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INTRODUCTION

Sustainable intensification of agricultural production: the challenge

Notwithstanding the efforts of the international community, and despite the progress that has been made, under-nutrition still persists on a massive scale in the countries of the South. In 2010, FAO estimated the number of people suffering from malnutrition at 925 million, in other words 13.6% of the world’s population, approximately 6.8 billion inhabitants\(^1\). The bulk of this poverty-stricken and undernourished population lives in rural environments and is composed primarily of small producers who are often forced into exile in cities where their situation does not improve, to say the least.

There are countless causes of malnutrition. The rising price of cereals in 2007-2008 plunged a significant section of the population into a situation of food insecurity. Natural disasters, conflict and climate change, not to mention the depletion of land and other natural resources – these are all factors that lead to a worsening food situation.

Short-term measures are not the answer to this extremely complex problem. Sustainable conditions of subsistence must be promoted and set in place and supported if the world’s population is to be protected. This implies a new structure for aid that will bridge the gap between short-term measures and long-term development assistance initiatives.

In such a situation, agriculture has to come to grips with three major challenges: feed the world’s growing population; contribute to the reduction of rural and urban poverty; and respond to concerns about natural resources management, whilst simultaneously ensuring an adequate food supply.

However, there is no way that current agricultural systems can meet these challenges in so many regions where water resources are being squandered, are being used in non-sustainable ways, jeopardizing land quality and threatening biodiversity.

So, time is of the essence in finding the ways and means that will lead to another, more sustainable, form of agriculture: i.e. one that is economically viable, socially acceptable and that respects both the earth’s natural resources and the environment.

Towards implementing sustainable agriculture programmes

ACF-IN intervenes in the aftermath of natural disasters or man-made (social, economic, conflict) crises. These situations are characterized by a reduction in food security and/or famine for vulnerable populations who then depend for their survival on international aid. Interventions targeting a given population take place either during a crisis, when emergency programmes are set in place, or immediately afterwards via rehabilitation and development programmes. In this latter case, ACF’s main goal is to restore the autonomy and self-reliance of beneficiaries without delay.

Seeking sustainable solutions in the fight against hunger and under nutrition is central to interventions of the Food Security and Livelihoods sector which works to set in place agricultural programmes whose goal is to support family agriculture to enable a given population to grow and consume food produced locally or to exchange these products with others required to satisfy other needs, whilst using natural resources in an equitable manner.

It would thus appear essential to develop agriculture in ways other than those that consist in reproducing agricultural production practices that rely on intensive use of external chemical inputs (fertilizers, pesticides). This is all the more crucial in that a growing number of small producers who have limited resources cannot afford to purchase these often very expensive inputs which, when used incorrectly, can have an extremely negative impact on the environment.

Alternative solutions are already available at local levels waiting to be more widely disseminated. These alternative production methods (which fall under some very diverse banners: agro-ecology, conservation

\(^1\) Food and Agriculture Organization, 2010 http://www.fao.org/
agriculture, organic farming, sustainable agriculture, reasoned management of resources, etc) combine often very traditional practices with innovative techniques all of which are working towards achieving the same goal: sufficient and sustainable production by means of “ecological intensification” that maximizes primary production per unit area without compromising the system’s ability to sustain its production capacity and respecting and giving the natural regulation functions of agro-ecosystems their due.

For its part, ACF has chosen to develop programmes that support small-scale sustainable agriculture focused on ensuring autonomy for farmers (low external input agriculture).

Why this handbook?

This document has been produced to serve as a reference tool for ACF-IN staff. It describes and explains practices aimed at improving the quality and sustainability of ACF-IN programmes in the field by facilitating their implementation.

To help beneficiary populations satisfy their needs by producing more, at lower cost, without depleting the basic resources on which they depend, ACF-IN field staff, whether agronomists or not, need to know what are the most suitable strategies and techniques.

ACF-IN intervenes mainly in regions where farmers depend primarily on local resources. By and large, modern technologies are not the first option when the issue is that of improving agriculture. In these regions, better use of local resources and optimization of natural processes can improve agricultural effectiveness. A change of direction from intensive agriculture towards agro-ecology to help feed the planet and safeguard the climate, is possible, affirmed UN Special Rapporteur on the Right to Food, Olivier De Schutter (August 2011).

The transfer of knowledge and dissemination of good practice to beneficiaries, humanitarian workers and decision-makers is the raison d’être behind this handbook.

Let us guide you…

This manual sets out a (non-exhaustive) review of “good agricultural practices”, based on real cases of implementation. The purpose is to pass on these skills and know-how and to encourage missions to apply them.

These good agricultural practices can be applied to any management systems, processes, or techniques that engender positive recognized results for beneficiaries.

Preference is given to the least expensive productive practices, relatively simple to implement and that use local materials. In this way they stimulate the revival or development of rural economies whilst curbing pressures on the environment and ensuring sustainable use and management of the natural resources that underpin agricultural activities.

Thematic Fact Sheets (Fliers) illustrating “good practices” applicable to each main stage of the agricultural production cycle, from the choice of the installation site through to preserving the harvest, have been drafted to make the manual easier to use. Each one suggests solutions to potential constraints at the local level and is illustrated with concrete examples.

Each Thematic Fact Sheet (Flier) also includes a bibliography of documents that could usefully be consulted for additional information.

2 http://www.thesolutionsjournal.com/node/971
A wide variety of relatively similar terms exist that refer to agricultural systems implementing “good agricultural practice”. For the sake of clarity and ease of comprehension these are very briefly defined below.

**Agroecology**

Agroecology [the science and practice of applying ecological concepts and principles to the study, design and management of ecological interactions within agricultural systems] advocates respect of the ecosystem and integrates the economic, social and political dimensions of human life. Taken in its broadest sense, agroecology is a whole-systems approach linking agricultural development with environmental protection. Its main goal is to move quantitative-based agriculture forward towards agriculture that is much more focused on quality; this implies revisiting both goals and processes.

It is based inter alia on:
- short circuit management of the cycles of water, carbon, nitrogen and minerals,
- maximum coverage of land by the vegetal biomass to meet the needs of photosynthesis, use of crop residues to provide animal fodder,
- recourse to organic soil conditioners (manure and compost) to fertilize the land
- regulation of the reproductive cycles of insect pests,
- maintenance of a large domestic and spontaneous biodiversity, etc.

Agroecology equally advocates intensive use of renewable natural resources (luminous energy, carbon and nitrogen in the air, rain water, etc) with very limited use of non-renewable natural resources (fossil fuels, underground water, phosphates, etc) and chemical inputs (artificial fertilizers, synthetic plant health care products, antibiotics, etc).

**Conservation agriculture**

According FAO⁴, the purpose of Conservation Agriculture (CA) is to achieve sustainable and profitable agriculture and improved livelihoods of farmers whilst conserving and improving both resources and the environment. Three main principles can be said to characterize CA:

- minimal soil tillage (even going so far as zero tillage, direct seeding)
- permanent soil cover with living and/or dead vegetal mulch (straw), soil cover rates being ideally over 30%
- diversification of crops and/or crop rotations

CA’s goal of sustainable and profitable agriculture has great potential for all types of farms and agro-ecological environments. It is a very attractive concept for small farmers whose limited production resources do not permit them to overcome time and labour constraints. These smallholdings are priority targets. It is one way of harmonizing agricultural production, improvement of living conditions and environmental protection.

**Sustainable agriculture**

In an agricultural context, “sustainability” primarily refers to the capacity of the agrosystem to remain productive whilst protecting the resources it needs and on which it depends (biodiversity, soil nutrients, water...) and at the same time being both socially acceptable and limiting negative impacts on the environment.

With reference to the “pillars” of sustainable development, sustainable agriculture encompasses:

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- An ecological dimension, sustainable agriculture being accountable for protecting the environment, safeguarding natural resources and biodiversity;
- An economic dimension; this refers to the viability of production systems, which must yield benefits sufficient to render manufacturing costs and investment profitable;
- A social dimension, the implementation of production systems that must maintain equity between all members of society in sharing power, resources and land, and guarantee conditions of access to sufficient capital and market opportunities.

**Biological farming or organic agriculture (often referred to as Organic Farming)**

Organic Agriculture (OA) is a production management system regulated at European and International levels based on respect of the environment, biodiversity, biological cycles and soil biological activity. Where possible it employs cultural, biological and mechanical methods, as opposed to using synthetic inputs.

OA regulations exclude any use of synthetic chemical products, seeds and genetically modified organisms (GMO), preservatives, additives and the practice of irradiation to preserve food and other agricultural produce. To an even greater extent than traditional agriculture, organic farming must be adapted to local contexts and adjusted to natural regulations to successfully contend with insects and other pests and to optimize efficient use of biogenic salts.

**Low input agriculture**

The expression “low [external] input” refers to the use of external production inputs, i.e. off-farm resources such as seeds, organic or synthetic fertilizers, pesticides and other crop protection products. It is in contrast to high external input agriculture that makes very intensive use of external renewable natural resources to produce the highest possible output with the minimum of [external] inputs.

Moreover, high input farming systems are also characterized by low capital investment and use of simple, locally available material.
The choice of a suitable site is of paramount importance in agriculture. Making the right choice is the key to success. Before beginning to plant a crop, choose the spot that best meets requirements, one that will allow the most advantageous use of resources (for example rain water) and involve the least arduous work (according to soil type, elevation…). Information usually sought before taking a decision about choosing a site focuses on:

- **Climate**: temperature, rainfall (quantity and distribution) relative humidity and wind.
- **Land**: soil depth and moisture holding capacity, texture, structure, source rock, pH levels, and drainage.
- **Topography**: important vis-à-vis exposure of crops to the elements and risk of erosion.
- **Existing vegetation**: composition and ecological characteristics of local flora and, if applicable, plants that have been introduced from elsewhere to the area.
- **Other biotic factors**: what effects, if any, have past events and current use of the land, had on the chosen site, in particular fire, domestic and wild animals, insects and disease.
- **Water table levels**: Knowing about depth and variations in water table levels in wet and dry seasons is invaluable and can be crucial in determining what type of trees and shrubs can be grown. Water table levels can be estimated by observing wells or boreholes drilled for this purpose.
- **Availability of additional water resources and distance from the site**: ponds, lakes, rivers and other water sources.

**What signs tell you that the land is good?**

- the soil is damp;
- it stays in a ball when you squeeze it in your hand and doesn’t crumble if you drop it;
- the height and colour (dark green) of the leaves on any plants present on the site;
- soil rich in fertile elements is dark;
- presence of earthworms;
- very few stones…

To assess soil quality, dig out (with a spade for example) a few samples from the plot and study:

- porosity: the earth should be porous;
- consistency: the sample should be crumbly and loose when moderately damp;
- texture: sandy soil feels gritty to the touch, clay soil feels sticky;
- colour: a dark colour indicates high organic matter content. However this criterion is not valid in soil that is naturally dark. Discoloured patches are indicative of excess water (rust colours), poor drainage or decomposition of organic matter (blue-grey);
- the presence of badly decomposed organic residue (old roots, straw) is symptomatic of poor soil function;
- living roots (if there are any) will be present in large numbers in all parts of a sample of well-structured soil;
- odour: in some cases, a rotting egg smell indicates poorly ventilated soil with little, if any, decomposition of organic matter.

Leaving aside biophysical data, **socio-economic factors** also play a significant role, in particular vis-à-vis ownership and tenure of land and buildings, availability of labour, motivation of the local population and distance of the cultivated plot from markets and shopping centres.
Where there is **no possible access to land**, in urban environments for instance, or when **weather conditions** put a temporary stop to growing crops in open fields, other solutions can be found to ensure production. "Alternative" supports can be obtained and conditions favourable to plant growth recreated.

Plants can be grown in a variety of containers, such as baskets and bags, pots or on rooftops (**Flier No. 2**). Greenhouse-like shelters can be erected to protect crops during bad weather and prolong the growing season (**Flier No. 3**).

Once the right site has been chosen, it must be **organized and designed** in ways that will optimize space and access to natural resources, such as water supply points. The land must then be shared equitably between beneficiaries. It is also a good idea to take advantage of any semi-natural elements present in the landscape in the vicinity of the plot of land, for instance hedges, thickets and meadows, which can be home to pollinators that provide invaluable protection against insects and other pests (**Flier No. 1**)

![Figure 2: Tomatoes grown in pots. ACF- Indonesia.](image)
Chapter 2: Selecting and sowing the best seeds

Seeds are the foundation of agriculture. They wield huge influence over yield and crop quality.

Since the Neolithic age, farmers have practised seed selection, setting aside varieties of seeds and seedlings that best meet a number of technical (size, ease of removing the seed coat, resilience…), and social (appearance, appetite, identity) criteria.

Furthermore, population movements of farmers, added to the colonization of new land, has resulted in seed selection that differs from one area to another, farmers adapting the varieties they choose to their (new) local environment.

This has lead to the emergence of a profusion of different varieties that form the base of what is commonly referred to as “domestic” vegetal diversity (Figure 4).

Nevertheless, FAO\(^5\) currently estimates that since the beginning of this century 75 percent of the genetic diversity of crops that existed at the beginning of the century has been lost.

Indeed, in the developed countries, and increasingly in the developing world, seed production is now mainly in the hands of professional seed merchants, companies specializing in the selection, production and marketing of seeds.

At the beginning of the 20th century, and to a much greater extent after the Second World War, the industrialization of agriculture and the very high cost of varietal selection lead to **loss of biodiversity in cultivated land**: population varieties with a broad and evolutionary genetic base are being gradually replaced by homogeneous varieties that, albeit more stable and more productive, have a very narrow genetic base.

