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SELECTED ISSUES IN AGRICULTURE INPUTS TECHONOLOGY

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The scope for yield increases

World agriculture has derived more of its growth from an increased intensive use of land already under crops than from expansion of agricultural areas, even though area expansion has been and still is the main force in a number of countries, mainly in sub-Saharan Africa. Improved farming practices, irrigation, improved varieties, modern inputs, etc. all contributed to the growth of yields that underpinned many of the increases in agricultural production. This trend is expected to continue.

Intensification and yield growth are subject to limits for reasons of plant physiology and because of environmental stresses associated with intensification .Moreover, in many circumstances it is simply uneconomical to attempt to raise yields above a certain percentage of the maximum attainable. Naturally, what is agronomical attainable changes over time as agricultural research produces higher-yielding varieties and farming practices improve.

The reasons why country average yields differ from one another are many. Some are agro-ecological, others socio-economic. Irrigation is important in the achievement of high yields in several countries, e.g. Egypt. In addition, agro-ecological and demand factors influence the mix of varieties of the same crop grown in each country, for example, low-yielding durum wheat versus common or soft wheat with higher yields. Given that we are interested in the physical/agronomic potential for yield growth, we need to separate out the part of these intercountry yield gaps that is caused by agro-ecological diversity from the part caused by other factors.

The results of the **global agro-ecological zones (GAEZ)** analysis provide a way of controlling agro-ecological diversity in such intercountry comparisons. In a nutshell, GAEZ describe at a fairly detailed geographic grid the agro-ecological conditions prevailing in each country. GAEZ also have models defining the agro-ecological requirements for the growth of each crop. Based on this, GAEZ derive estimates for attainable yields for each crop and in each grid cell in the different countries under three technology (input use and management) variants.

The agro-ecologically attainable yields can be used to draw inferences about the scope for raising yields in countries where actual yields are "low" in relation to what is attainable for their agro-ecologies. Actual yield data in the agricultural statistics are normally available only as country national averages, not by agro-ecological environments. Therefore, for comparison purposes, the estimates of the agro-ecologically attainable yields for any given crop must also be cast in terms of national averages specific to each country's agro-ecological endowments in relation to that crop. Also, since we compare agro-ecologically attainable yields under rainfed conditions, the remainder of this section will focus on countries with predominantly rainfed agriculture to minimize the distortion caused by the unknown contribution of the normally higher irrigated yields.

For each crop, averaging out over the whole country, the yields for each grid cell give an estimate of "attainable" national average yield for that crop. These yields can be compared with actual national average yields to form an idea of the physical/agronomic scope for yield growth compatible with the country's agro-ecological endowments. In principle, countries with similar attainable averages for any given crop and technology level may be considered to be agro-ecologically similar for that crop. Naturally, any two countries can have similar attainable yields but for very different reasons, e.g. in some countries the limiting factors may be temperature and radiation, in others soil and terrain characteristics or moisture availability. Nevertheless, the GAEZ average attainable yields for any crop can be taken as a rough index of agro-ecological similarity of countries for producing that crop under specified conditions.

The yield gap in relation to agronomic potential is an important element when discussing agronomic potentials for yield growth. For the countries in which we find large differences between actual and attainable, it seems probable that factors other than agro-ecology are responsible. Yields in these countries could grow some way towards bridging the gap between actual and attainable if some of these factors could be changed, e.g. if prices rose. We could then take the countries with a sizeable "bridgeable" gap and see their aggregate weight in world production of a particular crop. If the weight is significant, then the world almost certainly has significant potential for increasing production through yield growth, even on the basis of existing knowledge and technology (varieties, farming practices, etc.).

Among the major wheat producers, only the EU countries (the United Kingdom, Denmark, France and Germany) have actual yields close to, or even higher than, those attainable for their agro-ecological endowments under rainfed high-input farming. In all other major producers with predominantly rainfed wheat production (11 countries) the gaps between actual and attainable yields are significant.

