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BACKGROUND PAPER

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Agroecological Approaches to Agricultural Development

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AGROECOLOGICAL APPROACHES TO AGRICULTURAL DEVELOPMENT[1]

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Key Principles

What, then, do we now understand by agricultural sustainability? Many different expressions have come to be used to imply greater sustainability in some agricultural systems over prevailing ones (both pre-industrial and industrialised). Systems high in sustainability can be taken as those that aim to make the best use of environmental goods and services whilst not damaging these assets. The key principles for sustainability are to:

i. integrate biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, allelopathy, competition, predation and parasitism into food production processes;
ii. minimise the use of those non-renewable inputs that cause harm to the environment or to the health of farmers and consumers;
iii. make productive use of the knowledge and skills of farmers, so improving their self-reliance and substituting human capital for costly external inputs;
iv. make productive use of people's collective capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management.

The idea of agricultural sustainability, though, does not mean ruling out any technologies or practices on ideological grounds. If a technology works to improve productivity for farmers, and does not cause undue harm to the environment, then it is likely to have some sustainability benefits. Agricultural systems emphasising these principles also tend to be multi-functional within landscapes and economies. They jointly produce food and other goods for farmers and markets, but also contribute to a range of valued public goods, such as clean water, wildlife and habitats, carbon sequestration, flood protection, groundwater recharge, landscape amenity value, and leisure/tourism. In this way, sustainability can be seen as both relative and case-dependent, and implies a balance between a range of agricultural and environmental goods and services.

Capital Assets for Agricultural Systems

What makes agriculture unique as an economic sector is that it directly affects many of the very assets on which it relies for success. Agricultural systems at all levels rely on the value of services flowing from the total stock of assets that they influence and control, and five types of asset, natural, social, human, physical and financial capital, are now recognised as being important. Thus sustainable agricultural systems tend to have a positive effect on natural, social and human capital, whilst unsustainable ones feed back to deplete these assets, leaving fewer for future generations.

Agricultural Side-Effects and Externalities

There are surprisingly few data on the environmental and health costs imposed by agriculture on other sectors and interests. Agriculture can negatively affect the environment through overuse of natural resources as inputs or through their use as a sink for pollution. Such effects are called negative externalities because they are usually non-market effects and therefore their costs are not part of market prices. Negative externalities are one of the classic causes of market failure whereby the polluter does not pay the full costs of their actions, and therefore these costs are called external costs.

New data suggest that all types of agricultural systems impose some kinds of costs on the environment. It is, therefore, impossible to draw a boundary between what is and is not sustainable. If the external costs are high and can be reduced by the adoption of new practices and technologies, then this is a move towards sustainability. Agricultural sustainability is thus partly a matter of judgement, which in turn depends on the comparators and baselines chosen. One system may be said to be more sustainable relative to another if its negative externalities are lower. Monetary criteria do, though, only capture some of the values of agricultural systems and the resources upon which they impinge, and so choices may depend on wider questions about the sustainability of farm practices (on farm, in field) and the sustainability of whole landscapes (interactions between agricultural and wild habitats).

Improving Natural Capital for Agroecosystems

Agricultural systems, or agroecosystems, are amended ecosystems that have a variety of different properties. Modern agricultural systems have amended some of these properties to increase productivity. Sustainable agroecosystems, by contrast, have to seek to shift some of these properties towards natural systems without significantly trading off productivity. Modern agroecosystems have, for example, tended towards high through-flow systems, with energy supplied by fossil fuels directed out of the system (either deliberately for harvests or accidentally through side-effects). For a transition towards sustainability, renewable sources of energy need to be maximised, and some energy flows directed to fuel essential internal tropic interactions (e.g. to soil organic matter or to weeds for arable birds) so as to maintain other ecosystem functions.

There are several types of agroecological practices and resource-conserving technologies that can be used to improve the stocks and use of natural capital in and around agroecosystems. These are:

1. *Integrated pest management*, which uses ecosystem resilience and diversity for pest, disease and weed control, and seeks only to use pesticides when other options are ineffective.
2. *Integrated nutrient management*, which seeks both to balance the need to fix nitrogen within farm systems with the need to import inorganic and organic sources of nutrients, and to reduce nutrient losses through erosion control.
3. *Conservation tillage*, which reduces the amount of tillage, sometime to zero, so that soil can be conserved and available moisture used more efficiently.
4. *Agroforestry,* which incorporates multifunctional trees into agricultural systems, and collective management of nearby forest resources.
5. *Aquaculture*, which incorporates fish, shrimps and other aquatic resources into farm systems, such as into irrigated rice fields and fish ponds, and so leads to increases in protein production.
6. *Water harvesting* in dryland areas, which can mean formerly abandoned and degraded lands can be cultivated, and additional crops grown on small patches of irrigated land owing to better rain water retention.
7. *Livestock integration* into farming systems, such as dairy cattle, pigs and poultry, including using zero-grazing cut and carry systems.

It has also been argued that farmers adopting more sustainable agroecosystems are internalising many of the agricultural externalities associated with intensive farming, and so could be compensated for effectively providing environmental goods and services. Providing such compensation or incentives would be likely to increase the adoption of resource conserving technologies. Nonetheless, periods of lower yields seem to be more apparent during conversions of industrialised agroecosystems. There is growing evidence to suggest that most pre-industrial and modernised farming systems in developing countries can make rapid transitions to both sustainable and productive farming.

Effects on Yields

It is in developing countries that some of the most significant progress towards sustainable agroecosystems has been made in the past decade. The largest study comprised the analysis of 286 projects in 57 countries. In all, some 12.6 million farmers on 37 million hectares were engaged in transitions towards agricultural sustainability in these 286 projects. This is just over 3% of the total cultivated area (1.136 M ha) in developing countries. In the 68 randomly re-sampled projects from the original study, there was a 54% increase over the four years in the number of farmers, and 45% in the number of hectares. These resurveyed projects comprised 60% of the farmers and 44% of the hectares in the original sample of 208 projects. For the 360 reliable yield comparisons from 198 projects, the mean relative yield increase was 79% across the very wide variety of systems and crop types.

However, there was a wide spread in results. While 25% of projects reported relative yields > 2.0, (i.e. 100% increase), half of all the projects had yield increases of between 18% and 100%. The geometric mean is a better indicator of the average for such data with a positive skew, but this still shows a 64% increase in yield.

Positive Side-Effects

These sustainable agroecosystems also have positive side-effects, helping to build natural capital, strengthen communities (social capital) and develop human capacities. Examples of positive side-effects recently recorded in various developing countries include:

- *improvements to natural capital*, including increased water retention in soils, improvements in water table (with more drinking water in the dry season), reduced soil erosion combined with improved organic matter in soils, leading to better carbon sequestration, and increased agro-biodiversity;
- *improvements to social capital*, including more and stronger social organisations at local level, new rules and norms for managing collective natural resources, and better connectedness to external policy institutions;
- *improvements to human capital*, including more local capacity to experiment and solve own problems; reduced incidence of malaria in rice-fish zones, increased self-esteem in formerly marginalised groups, increased status of women, better child health and nutrition, especially in dry seasons, and reversed migration and more local employment.

Agriculture is an accumulator of carbon when organic matter is accumulated in the soil, and when above-ground biomass acts either as a permanent sink or is used as an energy source that substitutes for fossil fuels and so avoids carbon emissions. There are three main mechanisms by which positive actions can be taken by farmers by:

A) increasing carbon sinks in soil organic matter and above-ground biomass;
B) avoiding carbon dioxide or other greenhouse gas emissions from farms by reducing direct and indirect energy use;
C) increasing renewable energy production from biomass that either substitutes for consumption of fossil fuels or replacing inefficient burning of fuelwood or crop residues, and so avoids carbon emissions.

The potential annual contributions being made in the 286 projects to carbon sink increases in soils and trees were calculated to be 11.4 Mt C y^{-1} on 37 M ha. The average gain was 0.35 t C ha^{-1} y^{-1}, with an average per household gain of 0.91 t C y^{-1}. These projects also reduced pesticide use and improved water efficiency.

Social Outcomes of Agroecological Approaches

At some locations, agroecological approaches have had a significant impact on labour markets. Some practices result in increased on-farm demand for labour (eg water harvesting in Niger), whilst others actually reduce labour demand (eg zero-tillage in Brazil). Some result in the opening up of whole new seasons for agricultural production, particularly in dryland contexts, through improved harvesting of rainfall, leading to much greater demand for labour. Migration reversals can occur when wage labour opportunities increase as part of the project (eg watershed improvements), when more productive agriculture leads to higher wages and employment, when there are higher returns to agriculture, and when there are overall improvements in village conditions, such as infrastructure and services.

Recent Policy Progress

Three things are now clear from evidence on the recent spread of agroecological approaches:

i. Some technologies and social processes for local scale adoption of more sustainable agricultural practices are increasingly well-tested and established;
ii. The social and institutional conditions for spread are less well-understood, but have been established in several contexts, leading to more rapid spread in the 1990s and early 2000s;
iii. The political conditions for the emergence of supportive policies are least well established, with only a very few examples of real progress.

Most agricultural sustainability improvements seen in the 1990s and early 2000s have arisen despite existing national and institutional policies, rather than because of them. Although almost every country would now say it supports the idea of agricultural sustainability, the evidence points towards only patchy reforms.

Agricultural policies with both sustainability and poverty-reduction aims should adopt a multi-track approach that emphasises seven components:

1. Small farmer development linked to local and domestic markets;
2. Agri-business development – both small businesses and export-led;
3. Agro-processing and value-added activities – to ensure that returns are maximised in-country;
4. Urban agriculture – as many urban people rely on small-scale urban food production that rarely appears in national statistics;
5. Livestock development – to meet local increases in demand for meat (predicted to increase as economies become richer).
6. Consumer demand for more ethical and natural foods (as urban populations become more wealthy);
7. Supermarket and retail sector changes to connect up consumers with local and domestic producers.

1. Introduction

The interest in the sustainability of agricultural and food systems can be traced to environmental concerns that began to appear in the 1950s and 1960s. However, ideas about sustainability date back at least to the oldest surviving writings from China, Greece and Rome[3]. Today, concerns about sustainability centre on the need to develop agricultural technologies and practices that:

i) do not have adverse effects on the environment (partly because the environment is an important asset for farming);
ii) are accessible to and effective for farmers, and lead both to improvements in food productivity and have positive side-effects on environmental goods and services.

