on global climate has been highlighted recently with regard to peat soil clearing and burning for biomass cultivation (Hooijer *et al.*, 2006).

Bright spots are, by definition, cases where local food production has been improved (average crop yield increase of 83%, Noble *et al.*, Chapter 13, this volume), primarily through resource-conserving agricultural techniques, which include: integrated pest management, integrated nutrient management, conservation tillage, agroforestry, aquaculture, water harvesting, and livestock integration into farming systems (Pretty *et al.*, 2006). They have flourished within local contexts that often include resource degradation and market and investment constraints, resulting in a history of very low productivity (Noble *et al*., 2006). In all farming systems, a concentration of inputs is required to sustain productivity, and they thus have an ecological footprint that extends beyond the field and generates externalities that include energy and external input requirements (Pretty, 2002). Increased productivity requires an increased concentration of inputs, and may thus increase the ecological footprint of any particular farming system. Intensification through resource-conserving agriculture, as in bright spots cases, attempts to reduce the size of the footprint over conventional intensification, thus reducing environmental impacts, while making use of a whole variety of traditional and green revolution farming techniques. In resource-conserving farming systems, ecosystem benefits are thus achieved when resource-use efficiency can be improved, when external inputs (often also representing energy requirements) can be decreased, when ecosystem contamination by agricultural practices can be minimized and when the farming system results in increased ecosystem services to on- or off-site communities.

Analyses of global bright spots data published by Pretty *et al*. (2006) have demonstrated the magnitude of selected ecosystem benefits (i.e. benefits beyond productivity gains) at an aggregate level across surveyed bright spots. These analyses focused on: (i) water productivity as a case of local resource-use efficiency; (ii) pesticide use as an external input factor with direct relevance to human health and environment; and (iii) carbon sequestration giving rise to the mitigation of greenhouse gas emissions as an example of a global ecosystem benefit. In this chapter, we provide a summary of the results from Pretty *et al*. (2006) and then offer an expanded view of the variety of ecosystem benefits that are possible from bright spot cases based on resource-conserving agricultural practices (for a detailed analysis of food production benefits and drivers for success see Noble *et al*., Chapter 13, this volume). Benefits are illustrated through descriptive case study examples and a qualitative assessment of their ecosystem benefits.

## Global Analysis

### Water productivity

The potential for increasing food production while maintaining other water-related ecosystem services resides in the capacity to increase crop water productivity (WP), i.e. by realizing more kg of food per unit of water. Farmers and agronomists are more familiar with the idea of maximizing the productivity of land and other inputs, such as fertilizers and pesticides, while water has primarily been managed at optimum levels (irrigation systems), or considered beyond the realm of management (rainfed systems). Increasing conflicts over fresh water are serving to change this view. Many opportunities for improving water productivity (WP) in agricultural systems exist, and a growing consensus (Molden, 2007) calls for investments that target improved WP in agriculture. Resource-conserving agricultural practices may do this by: (i) removing limitations on productivity by enhancing soil chemical, physical and biological attributes; (ii) reducing soil evaporation through conservation tillage; (iii) using more water-efficient varieties; (iv) reducing water losses to unrecoverable sinks; (v) supplemental irrigation in rainfed systems to reduce crop losses and unproductive evapotranspiration; and (vi) inducing microclimatic changes to reduce crop water requirements.

By analysing 144 bright spots cases, it was possible to demonstrate that WP gains were very high in rainfed systems (70 and 100% for cereals and legumes, respectively), while WP gains in irrigated rice systems were more modest, approximately 15% (see also Bossio *et al*., Chapter 2, this volume). These results were in agreement with other studies (Kijne *et al*., 2003). Variability was high due to the wide variety of practices represented in the dataset, but the data indicate that gains in WP are possible through the adoption of sustainable farming technologies over a variety of crops and farming systems. These results, and others (cf. Rockström and Falkenmark, 2000), demonstrate that the greatest opportunity for improvement in water productivity is in rainfed agriculture, where a small amount of additional water can go a long way (Rockström *et al*., 2007). Better farm management, including supplemental irrigation and soil management, can significantly reduce uncertainty, and thus avoid the chronic low productivity and crop failure that are characteristic of many rainfed systems.

### Pesticide use

International awareness of the negative health impacts of pesticide use in agriculture is growing. Recent research linking pesticide exposure to Parkinson's disease (Coghlan, 2005) and reduced pesticide use to the improved health of Chinese farmers (Huang *et al*., 2005) is part of the rising tide of concern over agricultural chemical use and its impacts on society. Analysis of 62 integrated pest management (IPM) initiative bright spots cases suggests that, in many cases, pesticide use can be reduced while achieving higher yields. In ten cases (16%), both pesticide use and yields increased. These were mainly in zero-tillage and conservation agriculture systems, where reduced tillage creates benefits for soil health and reduces off-site pollution and flooding costs. These systems usually require increased herbicide use for weed control (Petersen *et al*., 2000), though there are examples of organic zero-tillage systems (Delgado *et al*., 1999). The five cases in which both pesticide use and yields declined showed a 4% decline in yields with a 93% fall in pesticide use. In the majority of cases (47 of 65), pesticide use declined by 71% and yields increased by 45%. The reasons for IPM-induced yield increases are complex. It is likely that farmers who receive good-quality field training will not only improve their pest management skills but also become more efficient in other agronomic and ecological management practices. They are also likely to invest cash saved from reduced pesticide applications in other inputs, such as higher-quality seeds and fertilizers. This analysis indicates considerable potential for lowering environmental costs by implementing IPM practices in developing-country agricultural systems (Pretty *et al*., 2006).

### Carbon sequestration

The 1860s witnessed the start of major global agricultural expansion. Since then, losses in soil carbon stocks due to land-use change are estimated to be between 22 and 39 Pg of carbon, representing 25–29% of all carbon released due to land-use change (Lal *et al*., 1997). This process continues, and in 1990, the annual net release of C from agricultural activities was estimated to be 1.7$\pm$ 0.8 Pg/year, or about 25% of fossil fuel emissions (Malhi *et al*., 2002).

One of the measures farmers can take is to increase carbon sinks in soil organic matter and above-ground biomass. Pretty *et al*. (2006) calculated the potential annual contributions being made to carbon sink increases in soils and trees in 286 bright spot projects, using an established methodology (Pretty *et al*., 2002). The analysis estimated what sustainable farming practices can do to increase quantities of soil and above-ground carbon, and thus did not take account of existing stocks of carbon. The projects potentially sequestered 11.4 mt C/year on 37 million ha. Assuming that 25% of the areas under the different global farming system categories adopted these same sustainability initiatives, this would result in the sequestration of 100 mt C/year. Such gains could partly offset current trends in carbon loss due to agricultural activities and may offer new opportunities for income generation to farmers under carbon trading schemes.

## Ecosystem Benefits of Bright Spot Case Studies

There are a wide variety of possible ecosystem benefits that can be gained through resource-conserving agricultural techniques. We focus here on a list of eight, which includes the three that were quantitatively analysed above and others that, at this point, can only be qualitatively assessed in the bright spots cases: soil quality, water productivity, low external inputs, integrated pest management, water cycling, biodiversity, carbon sequestration and social capital. It is unconventional to describe social capital as an ecosystem benefit. Social capital, however, typically forms as a consequence of particular types of resource use. Hence, an 'agricultural community' would not be discernible were it not for their exploitation of agroecosystem benefits.

As Gordon and Enfors (Chapter 3, this volume) point out, the interaction between societies and the resources on which they rely is two-way, and much recent ecological literature treats human communities as integral to our understanding of contemporary ecosystem processes (cf. Gunderson and Holling, 2002). In many cases, the type of management required to conserve a resource results in the development of social institutions for this purpose, a development particularly evident in the literature on the community-level management of common property resources (cf. Ostrom, 1990). Social capital is therefore very relevant to enhancing ecosystem benefits, particularly at scales larger than the individual field, and is included here to emphasize this point.