Some states in India, such as the Punjab, are often quoted as examples of areas where wheat and rice yields have been slowing down or are even reaching a plateau. Fortunately, India is one of the few countries for which data at subnational level and distinguished by rainfed and irrigated area are available.

The discussion above gives an idea of the scope for wheat production increases through the adoption of improved technologies and practices to bridge some of the gap that separates actual yields from obtainable yields. The broad lesson of experience seems to be that if scarcities develop and prices rise, farmers quickly respond by adopting such technologies and increasing production, at least those living in an environment of not too difficult access to improved technology, transport infrastructure and supportive policies. However, in countries with land expansion possibilities, the quickest response comes from increasing land under cultivation, including shifting land among crops towards the most profitable ones.

Moreover, even if there probably is sufficient slack in world agriculture to support further increases in global production, this is small consolation to food-insecure people who depend for their nutrition on what they themselves produce. Such people often live in semi-arid agricultural environments where the slack for increasing production can be very limited or non-existent. The fact that the world as a whole may have ample potential to produce more food is of little help to them.

The preceding discussion may create the impression that all is well from the standpoint of potential for further production growth based on the use of existing varieties and technologies to increase yields. Nothing is further from the truth, for two main reasons:

- Exploitation of the yield gaps as defined in the preceding discussion means further spread of the conventional high external input technologies, which is precisely what we should be trying to mitigate if we are to avoid aggravation of the related environmental problems.
- Perhaps more important from the standpoint of meeting future demand, ready potential for yield growth does not necessarily exist in the countries where the additional demand will be, e.g. in the mature green revolution areas of India and other developing countries. When potential demand is in countries with limited import capacity, as is the case in many developing countries, such potential can be expressed as effective demand only if it can be predominantly matched by local production. As noted in Chapters 2 and 8, increases in local production in these countries, in addition to adding to food supplies, stimulate the demand for food because they create employment and incomes and stimulate the wider rural economy. In such circumstances, the existence of large exploitable yield gaps elsewhere (e.g. in Argentina or Ukraine) is less important than it appears for the evaluation of potential contributions of yield growth to meeting future demand.

It follows that continued and intensified efforts are needed on the part of the agricultural research community to raise yields (including through maintenance and adaptive research) in the often unfavourable agro-ecological and socio-economic environments of the countries where the additional demand will be.

Technologies in support of sustainable agriculture

Various approaches have been developed in the past few decades to minimize the environmentally detrimental effects of agricultural production. Among the foremost of these are **integrated pest management (IPM), Integrated Plant Nutrient Systems (IPNS) and no-till/conservation agriculture (NT/CA).** Rather than as isolated technologies they should be seen as complementary elements of sustainable agriculture.

The conventional model of agricultural development stresses increased production and intensification through progressively specialized operations. By contrast, the approaches discussed in this section seek to meet the dual goals of increased productivity and reduced environmental impact. They do this through diversification and selection of inputs and management practices that foster positive ecological relationships and biological processes within the entire agro-ecosystem. With the help of participatory research and extension approaches, the principles of these technologies can be developed further into location-specific sustainable resource management systems. Even though each of these three approaches has some distinct features, many of the specific technologies used are, to various degrees, found in all of the approaches discussed in this section.

Sustainable agriculture is not a concretely defined set of technologies, nor is it a simple model or package that can be widely applied or is fixed over time. The lack of information on agro-ecology and the high demand for management skills are major barriers to the adoption of sustainable agriculture. For example, much less is known about these organic and resource-conserving technologies than about the use of external inputs in modernized systems.

Integrated pest management

Crop, forestry and livestock production systems throughout the world suffer losses caused by diseases, weeds, insects, mites, nematodes and other pests. The intensification of farming, forestry and livestock production favors pest buildup, and the high-yielding varieties and breeds utilized are often more susceptible to pests than traditional ones. The impact of many of these problems can be reduced with the help of pesticides but at a cost, including negative health and environmental effects. Because most chemical pesticides are hazardous to human health and toxic to many non-target organisms, there are potential hazards associated with their manufacture, distribution and application, particularly if pesticides are misused .These hazards include exposure during handling or application, pesticide residues in or on foodstuffs, pollution of the environment (soil, groundwater, surface waters and air) and killing of non-target organisms. Because of the disruption of natural enemies, there has been a resurgence of existing pests and an outbreak of new ones. Almost all economically significant pests are already resistant to at least one chemical pesticide.