Sustainability in agricultural systems incorporates concepts of both resilience (the capacity of systems to buffer shocks and stresses) and persistence (the capacity of systems to continue over long periods), and addresses many wider economic, social and environmental outcomes.

In recent decades, there has been remarkable growth in agricultural production, with increases in food production across the world since the beginning of the 1960s. Since then, aggregate world food production has grown by 145%. In Africa, it rose by 140%, in Latin America by almost 200%, and in Asia by 280%. The greatest increases have been in China, where a five-fold increase occurred, mostly during the 1980s and 1990s. In industrialised countries, production started from a higher base; yet it still doubled in the USA over forty years, and grew by 68% in western Europe[4].

Over the same period, world population has grown from three to six billion. Again, though, per capita agricultural production has outpaced population growth. For each person today, there is an additional 25% more food compared with 1960. These aggregate figures, though, hide important regional differences. In Asia and Latin America, per capita food production increased by 76% and 28% respectively. Africa, though, has fared badly, with food production per person 10% cent lower today than in 1960. China, again, performs best, with a trebling of per capita food production over the same period. These agricultural production gains have lifted millions out of poverty and provided a platform for rural and urban economic growth in many parts of the world.

However, these advances in aggregate productivity have not brought reductions in incidence of hunger for all. In the early 21st century, there are still more than 800 million people hungry and lacking adequate access to food. A third are in East and South-East Asia, another third in South Asia, a quarter in Sub-Saharan Africa, and 5% each in Latin America/Caribbean and in North Africa/Near East. Nonetheless, there has been progress, as incidence of under-nourishment was 960 million in 1970, comprising a third of all people in developing countries at the time.

Despite this progress in food output, it is likely that food-related ill-health will remain widespread for many people. As world population continues to increase, until at least the mid 21st century, so the absolute demand for food will also increase. Increasing incomes will also mean people will have more purchasing power, and this will increase demand for food. But as diets change, so demand for the types of food will also shift, with large numbers of people going through the nutrition transition. In particular, increasing urbanisation means people are more likely to adopt new diets, particularly consuming more meat, fats and refined cereals.

At the same time as these recent changes in agricultural productivity, consumer behaviour over food, and the political economy of farming and food agricultural systems are now recognised to be a significant source of environmental harm[5]. Since the early 1960s, the total agricultural area has expanded by 11% from 4.5 to 5 billion hectares, and arable area from 1.27 to 1.4 billion ha. In industrialised countries, agricultural area has fallen by 3%, but has risen by 21% in developing

[3] Cato, 1979; Hesiod, 1988; Conway, 1997; Li Wenhua, 2001; Pretty, 2002
[4] FAO, 2005
[5] Goodman and Watts, 1997; Tilman, 1999; Pretty *et al*., 2000; MA, 2005

countries. Livestock production has also increased, with a worldwide four fold increase in numbers of chickens, two fold increase in pigs, and 40-50% increases in numbers of cattle, sheep and goats.

During this period, the intensity of production on agricultural lands has also risen substantially. The area under irrigation and number of agricultural machines has grown by about two fold, and the consumption of all fertilizers by four fold (and nitrogen fertilizers by seven fold). The use of pesticides in agriculture has also increased dramatically, and now amounts to some 2.56 billion kg per year. In the early 21st century, the annual value of the global market was US $25 billion, of which some $3 billion of sales was in developing countries[6].

These factors of production have had a direct impact on world food production. There are clear and significant relationships between fertilizer consumption, number of agricultural machines, irrigated area, agricultural land area and arable area with total world food production (comprising all cereals, coarse grains, pulses, roots and tubers, and oil crops). The inefficient use of some of these inputs has, however, led to considerable environmental harm. Increased agricultural area contributes substantially to the loss of habitats, associated biodiversity and their valuable environmental services. Some 30-80% of nitrogen applied to farmland escapes to contaminate water systems and the atmosphere, as well as increasing the incidence of some disease vectors. Irrigation water is often used inefficiently, and causes waterlogging and salinisation, as well as diverts water from other domestic and industrial users, and agricultural machinery has increased the consumption of fossil fuels in food production[7].

Agricultural systems in all parts of the world will have to make improvements. In many, the challenge is to increase food production to solve immediate problems of hunger. In others, the focus will be more on adjustments that maintain food production whilst increasing the flow of environmental goods and services. World population is set to continue to increase for another 40 years to about 2040-2050, and then is likely to stabilise or fall because of changes in fertility patterns. The high fertility projection by the UN Population Division[8] is unlikely to arise, as shifts towards lower fertility are already occurring in many countries worldwide, and so there are very real prospects of world population eventually falling over the one to two centuries after the maximum is reached. This suggests that the agricultural and food challenge is likely to be most acute in the next half century, and thereafter qualitatively change according people's aggregate consumption patterns[9].

Further changes in environments and markets will bring substantial challenges to agricultural systems. The most significant is likely tobe climate change, as changes in temperature and rainfall distribution will cause farmers in most agricultural systems to re-evaluate their crops and livestock. It is also predicted that energy prices will have a substantial impact as markets for biofuels and demand for cereal and oil products changes dramatically. Finally, consumer behaviour will affect whole supply chains, as people increasingly choose food products that are labelled as having come from agricultural systems that can claim there are sustainable.

2. Agricultural Sustainability

2.1 The Development of Ideas about Sustainability

Although farmers throughout history have used a wide range of technologies and practices we would today call sustainable, it is only in recent decades that the concepts associated with sustainability have come into more common use. Concerns began to develop in the 1960s, and were particularly driven by Rachel Carson's book *Silent Spring*[10]. Like other popular and scientific studies at the time, it focused on the environmental harm caused by agriculture.

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6 Pretty (ed), 2005
7 Leach, 1976; Stout, 1998; Victor and Reuben, 2000; Smil, 2001; Pretty *et al*., 2003a; Townsend *et al*., 2003; Giles, 2005 MA, 2005
8 UN, 2005
9 Nestle, 2003; Land and Heasman, 2004
10 Carson R. 1963. *Silent Spring*. Penguin Books, Harmondsworth

In the 1970s, the Club of Rome identified the economic problems that societies would face when environmental resources were overused, depleted or harmed, and pointed towards the need for different types of policies to generate economic growth. In the 1980s, the World Commission on Environment and Development, chaired by Gro Harlem Brundtland, published *Our Common Future*, the first serious attempt to link poverty alleviation to natural resource management and the state of the environment. Sustainable development was defined as *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"*. The concept implied both limits to growth and the idea of different patterns of growth[11].

In 1992, the UN Conference on Environment and Development was held in Rio de Janeiro. The main agreement was Agenda 21, a 41 chapter document setting out priorities and practices in all economic and social sectors, and how these should relate to the environment. Chapter 14 addressed Sustainable Agriculture and Rural Development (SARD). The principles of sustainable forms of agriculture that encouraged minimizing harm to the environment and human health were agreed. However, progress has not been good, as Agenda 21 was not a binding treaty on national governments, and all are free to choose whether they adopt or ignore such principles[12]. There have in recent years been many sectoral successes (eg in irrigation, pest, watershed, catchment and joint forest management[13]) and generally improved national capacity to enforce environmental legislation. But many of these efforts remain somewhat disconnected and not joined-up as envisaged in Agenda 21.

The "Rio Summit" was followed by several important actions that came to affect agriculture:

1. The signing of the Convention on Biodiversity in 1995.
2. The establishment of the UN Global IPM Facility in 1995, which provides international guidance and technical assistance for integrated pest management.
3. The signing of the Stockholm Convention on Persistent Organic Pollutants in 2001, so addressing some problematic pesticides.
4. The ten years after Rio World Summit on Sustainable Development held in Johannesburg.

The concept of agricultural sustainability has grown from an initial focus on environmental aspects to include first economic and then broader social and political dimensions[14].

- *Ecological* – the core concerns are to reduce negative environmental and health externalities, to enhance and use local ecosystem resources, and preserve biodiversity. More recent concerns include broader recognition for positive environmental externalities from agriculture (including carbon capture in soils and flood protection).

- *Economic* – economic perspectives seek to assign value to ecological assets, and also to include a longer time frame in economic analysis. They also highlight subsidies that promote the depletion of resources or unfair competition with other production systems.

- *Social and political* – there are many concerns about the equity of technological change. At the local level, agricultural sustainability is associated with farmer participation, group action and promotion of local institutions, culture and farming communities. At the higher level, the concern is for enabling policies that target poverty reduction.

2.2 Key Principles

What, then, do we now understand by agricultural sustainability? Many different expressions have come to be used to imply greater sustainability in some agricultural systems over prevailing ones

[11] World Commission on Environment and Development, 1987
[12] Pretty and Koohafkan, 2002
[13] Pretty and Ward, 2001
[14] DFID, 2002; Cernea, 1991

(both pre-industrial and industrialised). These include biodynamic, community-based, ecoagriculture, ecological, environmentally-sensitive, extensive, farm-fresh, free-range, low-input, organic, permaculture, sustainable and wise-use[15]. There is continuing and intense debate about whether agricultural systems using some of these terms can qualify as sustainable[16].

Systems high in sustainability can be taken as those that aim to make the best use of environmental goods and services whilst not damaging these assets[17]. The key principles for sustainability are to:

i. integrate biological and ecological processes such as nutrient cycling, nitrogen fixation, soil regeneration, allelopathy, competition, predation and parasitism into food production processes;
ii. minimise the use of those non-renewable inputs that cause harm to the environment or to the health of farmers and consumers;
iii. make productive use of the knowledge and skills of farmers, so improving their self-reliance and substituting human capital for costly external inputs;
iv. make productive use of people's collective capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management.

The idea of agricultural sustainability, though, does not mean ruling out any technologies or practices on ideological grounds. If a technology works to improve productivity for farmers, and does not cause undue harm to the environment, then it is likely to have some sustainability benefits. Agricultural systems emphasising these principles also tend to be multi-functional within landscapes and economies. They jointly produce food and other goods for farmers and markets, but also contribute to a range of valued public goods, such as clean water, wildlife and habitats, carbon sequestration, flood protection, groundwater recharge, landscape amenity value, and leisure/tourism. In this way, sustainability can be seen as both relative and case-dependent, and implies a balance between a range of agricultural and environmental goods and services.