Representative bright spots case studies from Asia, Africa and Latin America presented here were described in detail by participating experts, based on studies conducted in 2003–2004. Aggregate benefits of these cases can be envisioned as increased socio-ecological resilience at community and regional scales. In a summary table (Table 14.1), the benefits are loosely arranged by scale of impact, such that the first are primarily factors contributing to the social–ecological resilience of communities (Gordon and Enfors, Chapter 3, this volume), while others become more important for increasing the resilience of ecosystems at regional scales. It should be noted, however, that increasing field-scale land and water productivity can be a key way in which community-level benefits can be scaled up if they reduce agricultural encroachment into natural ecosystems. This is important for both the terrestrial ecosystems being lost due to the expansion of agricultural land area, and aquatic ecosystems being harmed by the increased use of water for agricultural production. To develop the summary of benefits across case studies (Table 14.1), practices that have been changed, technologies implemented and/or descriptions from case studies are evaluated to determine which ecosystem benefits are likely to have been affected. Increased tree cover, for example, is considered to contribute both to increased biodiversity and to carbon sequestration, depending on initial conditions. Water harvesting that reduces erosion and increases groundwater recharge improves soil quality and water cycling.

**Table 14.1.** Summary of selected ecosystem benefits beyond increased production of food derived in bright spots case studies.

| | Social–ecological resilience | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Community | | | | | | | Landscape |
| | Ecosystem benefit | | | | | | | |
| | Resource-use efficiency ⇑ | | | | | | | |
| | | | Ecological footprint ⇓ | | | | | |
| | | | | Environmental pollution ⇓ | | | | |
| | | | | | Ecosystem services ⇑ | | | |
| Bright spot case study | SQ | WP | LEI | IPM | WC | BD | CS | SC |
| Huang-Huai-Hai, China | ■ | ■ | | | | | | |
| Bright spots, Uzbekistan | ■ | ■ | | | | | | ■ |
| Water harvesting, Ethiopia | | ■ | | | ■ | ■ | | |
| System of rice intensification, global | ■ | ■ | ■ | ■ | | | | |
| Bonganyilli-Dugu-Song, Ghana | ■ | ■ | ■ | | | ■ | | |
| Rio do Campo no-till, Brazil | ■ | ■ | ■ | ■ | | | ■ | ■ |
| Adarsha watershed, India | ■ | ■ | | ■ | ■ | | ■ | ■ |
| Powerguda watershed, India | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Quesungual, Honduras | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Farmer networks, Thailand | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

SQ, soil quality; WP, water productivity; LEI, low external imputs; IPM, integrated pest management; WC, water cycling; BD, biodiversity; CS, carbon sequestration; SC, social capital.

### Ecosystem benefits

Soil quality (SQ) improved: improving land productivity has both local and regional benefits. By improving agricultural output, agricultural livelihoods are not only improved but the need to expand cultivation into new areas to meet growing demands for food and fodder can also be reduced. Preserving remaining natural ecosystems and biodiversity are thus partly dependent on improving soil quality.

Water productivity (WP) increased: similarly, improving water productivity has both local and regional benefits. Agricultural livelihoods can be improved while reducing the need to increase water used in agriculture, thus reducing pressure on ecosystems (Molden, 2007).

Low external inputs (LEI): reduced external inputs and increased local recycling, especially of nutrients, has local benefits for cash-poor farmers by reducing the need for investment. Ecosystem benefits are more regional, by reducing the ecological footprint of agriculture (Pretty, 2002).

Integrated pest management (IPM): water quality and health benefits are achieved when agricultural water pollution is reduced. IPM approaches can achieve this by better targeting and managing chemical inputs, and often reducing the total quantities of chemicals applied. IPM is used here as a generic term, which can include the range from organic, chemical-free agriculture to reduced chemical use, including the control of both insect pests and weeds. All of these have the ability to reduce environmental pollution over more conventional approaches to pest management (Bajwa and Kogan, 2002).

Water cycling (WC) improved: the Millennium Ecosystem Assessment describes water-related supporting and regulating ecosystems services (MEA, 2005), including hydrologic cycle and water partitioning, which are necessary for maintaining ecosystem function. Agricultural practices can have enormous negative impact on these services, which includes the reduction in the ratios of infiltration to runoff and of transpiration to evaporation. The benefits from agricultural practices that help reduce negative impacts on water cycles are important both locally to increase production but also at regional scales, particularly as they affect downstream ecosystems and communities that rely on these ecosystem services (Falkenmark *et al*., 2007).

Biodiversity (BD) increased: agrobiodiversity and wild biodiversity can be improved within agricultural landscapes through a variety of on-farm practices. One way is to actively manage non-farmed land in and around farmed land. This includes wasteland and riparian zones (Bossio *et al*., 2007). Another way is to make greater use of perennials in the farm landscape, to create land-use mosaics, interspersing perennials and small patches of annuals or high-disturbance systems. A mosaic of perennials usually provides more stable plant cover, protecting the soil and increasing infiltration, and increases biodiversity (McNeely and Scherr, 2003).

Carbon sequestration (CS) increased: farming systems can contribute to climate change mitigation in several ways: by increasing the carbon stored in either soils or biomass, by reducing fossil fuel energy use, or by reducing agricultural expansion on to new land. Here, we focus on carbon sequestration as a climate change benefit commonly found in bright spots.

Social capital (SC) increased: building upon and enhancing social capacity is considered a key entry point for improving natural resources management (Pretty, Chapter 12, this volume; Pretty and Smith, 2004), which is particularly important for generating benefits at larger scales that require community management. Bright spots that have been based around significant community effort and social cooperation are considered to have increased social capacity.

## Case Studies

### Huang-Huai-Hai river plain (North China)[2]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

The project 'Improved Water and Soil Management for Sustainable Agriculture in the Huang-Huai-Hai River Plain' has increased wheat and maize yields by approximately 1 t/ha through improved water use and management practices, improving farmers' incomes. The project had an estimated impact on 2000 ha and affected 1000 households. The interventions have increased soil quality and resulted in the more sustainable use of groundwater resources in the area.

In the North China plain, priority for surface water allocation is given to non-agricultural water uses. Thus, irrigation in this area is predominantly based on extraction from groundwater resources. Over time, intensification of irrigated agriculture has contributed to the progressive depletion of groundwater reserves, particularly when rainfall is scarce and recharge is limited. Innovative solutions were therefore required to improve water and soil management practices that would save water, improve soil productivity and conserve groundwater supplies.

The project's objective was to better understand water and soil management problems through an improved knowledge of natural resources, and with that knowledge model the soil–water–plant–atmosphere continuum for a better understanding of processes and the impacts of agricultural practices on them. Models were then used to evaluate crop water requirements and to establish appropriate irrigation-scheduling programmes and practices. The development and implementation of field-evaluation methods for the characterization of the existing surface-irrigation systems and parameterization of surface-irrigation simulation models were also used to design appropriate practices. Study and testing of alternative soil management practices aimed at increasing rainfall infiltration, soil water availability and the soil conditions favouring plant growth and crop yields, and the evaluation of water management alternatives at project scale, were implemented, which could favour the sustainable use of groundwater resources.

#### Bright spots in Uzbekistan, Central Asia[3]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Following the dissolution of the former Soviet Union and the collapse of existing trade arrangements the newly independent states of central Asia have been left with the task of developing their own independent market economies. Significant agricultural reform has occurred, mainly by privatizing (to a certain degree) large collective farms in order to improve agricultural efficiency and the equity of existing production systems. In Uzbekistan, however, these reforms have, in the majority of cases, led to declining productivity and net incomes. A dominant resource problem is secondary salinization. There are, however, instances where privatized farms have been able to perform at levels exceeding the norm. These bright spots, Bukhara shirkat, Ikrom farm and Shermat farm, consistently outperformed other farms in the area. They achieved higher yields (40 and 64% higher cotton and wheat yields, respectively), reduced salinity, increased profits three- to sevenfold and increased farm workers' incomes by 125%.