The goal of IPM is to avoid or reduce yield losses by pests while minimizing the negative impacts of pest control.

- The term IPM was originally used to describe an approach to pest control with the primary aim of reducing the excessive use of pesticides while achieving zero pest incidence. The concept has broadened over time. Today IPM can best be described as a decision-making and action-oriented process that applies the most appropriate pest control methods and strategy to each situation. IPM promotes primarily biological, cultural and physical pest management techniques, and uses chemical ones only when essential.
- Naturally occurring biological control is encouraged, for example through the use of alternate plant species or varieties that resist pests, as is the adoption of land management, fertilization and irrigation practices that reduce pest problems. If pesticides are to be used, those with the lowest toxicity to humans and non-target organisms should be the primary option. Precise timing and application of pesticides are essential.
- Most IPM projects now develop around a dynamic extension model, the farmer field school (FFS), which emphasizes farmers' ability to experiment and draw conclusions, and enhances their ability to make decisions. The knowledge base has been expanded for a wide range of crops both in terms of new technologies and ecological aspects. Much of this IPM knowledge has still not reached the farm level and lacks site-specific adaptation.

In spite of these problems, IPM has been introduced successfully in many countries and for many different crops such as rice, cotton and vegetables. In Cuba, IPM has been integrated successfully into organic farming. Where farmers have had no previous access to chemical pesticides, the introduction of plant protection based on IPM is the preferred option to avoid financially and environmentally costly overdependence on pesticides.

Integrated Plant Nutrient Systems

Any agricultural crop production – extensive or intensive, conventional or organic – removes plant nutrients from the soil. Nutrient uptake varies according to soil types and the intensity of production. An increase in biomass production results in a higher plant nutrient uptake. Imbalance in the availability of nutrients can lead to mining of soil reserves of nutrients in short supply and to losses of plant nutrients supplied in excess. Insufficiency of one plant nutrient can limit the efficiency with which other plant nutrients are taken up, reducing crop yields. For a farming system to be sustainable, plant nutrients have to be replenished. The nutrient mining that is occurring in many developing countries is a major but often hidden form of land degradation, making agricultural production unsustainable.

IPNS aim to maximize plant nutrient use efficiency by recycling all plant nutrient sources within the farm and by using nitrogen fixation by legumes to the extent possible. This is complemented by the use of external plant nutrient sources, including manufactured fertilizers, to enhance soil productivity through a balanced use of local and external sources of plant nutrients in a way that maintains or improves soil fertility . At the same time IPNS aim at minimizing plant nutrient losses to avoid pollution of soils and water and financial losses to the farmer.

Improved plant nutrition management will be important for environmentally and economically sustainable crop production, be it conventional or organic. However, the rate of spread of IPNS and their implications for the use of mineral fertilizers in agricultural production cannot be predicted in isolation. Precise management of fertilizer use can raise efficiency by 10 to 30 percent and should therefore be included in all production systems aiming for sustainability, even if they do not emphasize IPNS.

No-till/conservation agriculture

By far the largest extent of agricultural land continues to be ploughed, harrowed or hoed before every crop. These conventional tillage practices aim to destroy weeds and loosen the topsoil to facilitate water infiltration and crop establishment. This recurring disturbance of the topsoil buries any soil cover and may destabilize the soil structure so that rainfall can cause soil dispersion, sealing and crusting of the surface. An additional problem of conventional tillage is that it often results in compacted soils, which negatively affect productivity.