As a more sustainable agriculture seeks to make the best use of nature's goods and services, so technologies and practices must be locally-adapted and fitted to place. These are most likely to emerge from new configurations of social capital, comprising relations of trust embodied in new social organisations, and new horizontal and vertical partnerships between institutions, and human capital comprising leadership, ingenuity, management skills, and capacity to innovate. Agricultural systems with high levels of social and human assets are more able to innovate in the face of uncertainty[18]. This suggests that there likely to be many pathways towards agricultural sustainability, and further implies that no single configuration of technologies, inputs and ecological management is more likely to be widely applicable than another. Agricultural sustainability implies the need to fit these factors to the specific circumstances of different agricultural systems.

A common, though erroneous, assumption about agricultural sustainability is that it implies a net reduction in input use, so making such systems essentially extensive (they require more land to produce the same amount of food). Recent empirical evidence shows that successful agricultural sustainability initiatives and projects arise from shifts in the factors of agricultural production (e.g. from use of fertilizers to nitrogen-fixing legumes; from pesticides to emphasis on natural enemies; from ploughing to zero-tillage). A better concept than extensive is one that centres on intensification of resources – making better use of existing resources (e.g. land, water, biodiversity) and technologies[19]. The critical question centres on the `type of intensification'. Intensification using natural, social and human capital assets, combined with the use of best available technologies and

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[15] Pretty, 1995; Conway, 1997; NRC, 2000; McNeely and Scherr, 2003; Clements and Shrestha, 2004; Cox *et al.*, 2004; Gliessman, 2005, 2008
[16] Balfour, 1943; Lampkin and Padel, 1994; Altieri, 1995; Trewevas, 2001
[17] Altieri, 1995; Pretty, 1995, 1998, 2005; Conway, 1997; Hinchliffe *et al.*, 1999; NRC, 2000; Li Wenhua, 2001; Jackson and Jackson, 2002; Tilman *et al.*, 2002; Uphoff, 2002; McNeely and Scherr, 2003; Swift *et al.*, 2004; Tomich *et al.*, 2004; Gliessman, 2004, 2005; MA, 2005
[18] Chambers *et al.*, 1989; Uphoff, 1998; Bunch and Lopez, 1999; Olsson and Folke, 2001; Pretty and Ward, 2001
[19] Conway and Pretty, 1991; Pretty *et al.*, 2000; Buttel, 2003; Tegtmeier and Duffy, 2004

inputs (best genotypes and best ecological management) that minimise or eliminate harm to the environment, can be termed `sustainable intensification'.

2.3 Capital Assets for Agricultural Systems

What makes agriculture unique as an economic sector is that it directly affects many of the very assets on which it relies for success. Agricultural systems at all levels rely on the value of services flowing from the total stock of assets that they influence and control, and five types of asset, natural, social, human, physical and financial capital, are now recognised as being important. There are, though, some advantages and misgivings with the use of the term capital. On the one hand, capital implies an asset, and assets should be cared for, protected and accumulated over long periods. On the other, capital can imply easy measurability and transferability. Because the value of something can be assigned a monetary value, then it can appear not to matter if it is lost, as the required money could simply be allocated to purchase another asset, or to transfer it from elsewhere. But nature and its wider values is not so easily replaceable as a commodity[20]. Nonetheless, as terms, natural, social and human capital are useful in helping to shape concepts around basic questions such as what is agriculture for, and what system works best. The five capitals are defined in the following ways:

1. *Natural capital* produces environmental goods and services, and is the source of food (both farmed and harvested or caught from the wild), wood and fibre; water supply and regulation; treatment, assimilation and decomposition of wastes; nutrient cycling and fixation; soil formation; biological control of pests; climate regulation; wildlife habitats; storm protection and flood control; carbon sequestration; pollination; and recreation and leisure.

2. *Social capital* yields a flow of mutually beneficial collective action, contributing to the cohesiveness of people in their societies. The social assets comprising social capital include norms, values and attitudes that predispose people to cooperate; relations of trust, reciprocity and obligations; and common rules and sanctions mutually-agreed or handed-down. These are connected and structured in networks and groups.

3. *Human capital* is the total capability residing in individuals, based on their stock of knowledge skills, health and nutrition. It is enhanced by access to services that provide these, such as schools, medical services, and adult training. People's productivity is increased by their capacity to interact with productive technologies and with other people. Leadership and organisational skills are particularly important in making other resources more valuable.

4. *Physical capital* is the store of human-made material resources, and comprises buildings, such as housing and factories, market infrastructure, irrigation works, roads and bridges, tools and tractors, communications, and energy and transportation systems, that make labour more productive.

5. *Financial capital* is more of an accounting concept, as it serves as a facilitating role rather than as a source of productivity in and of itself. It represents accumulated claims on goods and services, built up through financial systems that gather savings and issue credit, such as pensions, remittances, welfare payments, grants and subsidies.

As agricultural systems shape the very assets on which they rely for inputs, a vital feedback loop occurs from outcomes to inputs. Thus sustainable agricultural systems tend to have a positive effect on natural, social and human capital, whilst unsustainable ones feed back to deplete these assets, leaving fewer for future generations. For example, an agricultural system that erodes soil whilst producing food externalises costs that others must bear. But one that sequesters carbon in soils

[20] Coleman, 1988; Ostrom, 1990; Putnam, 1993; Flora and Flora, 1996; Benton, 1998; Uphoff, 1998, 2002; Costanza *et al.*, 1999; Pretty, 2003

through organic matter accumulation helps to mediate climate change. Similarly, a diverse agricultural system that enhances on-farm wildlife for pest control contributes to wider stocks of biodiversity, whilst simplified modernised systems that eliminate wildlife do not. Agricultural systems that offer labour-absorption opportunities, through resource improvements or value-added activities, can boost local economies and help to reverse rural-to-urban migration patterns[21].

Any activities that lead to improvements in these renewable capital assets thus make a contribution towards sustainability. However, agricultural sustainability does not require that all assets are improved at the same time. One agricultural system that contributes more to these capital assets than another can be said to be more sustainable, but there may still be trade offs with one asset increasing as another falls. In practice, though, there are usually strong links between changes in natural, social and human capital, with agricultural systems having many potential effects on all three.

Agriculture is, therefore, fundamentally multifunctional. It jointly produces many unique non-food functions that cannot be produced by other economic sectors so efficiently. Clearly, a key policy challenge, for both industrialised and developing countries, is to find ways to maintain and enhance food production. But a key question is: can this be done whilst seeking both to improve the positive side-effects and to eliminate the negative ones? It will not be easy, as past agricultural development has tended to ignore both the multifunctionality of agriculture and the considerable external costs.

2.4 Agricultural Side-Effects and Externalities

There are surprisingly few data on the environmental and health costs imposed by agriculture on other sectors and interests. Agriculture can negatively affect the environment through overuse of natural resources as inputs or through their use as a sink for pollution. Such effects are called negative externalities because they are usually non-market effects and therefore their costs are not part of market prices. Negative externalities are one of the classic causes of market failure whereby the polluter does not pay the full costs of their actions, and therefore these costs are called external costs[22].

Externalities in the agricultural sector have at least four features: i) their costs are often neglected; ii) they often occur with a time lag; iii) they often damage groups whose interests are not well represented in political or decision-making processes; and iv) the identity of the source of the externality is not always known. For example, farmers generally have few incentives to prevent some pesticides escaping to water-bodies, to the atmosphere and to nearby natural systems as they transfer the full cost of cleaning up the environmental consequences to society at large. In the same way, pesticide manufacturers do not pay the full cost of all their products, as they do not have to pay for any adverse side effects that may occur.

Partly as a result of lack of information, there is little agreement on the economic costs of externalities in agriculture. Some authors suggest that the current system of economic calculations grossly underestimates the current and future value of natural capital[23]. However, such valuation of ecosystem services remains controversial because of methodological and measurement problems and because of the role monetary values have in influencing public opinions and policy decisions.

What has become clear in recent years is that the success of modern agriculture has masked some significant negative externalities, with environmental and health problems documented and recently costed for Ecuador, China, Germany, the Philippines, the UK and the USA[24]. These environmental

[21] Carney, 1998; Dasgupta, 1998; Ellis, 2000; Morison *et al.*, 2005; Pretty *et al.*, 2006
[22] Baumol and Oates, 1988; Pretty *et al.*, 2000, 2003a ; Dobbs and Pretty, 2004
[23] Abramovitz, 1997; Costanza *et al.*, 1997; Daily, 1997; MA, 2005
[24] Pingali and Roger, 1995; Crissman *et al.*, 1998; Waibel *et al.*, 1999; Pretty *et al.*, 2000, 2001, 2003a, 2005; Cuyno *et al.*, 2001; Norse *et al.*, 2001; Buttel, 2003; Tegtmeier and Duffy, 2004; Sherwood *et al.*, 2005

costs begin to change conclusions about which agricultural systems are the most efficient, and suggest that alternatives which reduce externalities should be sought.

Examples of costs in developing countries include in The Philippines, where agricultural systems that do not use pesticides result in greater net social benefits because of the reduction in illnesses among farmers and their families, and the associated treatment costs[25]. In China, the externalities of pesticides used in rice systems cause $1.4 billion of costs per year through health costs to people, and adverse effects on both on- and off-farm biodiversity[26]. In Ecuador, annual mortality in the remote highlands due to pesticides is among the highest reported anywhere in the world at 21 people per 100,000 people, and so the economic benefits of IPM-based systems that eliminate these effects are increasingly beneficial[27]. In the UK, agricultural externalities have been calculated to be some £1.5 billion per year in the late 1990s, a cost that is greater than net farm income[28]. These, though, are exceeded by the environmental costs of transporting food from farm to retail outlet to place of consumption – these `food miles' in the UK result in a further £3.8 billion of environmental costs per year[29].

These data suggest that all types of agricultural systems impose some kinds of costs on the environment. It is, therefore, impossible to draw a boundary between what is and is not sustainable. If the external costs are high and can be reduced by the adoption of new practices and technologies, then this is a move towards sustainability. Agricultural sustainability is thus partly a matter of judgement, which in turn depends on the comparators and baselines chosen. One system may be said to be more sustainable relative to another if its negative externalities are lower. Monetary criteria do, though, only capture some of the values of agricultural systems and the resources upon which they impinge, and so choices may depend on wider questions about the sustainability of farm practices (on farm, in field) and the sustainability of whole landscapes (interactions between agricultural and wild habitats)[30].