Individual leadership was the most common key element in the success of these bright spots when compared with nearby farms in Uzbekistan that were not producing well. A variety of strategies were used in each case to improve productivity and resource conditions (Table 14.2). A common strategy amongst these bright spots was their efforts to enhance fertility status and, hence, soil quality through the use of inorganic fertilizers and the implementation of an organic matter conservation policy that resulted in increased levels of surface-horizon soil organic matter. Other striking commonalities amongst all the bright spots were: attention to recommended agronomic practices; the accumulation of farm machinery, ensuring timely agricultural operations; care and maintenance of infrastructure; use of smart financial and non-financial incentives to keep hired workers motivated and productive; honouring commitments made to workers and agencies; effective networking inside and outside the community; and anticipation and advance action for problems likely to reduce farm revenues. It is evident from these bright spots that social capital has been enhanced at the community level.

#### Water harvesting in northern Ethiopia[4]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Runoff water harvesting and micro-dam schemes have yielded various benefits in Ethiopia's Tigray Province, in the mountainous and

**Table 14.2.** Summary of strategies applied to address degradation issues by each of the successful farms.

| Bukhara shirkat | Ikrom farm | Shermat farm |
|---|---|---|
| Regular and scientifically planned leaching of salts, by flushing the furrows during the cotton irrigation season instead of postharvest leaching due to water shortage | Preparing field layouts to suit the major crops | Keeping livestock for accumulation of organic fertilizers and buying additional cow dung from surrounding communities if needed |
| Keeping livestock on the farm for manure application to the fields, directly or through the irrigation waters | Crop rotations and increasing cropping intensity | Fertilizer and manure application through irrigation waters |
| Compost application | Installation, maintenance and repairs to vertical drainage infrastructure in high-water-table fields | Installation and repair of vertical drains to lower groundwater |
| Keeping a balance between chemical and organic fertilizers | Cleaning drainage canals in a timely manner | Timely cleaning and repairs of channels |
| Following appropriate crop rotations so as not to deplete soil fertility | Using appropriate volumes of water for irrigation and leaching | Procurement of machinery to make operations timely, and income generation through renting out these services |
| Intensification of some areas, with nitrogen-fixing crops as a second crop | Reusing drainage water to meet water shortages, as the water availability is 75% of the demand | Weed removal |
| Extending irrigation and drainage infrastructure and repairing pumps and cleaning channelettes | Use of organic fertilizers | Maintaining appropriate cash flow to attract best labour force during peak seasons |
| Deploying mechanized means for large-channel cleaning | Weed control | |
| Frequent but short irrigations | Application of silt from irrigation and drainage channels to crop fields to supplement fertility | |
| | Hiring professional workers to do a quality job at various critical stages of crop growth | |
| | Mechanized agricultural operations | |

drought-prone north. The province is particularly vulnerable to low agricultural production and crop failure. Erratic rainfall means the primary water sources in this area are wells and springs. Increasing urban industry and a growing population mean, however, that demand has outstripped supply, draining groundwater resources that support the wells and springs. People often find themselves needing to travel long distances – up to 15 km – to collect water for drinking and livestock. This work is done primarily by women, adding to their already significant domestic responsibilities.

In response to this water stress, the Ethiopian government embarked on a programme of dam, pond and diversion construction. Improved water levels in wells, including some that had previously been dry, were subsequently observed. Water quality within wells also improved, as indicated by lower levels of dissolved solids. Groundwater levels were replenished in water-harvesting areas, while groundwater levels declined in areas that had not implemented such schemes. Springs, too, benefitted from the water harvesting. In three of the five localities studied, water discharge increased in extant springs to between 10 and 25 l/s (as compared with 0.5–5.0 l/s prior to the scheme's implementation). Springs that had been dry began yielding water again, doubling the number of functioning springs in three localities, Adigudom, Felegwaero and Aba'ala. Spring water quality also improved. It is of note that in the two other localities, Agula and Negash, springs remained dry or dried up.

In general, increased water availability allowed local farmers to water their livestock through drought periods and significantly decreased the workloads involved in carrying water long distances. Water availability also created opportunities for small-scale irrigation during dry periods, resulting in an average doubling of farmers' incomes. There was also an increase in grazing area fed by replenished groundwater resources or by irrigation.

This added greenery also improved the local microclimate, cooling and moistening air and providing spaces for grass growing (usable as livestock feed) around the micro-dams. Dam sites have also been ecologically beneficial by reducing erosion through soil collection, thereby reducing sedimentation and pollution of downstream reservoirs.

With the eradication of forest cover in Tigray, wildlife has been forced to migrate from these areas. This has contributed to the loss and/or reduction of biodiversity in the region. Contrary to this, new species of animals and birds have started to emerge around and within the micro-dams after their construction. Migratory birds now move between the micro-dams, and their waste products are becoming an important source of nutrients in the area.

### The system of rice intensification (SRI)[5]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

The system of rice intensification (SRI) was developed in Madagascar in the late 1980s by Father S.J. Henri de Laulanie, after 20 years of observation and experimentation, working with farmers to develop a low-input strategy for raising the yields and productivity of irrigated lowland rice. The main advantages of SRI include yield increase, reduced number of irrigations or irrigation-hours per irrigation round and per unit area (i.e. increased water productivity), reduced demands for cash inputs, improved seed quality and a higher milling ratio. In addition, SRI has wider benefits because of the reduced use of environmentally damaging inputs, such as herbicides and fertilizers.

SRI can help to overcome soil constraints, as demonstrated in a study of a project near Madagascar's Ranomafana National Park. The project was assisted under an integrated conservation and development project funded by USAID, with SRI extension work carried out by Association Tefy Saina, a Malagasy NGO. The soils of this zone were extremely poor: pH 3.8–5.0, available P 3–4 ppm and low to very low CEC in all horizons. Average rice yields before SRI interventions were in the region of 2 t/ha, which more than doubled following SRI interventions.

In Sri Lanka, analysis has demonstrated that net income benefits as a consequence of SRI increased by about 90–117%, while the per kg cost of production declined by 17–27%. Studies from India and Cambodia show comparable results. In Cambodia, 74.2% increases in net benefits were reported, and in India, 69.5% increases in net benefits were recorded. This is partly because SRI requires much lower seed use (as much as 90% less), meaning that farmers can immediately save as much as 100 kg of rice/ha, a significant benefit.

SRI is beneficial because of associated water savings. With SRI methods, paddy fields are not kept continuously flooded during the vegetative growth phase. Instead, fields are just kept moist, not flooded, with periods of drying of 3–6 days; or fields are flooded for 3–5 days and then drained and kept unflooded for 3–5 days. Overall water savings have been measured at between 40 and 60%.

### Bonganyilli-Dugu-Song Agrodiversity Project, Ghana[6]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

The United Nations University's project on People, Land Management, and Environmental Change (PLEC) sought to identify local land-use techniques to conserve agricultural biodiversity. One Ghanian study site was Bonganyilli-Dugu-Song, in the north of Tolon-Kumbugu District.

The main ethnic group here is the Dagomba people. The area has a population of about 2000 people, 90% of whom are subsistence farmers. Birth rates are high, with more than five children per woman, and education levels low, with 70% of the inhabitants illiterate.

Although the terrain in this region is sometimes marshy and waterlogged during the rainy season, there are no rivers; the only significant local water body is a dug-out that serves some ten communities. Average rainfall is 1000–1300 mm and falls over a 140–190-day rainy season. The vegetation is guinea savannah, consisting of natural grasslands and scattered trees, including shea butter (*Butyrospermum paradoxum*) and 'dawadawa' (*Parkia clapperoniana*). The major threats to vegetation are bush fires set to clear the land for farming and hunting, and grazing by livestock. Although two-thirds of the land area is under cultivation, it is not particularly fertile: soils are sandy or silty, retain low levels of moisture, and contain little in the way of organic matter that might provide nutrients.

