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Internal Resources for Sustainable Agriculture

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This Gatekeeper Series is produced by the International Institute for Environment and Development to highlight key topics in the field of sustainable agriculture. Each paper reviews a selected issue of contemporary importance and draws preliminary conclusions of relevance to development activities. References are provided to important sources and background material.

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INTERNAL RESOURCES FOR SUSTAINABLE AGRICULTURE

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The "Green Revolution" has been most successful where capital, infrastructure, and price incentives have combined to help farmers take advantage of the new production package. New varieties, the heart of the package, have responded to added fertiliser, improved weed control, and protection by chemical pesticides. This production technology has helped countries to buy time while working to control population and further develop agriculture and industry (Francis and Harwood, 1985).

But the majority of Third World farmers have been untouched by the new technology. The substantial inputs of chemical fertilisers, pesticides, and other fossil fuel derived production inputs needed for these technologies continue to be unavailable or unaffordable to most resource poor farmers. Of equal or greater importance is the indiscriminate use of fertilisers or pesticides which create immediate dangers for the farm family and long-term consequences in the environment. The alternative is to concentrate research and development efforts on technologies that are low-cost, appropriate in scale and application, safe and affordable.

The Nature of Internal Resources

Sustainable agriculture builds its foundation on the resources which are renewable within the farm and the immediate area. Rainfall, biologically fixed nitrogen, nutrients from lower soil strata, and biological pest control based on crop rotations are some examples of such 'internal resources'. They can be contrasted to external counterparts, namely irrigation water from a distant source, synthetic nitrogen fertiliser or phosphates brought in from outside, and chemical pesticides. Internal and external production resources are summarised in Table 1.

Internal resources are part of the naturally occurring local environment and their efficient use can promote an ecologically sound method of farming. We can consider these resources as the "natural capital" base for farming. Because they are renewable they generate "interest", for example the nitrogen produced by a green manure crop. In contrast, use of non-renewable resources such as fossil fuels is comparable to using up capital. In addition external resources such as fertilisers and pesticides have greater potential for contaminating groundwater as well as causing family and off-farm health problems, especially where educational level is low and technology is not easily and safely applied in farming. There is also a greater long-term fossil fuel energy investment, since most external production factors are ultimately dependent on this scarce resource.

Table 1 Agricultural production resources which are derived from internal and external sources (Francis and King, 1988).

Internal Resources	External Resources
Sun - source of energy for plant photosynthesis	**Artificial lights** - used in greenhouse food production
Water - rain and/or small, local irrigation schemes	**Water** - large dams, centralised distribution, deep wells
Nitrogen - fixed from air, recycled in soil organic matter	**Nitrogen** - primarily from applied synthetic fertiliser
Other nutrients - from soil reserves recycled in cropping system	**Other nutrients** - mined, processed and imported
Weed and pest control - biological, cultural and mechanical	**Weed and pest control** - chemical herbicides and insecticides
Seed - varieties produced on-farm	**Seed** - hybrids or certified varieties purchased annually
Machinery - built and maintained on farm or in community	**Machinery** - purchased and replaced frequently
Labour - most work done by the family living on the farm	**Labour** - most work done by hired labour
Capital - source is family and community reinvested locally	**Capital** -external indebtedness, benefits leave community
Management - information from farmers and local community	**Management** - from input suppliers, crop consultants

Labour, capital, and management may also be either internal or external to the farm. When labour and management are primarily internal – for example a family owned and operated farm – there is an integral involvement of people and their long-term goals with the decisions on the farm. There is greater concern over the safety and health of those working on the farm and the quality of the immediate environment in which they live and work. This tends to build in planning over longer time horizons. Similarly, when the primary source of capital is the family and community, there is a sharing of risk and reinvestment of profits into the farm and the same community. In contrast, an external indebtedness ties the farm into a larger economic structure, and benefits are more likely to leave the community. In general an environmentally sound and sustainable agriculture is more likely to be fostered by farming systems under management and financial control of families living directly on the land.