3. Improving Natural Capital for Agroecosystems

Agroecological approaches emphasise the potential benefits that arise from making the best use of both genotypes of crops and animals and their agro-ecological management. Agricultural sustainability does not, therefore, mean ruling out any technologies or practices on ideological grounds (e.g. genetically-modified or organic crops) – provided they improve biological and/or economic productivity for farmers, and do not harm the environment[31]. Agricultural sustainability, therefore, emphasises the potential dividends that can come from making the best use of the genotypes of crops and animals and the ecological conditions under which they are grown or raised. Agricultural sustainability suggests a focus on both genotype improvements through the full range of modern biological approaches, as well as improved understanding of the benefits of ecological and agronomic management, manipulation and redesign.

Agricultural systems, or agroecosystems, are amended ecosystems[32] that have a variety of different properties (Table 1). Modern agricultural systems have amended some of these properties to increase productivity. Sustainable agroecosystems, by contrast, have to seek to shift some of these properties towards natural systems without significantly trading off productivity. Modern agroecosystems have, for example, tended towards high through-flow systems, with energy supplied by fossil fuels directed out of the system (either deliberately for harvests or accidentally through side-effects). For a transition towards sustainability, renewable sources of energy need to be maximised, and some energy flows

[25] Rola and Pingali, 1993; Pingali and Roger, 1995; Cuyno *et al*., 2001
[26] Norse *et al*., 2001
[27] Crissman *et al.*, 1998 ; Sherwood *et al*., 2005
[28] Pretty *et al*., 2000, 2001
[29] Pretty *et al*., 2005
[30] Green *et al*., 2005
[31] NRC, 2000; Pretty, 2001; Nuffield Council on Bioethics, 2004
[32] Conway, 1985; Gliessman, 1998; 2005; Olsson and Folke, 2001; Dalgaard *et al*., 2003; Odum and Barrett, 2004; Swift *et al*., 2004

directed to fuel essential internal tropic interactions (e.g. to soil organic matter or to weeds for arable birds) so as to maintain other ecosystem functions. All annual crops, though, are derived from opportunist species, and so their resource use is inherently different to perennials.

Modern agriculture has also come to rely heavily of nutrient inputs obtained from or driven by fossil-fuel-based sources. Nutrients are also used inefficiently, and together with certain products (e.g. ammonia, nitrate, methane, carbon dioxide), are lost to the environment. For sustainability, nutrient leaks need to be reduced to a minimum, recycling and feedback mechanisms introduced and strengthened, and nutrients and materials diverted to capital accumulation. Agroecosystems are considerably more simplified than natural ecosystems, and loss of biological diversity (to improve crop and livestock productivity) results in the loss of some ecosystem services, such as pest and disease control. For sustainability, biological diversity needs to be increased to recreate natural control and regulation functions, and to manage pests and diseases rather than seeking to eliminate them. Mature ecoystems are now known to be not stable and unchanging, but in a state of dynamic equilibrium that buffers against large shocks and stresses. Modern agroecosystems have weak resilience, and for transitions towards sustainability need to focus on structures and functions that improve resilience[33].

Table 1. Properties of natural ecosystems compared with modern and sustainable agroecosystems

Property	**Natural ecosystem**	**Modern agroecosystem**	**Sustainable agroecosystem**
Productivity	Medium	High	Medium (possibly high)
Species diversity	High	Low	Medium
Output stability	Medium	Low-medium	High
Biomass accumulation	High	Low	Medium-High
Nutrient recycling	Closed	Open	Semi-closed
Trophic relationships	Complex	Simple	Intermediate
Natural population regulation	High	Low	Medium-High
Resilience	High	Low	Medium
Dependence on external inputs	Low	High	Medium
Human displacement of ecological processes	Low	High	Low-Medium
Sustainability	High	Low	High

Source: Gliessman (2005)

But converting an agroecosystem to a more sustainable design is complex, and generally requires a landscape or bioregional approach to restoration or management. An agroecosystem is a bounded system designed to produce food and fibre, yet it is also part of a wider landscape at which scale a number of ecosystem functions are important. For sustainability, interactions need to be developed between agroecosystems and whole landscapes of other farms and non-farmed or wild habitats (e.g. wetlands, woods, riverine habitats), as well as social systems of food procurement. Mosaic landscapes with a variety of farmed and non-farmed habitats are known to be good for birds as well as farms[34].

There are several types of agroecological practices and resource-conserving technologies that can be used to improve the stocks and use of natural capital in and around agroecosystems. These are:

1. *Integrated pest management*, which uses ecosystem resilience and diversity for pest, disease and weed control, and seeks only to use pesticides when other options are ineffective.

[33] Holling *et al*., 1998; Gallagher *et al*., 2005; Folke *et al*., 2005
[34] Bignall and McCracken, 1996; Kloppenburg *et al*., 1996; Higgs, 2003; Jordan, 2003; Odum and Barrett, 2004; Swift *et al*., 2004; Terwan *et al*., 2004; Gliessman, 2005; Shennan *et al*., 2005; Woodhouse *et al*., 2005

2. *Integrated nutrient management*, which seeks both to balance the need to fix nitrogen within farm systems with the need to import inorganic and organic sources of nutrients, and to reduce nutrient losses through erosion control.

3. *Conservation tillage*, which reduces the amount of tillage, sometime to zero, so that soil can be conserved and available moisture used more efficiently.

4. *Agroforestry,* which incorporates multifunctional trees into agricultural systems, and collective management of nearby forest resources.

5. *Aquaculture*, which incorporates fish, shrimps and other aquatic resources into farm systems, such as into irrigated rice fields and fish ponds, and so leads to increases in protein production.

6. *Water harvesting* in dryland areas, which can mean formerly abandoned and degraded lands can be cultivated, and additional crops grown on small patches of irrigated land owing to better rain water retention.

7. *Livestock integration* into farming systems, such as dairy cattle, pigs and poultry, including using zero-grazing cut and carry systems.

Many of these individual technologies are also multi-functional. This implies that their adoption should mean favourable changes in several components of the farming system at the same time. For example, hedgerows and alley crops encourage predators and act as windbreaks, so reducing soil erosion. Legumes introduced into rotations fix nitrogen, and also act as a break crop to prevent carry over of pests and diseases. Grass contour strips slow surface water run off, encourage percolation to groundwater, and can be a source of fodder for livestock. Catch crops prevent soil erosion and leaching during critical periods, and can also be ploughed in as a green manure. The incorporation of green manures not only provides a readily available source of nutrients for the growing crop but also increases soil organic matter and hence water retentive capacity, further reducing susceptibility to erosion.

Although many resource-conserving technologies and practices are currently being used, the total number of farmers using them worldwide is still relatively small. This is because their adoption is not a costless process for farmers. They cannot simply cut their existing use of fertilizer or pesticides and hope to maintain outputs, so making operations more profitable. They also cannot simply introduce a new productive element into their farming systems, and hope it succeeds. These transition costs arise for several reasons. Farmers must first invest in learning[35]. As recent and current policies have tended to promote specialised, non-adaptive systems with a lower innovation capacity, so farmers have to spend time learning about a greater diversity of practices and measures. Lack of information and management skills is, therefore, a major barrier to the adoption of sustainable agriculture. During the transition period, farmers must experiment more, and so incur the costs of making mistakes as well as of acquiring new knowledge and information.

The on-farm biological processes that make sustainable agroecosystems productive also take time to become established. These include the rebuilding of depleted natural buffers of predator stocks and wild host plants; increasing the levels of nutrients; developing and exploiting microenvironments and positive interactions between them; and the establishment and growth of trees. These higher variable and capital investment costs must be incurred before returns increase. Examples include for labour in construction of soil and water conservation measures; for planting of trees and hedgerows; for pest and predator monitoring and management; for fencing of paddocks; for the establishment of zero-grazing units; and for purchase of new technologies, such as manure storage equipment or global positioning systems for tractors.

[35] Orr, 1992; Röling and Wagermakers, 1998; Bentley *et al*., 2003; Lieblin *et al*., 2004; Bawden, 2005; Chambers, 2005

It has also been argued that farmers adopting more sustainable agroecosystems are internalising many of the agricultural externalities associated with intensive farming, and so could be compensated for effectively providing environmental goods and services. Providing such compensation or incentives would be likely to increase the adoption of resource conserving technologies[36]. Nonetheless, periods of lower yields seem to be more apparent during conversions of industrialised agroecosystems. There is growing evidence to suggest that most pre-industrial and modernised farming systems in developing countries can make rapid transitions to both sustainable and productive farming.

4. Outcomes of Agroecological Approaches: Yields and Environmental Services

4.1 Effects on Yields

One persistent question regarding the potential benefits of more sustainable agroecosystems centres on productivity trade-offs. If environmental goods and services are to be protected or improved, what then happens to productivity? If it falls, then more land will be required to produce the same amount of food, thus resulting in further losses of natural capital. As indicated earlier, the challenge is to seek sustainable intensification of all resources in order to improve food production. In industrialised farming systems, this has proven impossible to do with organic production systems, as food productivity is lower for both crop and livestock systems. Nonetheless, there are now some 3 M ha of agricultural land in Europe managed with certified organic practices. Some have led to lower energy use (though lower yields too); others to better nutrient retention, and some greater nutrient losses, and some to greater labour absorption[37].

Many other farmers have adopted integrated farming practices, which represent a step or several steps towards sustainability. What has become increasingly clear is that many modern farming systems are wasteful, as integrated farmers have found they can cut down many purchased inputs without losing out on profitability. Some of these cuts in use are substantial, others are relatively small. By adopting better targeting and precision methods, there is less wastage and so more benefit to the environment. They can then make greater cuts in input use once they substitute some regenerative technologies for external inputs, such as legumes for inorganic fertilizers or predators for pesticides. Finally, they can replace some or all external inputs entirely over time once they have learned their way into a new type of farming characterised by new goals and technologies[38].

However, it is in developing countries that some of the most significant progress towards sustainable agroecosystems has been made in the past decade. The largest study comprised the analysis of 286 projects in 57 countries[39]. This involved the use of both questionnaires and published reports by projects to assess changes over time. Data were triangulated from several sources, and cross-checked by external reviewers and regional experts. The study involved analysis of projects sampled once in time (n=218) and those sampled twice over a 4 year period (n=68). Not all proposed cases were accepted for the dataset, and rejections were based on a strict set of criteria. As this was a purposive sample of `best practice' initiatives, the findings are not representative of all developing country farms.