Before the arrival of PLEC, the landscape was virtually bare; continuous cultivation had degraded already infertile soils and maize yields were as low as 0.8 t/ha. PLEC encouraged the farmers to carry out soil- and water-conservation practices, including stone bunding, water harvesting, composting and tree planting. Tree nurseries of neem, acacia and mango were planted, to provide fuelwood and for poles/sticks to support yam plants. Farmers were also trained in the preparation of compost from household refuse, crop residue and domestic water; all house compounds in the community now have two to three compost heaps, which are regularly used. The steady application of compost to soils has improved water-holding capacity, and maize yields have increased to 1.5 t/ha, with the result that surrounding communities have adopted similar strategies. By 2003, 10 years after the project's inception, the number of participating villages had grown from three to 24.

### Rio do Campo watershed, no-till for smallholders in Brazil[7]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

The adoption of the no-till conservation system in Brazil can be considered as a bright spot of improved land and water management for tropical soils prone to soil and water losses under conventional land preparation methods. This system has contributed to enhancing the productivity and sustainability of annual cropping systems on both large and small farming units of the southern and Cerrados regions of Brazil. Smallholders adopting the systems have benefitted through labour reductions and increased profits. Widespread no-till adoption in Brazil is associated with strong participation by farmers in the development and implementation of the system, and to policies and incentives to improve environmental land and water quality at the watershed level.

No-till, while reducing soil losses and increasing carbon sequestration, can often increase water contamination due to increased herbicide and pesticide use. The Rio do Campo case illustrates the positive linkages that were developed between farmers, local goverment and the private sector to improve public health, control soil erosion and reduce water pollution at the watershed level. Collective action to improve environmental outcomes included the construction of a separate water supply for chemical sprayers, the implementation of biological control programmes to reduce pesticide use, and development of riparian zones to counteract contamination problems.

The management of Rio do Campo watershed has been recognized as a 'useful' watershed management model in Brazil. It has produced the following outputs: (i) installation of farm demonstration units to continually update producers and extension personnel on new technologies; (ii) a 12% increase in water productivity over the past 10 years; (iii) reduced flood risk; (iv) a steady and reliable water supply to the city of Campo Mourão, Paraná; (v) reduced water turbidity, from 286 to 33 NTU over 12 years; (vi) the expansion of no-till activities in the watershed; (vii) the expansion of the area under agriculture (16% for soybeans and 63% for maize); and (viii) a 7% increase in the catchment's forested area.

Although adequate policies and economic incentives accelerated the adoption of no-till systems at the landscape level, the system itself was initially tested and implemented by farmers almost independently of governmental initiatives. The greatest asset in the process of change was the local capacity and knowledge of local people.

### Adarsha watershed in Kothapally, India[8]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

A new science-based, farmer-participatory consortium model for the efficient management of natural resources, with the objective of improving the livelihoods of the poor, was tested/implemented in Adarsha watershed, Kothapally, India. The salient impacts of the model's implementation were reductions in runoff and soil loss, improvements in groundwater levels due to additional groundwater recharge, reductions in pesticide usage, improved land cover, increased productivity, and higher/better returns to farmers. Ecosystem benefits included improved water productivity and water cycling, reduced soil losses, the improved use of agricultural chemicals with IPM, increased local and organic sources of nutrients, and greatly increased social capital as a result of a farmer-centred and community-focused approach to development.

Adarsha watershed is in a drought-prone region of India, characterized by low and erratic rainfall, low rainwater-use efficiency, high soil erosion, inherently low-fertility soils and subsistence agriculture. The farmers are poor, and their ability to take risks and invest the necessary inputs for optimizing production is low. A few resourceful farmers exploit groundwater for food crops. Watershed programmes in the region have tended to focus on natural resource-conservation interventions, such as soil and rainwater conservation and, to some extent, afforestation on government forestlands. The success of these programmes has been disappointing, and it is now understood that sufficient emphasis and efforts were not targeted to build up the interest of communities. In addition, issues of gender equity were inadequately addressed. Natural resource management progress had focused mainly on the development of water-storage structures.

In Adarsha watershed, a farmer-participatory consortium model for integrated watershed management was used, which is holistic and participatory, and based on diversified livelihood opportunities that catered to the needs of the socially marginalized and landless, along with dryland farmers. It incorporated both community initiatives and interventions addressing the needs of individual farmers. Strategies implemented in the watershed included on-farm soil- and water-conservation measures (broad-bed and furrow, contour planting, fertilizers, weeding, field bunding, and *Gliricidia* planting on bunds for N-rich organic matter inputs and bund stabilization), community-based interventions in common resources (water-storage and gully-control structures), wasteland development and tree plantation, integrated pest management, integrated nutrient management and in situ generation of N-rich green manures, and the production of biopesticides (HNPV) and biofertilizers through vermicomposting, undertaken by self-help groups as a micro-enterprise.

Measured benefits include a 30–45% reduction in runoff and soil loss; improved groundwater levels and a 200 ha irrigation expansion in the post-monsoon season and 100 ha in the dry-season crops, mostly vegetables; improved land cover and vegetation; and increased productivity and incomes. Efforts are now underway to replicate this approach in other areas of India, Thailand and Vietnam. It is thought that the development of local self-help groups and other institutions as the starting point for diversified development will enable these initiatives to be sustained as these groups shift from implementation to sustained maintenance of community structures and small enterprises.

### The making of the new Powerguda, India[9]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Powerguda is in the semi-arid zone in India's Andhra Pradesh state, and suffers from low and variable rainfall, poor soils, high financial risk, and poor physical and social infrastructure. The village comprised indigenous people, who lived in poverty. Owing to low agricultural productivity, people migrated to nearby towns in search of work. Widespread alcoholism compounded social problems in the village. The success of the Powerguda transformation is attributed to a judicious mix of community empowerment, new technologies and institutional linkages to address rural poverty and ecosystem degradation. A key to their institutional success was the central role of women's self-help groups (SHGs). In Powerguda, these groups now go beyond thrift and mobilizing savings (which are a common role of SHGs in the region), to provide key services, such as tree nurseries and the management of watershed structure development, which were previously the responsibility of government agencies.

In October 2003, Powerguda became an environmental pioneer when it sold the equivalent of 147 t of verified carbon dioxide emissions reduction to the World Bank. The emission reduction was based on the substitution of pongamia oil for petroleum diesel over 10 years. Other successes included the development of watershed structures that have helped to recharge aquifers and raise the water table, contour trenches and planting over 40,000 trees to serve as vegetative barriers, which have helped to minimize soil erosion. Twenty per cent of rainwater runoff is now stored in check-dams, gully structures, minor irrigation tanks and diversion drains. Changes in cropping patterns have accompanied watershed management. The shift from cotton, which required large external inputs and depleted the soil, to soybeans has reduced external inputs and improved soil quality. Farmers are experimenting with local organic nutrient sources to replace inorganic fertilizers. IPM has been adopted. Household incomes increased by 77% over a 3-year period, with 95% of this increase coming from increased agricultural production on existing farmland, with no increase in cropped area.

In addition, people's knowledge of the natural environment has increased substantially by participating in watershed activities, protecting local forest and planting pongamia trees (Table 14.3). Soil-erosion prevention, moisture conservation, water replenishment in wells, climate change mitigation and medicinal plant preservation are some of the environmental services known to the people of Powerguda.

### Quesungual slash and mulch agroforestry system[10]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

The Quesungual Slash and Mulch Agroforestry System (QSMAS), as practised on the sub-humid hillsides of Honduras, can reverse land and water degradation, improve smallholder farmers' livelihoods and eliminate the environmental damage caused by burning and soil erosion under traditional slash and burn practices. The extension of QSMAS through community-based learning processes has increased the capacity of local communities to manage land and water resources sustainably. The QSMAS system has also shown a high degree of resilience to extreme weather events such as the El Niño drought of 1997 and Hurricane Mitch in 1998. This has been attributed to the permanent cover, which protects the soil from raindrop impact and crust formation and increases water-holding capacity while minimizing surface evaporation. In addition, surface residues favour nutrient recycling, improve soil fertility and result in higher carbon storage in soils.