Basic seeds are owned by the commercial seed companies producing them. Each year, ever-larger numbers of smallholders buy basic seed from them, in turn perpetuating this trading system.

An alternative solution could be to create a seed bank. However, this is not always the right answer. If there is sufficient information to indicate that farmers are already growing local varieties by exchanging seeds (between members of the same family or neighbours) then there is no need to create a seed bank, because farmers are already protecting biodiversity. However, if seed exchange is impossible, either because farmers live in remote locations or are so poor that they consume all they harvest and are not able to keep part of it then a well-managed seed bank could definitely be an effective solution.

In addition, “hybrid” seeds are generally very poorly adapted to local conditions; they tend to have been selected in “conventional” farming situations and require high inputs of chemical or other fertilizers.

So, it is crucial for this group of farmers to revert to traditional local selection methods, which have always existed and have already more than proved their worth.

**Seeds sometimes known as “farmers’ seeds”** are those sorted and selected by the smallholder himself in keeping with his land, prevailing regional climatic conditions and how his produce will be used.

In contrast to genetically engineered or “high-output” hybrid varieties, farmers’ seeds maintain maximum variability enabling them to continuously adapt to nature and the environment.

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6 Varieties with high genetic diversity, source of biodiversity and with good capacities of adaptation. This is the case for traditional that varieties it has been possible to maintain simply because certain rural communities continue to use them.
Each variety has its own specific qualities with which to defend itself against pests and adjust to the environment. This better adapts them to the conditions of agro-ecological farming.

There are many different methods of seed selection (Flier No. 4). When coupled with land sharing at local and regional levels these methods play a role similar to that of seed exchange by farmers in safeguarding biodiversity. At the same time seed selection allows producers to pick those varieties best adapted to their specific needs and that offer the best yields.

Seeds must be sown in a healthy environment if their full potential is to be developed and savings made in amounts of inputs used. In nurseries, for example, (Flier No. 5) the growth of young seedlings can be carefully monitored before they are planted out.

Similarly, transplanting seedlings is an often-underestimated phase of great importance during which innovative techniques make it possible to optimize results. This is the case, for instance, of the “Intensification System” used for growing rice (more commonly known as the “System of Rice Intensification” SRI), growing more with less, and that can be adapted to other cereals (Flier No. 6).
Chapter 3: Sustainable soil conservation techniques and agricultural practices

A. Soil management and conservation

The uppermost layer of the earth is called the crust; it is made up of mother rock that floated to the surface when the earth was formed and is enriched with organic matter.

The earth is also home to millions of living species and the nucleus of a multitude of biogeochemical activities. It both supports and produces life in all its forms.

It is a dynamic system fulfilling countless life-sustaining functions for human activity and the operation of the terrestrial biosphere.

Yet, this precious and finite resource is subject to the huge pressure that human activities exert on it: urbanization, industry, regional planning, and inadequate agricultural and forestry practices. These are just some of the factors that can have irreversible consequences for the earth and the diversity of life forms it supports.

A study published in 2008 by the United Nations Food and Agriculture Organization (FAO), asserts that rising and long-term land degradation threatens the lives of 1.5 billion people, i.e. a quarter of the world’s population.

This same study goes on to say that 20 percent of all cultivated areas, 30 percent of forests and 10 percent of grasslands are affected by this land degradation phenomenon. Approximately 22% of eroding land is located in arid or semi-arid and sub-humid areas and 78% in humid regions.

Tillage is the practice that most threatens farmed land. When soil is tilled carelessly, the land is laid bare, which can lead to soil erosion. In second place comes the movement of farm machinery (tractors, trailers, mechanical reapers). When used in conjunction with heavy equipment and/or in wet conditions this can deteriorate soil structure by compaction. Use of chemical fertilizers can cause soil acidification. When there are signs of humidity imbalance (for example when crop residues are removed and no organic soil conditioners are added to compensate for carbon loss), agriculture can weaken the organic matter content of the soil. Irrigating with poor quality water and evaporation can lead to soil salinization. And, finally, certain crop protection products can have effects (as yet little known) on soil biological activity.
In northern Cameroon, for example, just 10 to 15 years of annual ploughing, weeding and ridging of intensive cotton and cereal cultivation has sufficed to deplete soil fertility\(^7\).

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   http://www.fao.org/docrep/T1765F/t1765f03.htm
Soil degradation has a **direct influence on water and air quality, biodiversity and climate change and brings with it a drop in agricultural production capacity.**

Despite this, there are **countless numbers of simple methods that make it possible to produce enough, indeed even more than enough, whilst protecting the land and respecting nature’s balance.**

Agriculture conservation practices (**Flier No.7**) not unlike letting land lie fallow or with minimum tillage (**Fliers Nos. 8 and 9**), using the Zaï (planting pits) method (**Flier No. 10**) and direct seed planting with mulching (**Flier n°11**) are all examples that will be further explored in this handbook.

A further advantage of these techniques is their low cost and the fact that their implementation is both time and labour saving.

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**Figure 11: Deforestation in Madagascar (aerial view)**

**Figure 12: Mulching the soil in Laos.** Photo: conservationag.org.la [http://www.cansea.org.la/prosa/images/stories/sample/ca4.jpg](http://www.cansea.org.la/prosa/images/stories/sample/ca4.jpg)
B. Renewing soil fertility

Soil is formed by the alteration of mineral and organic material (mother-rock) and it is this parent material that gives soil its physical properties: stones, gravel, sand, silt and clay. However, soil formed only of these component minerals would be barren.

Soil fertility depends to a very great extent on the composition of its organic matter content and especially its humus content. Humus refers to any organic matter having reached a point of stability after a slow process of biochemical transformation of vegetable or animal waste by microorganisms, known as humification.

When clay combines with humus, it forms what is called the Clay-Humus Complex. This plays a crucial role in enhancing many of the physical, chemical and biological properties of soil.

Regarding the physical properties of soil, humus content influences structural stability (capacity of soil aggregates to resist water degradation) to a significant extent and even more so when soil has low clay content. So far as chemical properties are concerned, a negatively charged clay-humus complex “attracts” positively charged nutrient elements (cations), such as potassium, calcium, and magnesium, inter alia, necessary for plant growth.

Recycling occurs on a continuous basis in the natural environment. Organic matter goes back into the ground and is broken up by the microorganisms living in the soil before being mineralized (converted into a mineral substance, petrified) by bacteria. Soil fertility depends on the constant addition of organic matter to feed nutrient recycling.

In agriculture, on the other hand, this cycle is broken. During harvesting a significant proportion of organic matter (fully grown plants) is removed and little or none being left to replenish the earth.
Mineralization then produces far fewer mineral salts; to sustain agricultural production, plants will need the extra biogenic salts provided by organic soil conditioners (manure and other livestock waste) and synthetic (nitrogen oxide) or natural (potassium, phosphates) mineral fertilizers.

Then again, excessive fertilization can jeopardize the environment and cause organic or mineral pollution of ground water (nitrogen and phosphorus pollution) and underground water (nitrogen pollution). In addition, monetary and energy consumption costs are high. But above all, and most importantly, fertilizers have no effect on the soil’s humus content: chemical fertilizers and liquid manure contain virtually no vegetable matter and so cannot replenish the humus in the soil.

Figure 16: Organic pollution in Lake Tai, in China. http://www.chinadaily.

Liquid manure and other mineral fertilizers should be applied judiciously, and not used to excess. (Flier No. 17).

Organic matter will however need to be added to conserve soil properties. This is the core approach of basic agroecology. It is important to remember that many “natural” sources of organic matter, such as crop residues, dead leaves and twigs, can be found locally.

All these are also helpful in that they can be spread over the soil to form a protective cover (Flier No. 11), made into compost (Flier No.12) or mixed with manure from plant eating animals (herbivores) (Flier No.13).

Figure 17: Composting in Peru. Photo Jan Banou

Moreover, and to ensure long-term fertility, the natural properties of certain crops can be used: rotation farming (Flier No. 18) helps control soil depletion and intercropping (growing two or more crops in proximity) (Flier No. 19), especially pulses and legumes, can create an abundant biomass and enrich the soil’s nitrogen content.
They can also be used as green manure (Flier No. 14) if left on the topsoil after harvesting.

Finally, carbon (Biochar) inputs (Flier No. 15) and/or integrating livestock breeding (manure, fish farming, Flier No. 16) into agricultural systems are other examples of practices aimed at ensuring recycling of soil fertility and agricultural production systems using locally available and low-cost resources by completing the full circle of essential component cycles (carbon, nitrates, phosphorus, potassium).

Figure 18: Low-input garden. ACF-France, Zimbabwe.

Figure 19: Fishing in a Rice Paddy, India. http://photo.outlookindia.com/images/gallery/20100303/organic_farming_20100315.jpg
C. Preserving water resources

Water and food security are very closely intertwined.

Of the almost 925 million people worldwide suffering from hunger the majority live in regions where water is scarce. This slows down agricultural production potential to a significant extent.

Whilst rainfed agricultural production is still the dominant method today, low levels and/or irregularity of rainfall means that farming is well nigh impossible without irrigation.

At this point the issue of mobilizing water resources arises.

A whole range of practices need to be set in place to ensure the best possible use of water resources, limit production shortfalls and to make it possible to optimize water imports, reduce loss, and improve efficiency of use.

These practices are varied and based upon certain principles:

- **Design and establish the chosen site in ways that will make best use of rainwater sources** and, whenever possible, organize systems of rainwater recovery and storage;

- **Evaporation can be reduced** by avoiding irrigating land in the middle of the day, by watering the underside of leaves and laying down vegetation cover;

- **Conserve good soil structure and fertility**;

- **Avoid over-irrigation** to increase crop resistance to potential stress, make the most advantageous use of water;

- **Control weeds** which compete with crops for water;

- **Plant and harvest at the right time**;

- **Reduce water loss through leaks in irrigation canals** by applying protective coatings or by using closed conduits

Water resources, whether or not they are in short supply, must not be wasted. Crop cultivation methods should be adapted to environmental capacity, to the need for a particular crop to be grown and in the interest of conserving this vital resource and the environment.

This handbook will only focus on the methods that are simplest to implement and are the least expensive for vulnerable populations.
Water in sufficient quantity…. but water of sufficient quality

Agricultural practices do occasionally pollute. This can have a very negative effect on the quality of water.

Poorly managed livestock and other animal waste, unrestrained use of fertilizers and excessive use of pesticides and herbicides can have harmful effects both on human health and on the environment.

Consequently, if a sufficient supply of water is to be guaranteed it is crucial that a number of other additional pollution reduction practices be implemented. The following key elements are also described in more detail in the Handbook’s Fliers.

- Use carefully measured amounts of organic fertilizers (See Chapter 3. B)
- Do not use chemical herbicides or pesticides (or only in cases of dire necessity and only in very small doses) (Flier No. 17 and Chapter 3. D)
- Recuperate and use livestock manure in order to better control what happens to it. It also provides a valuable source of organic matter. (Flier No. 13)
- Maintain good soil structure to help fix minerals and limit how much is washed away. (Chapter 3. A)

Figure 24: [Image]

http://edaa.in/image/affectofwaterpollution.jpg/image

Figure 25: Papaya plants on a drip system. [Image]

http://www.pcdn-mali.org/local/cache-vignettes/L448xH287/irrigation_par_micro-jet-e4525.jpg

Figure 23: [Image]

http://www.agnet.org/images/library/nc167b2.jpg
D. Protecting crops from diseases, pests, and weeds

The extent of damage caused to crops and food stocks by various harmful bodies or microorganisms competing for soil resources (weeds, insect pests, fungus, virus, etc.) often obliges farmers to resort to protection measures.

These protection measures include chemical crop protection using synthetic pesticides, herbicides and fungicides. This practice was long considered to be the most effective and most easily practicable solution. However, besides being costly, these products have documented side effects on the environment and health.

Phytosanitary products can contaminate the environment either during a specific isolated instance of pollution (accidents during storage, tank overflow) or by diffuse pollution (run-offs and infiltration).

Their toxicity has long been recognized, in particular when these products are misused or the dosage is too high. This is all the more important in that some active substances tend to accumulate in the food chain. The greatest risks to human health are taken by those using these products, i.e. farmers, and also amateur gardeners, who always do not always comply with instructions for use and recommended health and safety guidelines and regulations.

The use of phytosanitary products is also believed to be a cause of biodiversity reduction particularly the decline in numbers of insects such as bees and butterflies or some species of plants. That can be explained in part by the use of broad-spectrum plant health products, i.e. those not targeting a particular species, or by unsuitable application methods.

The repeated application of products can trigger resistance to the molecules used in these products, which makes these products less effective and thus the increase of the applied doses.
Automatic recourse to chemicals to counter parasitic attacks and increase yield is not therefore an appropriate response to the needs of sustainable exploitation of agro-ecosystems ... nor is it the only possible solution to contend with pests.

It is essential that sustainable agronomic practices be put back under the spotlight by means of technical innovations and the exploitation of the environment's own natural defences.

Crop rotation (Flier No. 18) breaks the development cycle of pests that are harmful to crops, in particular arthropods and fungi, which tend to prefer certain crops to others.

Some plants even have a clearly suppressive effect on pests, for instance radishes on nematodes, mustard on a fungus that causes Gaeumannomyces graminis, commonly known as “take-all” disease or fungus and Ophiobolus graminis, diseases affecting cereals, or buckwheat on some types of weed (allelopathic effect).