Table 3 contains a summary of the location and extent of the 286 agricultural sustainability projects across the eight categories of FAO farming systems[40] in the 57 countries. In all, some 12.6 million farmers on 37 million hectares were engaged in transitions towards agricultural sustainability in these 286 projects. This is just over 3% of the total cultivated area (1.136 M ha) in developing countries. The largest number of farmers was in wetland rice-based systems, mainly in Asia (category 2), and

[36] Dobbs and Pretty, 2004
[37] Dalgaard *et al*., 1998, 2002; Løes and Øgaard, 2003; Gosling and Shepherd, 2005; Green *et al*., 2005; Morison *et al*., 2005; Pretty *et al*., 2003b; 2006
[38] Pretty and Ward, 2001
[39] Pretty *et al*., 2006
[40] Dixon *et al*., 2001

the largest area was in dualistic mixed systems, mainly in southern Latin America (category 6). This study showed that agricultural sustainability was spreading to more farmers and hectares. In the 68 randomly re-sampled projects from the original study, there was a 54% increase over the four years in the number of farmers, and 45% in the number of hectares. These resurveyed projects comprised 60% of the farmers and 44% of the hectares in the original sample of 208 projects.

Table 2. Summary of adoption and impact of agricultural sustainability technologies and practices on 286 projects in 57 countries

FAO farm system category[1]	Number of farmers adopting	Number of hectares under sustainable agriculture	Average % increase in crop yields[2]
1. Smallholder irrigated	177,287	357,940	129.8 (±21.5)
2. Wetland rice	8,711,236	7,007,564	22.3 (±2.8)
3. Smallholder rainfed humid	1,704,958	1,081,071	102.2 (±9.0)
4. Smallholder rainfed highland	401,699	725,535	107.3 (±14.7)
5. Smallholder rainfed dry/cold	604,804	737,896	99.2 (±12.5)
6. Dualistic mixed	537,311	26,846,750	76.5 (±12.6)
7. Coastal artisanal	220,000	160,000	62.0 (±20.0)
8. Urban-based and kitchen garden	207,479	36,147	146.0 (±32.9)
All projects	12,564,774	36,952,903	79.2 (±4.5)

1. Farm categories from Dixon *et al.* (2001)
2. Yield data from 360 crop-project combinations; reported as % increase (thus a 100% increase is a doubling of yields). Standard errors in brackets

For the 360 reliable yield comparisons from 198 projects, the mean relative yield increase was 79% across the very wide variety of systems and crop types. However, there was a wide spread in results. While 25% of projects reported relative yields > 2.0, (i.e. 100% increase), half of all the projects had yield increases of between 18% and 100%. The geometric mean is a better indicator of the average for such data with a positive skew, but this still shows a 64% increase in yield. However, the average hides large and statistically significant differences between the main crops (Figures 1 and 2). In nearly all cases there was an increase in yield with the project. Only in rice were there 3 reports where yields decreased, and the increase in rice was the lowest (mean = 1.35), although it constituted a third of all the crop data. Cotton showed a similarly small mean yield increase. It is not clear why there are these differences between crops. It may be because there is greater unexploited yield potential in some environments (eg sorghum and millet in the dryalnds), or that existing genetic material is already managed close to its maximum potential.

These sustainable agroecosystems also have positive side-effects, helping to build natural capital, strengthen communities (social capital) and develop human capacities. Examples of positive side-effects recently recorded in various developing countries include:

- *improvements to natural capital*, including increased water retention in soils, improvements in water table (with more drinking water in the dry season), reduced soil erosion combined with improved organic matter in soils, leading to better carbon sequestration, and increased agro-biodiversity;
- *improvements to social capital*, including more and stronger social organisations at local level, new rules and norms for managing collective natural resources, and better connectedness to external policy institutions;
- *improvements to human capital*, including more local capacity to experiment and solve own problems; reduced incidence of malaria in rice-fish zones, increased self-esteem in formerly marginalised groups, increased status of women, better child health and nutrition, especially in dry seasons, and reversed migration and more local employment.

What we do not know, however, is the full economic benefits of these spin-offs. In many industrialized countries, agriculture is now assumed to contribute very little to GDP, leading many commentators to assume that agriculture is not important for modernized economies. But such a conclusion is a function of the fact that too few measures are being made of the positive side-effects of agriculture[41]. In poor countries, where financial support is limited and markets weak, then people rely even more on the value they can derive from the natural environment and from working together to achieve collective outcomes.

4.2 Effects on Pesticide Use and Yields

Recent integrated pest management (IPM) programmes, particularly in developing countries, are beginning to show how pesticide use can be reduced and pest management practices can be modified without yield penalties[42]. In principle, there are four possible trajectories of impact if IPM is introduced:

i. both pesticide use and yields increase (A);
ii. pesticide use increases but yields decline (B);
iii. both pesticide use and yields fall (C);
iv. pesticide use declines, but yields increase (D).

The assumption in modern agriculture is that pesticide use and yields are positively correlated. For IPM, the trajectory moving into sector A is therefore unlikely but not impossible, for example in low input systems. What is expected is a move into sector C. While a change into sector B would be against economic rationale, farmers are unlikely to adopt IPM if their profits would be lowered. A shift into sector D would indicate that current pesticide use has negative yield effects or that the amount saved from pesticides is reallocated to other yield increasing inputs. This could be possible with excessive use of herbicides or when pesticides cause outbreaks of secondary pests, such as observed with the brown plant hopper in rice[43].

Figure 3 shows data from 62 IPM initiatives in 26 developing and industrialised countries (Australia, Bangladesh, China, Cuba, Ecuador, Egypt, Germany, Honduras, India, Indonesia, Japan, Kenya, Laos, Nepal, Netherlands, Pakistan, Philippines, Senegal, Sri Lanka, Switzerland, Tanzania, Thailand, UK, USA, Vietnam and Zimbabwe)[44]. The 62 IPM initiatives have some 5.4 million farm households on 25.3 M ha. The evidence on pesticide use is derived from data on both the number of sprays per hectare and the amount of active ingredient used per hectare. This analysis does not include recent evidence on the effect of some genetically-modified crops, some of which result in reductions in the use of herbicides and pesticides, and some of which have led to increases[45].

There is only one sector B case reported in recent literature[46]. Such a case has recently been reported from Java for rice farmers. The cases in sector C, where yields fall slightly while pesticide use falls dramatically, are mainly cereal farming systems in Europe, where yields typically fall to some 80% of current levels while pesticide use is reduced to 10-90% of current levels[47]. Sector A contains 10 projects where total pesticide use has indeed increased in the course of IPM introduction. These are mainly in zero-tillage and conservation agriculture systems, where reduced tillage creates substantial benefits for soil health and reduced off-site pollution and flooding costs. These systems usually require increased use of herbicides for weed control, though there are some examples of organic zero-tillage systems. Over 60% of the projects are in category D where pesticide use declines and yields increase. While pesticide reduction is to be expected, as farmers substitute pesticides by information,

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[41] MA, 2005
[42] Brethour and Weerskink, 2001; Wilson and Tisdell, 2001; Gallagher *et al*., 2005; Herren *et al*., 2005; Pretty and Waibel, 2005
[43] Kenmore *et al.,* 1984
[44] Pretty and Waibel, 2005
[45] Benbrook, 2003; Champion *et al.*, 2003; Nuffield Council on Bioethics, 2004
[46] Feder *et al*., 2004
[47] Pretty, 1998; Röling and Wagemakers, 1998

yield increases induced by IPM is a more complex issue. It is likely, for example, that farmers who receive good quality field training will not only improve their pest management skills but also become more efficient in other agronomic practices such as water, soil and nutrient management. They can also invest some of the cash saved from pesticides in other inputs such as higher quality seeds and inorganic fertilizers.

4.3 Effects on Carbon Balances

The 1997 Kyoto Protocol to the UN Framework Convention on Climate Change established an international policy context for the reduction of carbon emissions and increases in carbon sinks in order to address the global challenge of anthropogenic interference with the climate system. It is clear that both emission reductions and sink growth will be necessary for mitigation of current climate change trends[48]. A source is any process or activity that releases a greenhouse gas, or aerosol or a precursor of a greenhouse gas into the atmosphere, whereas a sink is such mechanism that removes these from the atmosphere. Carbon sequestration is defined as the capture and secure storage of carbon that would otherwise be emitted to or remain in the atmosphere. Agricultural systems emit carbon through the direct use of fossil fuels in food production, the indirect use of embodied energy in inputs that are energy-intensive to manufacture, and the cultivation of soils and/or soil erosion resulting in the loss of soil organic matter. Agriculture also contributes to climate change through the emissions of methane from irrigated rice systems and ruminant livestock. The direct effects of land use and land use change (including forest loss) have led to a net emission of 1.7 Gt C yr^{-1} in the 1980s and 1.6 Gt C yr^{-1} in the 1990s[49].

On the other hand, agriculture is also an accumulator of carbon when organic matter is accumulated in the soil, and when above-ground biomass acts either as a permanent sink or is used as an energy source that substitutes for fossil fuels and so avoids carbon emissions. There are three main mechanisms and 21 technical options (Table 3) by which positive actions can be taken by farmers by:

A) increasing carbon sinks in soil organic matter and above-ground biomass;
B) avoiding carbon dioxide or other greenhouse gas emissions from farms by reducing direct and indirect energy use;
C) increasing renewable energy production from biomass that either substitutes for consumption of fossil fuels or replacing inefficient burning of fuelwood or crop residues, and so avoids carbon emissions.