Agriculture in Honduras is characterized by its hills. Covering 80% of the country's area, these landscapes – vulnerable to water runoff, erosion, drought, floods and hurricanes – are where 75% of Honduras' annual crops, mainly maize and beans, and 67% of its perennial crops, mainly coffee, are grown. They also provide a home to nearly four million people;

**Table 14.3.** Awareness of environmental services in Powerguda (source: D'Silva *et al.*, 2004).

| Environmental factors | Public awareness |
|---|---|
| Hydrological functions | Substantial awareness as watershed management has increased the water table in village wells |
| Soil erosion | Some knowledge because of contour bunding along slopes to minimize soil erosion |
| Medicinal properties of trees | Most people are aware of the medicinal uses of some trees, in particular, *Pongamia pinnata* and neem |
| Biodiversity | Limited knowledge of the importance of multiple tree species |
| Reducing chemical fertilizer and pesticide use | Public awareness increasing with the introduction of integrated pest management. Pongamia oilcake is replacing chemical fertilizers |
| Mitigating climate change | Increase awareness of carbon sequestration and carbon emission reduction since the sale of carbon to the World Bank |

nearly the entire rural population lives below the one dollar a day poverty line.

Lempira department was a poor district in an already poverty-stricken region. It suffered from water deficits during the dry season and had poor and acidic soils, containing little organic matter or phosphorus. Crops grown here – primarily maize, millet and beans, with some livestock and a little fruit, root vegetables and pigs/chickens in house gardens – usually fell short of consumption needs. Slash and burn agricultural practices were common, with 10–15-year fallow periods in between. By the 1970s, population pressure and the deleterious effects of continued slashing and burning was degrading the land, depressing yields and maintaining a poverty cycle. In response, improved varieties and the use of fertilizers and herbicides were introduced to the region. Reliance on chemical fertilizers and herbicides increased from 25% to almost 80%, but there was little adoption by small farmers, who had limited capacity to purchase seed and fertilizer. In the early 1990s an anti-poverty development programme in Lempira discovered a small group of farmers practising QSMAS rather than the common slash and burn. Since that time, the benefits of the system have been validated with the active participation of farmers, and collective action and co-learning approaches to promote adoption have resulted in QSMAS uptake by more than 6000 farming households. Adoption was also supported by local government policy that banned burning. The impacts and beneficiaries of adoption of QSMAS were summarized in 2002 (Table 14.4).

### Farmer networks in north-east Thailand[11]

| SQ | WP | LEI | IPM | WC | BD | CS | SC |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Land degradation, resultant declining yields and concerns over the health impacts of agricultural practices have led to the formation of self-help farmer networks in north-east Thailand. Farmers in this region have experienced declining food resource availability at the village level, and food insecurity, primarily due to the degradation of soils and ecosystems, so severe that they could no longer sustain productivity without significant, and unsustainable, levels of external input application. Consequently, outmigration to cities increased and, in a negative feedback loop, reduced on-farm productivity further and also had negative impacts on the area's natural resources and family structures. Within these fast-growing networks, farmers discuss their concerns, plan options and solutions and move forward to create change. Three networks exemplify the positive social and environmental outcomes.

The Organic Farming Network is dedicated to organic rice production, and also promotes activities for the protection of forest resources, water and natural ecosystem rehabilitation. This network began with a group of farmers to address concerns over human health in their communities. Through a process of self-analysis and discussion of possible options to improve their livelihoods, the group decided that growing organic rice would be a viable option in addressing their problems. This has resulted in the reduction or cessation of chemical applications to production systems and the conservation of organic materials and production of green manure for soil improvement. The network includes more than 2000 households in several provinces, and their practices have resulted in the conservation of natural habitat and a gradual improvement in basic resources. Soils are more productive and higher water-use efficiencies have been achieved. After early criticism and opposition from the government, which perceived organic rice production to be a threat to overall rice production in the kingdom, the concept of organic farming is now widely integrated into provincial development plans.

The Integrated Farming Systems Network identified their biggest natural resource constraint as access to sufficient water resources during the long dry season. They had observed that, during the rice-growing season, there was some runoff from their fields, and they set out to capture this. In the first year, they dug shallow ponds to harvest rainwater. This allowed them to store enough water to start vegetable production and to grow fruit trees on the same plots. By repeating these water-harvesting activities for the second and third years, the group was able to grow sufficient food for household consumption and also to create a

**Table 14.4.** Impacts and beneficiaries of QSMAS in the Lempira region (source: Cherret and Welchez, 2002a,b,c,d; FAO-Lempira Project, 2002).

| Management components | Impacts | Beneficiaries |
|---|---|---|
| *Sustainable management of forest resources* | | |
| No burning | 6000 ha managed without burning | 12,000 small farmers |
| Integrated pest management | 1137 ha saved from the attack of *Dentroctonus frontalis*<br>Economic losses reduced by half | 137 families in 17 communities |
| Improved utilization of forest resources | 1118 ha under improved management<br>Local communities trained in the use of timber products | Four communities organized to manage forest resources<br>40 wood artisans producing timber products more efficiently |
| Improved knowledge of forest resources | Potential utilization of two native species documented | Wood artisans and small timber enterprises started using these two species to build furniture |
| *Improved water quality and availability* | | |
| Participatory watershed management | Methodologies for the integrated use of water resources disseminated among upstream and downstream users | 1150 producers benefited with irrigation projects on 43 ha |
| Improved soil water storage capacity | Water-holding capacity increased from 8 to 29% | Small farmers practising QSMAS |
| *Increased soil fertility and agricultural productivity* | | |
| Increase soil cover at the farm and landscape level | Averaged soil cover biomass increased by 7 t/ha<br>Length of the drought-stress period reduced by 38 days | Small farmers adopting QSMAS |
| Soil, water and nutrient losses reduced | Soil losses reduced from 300 to 16 t/ha<br>US$360/ha saved by reduced nutrient losses from erosion and runoff | Upstream farmers and downstream water users |
| Improved soil organic matter | SOM increased from 1 to 3 % | Small farmers after using QSMAS for more than 4 years |
| Increased crop production | Maize yields increased from 1.2 to 2.4 t/ha<br>Bean yields increased from 300 to 800 kg/ha<br>Seven soil management technologies adopted | 6000 farmers located in different sites in the landscape |
| Agricultural outputs diversified | 11 new crops adopted | Small farmers |
| Dissemination of improved soil and water management technologies | Seven farmer schools<br>Reduced crop losses due to drought | 400 community leaders trained to help farmers |
| Improved livestock production | Five new grass species validated and disseminated<br>Two new feeding options for the dry season<br>Increased milk production during the dry season<br>Calf mortality during the dry season reduced by 40% because of improved feeding options | Small livestock producers<br>Small milk-processing enterprises established in three municipalities<br>Ten women's groups participating actively in the production of cheese |
| *Local capacity to revert land degradation strengthened* | | |
| Local governments able to identify their own priorities and develop alternative solutions | 27 development committees established | 27 municipalities develop action plans and prepare proposals to support execution |
| Increased economical value to improved land-use systems | A system to assign economic value to different land-use systems developed | Two municipalities using QSMAS receive higher land price (La Campa and Tomalá) |

**Table 14.4.** – *continued.*

| Management components | Impacts | Beneficiaries |
|---|---|---|
| Individual capacity to drive change | Improved assistance to farmers to validate QSMAS | 670 communal leaders formed (43% women) |
| Improved financial availability | 105 communal Banks<br>Three cooperatives<br>Three small milk-processing enterprises | 962 members benefitted (55% male and 45% women) |
| Entrepreneurial capacity | Several financial systems developed | 185 direct jobs and 254 indirect |
| Improve capacity to develop projects | 648 development projects | 20 municipalities |
| *Education oriented to test and introduce innovations in NRM* | | |
| Teachers with better NRM knowledge | Five communal technical institutes | 867 students learn and apply new knowledge in 2001 |
| Rural education including innovations to improve land and water use | Four communal technical institutes incorporate NRM principles in their curricula | |
| New education materials available | Four manuals | Available for students in all five ICT |

surplus for sale to nearby households and villages.