This negative impact of soil tillage on farm productivity and sustainability, as well as on environmental processes, has been increasingly recognized. In response to the problem, no-till/conservation agriculture (NT/CA) has been developed. NT/CA maintains and improves crop yields and resilience against drought and other hazards, while at the same time protecting and stimulating the biological functioning of the soil. Various terms are used for variants of NT/CA in different countries, depending on the perceived importance of one or another aspect of the approach .

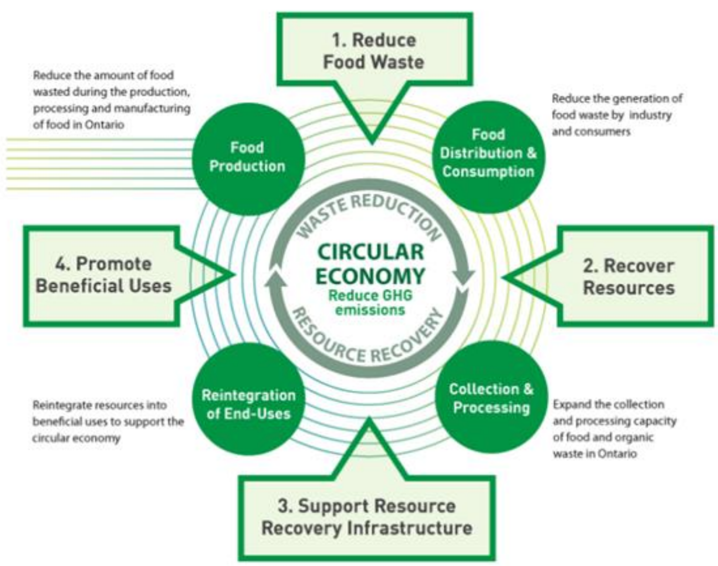
The essential features of NT/CA are:

- minimal soil disturbance restricted to planting and drilling;
- maintenance of a permanent cover of live or dead vegetal material on the soil surface;
- direct sowing;
- crop rotation combining different plant families (e.g. cereals and legumes);
- adequate biomass generation; and
- continuous cropland use.

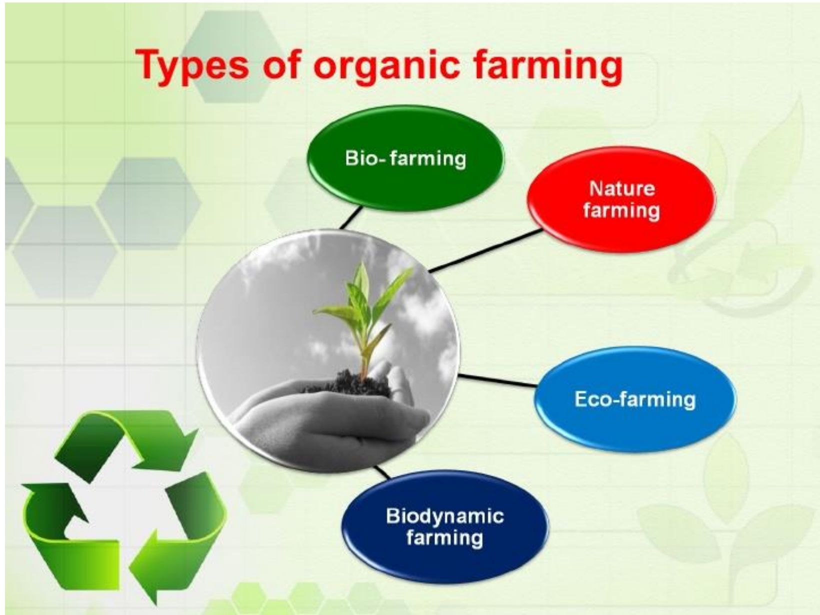
In some countries the above-mentioned systems might lack some essential features of NT/CA and will therefore not have the same beneficial effects.