Table 3. Mechanisms for increasing carbon sinks and reducing CO_2 and other greenhouse gas emissions in agricultural systems

Mechanism A. Increase carbon sinks in soil organic matter and above-ground biomass
• Replace inversion ploughing with conservation- and zero-tillage systems
• Adopt mixed rotations with cover crops and green manures to increase biomass additions to soil
• Adopt agroforestry in cropping systems to increase above-ground standing biomass
• Minimise summer fallows and periods with no ground cover to maintain soil organic matter stocks
• Use soil conservation measures to avoid soil erosion and loss of soil organic matter
• Apply composts and manures to increase soil organic matter stocks
• Improve pasture/rangelands through grazing, vegetation and fire management both to reduce degradation and increase soil organic matter
• Cultivate perennial grasses (60-80% of biomass below ground) rather than annuals (20% below ground)
• Restore and protect agricultural wetlands
• Convert marginal agricultural land to woodlands to increase standing biomass of carbon

48 Watson *et al.*, 2000; IPCC, 2001; Royal Society, 2001; Oelbermann *et al.*, 2003; Swingland, 2003
49 Watson *et al.*, 2000; Bellamy *et al.*, 2005

Mechanism B. Reduce direct and indirect energy use to avoid greenhouse gas emissions (CO_2, CH_4 and N_2O)
• Conserve fuel and reduce machinery use to avoid fossil-fuel consumption
• Use conservation or zero-tillage to reduce CO_2 emissions from soils
• Adopt grass-based grazing systems to reduce methane emissions from ruminant livestock
• Use composting to reduce manure methane emissions
• Substitute biofuel for fossil fuel consumption
• Reduce the use of inorganic N fertilizers (as manufacture is highly energy intensive), and adopt targeted- and slow-release fertilizers
• Use integrated pest management to reduce pesticide use (avoid indirect energy consumption)
Mechanism C. Increase biomass-based renewable energy production to avoid carbon emissions
• Cultivate annual crops for biofuel production, such as ethanol from maize and sugar cane
• Cultivate annual and perennial crops, such as grasses and coppiced trees, for combustion and electricity generation, with crops replanted each cycle for continued energy production
• Use biogas digesters to produce methane, so substituting for fossil fuel sources
• Use improved cookstoves to increase efficiency of biomass fuels

Source: Pretty et al., 2002

The potential annual contributions being made in the 286 projects to carbon sink increases in soils and trees were calculated, using an established methodology[50] (Table 4). As the focus is on what sustainable methods can do to increase quantities of soil and above-ground carbon, no account was taken of existing stocks of carbon. Soil carbon sequestration is corrected for climate, as rates are higher in humid compared with dry zones, and generally higher in temperate than tropical areas.

Table 4. Summary of potential carbon sequestered in soils and above-ground biomass in the 286 agroecological projects

FAO farm system category	Carbon sequestered per hectare ($t\ C\ ha^{-1}\ y^{-1}$)	Total Carbon sequestered ($Mt\ C\ y^{-1}$)	Carbon sequestered per household ($t\ C\ y^{-1}$)
1. Smallholder irrigated	0.15 (±0.012)	0.011	0.06
2. Wetland rice	0.34 (±0.035)	2.53	0.29
3. Smallholder rainfed humid	0.46 (±0.034)	0.34	0.20
4. Smallholder rainfed highland	0.36 (±0.022)	0.23	0.56
5. Smallholder rainfed dry/cold	0.26 (±0.035)	0.20	0.32
6. Dualistic mixed	0.32 (±0.023)	8.03	14.95
7. Coastal artisanal	0.20 (±0.001)	0.032	0.15
8. Urban-based and kitchen garden	0.24 (±0.061)	0.015	0.07
Total	0.35 (±0.016)	11.38	0.91

Note: ± standard errors in brackets
Source: Pretty et al. (2006)

These projects were potentially sequestering 11.4 Mt C y^{-1} on 37 M ha. The average gain was 0.35 t C ha^{-1} y^{-1}, with an average per household gain of 0.91 t C y^{-1}. The per hectare gains vary from 0.15 t C ha^{-1} y^{-1} for smallholder irrigated systems (category 1) to 0.46 t C ha^{-1} y^{-1} for category 3 systems. For most systems, per households gains were in the range 0.05 – 0.5 t C y^{-1}, with the much larger farms of southern Latin America using zero-tillage achieving the most at 14.9 t C y^{-1}. Such gains in carbon may offer new opportunities for income generation under carbon trading schemes[51]. However, there remain concerns about leakage (carbon sequestered that is later lost) and whether all potential hectares would be likely to be converted into carbon sinks. It is, therefore, important to be cautious about carbon sequestration potential unless there are supportive institutions and policies that could enable these technologies and practices to be implements on a very large scale.

[50] Pretty *et al*., 2002, 2006
[51] Swingland, 2003

4.4 Effects on Farm Water Use Efficiency

Widespread appreciation of the `global water crisis' recognizes that scarcity of clean water is affecting food production and conservation of ecosystems. By 2025 it is predicted that most developing countries will face either physical or economic water scarcity. Water diverted from rivers increased six fold between 1900 and 1995, far outpacing population growth. Increasing demand for fresh water now threatens the integrity of many aquatic ecosystems, and their associated environmental services. As agriculture accounts for 70% of current water withdrawals from rivers, so improving the productivity of water use in agriculture is a growing challenge.

The potential for increasing food production while maintaining water-related ecosystem services rests on capacity to increase water productivity (WP), i.e. by realizing more kg of food per unit of water. Sustainable agricultural practices may do this by: i) removing limitations on productivity by enhancing soil fertility; ii) reducing soil evaporation through conservation tillage; iii) using more water efficient varieties; iv) reducing water losses to unrecoverable sinks; v) boosting productivity by supplemental irrigation in rainfed systems; and vi) inducing microclimatic changes to reduce crop water requirements (23). We calculated changes in WP for field crops in 144 projects from the data set (Table 5) based on reported crop yields and average potential evapotranspiration (ETp), for each project location during the relevant growing season. Actual evapotranspiration (ETa) was assumed to equal 80% of ETp, and ETa to remain a constant at different levels of productivity.

Table 5. Summary of changes in water productivity by major crop type arising from adoption of agroecological technologies and practices in 144 projects

Crops	Water productivity before intervention (kg food m^{-3} water ETa)	Water productivity after intervention (kg food m^{-3} water ETa)	Water productivity gain (kg food m^{-3} water ETa)	% Increase in WP
Irrigated				
Rice (n=18)	1.03 (±0.22)	1.19 (±0.12)	0.16 (±0.04)	15.5%
Cotton (n=8)	0.17 (±0.04)	0.22 (±0.05)	0.05 (±0.02)	29.4%
Rainfed				
Cereals (n=80)	0.47 (±0.06)	0.80 (±0.09)	0.33 (±0.05)	70.2%
Legumes (n=19)	0.43 (±0.07)	0.87 (±0.16)	0.44 (±0.11)	102.3%
Roots and Tubers (n=14)	2.79 (±0.73)	5.79 (±1.08)	3.00 (±0.65)	107.5%
Urban and Kitchen Gardens				
Vegetables and Fruits (n=5)	0.83 (±0.29)	2.96 (±0.97)	2.13 (±0.71)	256.6%

Note: Standard errors in brackets
Source: Pretty *et al.* (1996)

WP gains were high in rainfed systems, and moderate in irrigated systems, and were in agreement with other studies reporting ranges of Water Productivity (WP). The very large increase for the vegetables and fruits is probably an overestimate as we did not adjust ETp for new crops or lengthened cropping periods. Variability was high due to the wide variety of practices represented in the dataset, but do indicate that gains in WP are possible through adoption of sustainable farming technologies in a variety of crops and farm systems. This demonstrates that the greatest opportunity for improvement in water productivity is in rainfed agriculture. Better farm management, including supplemental irrigation and fertility management can significantly reduce uncertainty, and thus avoid chronic low productivity and crop failure that are characteristic of many rainfed systems. Once again, it is important to be cautious about these potential water benefits. They illustrate what has been possible in the projects analysed, but not necessarily what might occur under other conditions. Nonetheless, for drought-prone agricultural systems where productivity is low (such as in large parts of Africa), there is clearly great potential for new sustainable and productive approaches to agricultural management to be developed.

5. Social Outcomes of Agroecological Approaches

5.1 Labour Markets and Migration Patterns

At some locations, agroecological approaches have had a significant impact on labour markets. Some practices result in increased on-farm demand for labour (eg water harvesting in Niger), whilst others actually reduce labour demand (eg zero-tillage in Brazil). Some result in the opening up of whole new seasons for agricultural production, particularly in dryland contexts, through improved harvesting of rainfall, leading to much greater demand for labour.

Migration reversals can occur when wage labour opportunities increase as part of the project (eg watershed improvements), when more productive agriculture leads to higher wages and employment, when there are higher returns to agriculture, and when there are overall improvements in village conditions, such as infrastructure and services.

There are several documented cases where these approaches have helped to reverse seasonal or even long-term migration:

- In the Guinope and Cantarranas regions of Honduras, families have returned from the capital city to take up labour opportunities brought by rural economic growth centred on improved agricultural productivity[52];
- In India, seasonal migration from a number of rainfed projects (eg in Maharashtra, Gujarat and Tamil Nadu) has declined as sufficient water is now available to crop the rabi season, with women in particular benefiting from being able to remain at home all year[53];
- In Niger, young men have been able to form labour-societies to meet the demand for water-harvesting construction, rather than migrate to the coast for work[54].

However, in some locations increasing labour requirements may be an impediment to adoption, and farmers may actually desire labour-saving technologies and practices. All transformations in agricultural systems are costly, thus always mitigating against the poorest households and economies. Given the appropriate institutional conditions, poor households may, however, be able to make use of new configurations of human and social capital to make more productive use of natural capital and available technologies. In some areas, but not all, this also means an increase in on-farm labour requirements. Within households, such additional labour is often supplied by women rather than men.

Where labour is scarce, such as in HIV affected populations, or where women suffer a particularly heavy double-load of domestic and agricultural labour, or when there are significant off-farm labor oportunities (eg, 52% of rural household income in latin america comes from non-agricultural employment[55]) then technologies for agricultural sustainability will either need to emphasise labour saving or result in sufficiently high productivity gains that labour can be hired. Examples of the former include zero-tillage using herbicides for weed control in Brazil and Argentina, and legumes as green manures and cover crops in Central America. Examples of the latter include raised-bed vegetable technology for women's groups in East Africa and fish-raising in paddy fields in South Asia[56].

What we do not know is how internal labour markets will affect incentives to work in agriculture and rural regions, and how best to promote regional rural development based on agricultural intensification.

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[52] Bunch and Lopez, 1999; Bunch, 2000
[53] Devavaram *et al.*, 1999; Pretty, 2002
[54] Reij, 1996; Kabore and Reij, 2004
[55] Reardon *et al.*, 2001
[56] Uphoff, 2002

5.2 Dietary and Reproductive Health

Sustainable agriculture has the potential directly and indirectly to influence the health of rural people. In the first instance, improved food supply throughout the year has a fundamental impact on health, which in turn allows adults to be more productive, and children to attend school and still be able to concentrate on learning. In Kenya, for example, the simple technology of double-dug beds has improved domestic food supply for several tens of thousands of households by producing a year-round supply of vegetables[57]. It is children who have been noted as major beneficiaries.