Once water supplies were secured, these integrated farming systems were intensively developed. These activities included the conservation of agricultural organic waste, such as rice straw for making compost, and the adoption of extensive green manure systems for soil improvement. Poultry, pig and cattle raisings have also contributed to development of organic soil amendments. Apart from water supply improvements, soil resources have gradually improved for both upland and lowland farming systems. The primary objective of households is to attain food sufficiency. Thereafter, income generation at the household level becomes the next goal. The concept of food sufficiency has also promoted a caring and sharing culture in rural communities. From a virtually drought-prone area with limited potential, the area has been transformed into productive and sustainable farming systems with low external inputs, which most farmers are able to follow. Currently, there are more than 3000 households that are active members of the network in the Khon Kaen, Nakorn Ratchasima and Chaiyapum provinces.

The Agroforestry Network began modestly in 1989, when a group of 15 farmers' households from Dongbang village, of the Wangyai district in Khon Kaen province, was approached by a non-governmental organization (World Vision). The network focused on food security at the household level by promoting the establishment of indigenous vegetables and native fruit trees. Over the years, the number of plant species established around homes has gradually increased to cover a wide range of food and timber species, as well as species for environmental protection. The positive impacts emerging from the Agroforestry Network include enhanced food security at the household level, increased fuelwood security and social security, and the revival of local wisdom with respect to agricultural production and development. In addition, there has been a positive impact on the rehabilitation of agricultural resources in the area.

Owing to the diversity of tree species that have been established, there has been a high degree of soil fertility improvement through ecosystem regeneration. In addition, there has been a significant increase in water-use efficiency associated with the establishment of the agroforestry system. With the productivity improvements that have been achieved for both food and forest products, it is considered that this approach has enhanced the sustainable use of soil and water resources to the benefit of the environment and network household members. The success of the group has stimulated awareness in nearby villagers, both within the same village and in surrounding villages. This awareness initiated the formation of an agroforestry farmers' network in Bua village, of Kudbak district in Sakon Nakon province, north-east Thailand. The site is currently the network centre of more than 30,000 household agroforestry network members. Their activities currently range across promoting tree planting, food processing, education development and support at community levels. In addition, the networking is promoting expansion to other areas, and to date the number of members has doubled annually.

## Discussion and Conclusions

The ecosystem benefits of 'bright' spots were quantified in three areas: water productivity, reduced pesticide use and carbon sequestration (Pretty *et al*., 2006). Benefits in all these areas are felt on a local level, by the farm family and farming community. Even carbon sequestration, most often thought of in terms of its global environmental benefits of mitigating rising atmospheric $CO_2$ concentrations, has very real local benefits. Restoring carbon stocks in degraded soils provides sustained land productivity improvement by both increasing the nutrient and water-holding capacities of soils and increasing resilience. In particular, resilience to extreme climate events due to climate change increases. The Quesungual slash and mulch system now being widely adopted in Honduras is already appreciated by farmers for improving the resilience of their agriculture to the extreme climatic events that are common in the region.

While it is not possible with currently available information on the 'bright spots' to quantify the extent or potential of the other benefits, the qualitative analysis of case studies gives weight to two important ideas. First, it is notable when comparing across the case studies (Table 14.1) that innovations which address primarily the individual farm scale, such as improved land and water management in Juang-Huai-Hai in China or in Uzbekistan, tend to result in a smaller range of ecosystem benefits than do those that tackle landscape management with community involvement, such as in farmer networks in Thailand or Quesungual slash and mulch in Honduras. Intermediate-range impacts were achieved in a system where interventions were focused on the farm scale but within larger-scale political processes, such as the Rio do Campo watershed in Brazil. In this case, no-till interventions attractive to farmers owing to reduced labour and increased soil quality and productivity also became a benefit for the landscape and downstream communities when government regulations were designed to improve environmental outcomes.

Second, it is also evident from the comparison of case studies that 'bright spots' with the greater range of diversity in technology innovations resulted in a greater range of ecosystem benefits. In India's Powerguda watershed, for example, innovations included a wide variety of soil- and water-conservation techniques at farm and community scale, tree plantations, IPM and biofertilizer production, resulting in a wide variety of benefits above and beyond increased agricultural productivity. In Ethiopia, emphasis on a single intervention – surface water harvesting structures – resulted in gains in water productivity, water cycling and biodiversity, a more limited set of benefits.

Social processes engaged in the various 'bright spots' vary considerably, from limited community engagement in SRI and China for example, to widespread community involvement through farmer groups in Thailand. In India, the goal was to engage disadvantaged groups in particular in income-generating activities that sustained good resource management. The validity, however, of including social capital as an ecosystem benefit, and successful models for achieving improved resource management through social processes, is not clear, and further research on this aspect is required. In the case of Rio do Campo watershed in Brazil, regulatory policies appeared to be the important enabling condition for communities to engage in activities that resulted in off-site benefits.

One important limitation of this qualitative analysis is that, in most cases, it is still not possible to understand the role of these bright spots at basin or larger scales, as called for in Gichuki and Molden (Chapter 10, this volume). To do so, the possible off-site benefits would have to be quantified in a way that allows an understanding of off-site impacts, both positive and negative. For carbon sequestration, off-site benefits are already an accepted reality, and integrated into schemes for compensatory payments (although currently limited), such as in the case of Powerguda (see also Trabucco *et* *al.*, Chapter 6, this volume for a discussion on engaging small farmers in carbon offset payments and their role in reversing land degradation). For off-site, water-related ecosystem services, credited in several of these cases, understanding and analysis is inadequate for assessing off-site and basin-scale impacts. Analysis to support schemes in which providing off-site, water-related benefits are used as an incentive for improved management is a priority for further research.

Resource-conserving agricultural techniques in general reduce external inputs, and usually increase internal cycling and reliance on organic sources of nutrients, thus in many cases reducing the ecological footprint of the agricultural activity as compared with conventional approaches. Thus it is not surprising that the described benefits exist in bright spots cases. It is often assumed, however, that this reduced footprint necessarily requires a trade-off in terms of reduced yield. While this trade-off may sometimes be real, particularly for high-input/high-producing systems in developed countries, the bright spots database demonstrates that this trade-off is often not found in developing countries. This is in agreement with another study by Badgley *et al.* (2007), a large survey and modelling exercise that compared organic, conventional and low-input food production. In that study, the average yield ratio (organic:non-organic) was slightly less than 1.0 in developed country examples but greater than 1.0 for developing countries (Badgley *et al.*, 2007). This study and bright spots cases in resource-conserving agriculture demonstrate the potential to find win–win situations with respect to increasing agricultural productivity and improving environmental outcomes in developing countries. These opportunities are greatest in agricultural systems currently generating yields at far below ecological potential, often because soils are degraded. In these situations resource-conserving agriculture often introduces an increase in nutrient inputs and/or improved management of water and other resources, compared with the initial condition.

An additional benefit is that these methods can be attractive to the poor, because they often substitute labour for external inputs and reduce the need for cash outlays, thus improving net benefits to smallholder farmers who do not have access to income-earning opportunities beyond farm labour. Analysis of the System of Rice Intensification, for example, showed it appealed to, and was adopted primarily by, poor farmers (Namara *et al.*, 2003). Net benefits compared with the conventional system increased by about 90–117% in Sri Lanka (Namara *et al.*, 2003), 74.2% in Cambodia (Anthofer, 2004) and 69.5% in India (Singh and Talati, 2005), because input costs were low. Increased labour is not required for all resource-conserving agricultural techniques, however. In contrast, no-till systems combined with integrated pest management, as adopted by 167 smallholder farmer households in a Brazilian watershed (Ralisch *et al.*, 2004), were attractive to smallholder farmers because they reduced farm labour while at the same time building soil quality and increasing returns.