Soil cover is needed to protect the soil from the impact of rainfall, which would destroy the porosity of the soil surface, leading to runoff and erosion. Crops are seeded or planted through this cover with special equipment or in narrow cleared strips. Direct planting or seeding is linked with NT/CA, since any more general tillage would bury most or all of the vegetal cover. Crop sequences are planned over several seasons to minimize the buildup of pests or diseases and to optimize plant nutrient use by synergy among different crop types and by alternating shallow-rooting crops with deep-rooting ones. When the same crop or cover crops are repeated on the same piece of land each year, NT/CA is an imperfect and incomplete system, because diseases, weeds and pests tend to increase and profits tend to decrease .

There are several reasons, however, for the continued dominance of conventional tillage-based agriculture. There is a natural reluctance to change approaches that have been working in past years or for decades. Conventional wisdom on the benefits of ploughing and a lack of knowledge on the resulting damage to the soil system tend to maintain plough-based agriculture. Also, the transition to NT/CA is not free of cost, nor particularly simple. During the transition years, there are extra costs for tools and equipment. Higher weed incidence may increase herbicide costs initially and the yields and resilience against drought will improve only gradually.



The spread of NT/CA approaches in the next three decades is expected to be considerable but, in addition to the constraints mentioned above, expansion will for several reasons vary widely across countries. Investment is needed to restore nutrient-depleted soils before crop residues can be produced in adequate amounts to satisfy the needs of livestock and maintain a soil cover. In arid areas without irrigation, the amounts of crop residues generally will not be sufficient for effective NT/CA systems. In some countries, established extension services or staff have been actively discouraging farmers from converting to NT/CA, while in others the scientific or extension institutes are not able to initiate the onfarm experiments needed to adapt and validate NT/CA systems locally.



ORGANIC AGRICULTURE

Organic agriculture is a production management system that aims to promote and enhance ecosystem health, including biological cycles and soil biological activity .It is based on minimizing the use of external inputs, and represents a deliberate attempt to make the best use of local natural resources. Methods are used to minimize pollution of air, soil and water ,although they cannot ensure that products are completely free of residues, because of general environmental pollution. Organic agriculture comprises a range of land, crop and animal management procedures. Unlike food labelled as “environmentally friendly”, “natural” or “free-range”, organic agriculture is circumscribed by a set of rules and limits, usually enforced by inspection and certification mechanisms. Other terms used, depending on the language, are “biological” or “ecological”. “Biodynamic” refers to commodities that are produced according to organic and other additional requirements.

Synthetic pesticides, mineral fertilizers, synthetic preservatives, pharmaceuticals, GMOs, sewage sludge and irradiation are prohibited in all organic standards. Plant nutrient or pesticide inputs derived directly from natural sources are generally allowed, as is a minimum of pretreatment before use (water extraction, grinding, etc.).

Most industrial countries, but few developing countries, have national organic standards, regulations and inspection and certification systems that govern the production and sale of foods labelled as “organic”.The growing interest in organic crop, livestock and fish products is mainly driven by health and food quality concerns. However, organic agriculture is not a product claim that organic food is healthier or safer, but rather a process claim intending to make food production and processing methods respectful of the environment.

Organic production system designed to

- Enhance biological diversity within the whole system.
- Increase soil biological activity.
- Maintain long-term soil fertility.
- Recycle wastes of plant and animal origin in order to return nutrients to the land, thus minimizing the use of non-renewable resources.
- Rely on renewable resources in locally organized agricultural systems.
- Promote the healthy use of soil, water and air as well as minimize all forms of pollution that may result from agricultural practices.
- Handle agricultural products with emphasis on careful processing methods in order to maintain the oranic integrity and vital qualities of the product at all stages.
- Become established on any existing farm through a period of conversion, the appropriate length of which is determined by site-specific factors such as the history of the land and the type of crops and livestock to be produced.