Crops and Varieties that Exploit Internal Resources

Crop hybrids and varieties have been the centrepieces of improved technological packages. New varieties increase the genetic yield potential of a cropping system to take advantage of other improvements in the production environment. Contrary to conventional wisdom among those interested in low-input agriculture, an improved hybrid or crop variety often performs as well or better than traditional varieties under a wide range of conditions, even under the climatic or biotic stress which often occurs under a resource-limited small farm situation.

The seeds of self-pollinated crop varieties such as rice, wheat, cowpea, or dry bean can be saved by the farmer for planting in the next season or year, providing some care is taken to maintain the disease-free nature of the variety through selection of healthy plants and seed. As a result of this process, the seed becomes an internal resource on the farm. Several other examples of crop varieties that exploit internal resources in cropping systems are:

- Much publicised rice varieties IR-8, IR-42 and others from the International Rice Research Institute in the Philippines were the core of the technical package of improved technology which revolutionised rice culture and productivity in Asia and Latin America. Although highest yields were reached with fertiliser and herbicide inputs, the varieties usually outperformed traditional varieties even without the new inputs.
- Virus-free seed of dry bean varieties from the International Center of Tropical Agriculture in Colombia is being grown by farmers in a number of countries in Central and South America; since there is no source of virus in bean fields, insecticides can often be eliminated since there is no need to control the vector.
- Selection of higher yielding pearl millet varieties in the Sahelian Center of the International Center for Research in the Semi-Arid Tropics in Mali is providing farmers with seed of a drought tolerant crop which can be grown in place of sorghum in some areas.

There is a perception that developing country farmers are content with their traditional varieties. Although this may be the case, the same farmers are constantly testing new strains from neighbours, private industry, or the government to see if another variety with the same nutritional or cooking characteristics and market potential would do even better under their current cropping systems. There is thus a potential to move new varieties into traditional systems - and this is one of the most cost-effective ways to improve productivity if the new cultivar makes better use of internal resources on the farm.

Internal Soil Fertility

Providing adequate nutrition to crops in the past has emphasised the use of fertilisers. Trials have been conducted to establish crop needs and responses, and there have been investments in the infrastructure required to import products or develop internal capacity to manufacture synthetic fertilisers. But crop plants are indifferent to fertility sources as long as they are adequate for growth and development. Developing countries have been encouraged to emulate the temperate zone industrial model and bring external fertilisers to the field, rather than assess the nutrient needs and consider all the available options, including those that are internally available.

Internal sources of plant nutrients include those present in the soil organic matter and mineral fraction, nitrogen fixed by legumes and other N-fixing species, rainfall, and lower soil strata. Although not available in all situations, when an internal source of fertility can be substituted for a purchased fertiliser there is a saving in production costs. In addition, most internal fertility sources provide less potential for harm to the environment. Examples of farming practices that can promote use of nutrients internal to the system are:

- When topsoil is continually lost through action of wind or water, the most valuable nutrients are lost at the same time. Contour tillage and planting, keeping crop residues on the soil surface, and multiple cropping systems with crops of different maturities all can reduce soil erosion and nutrient loss.
- Introduction of diversity in cropping sequences, especially rotations of cereals with legumes and other N-fixing species, can lead to substantial levels of fixed nitrogen from the atmosphere and build-up of organic matter.
- Catch crops planted late in the rainy season can take advantage of late season moisture, capture some nutrients, and maintain cover over the soil for more of the year.
- Alley cropping with woody legumes provides fixed nitrogen and mulch for crops, as well as a windbreak effect to reduce crop transpiration, forage for ruminants, and firewood. This last product is significant because it allows more animal manure to be returned to production fields rather than being burned for fuel.

These are all rational approaches to improving fertility with a minimal reliance on purchased fertilisers.

Internal Strategies for Pest Control

Conventional improved technology has relied on use of chemical herbicides and insecticides for control of unwanted species of weeds and insects in crops. Some experts estimate that 50% of crops are lost in tropical areas either in the field or in storage due to insect damage, while the insidious effects of weeds remove water and nutrients which would otherwise be available for crops. Ability to keep fields clean in fact limits the size of areas each family will plant in some regions. Chemical controls are dramatic in their visible effects, but prove to be expensive both in cash outlay and in environmental side effects of misapplication.