Climate change is expected to increase the incidence of extreme climate events; thus increasing resilience of the population and/or the ecosystem to extreme events is an important adaptation to climate change. Increasing soil quality and water-holding capacity, as was achieved in the bright spots cases, is one way to increase the resilience of farming systems, as is maintaining neighbouring ecosystems that provide insurance for many poor communities against such extreme events (Enfors and Gordon, 2007). It is also believed that taking the right steps now in agricultural water management, including increasing water productivity, will significantly reduce poor people's vulnerability to climate change by reducing water-related risks and creating buffers against unforeseen changes in rainfall and water availability (de Fraiture *et al.*, 2007).

On a larger scale, environmental benefit is also achieved when increased food production can be achieved through intensification rather than extensification, reducing the need to press new lands into service for agriculture, and preserving existing forests and biodiversity. This study of resource-conserving agriculture provides optimism that the required intensification can be achieved in many areas in developing countries. This concurs with Badgley *et al.*'s (2007) findings that organic agricultural practices could produce enough food to feed the current, and even a larger, population without increasing the agricultural land base.

## Notes

[1] A bright spots database of success stories (Noble *et al.*, 2006) was recently compiled from data sets from the SAFE World database at the University of Essex (Pretty *et al.*, 2000; Pretty and Hine, 2004); available are recently published success stories and new survey information (Noble *et al.*, 2006). The database comprises 286 cases from 57 countries. The impact of these bright spots has influenced 12.6 million households, covering an area of 36.9 million ha.

[2] Submitted by Professor Di Xu.

[3] Summarized from Noble *et al.*, 2005.

[4] Case study submitted by B. Mintesinot, W. Kifle and T. Leulseged (Mekelle University, Ethiopia), 'Fighting famine and poverty through water harvesting in Northern Ethiopia'. Summarized by Kaitlin Mara.

[5] Summarized from Namara *et al.*, 2003, with a contribution from Norman Uphoff, Director, Cornell International Institute for Food, Agriculture and Development (CIIFAD).

[6] Case study from Gyasi *et al.*, 2002, summarized by Olufunke Cofie and edited by Kaitlin Mara.

[7] Summarized from a submission by R. Ralisch and O.J.G. Abi-Saab (Universidade Estadual de Londrina, Parana, Brazil) and M. Ayarza (International Center for Tropical Agriculture – CIAT – Honduras), 'Drivers effecting development and sustainability of no-till systems for smallholders at the watershed level in Brazil'.

[8] Summarized from a case study submitted by T.K. Sreedevi, B. Shiferaw and S.P. Wani (International Crops Research Institute for the Semi-arid Tropics – ICRISAT – India), 'Adarsha watershed in Kothapally: understanding the drivers of higher impact'.

[9] Summarized from D'Silva *et al.*, 2004.

[10] Summarized from a case study by M. Angel Ayarza (CIAT – Central America, Tegucigalpa, Honduras) and L. Alvarez Welchez (FAO, Project Lempira Sur, Honduras), 'Drivers effecting the development and sustainability of the Quesungual Slash and Mulch Agroforestry System (QSMAS) on hillsides of Honduras'.

[11] Case studies submitted by Sawaeng Ruaysoongnern, Khon Kaen University, Thailand.

## References


Anthofer, J. (2004) The potential of the System of Rice Intensification (SRI) for poverty reduction in Cambodia. *Deutscher Tropentag* 5–7, 187.

Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M.J., Avilés-Vázquez, K., Andrea Samulon, A. and Perfecto, I. (2007) Can organic agriculture feed the world? *Renewable Agriculture and Food Systems* 22, 86–108.

Bajwa, W.I. and Kogan. M. (2002) Compendium of IPM definitions (CID) – What is IPM and how is it defined in the worldwide literature? IPPC Publication No. 998, Integrated Plant Protection Center (IPPC), Oregon State University, Corvallis, Oregon. http://www.ippc.orst.edu/IPMdefinitions/index.pdf

Bossio, D., Critchley, W., Geheb, K., van Lynden, G. and Mati, B. (2007) Conserving land – protecting water. In: Molden, D. (ed.) Water for Food, *Water for Life: a Comprehensive Assessment of Water Management in Agriculture.* Earthscan, London and International Water Management Institute, Colombo, Sri Lanka, pp. 551–583.

Cherret, I. and Welchez, L.A. (2002a) Socializando la Esperanza: experiencias de organización comunitaria para el manejo del agua y del bosque. Internal Publication. FAO-SAG and Gobierno de Holanda.

Cherret, I. and Welchez, L.A. (2002b) Socializando la Esperanza: Mejoramiento del Hogar y de la producción en la finca. Estudios de casos en Lempira. Internal Publication. FAO-SAG and Gobierno de Holanda.

Cherret, I. and Welchez, L.A. (2002c) Socializando la Esperanza: volviéndonos empresarios. Estudios de casos sobre microempresas rurales y alternativas financieras en Lempira. Internal Publication. FAO-SAG and Gobierno de Holanda.

Cherret, I. and Welchez, L.A. (2002d) Socializando la Esperanza: experiencias de participación ciudadana en el sur de Lempira. Internal Publication. FAO-SAG and Gobierno de Holanda.

Coghlan, A. (2005) Exposure to pesticides can cause Parkinson's. *New Scientist* 2501, 14. www.newscientist.com (accessed 30 May 2005).

de Fraiture, C., Smakhtin, V., Bossio, D., McCornick, P., Hoanh, C.T., Noble, A., Molden, D., Gichuki, F., Giordano, M., Finlayson, M. and Turral, H. (2007) Facing climate change by securing water for food, livelihoods and ecosystem. *Journal of Semi-arid Tropical Agricultural Research* 4 (1), 21p.

Delgado, C., Rosegrant, M., Steinfield, H., Ehui, S. and Courbois, C. (1999) *Livestock to 2020: the Next Food Revolution.* International Food Policy Research Institute, Washington, DC.

Dhillon, K.S. and Dhillon, S.K. (2000) Selenium accumulation by sequentially grown wheat and rice as influenced by gypsum application in a seleniferous soil. *Plant and Soil* 227 (1/2), 243–248.

D'Silva, E., Wani, S.P. and Nagnath, B. (2004) The making of new Powerguda: community empowerment and new technologies transform a problem village in Andhra Pradesh International Crops Research Institute for the Semi-arid Tropics (ICRISAT), Hyderabad, India.

Enfors, E. and Gordon, L.J. (2007) Analyzing resilience in dryland agro-ecosystems: a case study of the Makanya catchment in Tanzania over the past 50 years. *Land Degradation and Development,* 18 (6), 680–696.

Evenson, R.E. and Gollin, D. (2003) Assessing the impact of the green revolution, 1960 to 2000. *Science* 300, 758–762.

Falkenmark, M., Finlayson, M.C. and Gordon, L.J. (2007) Agriculture, water, and ecosystems: avoiding the costs of going too far. In: Molden, D. (ed.) *Water for Food, Water for Life: a Comprehensive Assessment of Water Management in Agriculture.* Earthscan, London and the International Water Management Institute, Colombo, Sri Lanka, pp. 233–277.

FAO-Lempira Project (2002) Informe Terminal Proyecto de Desarrollo Rural del Sur de Lempira, Fase II. Project report, Lempira, Honduras.

Guillette, E.A., Meza, M.M., Aquilar, M.G., Soto, A.D. and Garcia, I.E. (1998) An anthropological approach to the evaluation of preschool children exposed to pesticides in Mexico. *Environmental Health Perspectives* 106 (6), 347–353.