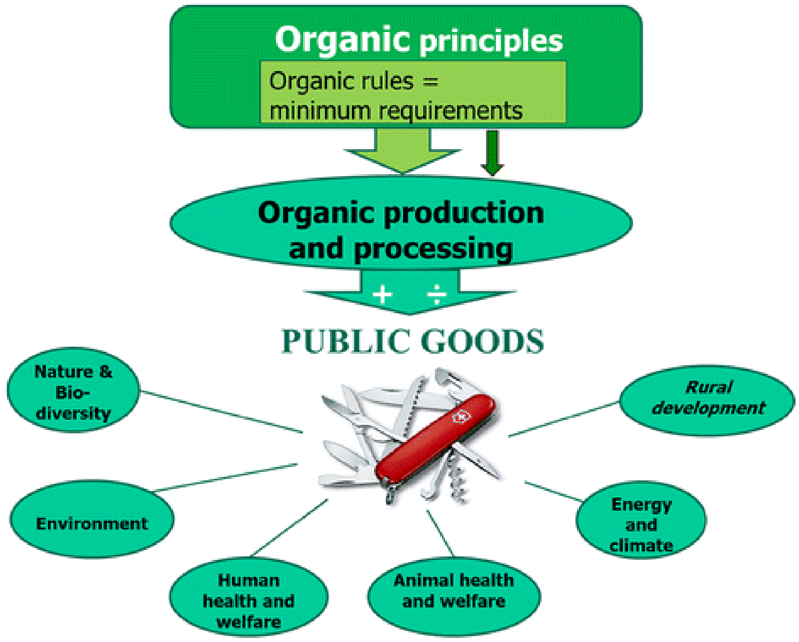
Organic agriculture, broadly defined, is not limited to certified organic farms and products only. It also includes non-certified ones, as long as they fully meet the requirements of organic agriculture. This is the case for many non-certified organic agricultural systems in both developing and industrial countries where produce is consumed locally or sold directly on the farm or without labels. The extent of these systems is difficult to estimate since they operate outside the certification and market systems .

Organic practices that encourage soil biological activity and nutrient cycling include: manipulation of crop rotations and strip cropping; green manuring and organic fertilization (animal manure, compost, crop residues); minimum tillage or zero tillage; and avoidance of pesticide and herbicide use. Research indicates that organic agriculture significantly increases the density of beneficial invertebrates, earthworms, root symbionts and other micro-organisms (fungi, bacteria) (FiBL, 2000). Properly managed organic agriculture reduces or eliminates water pollution and helps conserve water and soil on the farm. Some countries (e.g. France and Germany) compel or subsidize farmers to use organic techniques as a solution to nitrate contamination in groundwater.

Yields and profitability

Typically, farmers experience some loss in yields after discarding synthetic inputs and converting their operations from conventional, intensive systems to organic production. Before restoration of full biological activity (e.g. growth of soil biota, improved nitrogen fixation and establishment of natural pest predators), pest suppression and fertility problems are common. The degree of yield loss varies and depends on inherent biological attributes of the farm, farmer expertise, the extent to which synthetic inputs were used under previous management and the state of natural resources .It may take years to restore the ecosystem to the point where organic production is economically viable.

Transition to organic management is difficult for farmers to survive without financial compensation, especially in high intensive input agriculture and in degraded environments. After the conversion period, organic agriculture achieves lower yields than high external input systems. Depending on the previous management level of specialization, yields can be 10 to 30 percent lower in organic systems, with a few exceptions where yields are comparable in both systems. In the medium term, and depending on new knowledge, yields improve and the systems' stability increases. In the longer term, performance of organic agriculture increases in parallel with improvements in ecosystem functions and management skills.



For example, India is collecting nationwide information regarding the experiments being carried out in organic agriculture, with a view to reintroducing it as part of its traditional "rishi agriculture". In Latin America, hundreds of thousands of indigenous farmers along the Andes have turned to the organic movement to reinstate sophisticated agricultural practices developed by the Incas. Individual small family vegetable plots and groups/associations managing organic produce for domestic urban markets and small informal fairs are widespread.