These plants can be used in combination with the main crop (Flier No. 19) to repel or control pests.

Other plants can also be used as biopesticide sprays, for which wide variety of “recipes” are available. This is the case for example of garlic, Indian Lilac (Azadirachta indica), peppers, etc.

These practices can prove very effective when combined with the protection of meadows and grassland (planting hedges, mulching...).
Chapter 4: Proper storage and conservation of seeds and productions

The ineffectiveness of local production systems is not alone to blame in countries where food autonomy has yet to be achieved. In reality, the extent of post-harvest shortfalls can significantly curb the impact of efforts to increase food production, which in turn reduces availability of food at the local level.

Once harvested, crops undergo a whole series of processes during which quantitative and qualitative losses can occur.

Late harvesting can result in losses of grains and cereals due to their having been attacked by birds and other pests whilst waiting to be reaped. Insufficient drying can cause mould to develop. Grains can crack during threshing, encouraging infestations of grain beetles.

Poor storage conditions generate losses through the combined action of mould, (in particular in wetlands), insects, rodents and other pests, not to mention hazards such as fire and flooding.

Finally, substandard transport or packing of grains can lead to shortfalls in produce.

Similarly, there are numerous ways in which root vegetables, leafy greens and bulbs can be ruined during storage. On the one hand, there are endogenous physiological factors, such as sweating (that have an especial impact on weight and size), respiration and germination.

And on the other, exogenous factors, such as insect pests, nematodes, rodents and bacteria also cause decay and fungi in stored produce with consequent post-harvest crop losses.

<table>
<thead>
<tr>
<th>Group</th>
<th>Principal causes of loss and poor quality</th>
</tr>
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</table>
| Root vegetables (carrots, beetroot, potatoes, sweet potato, manioc,) | Mechanical injuries  
Improper curing  
Sprouting and rooting  
Water loss (shrivelling)  
Decay |
| Bulbs (onions, garlic)             | Mechanical injuries  
Improper curing  
Sprouting and rooting  
Water loss (shrivelling)  
Decay |
| Leafy vegetables (lettuce, chard, spinach, green onions) | Water loss (wilting)  
Loss of green colour (yellowing)  
Mechanical injuries  
Relatively high respiration rates  
Decay |
| Flower vegetables – before fully ripe (cucumbers, squash, egg plant, peppers, okra, snap beans) | Over-ripeness at harvest  
Loss of water (wilting)  
Bruising  
Chilling injury  
Decay |
|---|---|
| Mature fruit and vegetables (tomatoes, melons, citrus, mangoes, stone fruits) | Bruising  
Too ripe (soft) during harvesting  
Water loss  
Compositional changes  
Decay |


After storage, or directly after harvesting, part of a crop is also set aside for processing (saucers, preserves, dried food…). At this stage, it is also important to comply with food processing standards related to the safety, nutritional value, flavour of foodstuffs and their correct preservation treatment (Flier No. 25). So, post-harvest crop management is especially important and must be paid careful attention.

Furthermore, poor conservation of seeds selected for the next season’s replanting brings with it a very high risk of future production deficit and, in consequence, poses a threat for food security (Flier No. 24).

The methods discussed in this report consist of a non-exhaustive set of examples of simple, low-cost good practice for the management of production, storage and processing.

These practices are flexible and adaptable, in particular with respect to the climate, intended use of stored goods, and socio-cultural aspects of storage (symbols of prosperity, cultural use).

The choice of storage structures also depends on what building materials are available, as well as on what resources farmers have at their disposal, in particular in terms of labour and capital.
Before you start to plant or prepare the seedbeds, it is important to plan the layout of the chosen site. One has to plan different aspects of the garden such as seedbeds, trees, compost heaps, nurseries and other attributes in order to able to maximize on the available space and to optimize the working conditions.

In the community gardens, it is particularly important to ensure that all the members have adequate space to grow as many crops as possible.

The size of the garden will be determined by the space required by each beneficiary. In order to properly assess the required area and plan its layout, the sowing criteria of each selected crop need to be taken into account. In addition, the percentage of potential losses must be considered. For example, under ideal conditions in tropical areas, you can sow between 1.2 and 2.5 tons of potatoes per hectare.

The plots must contain a wide variety of crops based on the specific food groups, essential for a healthy nutrition. Furthermore, crop diversification has a number of advantages including, amongst others:

- A method of conservation; improving/enriching soil fertility in the long term (See Fliers n°10 and 18)
- A natural defense against pests (See Flier n°19)

To minimize the spread of pests and diseases, different crops of should be planted in a patchwork pattern, so that multiple plots of the same crop are separated by another crop.

In addition, adapting the shape of the plots can increase the available space for cultivation.

For example, the inter-rows in rectangle plots are a significant loss of space, which could be used to grow other crops or provide a larger space for the development of crops in-situ.

It is also important to ensure that beneficiaries have equal access to water. However, the oldest or sick people can be given preference to situate their plots near to the water source.

For more information:

- John Snow international. Growing positively, a handbook on developing low-input gardens.
In cases when a shortage of land limits agricultural production, micro-gardening in bags or jars (or any other container) may offer an alternative solution to populations without land. For example, when land access is very expensive or impossible, in refugee camps, in situations of discrimination, in the urban areas, etc.

The sacks used in farming in bags are multipurpose with a minimum capacity of 100kg. The center of the bag is filled (with the help of a hose pipe, which can later be removed) with small stones or gravel and this makes up the watering area. Bricks or a few large stones should be added to the bottom of the bag to form a solid base.

Lastly, the bag is completely filled with loam soil. The seeds are planted on the top of the bag, which basically acts as a nursery. Seedlings can also be transplanted by poking small holes on the side of the bag, spaced about 20cm apart. Various vegetables can be planted in this way: tomatoes, cabbages, onions, etc.

A bag with volume of 1m$^3$ represents a plot of 5m$^2$, when all the sides of the bag are used for planting. A single bag can hold up to 50 plants of spinach or cabbage and 20 tomato plants, and can be used to produce several kilos of vegetables every month.

In 2004, ACF-USA initiated a micro-gardening project in Gulu, Uganda.

Out of 940 beneficiaries, mostly women, over 85% claimed they were satisfied with the project and 94% wanted to continue with the project the following season. At the time of the evaluation, 37% of households of about 6 people, were able to eat 6 meals on average supplied by their gardens, which enabled the households, and in particular children, to increase their vegetable consumption. When interviewed, 80% of neighboring households expressed their interest to participate in a similar project.

In 2007, Solidarités International implemented a micro-gardening program in Kenya

Following the presidential elections, the country and specifically the slums of Kibera and Kiambu, strongly affected by poverty and unemployment, became the forefront for riots and clashes. The program has led to the creation of farm nurseries in the slum. 6000 families grow their vegetables in micro-gardens (sacks), and this in turn has increased their income by about 1USD per day, keeping in mind that the average rent payment is about 6USD per month.

Other possible solutions for micro-gardens, include “rooftop gardens” or “hanging gardens”, (gardens suspended from different supports such as “gazebos” or arches).

The latter method is mainly used for vegetable species that bear their product in the open air, such as vine crops (squash, pumpkins, cucumbers, gherkins…) or certain nightshade plants (tomatoes, peppers, eggplant…).

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
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<tbody>
<tr>
<td>✓ An “intensive” gardening method by means of using a limited space to its maximum and for relatively cheap cost;</td>
<td>× Requires regular watering. Constant excessive watering leads to soil compaction and leaching. Therefore technical guidance is essential;</td>
</tr>
<tr>
<td>✓ Does not require much land/space and conserves soil and water;</td>
<td>× Lastly, crops need to bee adequately protected (e.g. by a barrier…);</td>
</tr>
<tr>
<td>✓ Method of cultivation is simple and independent of seasonal crop variations, allowing for crops to be harvested throughout the year;</td>
<td></td>
</tr>
<tr>
<td>✓ Pest and disease control is relatively easier, mainly as a result of intercropping.</td>
<td></td>
</tr>
</tbody>
</table>

For more information:

- Capitalization ACF-USA, Holly Welcome Radice. *Farming in bags: micro gardening in IDP camps in Gulu district, Uganda.*

For information on rooftop gardens or gardens in different containers:

Cultivation under a protective shelter allows the planting season to be extended, especially for vegetables (tomatoes, cucumbers, etc.), over a longer time period. Moreover, it enables cultivation to begin earlier in the year, increases the number of harvests and results in higher yields in comparison to cultivation in an open field, particularly in cold climates.

Under a shelter, the warmer microclimate is conducive to seed germination and protects the seeds from frost. Favorable conditions for cultivation are provided: adequate humidity and fertilization, optimal light and air circulation and a temperature between 10 and 30 °C. In addition, mature plants can be transplanted earlier, at the start of the season. This in turn allocates more time for the crops to grow and for fruits and vegetables to ripen before the onset of frost.

The techniques, in which crops can be protected, to enhance growth and improve the growth period, can vary from simple, cheap methods to more complicated methods that require large capital input.

However, there are different types of structures, and basic and inexpensive materials.

For example, the crops can be covered with a simple tarpaulin, greenhouse “tunnels” of varying height, greenhouses with stronger frames, or even “cold frames”.

The tunnels retain heat from the sun and protect the crops from predators.

They can be constructed using a plastic film covering or wintering veil and hoops made up of plastic, strong wire or flexible tree branches (e.g. from willow trees…).

The greenhouse tunnels can accommodate high-growing crops (tomato plants, eggplants and peppers…)

Between 2002 and 2008, ACF has supported the development of vegetable gardening and the creation of a network of farming educators in vulnerable communities experiencing food insecurity and living in suburbs situated in the outskirts of Ulan Bator in Mongolia.

The results show the positive impact of protected cultivation.

21.4% of the harvested crop in 2008, having benefited from the protection against the cold, made up 61% of the revenue generated.

Similarly, 3.9% of the total crop harvested came from greenhouse cultivation and contributed up to 11.3% of the revenues.
The “cold frames” are also highly adapted for cold climates (Mongolia, Nepal…).

The shelter consists of a wooden trunk with a window frame on top (basically just the frame) covered with a pane of glass or a transparent plastic film if available, otherwise a woolen blanket, etc.

Similarly to the other type of greenhouses, cold frames produce early season crops protected from bad weather and pests.

Cold frames in Mongolia. The photo on the right shows the cold frames covered with blankets and wooden planks. ACF-France, Nalaikh, Mongolia, 2004.

Whenever possible, larger-scale facilities and the use of renewable energy, such as solar greenhouses, are also recommended.

_**Project LIGHT: Income generation activities for rural communities in the Western Indian Himalayas/ 2005 – 2009, GERES.**_

_Beneficiaries: Rural communities in Ladakh, Spiti and Lahaul, living on less than de 0.7€ / day_

_Vegetables are usually grown from May to September. During the six winter months, the roads are closed. Only a few fresh vegetables, flown in at high cost, are available._

_The improved greenhouse technology enabled farmers to grow vegetables even during the peak winter season and as a result 600 families used solar greenhouses, harvested vegetables in winter, improved their health and increased their revenues by 30%. In many areas, this was the first time that fresh vegetables were available in winter and that women were able to generate their own income, often used to finance their children’s education._

_In Chang Tang, the nomadic communities depend entirely on livestock breeding. As a result of the night temperatures that drop to 30°C, the livestock mortality rate is high, particularly among the lambs and pregnant females. Experience shows that the use of passive solar energy in sheepfolds can reduce mortality by 50%._

_The project supported the construction of 80 individual and collective sheepfolds and trained masons and carpenters in the construction techniques._

_http://india.geres.eu/docs/DOSSIER-PRESSE-SEM-HIMALAYA-09.pdf_

Other simple solutions can also be used to improve production.

For example, in tropical regions, constructing a sloping roof over the cultivation plot can protect the plants against heavy rains as well as from intense dehydration.

However, the roof should be well orientated to the sun and prevailing winds.

The roof can be made out of different locally available materials, such as bamboo, palm fronds, banana leaves, etc.

_Agrodok 23, Fondation Agromisa, Wageningen, 2004._

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
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<tbody>
<tr>
<td>✓ Increased crop yields as a result of lengthening the growing season and the number of harvests;</td>
<td>✗ Requires time and manpower for installation and maintenance;</td>
</tr>
<tr>
<td>✓ Control the conditions of cultivation;</td>
<td>✗ Requires good management of irrigation and ventilation;</td>
</tr>
<tr>
<td>✓ Protection from pests and frost.</td>
<td>✗ Additional costs may be incurred during installation.</td>
</tr>
</tbody>
</table>

**For more information:**


“Seed production primarily serves to perpetuate a line of plants; it is the result of centuries of natural evolution and human selection.” (Goust, 2003)

Seed production and selection involves “saving” some of the harvested grains and replanting them the following season. Seed selection and preservation vary depending on the mode of plant reproduction concerned (sexual reproduction producing seeds or fruits, or vegetative propagation by tubers, cuttings, etc.).

In any case, producing seeds in this way has certain advantages over marketed hybrids and GMOs both from an economically and environmental perspective.

In fact, the hybrid varieties require special use of pesticides and fertilizers, and lead to the dependence of small farmers on multinationals.

In contrast, sorted and selected seeds by the peasant farmer alone, are best adapted to the soil and climatic conditions of the region and future seed production.

Visual seed selection and float test

In general, the choice of seeds depends on the plants with:

- the best characteristics, the strongest,
- a good germination and steady growth,
- vibrant flowering and producing the most seeds or fruits,
- the best form,
- the biggest size.