In some cases, a more sustainable agriculture can also help to remove threats to health in the environment - such as consumption of mosquito larva by fish in rice fields - with measurable reductions in malaria incidence noted in China. In Jiangsu Province**,** there has been rapid growth of rice aquaculture: from about 5000 ha in 1994 to 117,000 ha of rice-fish, rice-crab and rice-shrimp systems. Rice yields have increased by 10-15%, but the greatest dividend is in protein: each mu (one fifteenth of a hectare) can produce 50 kg of fish[58]. Additional benefits come from reduced insecticide use, and measured reductions in malaria incidence owing to fish predation of mosquito larvae.

Sustainable agriculture can also have an indirect effect on reproductive health. Where women are organised into groups, such as for microfinance delivery (credit and savings), livestock raising or watershed development, such social capital creation offers opportunities or `entry points' for other sectors to interact closely with women. In Ecuador, for example, the World Neighbors programme working with remote rural communities on sustainable agriculture and natural resource management has been able to make a substantial impact on family planning. WN actively compared two types of programme in Guaranda canton, Bolivar Province, by working in six communities that only received health input, and another six that received an integrated programme involving soil and water conservation, green manures, vegetable gardening, and farmer-experimentation with barley, wheat, maize and potato varieties, combined with group formation. The health interventions yielded few results. But the integrated approach brought pronounced changes in attitudes and values. Contraceptive use in these communities was double that in the `health only' villages. The family planning clinic, on the verge of closure in 1992, provided 18,000 consultations in 1998[59].

In Nepal, World Neighbors also found that reproductive health and family planning were not effective entry points. Instead, women's reproductive health, status, work and fertility could be better addressed by forming and working with women's savings and credit groups that could participate in planning a wide range of development activities. Confident groups with better literacy, income and food security were able to challenge traditional roles and norms, leading to capacity to deal directly with reproductive health[60].

5.3 Large Farms, Small Farms and Landless Families

In certain circumstances, sustainable agriculture practices appear to be currently more accessible to larger farmers – particularly the zero-tillage systems in Argentina, Brazil and Paraguay. However, evidence from Paraguay and Brazil also suggests that larger numbers of small farmers are now adopting and adapting elements of these practices. It is important to note that adoption of conservation agriculture by large farmers may still result in significant regional change: *"zero-tillage has been a major factor in changing the top-down nature of agricultural services to farmers towards a participatory, on-farm approach"*[61]. It is estimated that there are 16 million peasant farmers in Latin America who remain untouched by sustainable agriculture or zero-tillage systems[62].

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[57] Hamilton, 1998; Pretty, 2002
[58] Li Wenhua, 2001
[59] Ruddell, 1995; Hinchcliffe *et al.*, 1999;l Uphoff, 2002
[60] Hinchcliffe *et al.*, 1999
[61] John Landers, pers comm
[62] In Brazil, for example,: 1.6% of all farms are over 1000 ha, and these comprise 53% of all agricultural land. Some 30% of farmers own less than 10 ha each, comprising only 1.5% of land (Langevin and Rosset, 1997).

But in other contexts, sustainable agriculture has first been adopted by small farmers, and is only now spreading to larger ones once they have seen the success. In Bangladesh, the rice-fish and rice-IPM technologies were adopted by very small farmers first, with larger farmers attracted only when success had been proven[63].

Can agroecological approaches result in improvements in livelihoods for landless families and the core poor? There are three possibilities: improvements to labour markets, improved access to land through land reform, or changed social norms that encourage greater equity and sharing. The first of these seems more likely than the others – though as noted above, some sustainable agriculture applications are favoured by farm families precisely because they reduce labour requirements.

There is some evidence that social capital formation can result in new equitable arrangements within communities. Landless families, for example, have been given new opportunities to join farmers' groups in western and central Kenya. Such changes cannot be directly attributed to sustainable agriculture - more it is changes in values and norms arising from new configurations of local social capital[64].

6. Priorities for Agroecological Development

6.1 Since Agenda 21

The 1990s have seen considerable global progress towards the recognition of the need for policies to support sustainable agriculture. In a few countries, this has been translated into highly supportive and integrated policy frameworks. In most, however, sustainable agriculture policies remain at the margins, with recognition of need not yet to be translated into actual policies.

The 1991 Den Bosch Declaration on SARD, adopted by the 1992 Rio Conference, called for the attainment of three essential goals: a) food security by ensuring an appropriate and sustainable balance between self-sufficiency and self-reliance; b) employment- and income-generation in rural areas, particularly in order to eradicate poverty; and c) natural resource conservation and environmental protection.

These goals were further elaborated as the blueprint for SARD in Chapter 14 of Agenda 21 on 'Promoting Sustainable Agriculture and Rural Development'. The challenge was set: ways had to be found to satisfy the demands of this growing population by creating the conditions for sustainable agriculture and rural development (SARD) that will increase food production in a sustainable way and enhance food security. It was recognised that this would require major adjustments in agricultural, environmental and macroeconomic policy, at both national and international levels, in developed as well as developing countries. The main tools of SARD would be policy and agrarian reform, participation, income diversification, land conservation and improved management of inputs. Its success would depend largely on the support and participation of rural people, national governments, the private sector, and international cooperation.

The Commission on Sustainable Development agrees that there has been growing awareness in most countries of the necessity and desirability of integrating environmental concerns into agricultural policies. OECD countries had expanded the use of economic as opposed to regulatory measures in recent years. Environmental taxes in the agriculture sector focused primarily on pesticides, fertiliser and manure wastes. Denmark, Norway and Sweden had all introduced taxes on pesticide use. Some OECD countries had set agrochemicals reduction targets. For example, Canada and the Netherlands had opted to cut pesticide use by 50 percent (base year 1985-88) by 2000, and Denmark by 25 per

[63] Uphoff, 2002
[64] Pretty and Ward, 2001; Pretty, 2003

cent (base year 1991) by 1997. The Netherlands has also imposed an excess manure tax. Norway and Finland had introduced fertiliser taxes. Austria, Italy, Spain and Italy had established minimum forage areas for cattle.

Notable progress on social capital development at local levels had been achieved in countries such as Indonesia, Sri Lanka, Pakistan, Tanzania and Zambia, where governments were experimenting with the introduction of new participatory and small community-based approaches for supplying farm inputs and services. Bolivia had recently embarked on an ambitious programme to promote more effective participation of rural people at the municipal level, and other Latin American countries such as Chile, Ecuador, Mexico and Venezuela had embarked on similar schemes. New cooperative legislation was in the process of being discussed and debated in a broad range of countries including Zambia, Guinea, India and Vietnam. With declining budgets for rural development, many NGOs were now playing more significant roles towards enhancing people's participation. Rural people's organisations were now entering into the dialogue processes with Governments in shaping sustainable agricultural policies.

6.2 Recent Policy Progress

Three things are now clear from evidence on the recent spread of agroecological approaches:

i. Some technologies and social processes for local scale adoption of more sustainable agricultural practices are increasingly well-tested and established;
ii. The social and institutional conditions for spread are less well-understood, but have been established in several contexts, leading to more rapid spread in the 1990s and early 2000s;
iii. The political conditions for the emergence of supportive policies are least well established, with only a very few examples of real progress.

Most agricultural sustainability improvements seen in the 1990s and early 2000s have arisen despite existing national and institutional policies, rather than because of them. Although almost every country would now say it supports the idea of agricultural sustainability, the evidence points towards only patchy reforms. Only three countries have given explicit national support for sustainable agriculture – putting it at the centre of agricultural development policy and integrating policies accordingly:

- Cuba has a national policy for alternative agriculture;
- Switzerland has three tiers of support to encourage environmental services from agriculture and rural development;
- Bhutan has a national environmental policy coordinated across all sectors.

Several countries have given significant sub-regional support to agricultural sustainability[65], including:

- the states of Santa Caterina, Paraná and Rio Grande do Sul in southern Brazil supporting zero-tillage, catchment management and rural agribusiness development
- some states in India supporting participatory watershed and irrigation management
- China's support for integrated ecological demonstration villages,
- Kenya's catchment approach to soil conservation,
- Indonesia's ban on pesticides and programme for farmer field schools,
- Bolivia's regional integration of agricultural and rural policies,
- Burkina Faso's land policy,
- Sri Lanka and the Philippines' stipulation that water users' groups be formed to manage irrigation systems.

[65] Pretty, 2002

A good example of a carefully designed and integrated programme comes from China. In March 1994, the government published a White Paper to set out its plan for implementation of Agenda 21, and put forward ecological farming, known as *Shengtai Nongye* or agro-ecological engineering, as the approach to achieve sustainability in agriculture. Pilot projects have been established in 2000 townships and villages spread across 150 counties. Policy for these `eco-counties' is organised through a cross-ministry partnership, which uses a variety of incentives to encourage adoption of diverse production systems to replace monocultures. These include subsidies and loans, technical assistance, tax exemptions and deductions, security of land tenure, marketing services and linkages to research organisations. These eco-counties contain some 12 million hectares of land, about half of which is cropland, and though only covering a relatively small part of China's total agricultural land, do illustrate what is possible when policy is appropriately coordinated[66].

An even larger number of countries has seen some progress on agricultural sustainability at project and programme level. However, progress on the ground still remains largely despite, rather than because of, explicit policy support. No agriculture minister is likely to say they are against agricultural sustainability, yet good words remain to be translated into comprehensive policy reforms.

6.3 Scaling Up Difficulties and Trade Offs

Like all major changes, transitions towards sustainability can also provoke secondary problems. These include:

- Building a road near a forest can help farmers reach food markets, but also aid illegal timber extraction.
- If land has to be closed off to grazing for rehabilitation, then people with no other source of feed may have to sell their livestock;
- If cropping intensity increases or new lands are taken into cultivation, then the burden of increased workloads may fall particularly on women.
- Additional incomes arising from sales of produce may go directly to men in households, who may be less likely than women to invest in children and the household as a whole.
- Projects may be making considerable progress on reducing soil erosion and increasing water conservation through adoption of zero-tillage, but still continue to rely on applications of herbicides.

New winners and losers may also emerge with the widespread adoption of agricultural sustainability. Producers of current agrochemical products are likely to suffer market losses from a more limited role for their products. The increase in assets that could come from sustainable livelihoods based on sustainable agriculture may simply increase the incentives for more powerful interests to take over. Not all political interests will be content to see poor farmers and families organize into more powerful social networks and alliances.