In organic systems, external inputs such as fertilizers, herbicides and machinery are replaced by labour, most often increasing women's work. Labour can either be a major constraint to organic conversion, or an employment provider to rural communities. Often the introduction of organic agriculture shifts gender distribution of labour as men prefer to be involved with mechanized agriculture. Women rarely own land and are dependent on access to common property. Since access to credit frequently requires land as collateral, women (and landless people) are largely excluded from the formal credit market. As a result, women seek methods that require little external inputs. Organic agriculture facilitates women's participation as it does not rely on financial inputs and access to credit.

The economic performance of organic agriculture in industrial countries (mainly in Europe) is determined by financial support from governments, premium prices for produce and high labour costs. An extensive analysis of European farm economics in terms of labour use, yields, prices, costs and support payments, concludes that profits on organic farms are, on average, comparable to those on conventional farms .

Demand for organic products

On the demand side, promotion and marketing strategies of retailers and supermarkets, in particular of major food-retailing chains, have created new market opportunities for organic agriculture in industrial countries. Food-retailing chains, which also stock and promote organic foods as a tool to improve their public image, account for a major share of the retail markets for fresh as well as processed organic foods. Concerns about growth-stimulating substances, GM food, dioxin-contaminated food and livestock epidemics (such as bovine spongiform encephalopathy) have given further impetus to organic food demand as consumers increasingly question the safety of conventional foods. The most recent outbreak of foot-and-mouth disease has added to concerns over the soundness of industrial agriculture. Several governments have responded with declarations of targets for the expansion of organic production. Many consumers perceive organic products as safer and of higher quality than conventional ones. These perceptions, rather than "science", drive the market.

The market opportunities arising from these concerns have also opened possible niche markets for developing country exporters. Major industrial countries' markets offer good prospects for suppliers of organic products that are not produced domestically (e.g. coffee, tea, cocoa, spices, sugar cane and tropical fruit) as well as off-season products (such as fruit and vegetables) and processed foods. Liberalization and privatization policies in developing countries open the way for a greater role for organic entrepreneurs and producers' organizations. Markets for value-added products such as organic commodities can help counterbalance falling commodity prices and withdrawal of government support for agricultural inputs and other services.

Long-term prospects for organic agriculture

The future growth of organic agriculture will depend more on supply constraints than on developments in demand, at least over the medium term. The tendency so far has been for the rate of demand growth to outstrip the rate of growth in available supplies. Developing countries are just starting to benefit from organic market opportunities but present conditions benefit primarily large producers and operators.

The supply and quality of organic raw material and rules governing organic production and processing might limit the extent to which developing countries could satisfy the demand for organic food in industrial countries. Organic food trade might be discouraged by difficulties in complying with foreign standards and costly control systems, especially if international equivalency is not established. Access to inspection and certification, as well as the need to develop new methods of processing organic food, are major challenges that are likely to be taken up by large and established food companies .Multinational food companies are expected to contract for and certify organic foods. In particular, the growth of processed organic foods will be facilitated by these companies' capacities to assemble ingredients from different parts of the world and to guide production to meet their specific needs. At the same time there are numerous opportunities for developing country producers and exporters to enter the markets for value-added organic products using simple technology.

Further long-term impetus towards adoption of environmentally friendly farming systems, including organic agriculture, will stem from moves towards decoupling agricultural support from purely production-oriented goals. There will be increasing emphasis on support to agriculture's role in providing public goods. Agricultural and environmental policies, including those responding to food safety concerns, will play a large role in facilitating or hindering the adoption of organic agriculture.

Besides financial support for conversion and regulations to protect the claim of organic producers, public investment in research and training is fundamental for such a knowledge- and management-intensive production system. It is still difficult for farmers and extension services to draw on a wide selection of well-researched methods and approaches. This often limits adoption to the most innovative farmers. Organic agricultural research receives only a fraction of the funds going to biotechnology research.

In developing countries, non-market organic agriculture and domestic certified organic agriculture are expected to increase in the long term. In particular, areas where economic growth is lagging (e.g. sub-Saharan Africa) and external inputs are unavailable or unaffordable, non-market organic agriculture could contribute to achieving local food security.