A float test can be conducted in order to identify the most viable seeds. The seeds are immersed in water containing 10% of salt.

The seeds that settle at the bottom of the container are selected for planting and the seeds that float on the top are discarded.

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The SOS Seeds of Survival program, funded by USC Canada, discovered that Ethiopian farmers were using 500 hectares of land to grow up to 60 different varieties of sorghum.

Studies conducted between 1990-1998 revealed that, in the fields of the Shewa region (in the centre of Ethiopia), yields from the elite selections of natural varieties of durum wheat (also called composites) were 25% higher than that of inbred varieties.

The Ghana Organic Agricultural Network noted that the aid program for the cultivation of hybrid maize, “Sasakawa 2000” (including subsidized fertilizer and pesticides) had produced good yields for a few years in Ghana. But this resulted in the high salinization of soils, which were soon depleted, and price of fertilizer cost soared when the subsidies were stopped. Meanwhile, local farmers abandoned their traditional seeds.

The network is currently trying to conserve and increase the surviving seeds, with help from the national gene bank’s collection.


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<tr>
<th>ADVANTAGES</th>
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<tbody>
<tr>
<td>✓ New seeds do not have to be purchased every year, reducing the economic costs and granting independence to a certain degree in comparison to commercial firms; ✓ This also has the advantage of preserving and improving local varieties that are adapted to soil and climatic conditions, cultural practices, etc., and thus protects biodiversity.</td>
<td>✗ Need to pay attention to the method and duration of seed preservation. For example, under good conditions potatoes can be preserved for several months at 4°C, whilst tomatoes can be preserved for 1 month at 13°C or for 4 days at 25°C (Flier n°24).</td>
</tr>
</tbody>
</table>

For more information:


⇒ BEDE (Biodiversity: Exchange et Diffusion of Experiences), December 2009. Improved seed varieties are not always the best. Agricultural research on assessing peasant farming in West Africa.


⇒ ADRA. Manual on bio intensive mini farming, Cf. “How to save seeds”

⇒ http://www.kokopelli.asso.fr/
Certain crops require nursery cultivation phase such as peppers, eggplants, tomatoes, beetroot, lettuce, cabbage, onions, rice, etc. For example, nursery cultivation is used in the SRI method (Flier n°6).

The production of **healthy and robust plants** in the nursery is the primary key for successful crop. It is therefore advisable to place the plants in a **healthy environment** from seedling to the transplanting stage.

Nursery cultivation aims to produce healthy and vigorous plants in a **controlled environment with adequate water, sunshine and optimal cultivation techniques**.

It also can lead to **income generating activities** in the nursery: activities, which can possibly be combined with other agricultural activities.

A nursery can be set up in different locations, for example near **household dwellings** to facilitate the monitoring of the nurseries, in plastic pots, in bamboo trays, in banana leaves or even in the open ground, **near the cultivation and water source** as long as it is well protected.

**Elevated nurseries** (also known as „table“ or „on stilts“) are also recommended, particularly in regions that experience a wet season.

Before constructing a nursery, a suitable **location** needs to be considered, taking into account the seasons (risk of heavy rains, drought, etc.), as well as the **size of the area to transplant**.

For example, 3 grams of cabbage seed sown in line will be kept in a nursery for 25 to 30 days and produce about 400 cabbage plants for transplantation, covering an area of up to 96m².

Like for the outdoor cultivation, the nursery substrates must be adequately prepared. The depth has to be about 3 times greater than the size of the seed, and **water and organic matter** must be supplied after the seeds are sown. Outdoor nurseries must be protected by a **suitable mulching**, and can also be **covered** to ensure protection from predators and bad weather.
**For more information:**


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**ADVANTAGES**

- Control of the cultivation environment;
- Save water as water loss by runoff is limited (except for in-ground nurseries);
- Allows well-targeted fertilization providing the seedling with vigor and ensuring steady growth;
- Time is saved: while plants are kept for weeks in the nursery, the plot where the plants will be eventually transplanted can be occupied by the preceding crops;
- The cultivation medium is free of enemies to plants and offers protection from bird attacks and other pests.

**LIMITATIONS**

- Some types of nurseries require certain infrastructure to be put in place;
- The nurseries in the ground are less protected from pests and diseases.

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**Integrated capacity building program for vulnerable communities in Indonesia ACF-France, 2007-2010.**

This program supported small-scale farmers in West Timor in the sustainable production of nursery plants, amongst other things. Given the objective of sustainable and inexpensive production, farmers have learned to take advantage of local materials.

*Therefore, pots made of banana leaves, instead of plastic pots, are used in the nurseries. Farmers had to collect banana leaves that are still green, roll the leaves in the form of a pot and then secure them using the stalks.*

The pots are then filled with soil, planted and placed in the nursery. The leaves harden as they dry and hold everything in place. The advantage for farmers is that these materials are accessible in terms of availability and affordability, and farmers can do without plastic, which is more expensive and poses an environmental risk.


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**For more information:**


This technique was developed in Madagascar in 1970-1980. It is currently implemented in at least 47 countries, in Asia and in the Pacific, in North and sub-Saharan Africa, in Latin America and in the Caribbean.

Six main steps distinguish SRI from the “conventional” cultivation of rice:

✓ **Early transplanting** of very young seedlings that are about 8 days old (or at “leaf” stage);
✓ The seedlings are **replanted singly** and not in clumps, **spaced 25 to 40 or even 50 cm** from apart, depending on the fertility of the soil, which may require wider spacing between seedlings;
✓ Each seedling is widely spaced, which **increases exposure to sunlight and nutrition**;
✓ **Intermittent irrigation** (without flooding the cultivation) allows an optimal use of water resources;
✓ **Good soil aeration**, which results in better weed control;
✓ Use of new **organic fertilizers**.

**In the Philippines**, the farmers make their own fertilizer from “waste” locally available such as rice straw, animal dung, banana pulp and microorganisms. ([SRI toolkit, World Bank 2008](http://info.worldbank.org/etools/docs/library/245848/applying.html))

**In Haiti**, the peasant farmers integrate **livestock and fish farming with the SRI practices**. The rice straws are used as litter for the chickens and the ducks, and also as fertilizer for the fishponds.

The rice paddies are located next to the fishponds where they can be irrigated with the water from the fishponds, which is rich in nutrients. ([Introducing the System of Rice Intensification (SRI) to Haiti, Follow-up Field Visit to SRI Introductions, CIIFAD & Better U Foundation, 2010.](http://sri.ciifad.cornell.edu/countries/pakistan/index.html))
The work by Fr. Henri de Laulanie of Sainte Croix, the originator of SRI in Madagascar, has shown outstanding results.

Observations made on the same land during the same time period show that the conventional 30-day-old rice plants yield 6 tillers with poor root development, in comparison to 2-leaf plants under SRI yield 72 tillers supported by a well-developed root system.

10 Malagasy peasant farmers that cultivated areas less than 80 acres, obtained yields of 15tons/ha in one single harvest.

(Organization for research, training and support to rural communities. http://www.tefysaina.org)

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
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</thead>
<tbody>
<tr>
<td>✓ SRI increases plant productivity and the productivity of water and soil resources through better aeration and better utilization of nutrients by the plants.</td>
<td>✓ Use of controlled irrigation techniques (drainage, adjusted delivery, etc.) This also refers to the quality of the existing irrigation structures and need for a water management system on site (“on the farm”).</td>
</tr>
<tr>
<td>✓ Overall, SRI substantially increases yield, with less seeds and less water and other inputs, which in turn significantly raises the revenues generated.</td>
<td>✓ Large labor input demanded for transplanting, water management, application of organic fertilizer, etc.</td>
</tr>
<tr>
<td>✓ This sustainable intensification technique can be also adapted to other crops, for example, to wheat (System of Wheat Intensification).</td>
<td>✓ Sometimes considered a controversial method, as it does not always produce good results depending on the different contexts in which it is applied.</td>
</tr>
</tbody>
</table>

Following the earthquake in Haiti in 2010, two initiatives to introduce SRI began (the SRI-Rice - Better U Foundation Initiative and the WINNER initiative)

In March 2011, the results from 9 selected sites showed that yields increased from 2.5 to 3.5 tons/ha in the Artibonite valley, and from 1.5 to 4.5tons/ha and even up to 5 tons/ha per harvest in other areas.

As a result of SRI, up to 100% of seed and 30% of water has been saved, and the use of chemical fertilizer has been halved thus allowing farmers to double and even triple their output.

(http://sri.ciifad.cornell.edu/countries/indonesia/index.html/index.html)
For more information:

- Operational note on the SRI technique

The SRI “tool box” developed by the World Bank Institute

- [http://info.worldbank.org/etools/docs/library/245848/about.html](http://info.worldbank.org/etools/docs/library/245848/about.html)

The “SRI International Network and Resources Center” (SRI-Rice) under the Cornell International Institute for Food, Agriculture and Development (CIIFAD), established in 2010 to collect, organize, store and share knowledge on the SRI practices, as well as SRI variations or adaptation to local conditions.

A list of projects implemented by country as well as the results obtained in each situation can also be found.

- [http://sri.ciifad.cornell.edu/countries/index.html](http://sri.ciifad.cornell.edu/countries/index.html)

A presentation by Norman Uphoff, Professor of Public Administration and International Agriculture at Cornell University, former director of the Cornell International Institute for Food, Agriculture and Development. He presents SRI and the comparative results between the “conventional” method and the SRI.

- [http://www.slideshare.net/ifad/the-system-of-rice-intensification-sri](http://www.slideshare.net/ifad/the-system-of-rice-intensification-sri)


- Manual on “How to help plants to grow better and produce more: teach yourself and others”, by Norman Uphoff from CIIFAD and the Association TEFY SAINA (founded by Farther Henri de Laulanie who developed SRI) in Madagascar. [http://tefysaina.org/manuelSRI.pdf](http://tefysaina.org/manuelSRI.pdf)


Conservation agriculture refers to the application of three principles, which are described in the following Fliers:

- **Minimum soil disturbance** (Fliers n° 8 and 9);
- **Adequate soil cover** in critical periods during the growth cycle. Soil cover may be maintained by crop residues, cover crops, and woody mulch from pruned trees or even by biomass produced ex-situ. (Flier n°11);
- **Diversified crop rotation** (Flier n°18).

Conservation agriculture stimulates dynamic and “natural” ecological processes, similar to those active in natural ecosystems.

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**A success story of “Conservation Agriculture for Sustainable Agriculture and Rural Development (CA-SARD) Project” implemented by FAO and governments of Kenya and Tanzania.**

Veronica is an FFS member of Amani group from Mlangarini village in Arumeru district, Tanzania. She possesses a farm field of 15 acres, of which before joined CA practices the harvest was 4-5 bags of maize per acre. In the previous years, she used to have low crop yield and therefore force to sell livestock (Goats, sometimes even Cattle) to meet other household social and economic needs including food and school fees for her children.

In 2005, she put aside 1.25 acres for CA practices to find out the difference in crop yields. With CA skills and use of improved seeds, she harvested 23 bags of maize. In that season, after bumper harvests, she managed to keep enough food for her family and even to get a surplus which she sold.

The benefits allowed her paying the schools fees for her children without selling livestock and purchasing 5 bags of cement for her house construction.

For more information:

ACF and other members of the Zimbabwe Conservation Agriculture Task Force in 2009 developed a manual to help the government, researchers, support extension workers, NGOs, donors, and farmers improve the implementation of programs and projects targeting agricultural conservation in Zimbabwe. Based on the concept of “learning by doing” this tool provides key elements on starting and managing conservation agriculture projects in Zimbabwe.

- **Capitalization ACF-F, Anna Brazier, 2008. Low Input Gardening Trainers Manual.**
- Guides on best practices in sub-Saharan Africa, illustrated with “case studies” (WOCAT and FAO)
  - **Sustainable Land Management in Practice, Guidelines and Best Practices for Sub-Saharan Africa, Field Application, WOCAT Coordinated by the FAO of the UN, A TerrAfrica Partnership, 2011.**

FAO websites on Conservation Agriculture:

CIRAD’s SCAP Project: Smallholder Conservation Agriculture Promotion in Western and Central Africa

Tillage is the principal operation in conventional agriculture. The plow, the most common machinery for tillage and has become a symbol of farming.

However, tillage, in particular mechanized tillage, like all other cultivation activities, leads to a number of problems. For example, mixing organic matter in the soil can lead to mineralization. And if the reduction in the amount of organic matter is not offset by adequate inputs of humus this can lead to soil degradation, as a result of a decreasing rate of organic matter accumulation.

In addition, repeated mechanized tillage every year can lead to the creation of a compacted layer of soil (a plow pan); an obstacle to deeply rooted crops. Lastly, tillage leaves the soil bare, which increases the risk of erosion.

In conservation agriculture, where one of the fundamental principles is the protection of the soil surface, conventional tillage using the plow is replaced by minimal tillage without turning or by direct seeding, without any tillage (names and terms may differ).

Minimum tillage can take the form of:

- **Very shallow tillage** like harrowing or hoeing (Flier n° 9).

- "**Biological tillage**" carried out by organisms in the soil (earthworms, bugs, etc.), often interrupted by mechanized tillage.