Gunderson, L.H. and Holling, C.S. (eds) (2002) *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press, Washington, DC.

Gyasi, E.A., Asante, F. and Gyasi, Y.A. (2002) Integrated final report of PLEC work in Ghana, August 1992–February 2002. PLEC Publication 2002, People, Land Management, and Environmental Change, Accra, Ghana.

Herbel, M.J., Johnson, T.M., Tanji, K.K., Gao, S. and Bullen, T.D. (2002) Selenium stable isotope ratios in California Agricultural drainage water systems. *Journal of Environmental Quality* 31, 1146–1156.

Hira, C.K., Partal, K. and Dhillon, K. (2004) Dietary selenium intake by men and women in high and low selenium areas of Punjab. *Public Health Nutrition* 7 (1), 39–43.

Hooijer, A., Silvius, M., Wösten, H. and Page, S. (2006) PEAT-$CO_2$, Assessment of $CO_2$ emissions from drained peatlands in SE Asia. Delft Hydraulics Report Q3943 (2006). University of Delft, the Netherlands.

Huang, J., Hu, R., Rozelle, S. and Pray, C. (2005) Insect-resistant GM rice in farmers' fields: assessing productivity and health effects in China. *Science* 308 (5722), 688–690.

Jacks, G., Bhattacharya, P., Chaudhary, V. and Singh, V.P. (2005) Genesis and the control of some high-F groundwaters in India. *Applied Geochemistry* 20 (2), 221–228.

Jaglan, M.S. and Qureshi, M.H. (1996) Irrigation development and its environmental consequences in arid regions in India. *Environmental Management* 20, 323–336.

Kijne, J.W., Barker, R. and Molden, D. (eds) (2003) *Water Productivity in Agriculture: Limits and Opportunities for Improvement*. CAB International, Wallingford, UK.

Krishnamachari, K.A.V.R. (1976) Further observations on the syndrome of endemic genu valgum of South India. *Indian Journal of Medical Research* 64 (2), 284–291.

Lal, R., Kimble, J. and Follett, R. (1997) Land use and soil C pools in terrestrial ecosystems. In: Lal, R., Kimble, J.M., Follett, R.F. and Stewart, B.A. (eds) *Management of Carbon Sequestration in Soil*. Advances in Soil Science. CRC Press, Boca Raton, Florida, pp. 1–10.

Lipton, M. and Longhurst, R. (1989) *New Seeds and Poor People*. John Hopkins University Press, Baltimore, Maryland.

Malhi, Y., Meir, P. and Brown, S. (2002) Forests, carbon and global climate. In: Swingland, I.R. (ed.) *Capturing Carbon and Conserving Biodiversity*. Earthscan Publications Ltd, London, pp. 15–41.

McNeely, J.A. and Scherr, S.J. (2003) *Ecoagriculture: Strategies to Feed the World and Save Biodiversity.* Island Press, Washington, DC and Covelo, London.

MEA (Millennium Ecosystem Assessment) (2005) *Living Beyond Our Means: Natural Assets and Human Well-Being.* Island Press, Washington, DC.

Molden, D. (ed.) (2007) *Water for Food, Water for Life: Comprehensive Assessment on Water in Agriculture*. Earthscan, London and the International Water Management Institute, Colombo, Sri Lanka.

Morris, B.L., Lawrence, A.R.L., Chilton, P.J.C., Adams, B., Calow, R.C. and Klinck, B.A. (2003) Groundwater and its susceptibility to degradation: a global assessment of the problem and options for management. Early Warning and Assessment Report Series, RS. 03–3. United Nations Environment Programme, Nairobi, Kenya.

Namara, R.E., Weligamaghe, P. and Barker, R. (2003) Prospects for adopting system of rice intensification in Sri Lanka: a socioeconomic assessment. IWMI Research Report 75. International Water Management Institute, Colombo, Sri Lanka.

Noble, A., ul Hassan, M. and Kazbekov, J. (2005) 'Bright spots' in Uzbekistan, reversing land and water degradation while improving livelihoods: key developments and sustaining ingredients for transition economies of the former Soviet Union. IWMI Research Report 88. International Water Management Institute, Colombo, Sri Lanka.

Noble, A.D., Bossio, D.A., Penning de Vries, F.W.T., Pretty, J. and Thiyagarajan, T.M. (2006) Intensifying agricultural sustainability: an analysis of impacts and drivers in the development of 'bright spots'. Comprehensive Assessment of Water Management in Agriculture Research Report 13. International Water Management Institute, Colombo, Sri Lanka.

Ostrom, E. (1990) *Governing the Commons: the Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge, UK.

Petersen, P., Tardin, J.M. and Marochi, F. (2000) Participatory development of no-tillage systems without herbicides for family farming. *Environment, Development and Sustainability* 1, 235–252.

Pretty, J. (2002) *Agri-Culture: Reconnecting People, Land and Nature*. Earthscan Publications Ltd, London.

Pretty, J. and Hine, R. (2004) Measuring progress towards agricultural sustainability in developing regions. Report to DFID for project CNTR 02 4047: an analysis of findings from the University of Essex SAFE 2 Project.

Pretty, J.N. and Smith, D. (2004) Social capital in biodiversity conservation and management. *Conservation Biology* 18, 631–638.

Pretty, J., Brett, C., Gee, D., Hine, R., Mason, C.F., Morison, J.I.L., Raven, H., Rayment, M. and van der Bijl, G. (2000) An assessment of the total external costs of UK agriculture. *Agricultural Systems* 65, 113–136.

Pretty, J., Ball, A.S., Xiaoyun, L. and Ravindranath, N.H. (2002) The role of sustainable agriculture and renewable resource management in reducing greenhouse gas emissions and increasing sinks in China and India. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 360, 1741–1761.

Pretty, J., Noble, A., Bossio, D., Dixon, J., Hine, R., Penning de Vries, F.T.W. and Morison, J. (2006) Resource-conserving agriculture increases yields in developing countries. *Environmental Science and Technology* 40 (4), 1114–1119.

Ralisch, R., Ayarza, M. and Abi-Saab, O.J.G. (2004) Drivers effecting development and sustainability of no-till systems for smallholders at the watershed level in Brazil. 'Bright' spots project case study report: www.iwmi.cgiar.org/brightspots

Rockström, J. and Falkenmark, M. (2000) Semiarid crop production from a hydrological perspective – gap between potential and actual yields. *Critical Review of Plant Science* 19 (4), 319–346.

Rockström, J., Hatibu, N., Oweis, T. and Wani, S. (2007) Managing water in rainfed agriculture. In: Molden, D. (ed.) *Water for Food, Water for Life: Comprehensive Assessment on Water in Agriculture*. Earthscan, London and the International Water Management Institute, Colombo, Sri Lanka, pp. 315–352.

Shah, T., Burke, J. and Vilholth, K. (2007) Groundwater: a global assessment of scale and significance. In: Molden, D. (ed.) *Water for Food, Water for Life: a Comprehensive Assessment of Water Management in Agriculture*. Earthscan, London and International Water Management Institute, Colombo, Sri Lanka, pp. 395–423.

Shiva, V. (1991) *The Violence of the Green Revolution: Third World Agriculture, Ecology and Politics*. Vandana Shiva Third World Network and ZED Books, London.

Singh, S.K. and Talati, J. (2005) Impact of the system of rice intensification (SRI) on rice yields: results of a new sample study in Purulia district, India. IWMI-Tata Water Policy Research Highlight No. 47. International Water Management Institute, India Program, Anand, India.

Stocking, M.A. (2003) Tropical soils and food security: the next 50 years. *Science* 302 (5649), 1356–1359.

WRI (World Resources Institute) (2000) *World Resources: 2000–2001: People and Ecosystems. The Fraying Web of Life*. Elsevier Science Limited, Oxford, Oxford, UK.