In the University of Essex-IWMI study of 286 projects[67], it was found that progress was hindered in many projects by the need for more labour, and constraints arising from rural to urban migration, especially where labour productivity in urban areas was likely to be higher (whilst agriculture was low yielding). The role of HIV/AIDS in reducing available labour is critical in some regions. In some projects, women bear the main brunt of additional labour needs.

Nonetheless, many projects also noted that although more labour may be required, many families are content to make the investments when they see the benefits of increased food production and gross income. Others noted that some technologies needed additional labour only in certain periods of the year, such as in the dry season or during rice transplanting. Other projects dispute whether agricultural

[66] Li Wenhua, 2001
[67] Pretty *et al*., 2006

sustainability does need more labour, such as in rice IPM projects where regular field observation is traded-off with avoided insecticide applications.

Many projects noted the lack of explicit government support for sustainable agriculture, and some specifically were concerned with programmes that targeted compliant farmers or those most likely to change, rather than the poorest. Lack of land tenure reform was seen by some as a persistent problem hindering the long-term investment in natural capital.

What we do not know is how best to scale up relatively small-scale successes to whole regions and countries. What are the best incentives to use? How should institutions be configured to help? What are the best policies?

6.4 The Need for a Multi-Track Approach

Many countries have national policies that now strongly advocate export-led agricultural development. Access to international markets is clearly important for poorer countries, and successful competition for market share can be a very significant source of foreign exchange.

However, this approach has some drawbacks:

- Poor countries are in competition with each other for market share, and so there is likely to be a downward pressure on prices, which reduces returns over time unless productivity continues to increase;
- Markets for agri-food products are fickle, and can be rapidly undermined by alternative products or threats (e.g. avian bird flu and the collapse of the Thai poultry sector);
- Distant markets are less sensitive to the potential negative externalities of agricultural production and are rarely pro-poor (with the exception of fair-trade products);
- Smallholders have many difficulties in accessing international markets and market information;

There is little clear evidence that export-led poverty alleviation has worked as envisaged. Even Vietnam, which has earned considerable foreign exchange from agricultural development has had to do so at very low prices and little value-added[68].

More importantly, an export-led approach can seem to ignore the in-country opportunities for agricultural development focused on local and regional markets. Agricultural policies with both sustainability and poverty-reduction aims should adopt a multi-track approach that emphasises seven components[69]:

1. Small farmer development linked to local and domestic markets;
2. Agri-business development – both small businesses and export-led;
3. Agro-processing and value-added activities – to ensure that returns are maximised in-country;
4. Urban agriculture – as many urban people rely on small-scale urban food production that rarely appears in national statistics;
5. Livestock development – to meet local increases in demand for meat (predicted to increase as economies become richer).
6. Consumer demand for more ethical and natural foods (as urban populations become more wealthy);
7. Supermarket and retail sector changes to connect up consumers with local and domestic producers.

[68] Lipton, 2004
[69] Pretty, 2002; Pretty *et al*., 2005; Reardon and Berdegué, 2002; Reardon and Timmerl, 2007

What we do not yet know is how to engage governments in the debate about the various priorities, and then how to implements change in national policies.

7. Closing the Gap: Priorities for Development Assistance and National Governments

There has been a real decline in development assistance support for agriculture over the past twenty years. Some commentators believe that agriculture has become marginalised, with other social and economic development sectors becoming higher priorities. Recently, however, many development assistance agencies have re-engaged with the agricultural policy debate through a growing recognition that poverty reduction and better livelihoods for poor people cannot be achieved without substantial improvements in agricultural productivity.

What, therefore, should development assistance agencies do to incorporate emerging ideas about agricultural sustainability into its policies and strategies for wider poverty reduction?

The overarching priority is to engage with all recipient countries to put the idea of sustainability at the centre of agricultural policies rather than at the edge. Such policies would have implications for all natural resources within and affected by the countries in question, as well as for all social groups and farm systems.

There are none more specific priorities for development assistance agencies and national governments:

1. Invest in research and extension for agricultural sustainability – as public-sector research does pay, and public extension systems are essential for adapting and transferring technologies;

2. Provide technical assistance and capacity-building for ministries of agriculture and natural resource management;

3. Invest in both dryland and wetland water management systems to increase water productivity (both social capital building and spread of simple technologies);

4. Engage in debate with recipient countries over appropriate land reform, as poor people cannot be expected to invest in asset building (especially of natural capital) if they have no guarantee over long-term access to their land;

5. Promote support for agricultural development programmes that build rural social capital, particularly for women to access credit and microfinance;

6. Develop new approaches for supporting small-scale agri-businesses in rural areas (so that food commodities can be value-added before leaving the local economy), such as loan guarantees, underwriting debt, providing equity funds, and providing grants for social infrastructure and community projects;

7. Ensure support for urban agriculture, which is often missed by mainstream agricultural development;

8. Work with farmers' and rural people's organisations to develop better methods for accessing market information.

9. Establish appropriate incentives to encourage transitions towards sustainability (including both economic incentives and regulatory mechanisms).

How, then, should development assistance agencies and national governments address these priorities?

1. Take a regional approach – emphasise structural reforms and support within specified regions to maximise synergies between different sectors, actors and resources;

2. Develop partnerships and use participatory approaches – with implementing and policy NGOs, with CGIAR institutes and national research and extension systems, with the private sector, and with policy-making departments;

3. Ensure that policy making is evidence-based by developing good monitoring and lesson-learning systems;

4. Integrate the concept of agricultural sustainability into poverty reduction strategies and policies, in particular measure all agricultural and rural development strategies against the primary target of mass, pro-poor farm-based progress;

5. Provide long-term support – there is no simple `magic bullet' for agricultural development, and agencies involved for the long-term see the greatest impacts;

6. Increase support for research, which in some disciplines is increasingly being privatised and driven to specialise in farming systems of the rich, rather than address the needs for sustainable intensification of farming for the employment-intensive poor.

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Figure 1

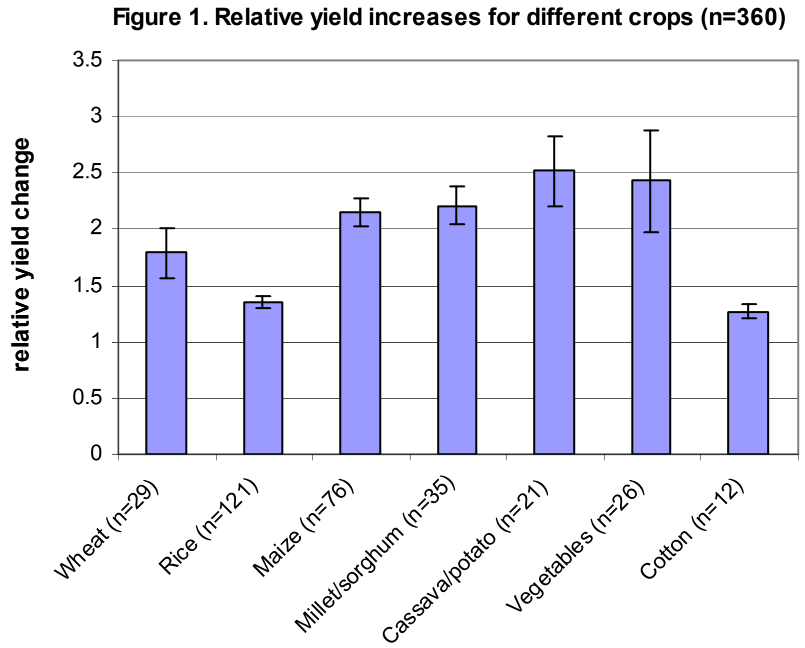

Figure 1. Relative yield increases for different crops (n=360)
relative yield change
3.5
3
2.5
2
1.5
1
0.5
0
Wheat (n=29)
Rice (n=121)
Maize (n=76)
Millet/sorghum (n=35)
Cassava/potato (n=21)
Vegetables (n=26)
Cotton (n=12)

Figure 2

Figure 2. Changes in crop yields with agricultural sustainability technologies and practices (360 crop yield changes in 198 projects)

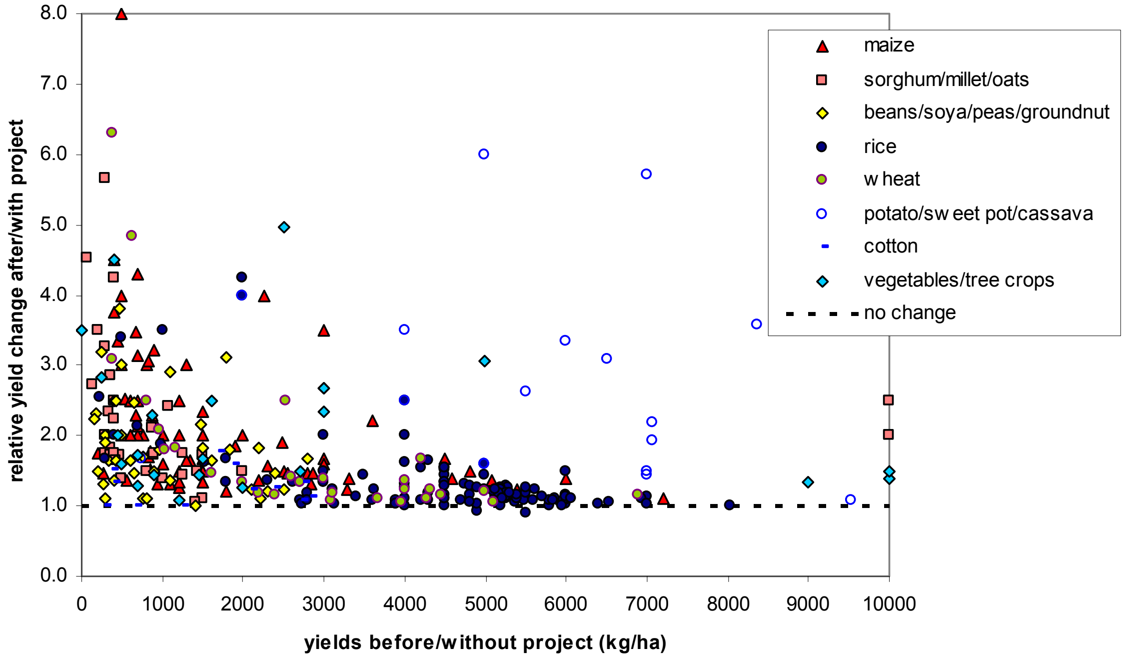

Figure 3

Figure 3. Association between pesticide use and crop yields (data from 80 crop combinations, 62 projects, 26 countries)