Farming with minimum tillage is only possible if living organisms, through their activities, are able to maintain the soil porosity, which is no longer guaranteed by tillage. This has direct implications on the use of chemical products.
Discharges from earthworms on the soil surface, “worm castings”, play a very important role in improving the soil structure and fertilization as these castings are very rich in organic matter and minerals, particularly in nitrogen, phosphorous, potassium, but also in calcium and magnesium.

http://www.pariscotejardin.fr/wp-content/P1000586.jpg

The conservation agriculture practices covered 62 million hectares in 2001, of which, 21 million hectares were in the United States, 14 in Brazil, more than 10 in Argentina, nearly 9 in Australia, and 5 in Canada. In addition, 21 million hectares must be attributed to minimum tillage in the United States.

In Asia, the development of no-tillage and direct seeding started with irrigated rice cultivation, and was subsequently used on a larger scale for wheat-rice due to the substantial gain in labor effort saved from no-tillage and also via the transplanting of rice. Furthermore, soil fertility improved through nutrient recycling, which can offset certain problems identified by the green revolution.


**ADVANTAGES**

- Reduced labor, energy savings and equipment needed, in preparing the land;
- Preserves biological activity (less disturbance);
- Limits soil erosion by water runoff, by in allowing better infiltration and reducing evaporation;
- Facilitates good air and water circulation in the soil by maintaining bio-pores in the soil and the vegetative cover, and developing a good root system;
- Increases fertility and yield in the poorest soils;
- Saves time and allows for flexibility in choosing the dates for sowing. Planting can take place immediately after a rainfall.

**LIMITATIONS**

- Requires a major change in practices and “mentalities”, particularly in relation to the appearance of the field, which may seem “neglected”;
- Particular attention must be paid to the control of weeds and work schedule.
For more information:

Guide on best practices in sub-Saharan Africa, illustrated with “case studies” (WOCAT et FAO)

- **Sustainable Land Management in Practice, Guidelines and Best Practices for Sub-Saharan Africa**, Field Application, WOCAT Coordinated by the FAO of the UN, A TerrAfrica Partnership, 2011.


Manual weeding consists of pulling out, cutting or removing weeds in a cultivated plot by hand, with a hand-weeding tool, or a hoe respectively.

If allowed to grow, weeds will compete with the crop for light, water and nutrients. In tropical areas, manual weeding continues to be the main method used to combat the most prevalent weeds.

It is recommended that weeding should immediately begin on the emergence of weeds, before they become too harmful. In order not to disturb the micro-fauna and not to destroy the vertical structure of the soil, the weeding must take place at a shallow depth.

Moreover for an optimal weeding effect, the collected residues, which contribute to restoring organic matter in the soil, can be recycled. These residues can be composted or left in place to serve as a cover and protect the soil.

Often weeding and hoeing are confused as both techniques are carried out using the same tools. However, weeding consists of removing weeds by scraping the surface of the soil while hoeing aims to aerate the soil at a deeper level.

If weeding is accompanied by light tillage, this process is called “weed hoeing”, which breaks the soil surface crust, enhancing soil aeration and subsequently facilitating the penetration of rainwater or irrigation water. This activity is technically easier to perform, however faces some constraints.

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Simple technique and easy to implement;</td>
<td>✓ Tillage that takes place during weeding, may promote the germination of other weed seeds, which should be quickly removed by an additional action;</td>
</tr>
<tr>
<td>✓ Non-chemical weed control (see Chapter D);</td>
<td>✓ Manual weeding takes time and requires labor;</td>
</tr>
<tr>
<td>✓ Destroys weeds and in certain cases improves soil structure, provided that only the topsoil layer is disturbed.</td>
<td>✓ Need to be careful not to damage the crop while weeding.</td>
</tr>
</tbody>
</table>
**Hoeing**

Manual hoeing serves to **loosen and aerate the top layer of the bare soil between the plants**. Breaking this crust, which forms as a result of watering and rainfall, facilitates the penetration of water.

- The evaporation of water by capillary action is limited. It is often said that, **“One time hoeing is worth two times watering”**: by disrupting the path of the water towards the surface, hoeing maintains water in the soil at a certain depth (“mulch effect”) this is the first watering. The second watering lies in the destruction of weeds by hoeing, which are consumers of water.

Hoeing improves the respiration of roots, which in turn reduces the growth of mold. From repetitive hoeing, the **earth remains loose** and easier to work.

> *Hoeing can be performed with various traditional tools (hand hoe, rotary hoe, etc.) but also improved tools such as the gardening wheel hoe.*

**ADVANTAGES** | **LIMITATIONS**
---|---
✔ Non-chemical weed control; | ✗ Takes time and requires labor;
✔ Provides better soil aeration; | ✗ Need to be careful not to damage the crop while hoeing.
✔ Facilitates the penetration of water down to the roots; |
✔ Limits capillary rise and evaporation. |  

Although these manual techniques are relatively simple to use with less impact than if mechanized, **they must be used appropriately or stopped when signs of soil degradation appear.**

Moreover, they should always be applied in combination with other soil conservation practices such as mulching for weed control, and if in excess supply, the use of weeds in composting.

These methods are a temporary solution to a management style that is more respectful of the organic life in soil. Conservation Agriculture (**Flier n° 7**) proposes a **milder soil management system**, which tends to minimize tillage, and **aims to restore and maintain a good soil structure and fertility.**
Ridging

Ridging consists of accumulating earth in the form of a “mound” around the plants. This has different objectives such as to strengthen root development that promotes the growth of tubers (potatoes, cassava, sweet potato…), or to cover a portion of the plants to force them to blanch. This is usually the case for stem-vegetables such as asparagus and leeks.

It is a common technique, especially in Africa, that:

- Ensures the healthy development of tubers (cassava, yam…);
- Allows good drainage in temporary wet areas (including Sudanian regions);
- And also is a way to gather fertile soil around cultivated plants grown on the most degraded lands.

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Reduces erosion and conserves soil humidity;</td>
<td>✗ Requires equipment and increases time of soil preparation;</td>
</tr>
<tr>
<td>✓ Easy to use, and equipment can be manufactured locally;</td>
<td>✗ In regions with variable rainfall, the ridges may be flooded.</td>
</tr>
<tr>
<td>✓ Higher yields.</td>
<td></td>
</tr>
</tbody>
</table>

For more information:


“Zaï” is derived from the Moore word (language of the Mossi people from Burkina Faso) “zaïégré”, which means, “to wake up early and rush to prepare the land”. In fact, it is used to rehabilitate degraded land, crusted and eroded by the wind, or runoff rainwater that is no longer able to infiltrate into the ground.

The method consists of digging pits in the soil, which will serve as the seed pockets (or “holes”). The planting pits are on average 20 to 40 centimeters in diameter with a depth of 10 to 20 centimeters – these dimensions vary depending on the type of soil.

After digging the pits organic matter is added, and after the first rainfall the organic matter is covered with a thin layer of soil and the seeds are sowed (or seedlings are transplanted) in the pit.

In addition, the Zaï pits can be shaped in half-moons. This can be done manually but can also be carried out mechanically whenever possible, and can even be a forestry technique.

In settings with scarce organic matter and water resources, cultivation in pits or the “Zaï” system are particularly useful in order to meet the needs of the plant while limiting the waste of these resources.

This method is especially adapted to arid climates and crusted soil surfaces (degraded by erosion), receiving between 400 and 800mm mean annual rainfall, such as the Sudano-Sahelian region.

Zaï technique and cultivation of sorghum in Burkina Faso

As part of their objective to assist local communities to strengthen their local capacity by using their local knowledge, the World Bank program on Indigenous Knowledge for Development provided support to farmers for scaling up the dissemination of the Zaï technique in three provinces in central Burkina Faso.

The Association for Outreach and Support to Agro-ecological Producers in the Sahel region (AVAPAS) provided day-to-day guidance to farmers. The campaign was carried out during the period 2002-2003. The farmers highly appreciated the technique particularly due to the increases in productivity. Unfortunately, the farmers did not always follow all the recommended steps so as to benefit more from the technique.

The yield of sorghum grain was evaluated in both the Zaï and non-Zaï cultivated plots during two growing seasons. Data comes from 16 villages in 2002 and 32 villages in 2003. The results show significant differences between the Zaï and non-Zaï plots. The findings are consistent with those from other studies on the Zaï technique in other regions, which show the impact of the practice on the yield of sorghum (Sawadogo, 2001, Dakuo, 2000, Bambo, 1996, Kabore, 1991). The increase in output is attributed to more efficient use of rainfall and to the improvement of soil fertility as a result of placing organic matter in the pits.

Variation: Cultivation in a “hole”

In situations where resources are insufficient to provide compost, organic waste can be reused in the seed “holes”. This method requires little labor and is a good way to recycle kitchen waste. The vegetables are planted around the hole and their roots feed directly in the compost.

How to do it?

- Dig a hole, 75cm deep and 50-75cm in diameter.
- Using the earth dug up, shape a ridge around the hole, making sure to leave a space that will serve as “the entry” into the hole.
- Cover the bottom of the hole with a bag, or even better, with banana leaves.
- Fill the hole with organic matter, placing dry matter on the top.
- Make a hole in the pile of waste to aerate it.
- Plant the vegetables on the ridge around the hole.

Advantages

- Inputs are adapted to the needs of the crop (and thus also to resources) despite the lack of organic matter and water;
- It is a complementary technique to other agro-ecological practices (mulching, fertilization, etc);
- Reduces work on removing weeds and decreases the worked surface through the localization of different activities;
- Method of soil restoration.

Limitations

- Requires a lot work if the soil is compacted, and is difficult on very sandy soils.
- Time is needed to carry out a simple tillage during the preparation of the ground;
- In regions with variable or very abundant rainfall, the seed holes can become flooded.
For more information:


Guide on best practices in sub-Saharan Africa, illustrated with “case studies” (WOCAT et FAO)


- AGRIDAPE, Bernard Nonguierma, September 2010 - volume 26 n°2. Tomato troughs to face water scarcity. AGRIDAPE (Sustainable Agriculture with Low External Input) is the Francophone Africa regional edition of the LEISA magazine, co-published by ILEIA and IED Africa.

- Association Sahel People Service (SPS) and Aide aux Forces vives Africaines par la Formation à l’Agroécologie (AFAFA). Technical note on Zaï technique.


- John Snow international. Growing positively, a handbook on developing low-input gardens.
Vegetal cover seeks to ensure, as much as possible, that soil is not left bare between plants or between two cultivated plots. This in turn prevents erosion, limits the emergence of weeds, and improves the balance of humus and biological activity in the soil.

- The vegetal cover can consist of **mulch (covering of dead plant residues)** from the decay of a cover crop in-situ or brought in from the exterior;
- Or a **living plant** (cover crop) associated with the main crop (Flier n°19).

**Mulching**

This activity can be performed **before seeding and before transplanting**. Glumes, and husks of rice and millet, sawdust, woodchips, and other debris that are usually not recycled, can be used to make an effective mulching.

In cold climates, in winter, mulching can help to **prevent the ground from freezing**.

By decomposing gradually, the mulch ensures a supply of **humus** and contributes to the replenishment of soil fertility.

To further increase the soil fertility, **mulching can be combined with liquid compost**; this allows a rapid decomposition of the mulch, which enriches the soil in organic matter.
In the South Pacific some farmers practise mulching to maintain yields, most commonly with dadap leaves (Erythrina spp), grass, weeds, dried coconut fronts, and banana and breadfruit leaves (Artocarpus altilis).

In Western Samoa, research showed that the application of dadap leaves and grass mulches at a rate of 30t/ha can increase taro yields by 65% and 54% respectively.

In the Atolls, where the availability of organic matter is limited, farmers use shredded coconut logs, wood chips and coconut husks. The leaves of Scaveloa frutesens and Pisionia grandis, two of the few tree species growing in atolls, are also used for mulch.

In the Fiji Islands, the farmers use also poultry manure on their crops.


Cover crops

Cover crops are plants that are able produce a large amount of biomass and have a root system capable of structuring the soil in great depth.

Depending on their characteristics, cover crops can be used for various purposes: supply nitrogen, (especially pulse crops like peas, alfalfa…), used for animal-feed and to discourage pests (Fliers n°19 and 23) etc.

http://agroecologie.cirad.fr
Selection of cover crops

Selection is not carried out randomly but is rather a function of the surrounding, environment (structure, acidity, water saturation and fertility of the soil, rainfall, etc.) the capacities of different cover crops, the ability of the farmers to invest and so on. The difficulty lies in controlling the vegetal cover. Here, mechanical control methods are emphasized in order to limit water and soil pollution.

*Brachiaria* (a herbaceous grass), *Stylosanthes* (alfalfa), *Mucuna* (Mascate peas) or *Pueraria* are amongst the main cover crops used in farming systems applying vegetal cover.

The Ramial Chipped Wood (RCW)

The RCW generally consists of small pieces of wood, twigs, and branches that do not exceed 7cm in diameter.

The technique, known as RCW, aims to supply the topsoil directly with small branches of chipped hardwood, from hedge trimming or pruning. In general, mixtures of different species of wood are more favorable to RCW than using a single species.

The increasing popularity of cover crops

In just a few years, more than 10 000 farmers in Benin starting using *Mucuna pruriens* (velvet beans) to fight against quack grass and to improve soil fertility. Farmers from Burkina Faso, Ghana, Guinea, the South of Mali and Togo have also adopted the use of *Mucuna*. Meanwhile, in Latin America, more than 125 000 farmers are using cover crops, notably in the state of Santa Catarina and in the South of Brazil, and several other neighboring states of Parana and Rio Grande do Sul are following in their steps. In Central America and in Mexico, more than 200 000 farmers are using cover crops in cultivating many crops.