A rational lower cost alternative is integrated pest management, a strategy which looks for economic and biological threshold levels before using any chemical or other control. Other internal resource approaches include:

- Crop rotations can drastically reduce pest populations by breaking their reproductive cycles. Even if chemical pesticides are used, they should be applied in minimal effective concentrations and should be rotated as well to prevent natural selection within pest species populations for resistance to a specific product.
- Genetic resistance or tolerance to insects and pathogens provides a potential for control with the "internal" resource of a new variety - a part of the system once it is introduced. Tolerance to pests is a better option than complete control, since this puts less pressure on the organism to evolve and overcome the resistance.
- Biological control agents such as the bacterium *Bacillus thuringiensis* have been shown to be effective against a wide range of vegetable attacking insects (Yepsen, 1984).
- Intensive cropping of more than one species in the field has been shown to reduce both weed and insect problems. For example, leaf beetle in dry beans as well as fall armyworm in maize were controlled by intercropping the two species in the Cauca Valley of Colombia (see chapter by Altieri and Liebman, in book by Francis, 1986). These are practical options and alternatives to chemical pesticide use.

Intercropping Systems

To date research and development efforts in the international centers and national programs have concentrated on monocrop systems. This was perceived as the most logical and direct route to successful increases in productivity, since most of the models in the developed world were centred on monocrop culture. In fact, much of the production of major food crops in developing countries takes place in more complex systems, often involving intensive intercropping with more than one crop in the field at the same time.

Intercropping systems bring diversity and resource use intensity to environments which are often harsh - in terms of scarcity of some key resource. This may be water, nitrogen or phosphorus, or chemical inputs to control pests. Farmers are rational in their use of intensive systems to provide some cultural control of fertility, insect pests and weeds. When the crops are destined to provide both food 'supply and income, the greater diversity of multiple species systems gives a better balance to the family diet - especially when there are limited cash resources to access food in other ways.

- Intercropped maize and beans in Colombia reached yields of 2 tonnes/ha of beans in 90 days and over 4 tonnes/ha of maize in 150 days; intercropping consistently produced greater total grain yield than either of the monocrop components.
- Agronomic and economic analysis of maize/bean and sorghum/pigeonpea combinations in more than 150 environments in Colombia and India showed that the intercropping was more stable in yield and presented less economic risk of failure; this was an experimental confirmation of why many limited resource farmers continue to use intercropping systems (Francis, 1986).
- Pest protection and rotation benefits of intercropping have been mentioned above in other sections. Further research is giving scientists greater confidence in developing extension recommendations on how to implement new practices and build on the value of biological diversity inherent in complex plant systems which more closely resemble natural ecosystems.

Above all, the diversity of intercrop systems provides a capacity for both biological and economic buffering in the system in ways that are not possible with monoculture. Much of the structuring of intercropping systems and the management decisions needed for rotation of crops depend on new information. Once these recommendations are used by the farmer, they become "internalised" as part of the local resource base. The greatest potential for improving productivity while reducing purchased fertiliser and chemical inputs is to build an efficient use of internal production resources. This will also lead to systems which have less adverse effect on the environment.

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The Sustainable Agriculture and Rural Livelihoods Programme

The Sustainable Agriculture and Rural Livelihoods Programme of IIED promotes and supports the development of socially and environmentally aware agriculture through policy research, training and capacity strengthening, networking and information dissemination, and advisory services.

The Programme emphasises close collaboration and consultation with a wide range of institutions in the South. Collaborative research projects are aimed at identifying the constraints and potentials of the livelihood strategies of the Third World poor who are affected by ecological, economic and social change. These initiatives focus on the development and application of participatory approaches to research and development; resource conserving technologies and practices; collective approaches to resource management; the value of wild foods and resources; rural-urban interactions; and policies and institutions that work for sustainable agriculture.

The Programme supports the exchange of field experiences through a range of formal and informal publications, including *PLA Notes* (*Notes on Participatory Learning and Action - formerly RRA Notes*), the *IIED Participatory Methodology Series*, the *Working Paper Series*, and the *Gatekeeper Series*. It receives funding from the Swedish International Development Cooperation Agency, the British Department for International Development, the Danish Ministry of Foreign Affairs, the Swiss Agency for Development and Cooperation, and other diverse sources.

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