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<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Practice can be carried out with a variety of different plants that are locally available;</td>
<td>✗ Requires technical expertise to prevent competition between cover crops and the main crop;</td>
</tr>
<tr>
<td>✓ Can be used for multiple purposes: soil protection, livestock fodder, green manure, etc.;</td>
<td>✓ Demands an investment in cover crops</td>
</tr>
<tr>
<td>✓ Reduces time spent working (on weeding and maintenance);</td>
<td></td>
</tr>
<tr>
<td>✓ Decreases costs by reducing inputs of organic fertilizers and minerals, while simultaneously improving yields.</td>
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</tbody>
</table>

The Ramial Chipped Wood (RCW)

The technique, known as RCW, aims to supply the topsoil directly with small branches of chipped hardwood, from hedge trimming or pruning. In general, mixtures of different species of wood are more favorable to RCW than using a single species.
In tropical climates, the twigs and branches must be collected preferably at the end of the rainy season.

It is especially **recommended for vegetables** and specifically for those sensitive to drought (cabbages, peppers, tomatoes, berries), and can be used to complement **bedding materials for livestock**, which will **accumulate manure and can be reused** thereafter (Flier n°13).

In addition it can be used as mulch as the RCW act as a form of composting on the surface of or buried in the soil.

The first trials of the RCW technique date back to the 1970s in Quebec. Modified and adapted for **different types of crops and under different climatic conditions**, the results of the tests are very promising.

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
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</tr>
</thead>
<tbody>
<tr>
<td>✓ Recycles waste from plants;</td>
<td>✗ Requires adequate biomass to be locally available or hedges need to be planted;</td>
</tr>
<tr>
<td>✓ Substantial production of humus;</td>
<td>✗ Prohibited on waterlogged soils;</td>
</tr>
<tr>
<td>✓ Markedly improved soil structure;</td>
<td>✗ Some time demanded if the wood has to be chopped up manually;</td>
</tr>
<tr>
<td>✓ Increases yields with prolonged effects over several years;</td>
<td>✗ The appropriate size of the wood chips must be respected; branches and pieces of bark that are too big cannot be used.</td>
</tr>
<tr>
<td>✓ Significantly reduces water requirements;</td>
<td>✗</td>
</tr>
<tr>
<td>✓ Reduces need for weeding and diminishes diseases and pests.</td>
<td>✗</td>
</tr>
</tbody>
</table>

Garden plots without RCW (LEFT) and with RCW (RIGHT) after a heavy rainfall.
According to the Coordination Group on Ramial Wood under the Faculty of Forestry and Geomatics in Quebec, twenty years of experience of RCW farming and forestry in Quebec, Africa, Europe and Caribbean have resulted in the following:

- Better soil conservation due to an increase in the water retention capacity of the soil, and increase in the content of humus and important micro-fauna in the soil.
- Increase in pH from 0.4 to 1.2 under tropical conditions,
- Increase in yields by 1000% of tomatoes in Senegal by 300% of strawberries in Quebec.
- Increase in maize production (mass) by 400% in Ivory Coast (Africa) and in the Dominican Republic (Caribbean).
- Marked increase in resistance to dry conditions and frost,
- Better root development, strongly mycorrhizal,
- Fewer and less diversified weeds;
- Decrease or complete elimination of pests and notably in tropical climates, a complete control of nematodes (roundworms),
- Increase in dry matter, phosphorous, potassium and magnesium content in the potato tubers of potatoes.

http://www.sbf.ulaval.ca/brf/regenerating_soils_98.html
**For more information:**

Use of local organic matter in the Pacific:

- External inputs for sustainable agriculture, by Weeraratna, C. Stanley
  

Various associated techniques and selection criteria for plants according to their characteristics and environment:

  
  http://www.tropicalforages.info/key/Forages/Media/Html/index.htm

  

- CIRAD website “Agro-ecology, direct seeding on vegetal cover” where several documents can be consulted:
  
  http://agroecologie.cirad.fr/

- Technical note: *mulch-based cropping, a technically simple alternative.*

- Technical notes on cover crops: *Leguminous perennial species.*

Capitalization Report CIRAD - Sudan

- Support Project for Agricultural Services and Producer Organizations: Study on improving the soil fertility in the Sudanian region in Chad through the dissemination of techniques on direct seeding on living or dead vegetal cover,
  
  http://agroecologie.cirad.fr/pampa_et_projets/autres_projets/tchad

Other reports on various programs: Madagascar, Cameroun, Laos, Mali, Tunisia, Algeria, Brazil, Cambodia, China, Ivory Coast, French Caribbean, Guinea, Indonesia, Maghreb region, Morocco, Mexico, Chad, Thailand, Vietnam and Zimbabwe.

Ramial Chipped Wood:


- «Regenerating soils with Ramial Chipped Wood (RCW)», 1998, by Céline Caron, Gilles Lemieux and Lionel Lachance, Faculty of Forestry and Geomatics, Department of Wood and Forest Sciences, Coordination Group on Ramial Wood, Québec, Canada, publication n°83, http://forestgeomat.for.ulaval.ca/brf

- “Ramial Chipped Wood: the clue to sustainable fertile soil” by G. Lemieux & D. Germain, Faculty of Forestry and Geomatics, Department of Wood and Forest Sciences, University of Québec, Canada.

  
  http://brf276.free.fr/index.php
Composting is the acceleration of natural decomposition of organic waste, and thus the formation of humus (called compost). Intense bacterial activity is primarily responsible for decomposition and this process requires oxygen and generates heat.

The compost is a result from a function of soil amendment and fertilizer. The quality of the compost depends on physicochemical conditions during the composting process, particularly: aeration, humidity, temperature, pH, etc.

There are a large variety of composting techniques (anaerobic composting, passive aeration, high temperatures, high temperature with inoculation, turned windrows, passively aerated windrows, aerated static piles, in bins, in cribs (“cradles”), in rectangular agitated beds, liquid, in silos, vermicomposting)

Each technique is adapted to climatic and edaphic conditions or is dependent on the composition of the compost.

The use of compost enriches the soil in the long term and has a significant impact on output.

In 1996, the Institute for Sustainable Development (ISD) developed a project with local farming communities of smallholder farmers in Tigray, in Ethiopia, using an ecological, low external input approach.

Between 2000 and 2006, grain and straw yields of 9 different crops (7 cereal and 2 pulse crops) from 974 plots situated in arid regions were recorded.

The observations were based on a sample and aimed to compare yields of grain and straw, and the percentage of grains in the total biomass per crop, in three different treatments: without fertilizer, with the addition of compost, and with chemical fertilizer.

The results showed that the addition of compost generally doubled the yield of grains compared to the cultivated plots without compost, with the exception of the pea crop. The yield of straw was also higher.

The use of compost also tended to produce higher yields compared to the use of chemical fertilizer, except for sorghum and Faba bean, where the use of chemical fertilizer and the use of compost in a crop produced similar yields.

**Which elements can be composted?**

All plant waste can be composted (stubble, vegetable peelings, dead leaves...). In the composition of compost can consist of:
- earth
- "green" plants and kitchen waste
- dried plants

In addition, you can add other organic waste materials, which can enrich the compost in phosphate and potassium like:
- manure (previously enriched with dry organic matter) *(Flier n°13)*
- eggshells
- crushed bones,
- wood ash.

To improve the quality of the compost and make the decomposition process faster, you can also add:
- nitrogen fixing micro-organisms,
- earthworms, etc.

**Which elements SHOULD NOT be composted?**

- Cooked plants if they are numerous and have a high water content,
- Very thick tree branches that are difficult to compost,
- Plants with diseases,
- Kitchen waste such as fats and animal wastes (oils, fish, meat, dairy products…)
- Plastics, metals, pollutants, and other household waste (barbecue ashes…)
- Citrus fruit peels should be avoided as they contain natural insecticides (toxic to many invertebrates). However, you can cut them into small pieces and leave them to dry in the open air before integrating them into the compost.

**Rules for a good composting:**

- Grind or shred large materials (e.g. branches…). This facilitates a complete and rapid decomposition. The grinding can be mechanical or manual.
- Add some soil, particularly on starting the process, to enrich the compost in microorganisms.
- Mix the contents of the compost, once a month, or even better with each addition of materials, with a spade, a gardening fork or a shovel.
- Monitor the level of moisture. If the compost becomes too dry, the microorganisms responsible for decomposition will die. The pile should be as moist as a wrung out sponge.

**The smooth running of the composting process can be confirmed by:**

- The absence of bad smells
- A rise in temperature in the pile (up to 65°C)
- Presence of earthworms and other invertebrates

**When is the compost mature?**

When the compost pile is no longer heating up and when only a few raw materials are recognizable.

**Compostable waste + Microorganisms and Insects + Oxygen + Water = Compost!**
<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reuse of organic waste, otherwise placed in a landfill or buried;</td>
<td>Requires adequate expertise to properly control the fermentation process;</td>
</tr>
<tr>
<td>Can be made from local organic waste; there are several adapted “recipes” for a good composting. Thus this is a way to use elements readily available, reducing transportation time and costs;</td>
<td>Competes with livestock breeding for use of straw;</td>
</tr>
<tr>
<td>Improves the soil structure and develops biological activity;</td>
<td>Demands considerable manpower;</td>
</tr>
<tr>
<td>Increases the soil’s capacity to retain water and nutrients, which in the medium term saves water and reduces costs associated with purchasing fertilizer;</td>
<td>Production costs may be incurred depending on technique adopted, notably for the construction of a shelter in humid areas or a pit in dry zones.</td>
</tr>
<tr>
<td>Provides a high quality fertilizer, which improves yields in a sustainable manner;</td>
<td></td>
</tr>
<tr>
<td>Contributes to improving “hygiene” by killing certain types of pathogens during the fermentation process.</td>
<td></td>
</tr>
</tbody>
</table>

For more information:


Manual on best practices in sub-Saharan Africa, illustrated with “case studies” (WOCAT et FAO)

Composting in cold climates (Mongolia)

Composting in windrows, cribs and in liquid:

Compost bins
- Practical Action, 2006. Compost bin manufacturing,
- Practical Action, 2006. Home composting bins,
In general, farmers store manure (feces, raw or mixed with bedding) in piles in the open air over a long time period. After which they are applied directly to the plot.

This storage method has the following consequences:
- **Loss in quality** of the manure due to exposure to heat and rain;
- **Incomplete and non-uniform decomposition** of the manure;
- **Risk of contaminating the plots** during fertilization (spread of diseases and seeds of weeds)

However, the use of manure is generally the most common method of fertilization as it is **locally available and at low cost** (as opposed to chemical fertilizers).

Therefore it is recommended to use previously recycled manure to:
- **Preserve quality** through better storage conditions;
- **Improve decomposition** for more effective use without risk to the plant.

The practice consists of facilitating the fermentation of manure of a composting technique (aerated and at a high temperature). Two techniques are possible depending on the climatic conditions of the region: composting in piles, about one meter high in humid areas, and in pits, 20 to 30cm deep, in dry to arid regions.

Manure that is buried in a pit must be watered about once a week and turned over after 2 to 3 week intervals, once cooled. In humid areas the pile is turned and then watered every two weeks. The manure is ready to be used with it has completely cooled off.

**Recycled manure or compost?**

Recycling manure is **easy to carry out**, and is vital and effective in order to be able to reuse this animal by-product.

Although less efficient than composting, this practice is seemingly better **adapted for Sahelian regions** with regards to socio-economic and environmental conditions, that is:
- **Competition for plant materials**
- **Limited availability of straw**
- **Importance of livestock activities**

It is also possible to **recover human excrements to make manure**, following a similar process. Human feces are collected in using a dry toilet system where they are mixed with dry materials (sawdust, wood chips...). This process helps to “sanitize” the manure; the fermentation **kills a large number of germs and removes bad smells**.

Although, this practice has already been carried out, its **potential field application needs to be carried out systematically and a study of acceptability needs to be conducted on the beneficiary population**. It must therefore be considered on a case-by-case basis, taking into account the view of the beneficiaries.
### ADVANTAGES
- Simple practice to implement;
- Better quality than raw manure;
- Limited use of labor and at low cost if farmer already has manure;
- Practice is adapted to breeding areas (recycles waste);
- Can be achieved with local organic waste and there are several “recipes” suitable for a good composting. It is therefore a way to use materials already in place, limiting transportation costs and time;
- Improves soil structure and develops biological activity;
- Increases the soil’s capacity to retain water and nutrients, thus in the medium term reduces expenses related to purchasing fertilizer and allows for water savings;
- Produces a quality fertilizer, which has a positive and sustainable impact on output;
- Helps to improving “hygiene” by killing certain pathogens during the fermentation process.

### LIMITATIONS
- Sufficient expertise needed to adequately control the fermentation process;
- Risk of organic pollution in the case of over-watering;
- Less rich than a good compost;
- Competes with livestock breeding for use of straw.

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**For more information:**


  [http://lbewww.epfl.ch/DA/JEANMAIRE_1999/1fumiers.htm](http://lbewww.epfl.ch/DA/JEANMAIRE_1999/1fumiers.htm)

Green manures are cultivated plants which enrich the soil, or vegetable matter brought from outside the field. The cultivation of a cover crop which is then incorporated into the soil permits the maintenance or improvement of soil fertility. In market gardening, green manures are one of the solutions to the numerous concerns encountered:

- **The protection of the soil** against wind or water erosion, against the development of a slaking crust on the surface by rains, or by limiting evaporation in case of dry climate or by preventing the growth of self-propagating weeds.
- **The improvement of the structure and ventilation of the soil** by the presence of roots breaking through the soil. This also stimulates biological activity and the decomposition of organic matter.
- **Better availability of nutritive elements** due to certain plants such as legumes (peas, alfalfa, beans etc.) which fix atmospheric nitrogen due to the presence of bacteria. Other deep-rooted plants can raise nutrients from deep in the soil and restore them on the surface as they decompose.

Example of green manure: UFA Alpha blend, a much appreciated green manure:

The planting of green manures should be determined with regards to the gain/loss balance taking into account the soil, the climatic conditions at the time of planting and decomposition, crop rotation in the farm and the characteristics proper to each plant.

**The adoption of lupine into maize crop rotations in Bolivia – Integrated development programme – World Neighbours – Northern Potosi**

Lupine can fix 200 kg N/ha/year, and benefits soils when turned under as a green manure. Farmers were at first incredulous, but their long association with the benefits of experimentation persuaded them to test the practice. Potato yields immediately increased from 1,780 kg/ha to 8,500 kg/ha with lupine, and rose to 13,000 kg/ha when sheep manure was also incorporated. The cash outlay for lupine is US$18/ha, which compares with the US$170/ha for an equivalent amount of inorganic fertilizer.

Left: Mucuna planted as green manure, after 2 months. Right: Placing of green manures on the cultivated plots. Photos [Link to photos](http://naitaubafarm.org/NF/?p=1093)

### ADVANTAGES

- Practice which can be carried out with a wide range of plants available locally;
- Produces many benefits: protection of soils, fodder for the animals, green manure etc.;
- Reduces work time (hoeing and maintenance);
- Restricts costs by reducing the addition of organic and mineral manures, whilst improving yields.

### LIMITATIONS

- Most of the limitations attributed to green manures come as a result of errors in agricultural techniques: laying down or ploughing in too late, on a compact or badly drained soil etc.

### For more information:

- Techn’itab market gardening, file drafted by Hélène LEPLATOIS VEDIE, Biological Agriculture Research Group (Groupe de Recherche en Agriculture Biologique - GRAB) and Technical Institute for Biological Agriculture ( l’Institut Technique de l’Agriculture Biologique - ITAB). *Green manures in biological market gardening.*
- Chambre Régionale d’Agriculture de Poitou-Charentes, January 2010. *Legumes, how can they be used as intercrops?*
Biochar is a neologism composed of the prefix “bio” and the English word “charcoal”.

It is a biomass (agricultural waste, wood shavings, manure etc.) which has undergone pyrolysis in an anaerobic atmosphere, or one with a low level of oxygen.

Whilst biochar is produced more and more on an industrial scale, the process has been used for thousands of years by the indigenous peoples of the Amazon to make the very poor soils fertile. It would become the basis of Amazonian black earth or Terra Preta, one of the most fertile soils on earth.

The traditional method for the production of charcoal consists in piling up organic waste or placing it in holes dug into the earth and then burning it slowly, limiting the air supply by covering the pile with soil.

Its main use is for restoring or improving soils. It is added just once in powder form or as small fragments to nursery, forest, agricultural, garden or horticultural soils, with the purpose of improving the pedological properties (physical, chemical, biological) of the substrata. It is particularly used for improving and stabilising tropical soils, acid and poor by nature, therefore fragile, which have been seriously deteriorated by farming and/or deforestation and which are currently eroded or threatened by erosion.

Experiments carried out in the field by the “Cornell University Department of Crop and Soil Sciences” in Kenya since 2005:

Biochar was added to maize fields presenting different states of soil degradation. The purpose is to determine at which level of degradation the addition of biochar is most effective. The results show that the more degraded the soil, the greater the increase in yields by the addition of biochar. Yields doubled at the most degraded sites, increasing from 3 to 6 tons of grain per hectare (Kimetu and others, 2008).

Several studies show that biochar can improve the chemical, biological and physical properties of the soil. The productivity of soils enriched with biochar increases by 20 to 220%, with a rate of enrichment of 0.4 to 8 tons of carbon per hectare. These advantages could lead to “slash and char” becoming an alternative to “slash and burn” to reduce the impact of deforestation.

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Capture and redistribution of nutrients:</td>
<td>✗ The scale and types of physical, hydrological and ecological changes resulting from the regular addition of biochar in the long term must be evaluated;</td>
</tr>
<tr>
<td>Wood charcoal is in fact carbon where the</td>
<td>✗ Furthermore it should be noted that not all biochars will produce the same reaction in function of the original composition, the reaction of different crops produced as well as the place of production (in particular the edaphic and climatic factors);</td>
</tr>
<tr>
<td>structure consists of millions of air bags</td>
<td>✗ So, biochar raises a number of questions for agronomic research. Additionally very few quantitative results have been published to date.</td>
</tr>
<tr>
<td>which help to trap micronutrients and water in</td>
<td></td>
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<tr>
<td>the soil and to put them at the disposal of</td>
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<tr>
<td>the plants. It also harbours the microorganisms</td>
<td></td>
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<tr>
<td>which participate in the decomposition of the</td>
<td></td>
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<tr>
<td>organic matter in the soil;</td>
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<tr>
<td>✓ It allows for a greater capacity for cat-ion</td>
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<tr>
<td>exchange and consequently the control of the</td>
<td></td>
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<tr>
<td>pH by restricting soil acidity;</td>
<td></td>
</tr>
<tr>
<td>✓ Durability: As it remains stable in the soil</td>
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<tr>
<td>its ability to capture nutrients can last for</td>
<td></td>
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<tr>
<td>thousands of years;</td>
<td></td>
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<tr>
<td>✓ Production of biofuels: When biochar is</td>
<td></td>
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<tr>
<td>produced industrially, the pyrolysis of the</td>
<td></td>
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<tr>
<td>organic matter can also lead to the production</td>
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<tr>
<td>of biofuels, particularly hydrogen and oil</td>
<td></td>
</tr>
<tr>
<td>which in turn can be used to produce heat or</td>
<td></td>
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<tr>
<td>energy;</td>
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<tr>
<td>✓ Role as a carbon sink: Biochar also has the</td>
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<tr>
<td>function of an atmospheric carbon sink which</td>
<td></td>
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<tr>
<td>makes it interesting with regard to climate</td>
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<tr>
<td>warming. The production of biochar and biogas</td>
<td></td>
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<tr>
<td>«sequesters» part of the carbon from its cycle</td>
<td></td>
</tr>
<tr>
<td>by trapping it;</td>
<td></td>
</tr>
<tr>
<td>✓ It can be produced from a wide range of plants</td>
<td></td>
</tr>
<tr>
<td>which are available locally.</td>
<td></td>
</tr>
</tbody>
</table>
For more information:

The section of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) dedicated to biochar:

⇒ Additionally, an overview presented by the CSIRO

The website of the “Cornell University Department of Crop and Soil Sciences” Management compiles information on the concept, projects and experiments carried out by this centre and other organisations, illustrations and a review of the main references for biochar.

⇒ [http://www.css.cornell.edu/faculty/lehmann/research/biochar/biocharmain.html](http://www.css.cornell.edu/faculty/lehmann/research/biochar/biocharmain.html)

The website of the International Biochar Initiative, a non-profit association supporting researchers, commercial structures, political decision-makers, development agencies and committed to promoting the production and use of biochar.

⇒ [http://www.biochar-international.org/](http://www.biochar-international.org/)
⇒ [http://www.biochar-international.org/developingeconomies](http://www.biochar-international.org/developingeconomies)

The website of the Comité Scientifique Français de la Désertification (French Scientific Committee for Desertification)


The « United Nations Convention to Combat Desertification »


⇒ The super market garden with biochar concept marketed by Pro-Natura International

⇒ Pro-Natura International. 25 years of real innovations for rural development in the countries of the south. Innovation for sustainable development. “That’s not how we will resolve hunger and poverty”.


⇒ Simple technologies for charcoal making FAO, Rome, 1987 [http://www.fao.org/docrep/X5328E/x5328e06.htm#5.1.%20the%20pit%20method](http://www.fao.org/docrep/X5328E/x5328e06.htm#5.1.%20the%20pit%20method)
Rizi-pisciculture is the breeding of fish in a flooded rice paddy and the farmers harvest both fish and rice.

However, this term does not only refer to the simultaneous farming of rice and fish in a paddy field, there are other methods such as the rotation system, or a crop of rice followed by a crop of fish, or systems whereby breeding and growing take place side by side, sharing the water resources.

It is extremely profitable to use the same plot to simultaneously produce carbohydrates and animal protein.

Based on the integration of agricultural products and waste, rizi-pisciculture is an example of agronomic success. It leads to the re-valuing of the water in the paddy. Furthermore, this association brings numerous advantages for the maintenance of high yield rice crops whilst permitting the breeding of fish, although it requires a reduction in the rice growing area as a result of specific indispensable adjustments. This method of breeding also gives the farmer crop diversity and a source of proteins for his rice-based diet. Widely practised in Asia, experiments are also being made with this method in Africa.

**Extensive Fish Culture in the Forested Guinea Model for integrated development and rizi-pisciculture, 2001**

An experience lead by the IRD (Institute for Research and Development) at the Gwi station in two ponds with the same surface area (400 m²), between 1999 and 2001. The experimental protocol was designed to determine the effects of the cultivation of rice on fish and their growth. Two groups of 400 Niloticus fry, initially all siblings, were introduced into two different environments: One into a classical fish culture pond and the other into a pond of the same surface area but where rice had been planted for cultivation in the usual manner.

The stocking of the rice plots with fish did not reduce the rice yield and it is even estimated that, with the accumulation of fish faeces over the years, the fertility of the soil has improved and, just as has been observed in Asia, this has led to a considerable increase in rice yields. Rizi-pisciculture undeniably accelerates the growth of the fish leading to very much improved yields and average weight, the addition of rice bran improving these yields even more.

Rizi-pisciculture encourages high production of fry which serve to restock the plot for the next cycle of cultivation. This relieves the farmer of the economic pressure of supplying fry for at least 4 years.

The absence of weeds as a result of maintaining the water in the plots makes it possible to prick out the rice right after harvesting the fish. This advantage represents a net labour gain of 40 men per day per hectare on the task of ploughing and weeding before cultivation starts. In the domain of the fight against harmful insects and molluscs it has not yet been possible, as in China, to reach any conclusions, but a clear reduction in the frequency of leeches has been noted in rizi-pisciculture environments. Fish could also play the role of predator against molluscs which carry bilharzia (schistosomiasis).

*Extensive Pisciculture in the Forested Guinea Model for integrated development and rizi-pisciculture, final report, 2001 IRD*


*Photo: [http://www.veosearch.com/fr/association/photo_parcelle-rizi-piscicole_5578](http://www.veosearch.com/fr/association/photo_parcelle-rizi-piscicole_5578)*
### ADVANTAGES

- Increased organic fertilisation by fish excrements and food remains;
- Better tillering of the rice plants as a result of the activity of the fish;
- Reduction in the number of harmful insects whose larvae are eaten by the fish;
- Increased mineralisation of organic matter and better ventilation of the soil resulting from formation of mud by benthic micro-fauna;
- Control of the algae and weeds, which compete with the rice for light and nutrients, by phytophagic fish;
- Helps to reduce if not to eliminate the use of chemical fertilisers or pesticides (not tolerated by fish).

### LIMITATIONS

- Requires a greater quantity and depth of water for fish culture;
- Additional investment and work may be required for the installation and maintenance of the fish culture plots, particularly the frequent raising of the dykes;
- Fish may occasionally damage the young plants by uprooting or eating them;
- Continuous flooding may not be possible with all soil types and irregular rainfall and the lack of water for irrigation may limit its use.

### For more information:

The use of chemical fertilisers, apart from their high cost, presents a high risk of dependence for small producers. If the maintenance of production capacity is correlated to the use of chemical fertilisers, this only serves to create a vicious circle: Soils are exhausted by over-exploitation, yields are therefore weak and the farmer barely makes a profit, which makes it impossible for him to buy enough fertiliser to re-enrich the soil in depth, leading to even worse yields.

Moreover, the negative impact of the use of chemical fertilisers on the environment is widely recognised. However, in the absence of anything better, agrochemical products can play a temporary role in the improvement of alimentary and nutritional safety, providing that their use is limited and restricted to specific circumstances such as severe infestation by weeds.

In this case, as a complement to good agricultural practices which are low-cost and respect the environment, the technique of micro-dosing can be an acceptable solution.

Micro-dosing is the targeted application of mineral fertilisers, with a dosage of a quarter to a third of that recommended by the manufacturer. The application of fertilisers is carried out at the time of sowing or directly onto the soil about 3 to 4 weeks after the appearance of the seedling. This leads to improved efficiency in the use of fertilisers and a reduction in losses caused by spreading the fertiliser over the entire field. Productivity is improved and economic costs reduced.

The amount, the application calendar and the placement of the fertilisers in relation to the crop are very important and vary in accordance with a number of factors (variety, type of fertiliser, climate).

**Micro-dosing and warrantage credit system for small scale farmers in the Sahel**

The Sahel is one of the poorest regions on earth, where the arid climate is extremely harsh, with an annual rainfall ranging from 350 to 800 mm per year. Inter-annual variability in the amount and the distribution of the rainfall translates into sizeable year-to-year fluctuations in millet and sorghum yields.

The main objectives of the USAID (United States Agency for International Development) financed project were to increase and stabilise production, farm household incomes and food security and help farmers better manage natural resources. From 2002 to 2003 the project established 2,530 demonstration plots of the fertiliser micro-dosing technology for millet and sorghum crops in Burkina Faso, Mali and Niger.

As a consequence of this project, soil erosion was significantly reduced and soil fertility and water usage were enhanced. Results of the demonstration trials showed that sorghum and millet yields were 44 to 120% higher when using fertiliser micro-dosing than when using “standard” practices. The income of farmers using fertiliser micro-dosing and inventory credit system (warrantage) increased by 52 to 134%.

Fertilizer micro-dosing and warrantage credit system for small-scale farmers in the Sahel, ICRISAT, 2004.
Photo: http://underthemosquitonet.wordpress.com/2010/07/22/59/
For more information:


Guide to good practices in Sub-Saharan Africa, illustrated with “case study” files (WOCAT and FAO)


- Fertilizer microdosing. Boosting production in unproductive lands, 2009, ICRISAT.

- Improving crop productivity and farmer income using fertilizer microdosing and the warrantage system in the Volta. Institut de l'Environnement et de Recherches Agricoles (INERA), Burkina Faso, ICRISAT Savanna Agricultural Research Institute SARI, Centro Internacional de Agricultura Tropical (CIAT).

- Strategic Application of fertilizers (micro dose) for small farmer prosperity in the Sahel. Poster presented at the international symposium for sustainable dryland agriculture systems, Niamey, Niger. 2-5 December 2003. ICRISAT, FAO Projet Intrants, INERA and other partners

- Fertilizer micro-dosing and warrantage credit system for small-scale farmers in the Sahel, ICRISAT, 2004.


<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔ Reduction of input costs for the farmer;</td>
<td>✗ Use of chemical fertilisers;</td>
</tr>
<tr>
<td>✔ Restriction of the impact on the environment and on health;</td>
<td>✗ Time consuming;</td>
</tr>
<tr>
<td>✔ Increase in productivity;</td>
<td>✗ Difficult for the farmers to calculate the correct dose for each plant.</td>
</tr>
<tr>
<td>✔ Easy to put into practice and combines well with the “warrantage” credit system.</td>
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</tbody>
</table>
Crop succession is the planting of different crops, one after the other, on the same plot.

When the same crop succession is reproduced in time on a regular cycle, then we speak of crop rotation. It can be biennial, triennial, five-yearly etc.

It is an ancient practice where the main objective is to avoid soil exhaustion as well as the propagation of the diseases or the pests associated with mono cultivation.

Crop rotation can also improve the global structure of the soil by alternating deep-rooted and shallow-rooted plants, tilling the soil and restricting the appearance of plough sole. There are numerous rotation possibilities. The main “rules” to follow are:

✓ Avoid successive cultivation of plants of the same family (e.g. cabbages and turnips or courgettes and cucumbers);

✓ Avoid successive cultivation of the same type of plant (fruit, leaf, or root);

✓ Place at the “top” of the rotation crops which have the highest consumption of nutrients (e.g. aubergines, celery, cabbage, cucumber, marrow, spinach, fennel, maize, melon, leek, sweet pepper, potato, pumpkin, tomato, courgette etc.);

✓ Finish the rotation with the crops which have the lowest consumption (e.g. garlic, broad bean, shallot, turnip, onion, radish, bean, pea);

✓ Alternate “dirty” crops (carrot, turnip, onion etc.) with “clean” crops (tomato, pea, potato etc.). The so-called clean crops suffocate the weeds by covering the soil, and their manner of growth permits hoeing or mulching;

✓ Wait long enough before planting the same crop in the same place (2 to 3 years).
There is no such thing as a template for carrying out crop succession, it all depends on the crop environment, the choice of production systems and farmer’s the margin for manoeuvre. Nevertheless it is necessary for the programme to take crop families and their demand for nutrients (type and quantity of fertiliser) into account.

For example, the presence of nodules on the roots gives legumes a high capacity for fixing atmospheric nitrogen. They are therefore of interest in the rotation especially:
- before a plant with high demand (solanaceae, “greedy” legumes)
- at the end of a succession to enrich the soil
Furthermore, they can be eaten, used as feed, ploughed in as green manure or used as a cover crop.

Other plants have the ability to eliminate parasites, above and beyond the effects of crop succession on pests and diseases.
For example, the French marigold (Tagetes patula) acts as a repellent of nematodes before a susceptible crop such as potatoes or tomatoes. Peanuts, radishes or turnips are also plants which act as nematode « traps ».
(Filers n°19 and 23).

In the west of Kenya a small scale farmer has set up a production system which combines biochar and crop rotation. Already accustomed to the bean/maize rotation, an input of biochar has been added. 20% of the available biomass from the farm has been used to make up the biochar which has led to the addition of about 2.4 tons of biochar per year to the 0.62 hectares of land. With this system and the addition of absolutely no fertiliser a 25 to 67% increase in maize yield has been observed over 3 consecutive seasons. Lehmann, Johannes, Joseph, Stephen. Biochar for Environmental Management. Earthscan, London 2010, in “Improved soil management techniques for poverty reduction in Malawi” Matthew Digman, Dowling Catholic High School.


## Inter cropping

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Garlic</th>
<th>Aubergine</th>
<th>Carrot</th>
<th>Cabbage</th>
<th>Cauliflower</th>
<th>Cucumber</th>
<th>Gherkin</th>
<th>Shallot/cive</th>
<th>Spinach</th>
<th>Strawberry Plant</th>
<th>Small Bean</th>
<th>Runner Bean</th>
<th>Lettuce</th>
<th>Corn</th>
<th>Water Melon</th>
<th>Turnip</th>
<th>Onion</th>
<th>Parsley</th>
<th>Leek</th>
<th>Pea</th>
<th>Potato</th>
<th>Winter Squash</th>
<th>Radish</th>
<th>Tomato</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beneficial inter cropping</td>
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</table>

**Legend:**
- Beneficial inter cropping
- Unfavourable inter cropping
<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Basic principles easy to apply and adaptable to the needs of the farmers;</td>
<td>✗ Difficult to implement on small farms;</td>
</tr>
<tr>
<td>✓ Reduces input costs (pesticides, herbicides);</td>
<td>✗ Requires the availability of a wide range of seeds;</td>
</tr>
<tr>
<td>✓ Contributes to higher yields and better quality food;</td>
<td>✗ Requires expert knowledge of the varieties cultivated.</td>
</tr>
<tr>
<td>✓ Encourages diversification of crops and therefore biodiversity;</td>
<td></td>
</tr>
<tr>
<td>✓ Reduces pressure from pests and minimises recourse to phytosanitary products;</td>
<td></td>
</tr>
<tr>
<td>✓ Maintains and improves soil structure.</td>
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</table>

**For more information:**


Intercropping is the practice of **cultivating more than one crop in the same field at the same time**.

Intercropping was a common practice before the arrival of herbicides in the 1950’s. The aim is to prevent **weeds by competition or by allelopathy**.

It can also **reduce soil erosion**, contribute to the maintenance or increase the level of **organic matter**, retain a part of the leachable mineral elements, improve or avoid the deterioration of the soil structure and **fix nitrogen** in the case of legumes (peas, clover, alfalfa etc.)

The crops can be **sown at the same time** (mixed crops) or **at different times** (relay intercropping). The association is generally made in strips (generally the width of a seed drill) in the same field.

Intercropping can be approached from two angles:

- **Two or more crops cultivated together to maximise the total yield of all the intercropped elements.**
  The yield of each crop is no doubt lower than when a single crop is cultivated, but the total yield is greater than it would be if each crop were cultivated separately.

- **One main crop with one or several secondary crops sown under cover to eliminate weeds, control erosion, to fix nitrogen etc. with the aim of maximising the yield of the main crop.**

  A number of cover crop systems (also called smoother crops) also fall into this category.

As certain plants have the virtue of **repelling parasites or diseases**, it is also possible to use a plant which repels in association with one which attracts as a means of defending the main crop.

This is the case of the **“push-pull”** method (see insert).

Aromatic plants (basil etc.) or certain flowers (French marigold etc.) can also be intercropped as repellents (**Fliers n°19 and 23**)
A vegetable association to combat Striga weed, a parasitic plant which attaches itself to the roots of other plants, and the cornborer, in Sub-saharan Africa.

The push-pull method of vegetable association has been developed by scientists at the International Centre of Insect Physiology and Ecology (ICIPE), in Kenya and Rothamsted Research, in the United Kingdom in collaboration with other national partners. Its aim is the integrated management of Striga weed and the cornborer together with the improvement of soil fertility. The technology is appropriate for smallholders as it is based on locally available plants and not on external inputs. Furthermore it is adapted to traditional mixed cropping systems in Africa.

The "push-pull" technology involves intercropping a repellent plant (Desmodium uncinatum or Spanish clover) with maize and planting an attractive trap plant (Pennisetum purpureum or elephant grass) as a border crop.

This technique is effective against lepidoptera cornborders which are especially harmful in this country. The result is that the insects attack the attractive trap crop and abandon the maize. Furthermore, Spanish clover emits root substances which inhibit Striga weed, a maize plant parasite. The maize yield losses as a result of the competition from the intercrop are less than the gains resulting from the decline of the parasites. To date it has been adopted by more than 35,000 smallholders in East Africa where maize yields have increased from about 1 ton/hectare to 3.5 tons/hectare achieved with minimal inputs.

Finally, crop association provides feed useful for subsistence farming. It also fixes nitrogen because of the nodules, maintains soil humidity, enhances arthropod abundance and diversity and improves soil organic matter.


<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Simple to put into practice and easily adaptable;</td>
<td>✗ Requires knowledge of associations of interest and know-how to carry them out;</td>
</tr>
<tr>
<td>✓ Protects soil and crops (from solar radiation and winds, weeds etc.);</td>
<td>✗ Sometimes makes for harder work.</td>
</tr>
<tr>
<td>✓ Leads to an improvement of the land in time (association of short cycle crops with long cycle crops);</td>
<td></td>
</tr>
</tbody>
</table>
For more information:

Website - Weed management for the reduction of risks associated with pesticides - Agriculture and Agri-food Canada.

Website of ATTRA - National Sustainable Agriculture Information Service, managed by the National Center for Appropriate Technology (NCAT), USA.
⇒ http://www.attra.org/attra-pub/intercrop.html

Website of Biovision Foundation for Ecological Development, Swiss NGO operating in Africa
⇒ http://www.infonet-biovision.org/default/ct/253/soilFertilityManagement


Shaping of crop beds or paddy fields

The technique of cultivation in beds consists of organising the garden into beds, separated from each other by narrow pathways which reduce the compacting of the soil by trampling at the level of the crops. The beds will generally be one metre wide, whilst those intended for cucurbits will be wider.

Where the soil is light and sandy, the beds are raised no more than 10 cm to avoid the problem of them drying out. Where the soil is heavy and clayey they are raised up to 20 cm to boost drainage. The height can also be increased to about 50 cm and in this case we speak of cultivation in raised beds.

The beds are laid out in lines usually spaced 1 to 2 metres apart. The runoff water is collected in the pathways between the beds on which the crops are planted. The system is easy to construct – by hand or by machine – and reduces tillage, which helps to maintain and improve soil structure.

The channelling of water is made in the best possible way, with very little loss. It allows work on extensive areas. Furthermore this system ensures the homogeneous plant growth as they all receive the same amount of water.

It requires a rainfall of from 350 to 750 mm and is suitable for all crop soils. Nevertheless, heavy or compact soils may make manual construction of the beds difficult. Furthermore, it should be avoided on soils where there are channels or undulations. It can be carried out on land which is either flat or with an up to a 5% slope.

In the wet season or in tropical regions subjected to heavy rains the raised beds should be set up to allow good drainage and so avoid the risks of excess water.

As the beds are raised any flooding will only affect the pathways and the soil in the beds will be particularly well drained.

On the other hand, in dry periods, rainwater ingress will be at the level of the pathways which result in the bed being better irrigated in depth. This will allow plant roots to develop as much as possible. Where the climate is very dry, the structure of the top of the bed can be inverted making it concave so as to better retain water at the level of the crop.

Paddy fields are mainly used for rice-growing. The rice fields are divided into paddy fields by earthen levees which permit the control of irrigation so that each field gets the right amount of water.

Other set ups can be used, such as the Zaï system, very useful in an arid climate and useful for the rehabilitation of the most deteriorated soils. The Zaï can take the form of pockets or half-moons; they can also be in the form of small pits, which is the simplest variation of the Zaï system. (Flier n°10)
The construction of cultivation plots in terraces or in flat beds perpendicular to the slope

Cultivation in terraces is practised both in humid tropical regions and in those with a Mediterranean climate, in mountain areas or where there are steep slopes.

This enables them to fight against soil erosion, permits flood irrigation and increases the cultivable area in regions with steep slopes. There are two main types; rice fields and other types of crop.

A farming terrace can be surrounded with different kinds of supports:

- A simple grassy bank or one covered with stones, in the case of a gentle slope.
- A retaining wall, generally a dry stone wall, in the case of a steep slope permitting narrower plots.

In a slope area crops are planted following the contour lines to avoid channelling the water in the direction of the slope and to facilitate dispersion.

Land shaping in Bengal

The Sundarbans are situated in the southernmost part of the state of West Bengal. The area is subject to frequent cyclones and flooding. The villages of the Chandipur Island are flooded for half the year by rainwater and in the dry season the land dries out and becomes very salty and difficult to cultivate. A land shaping project of dykes of different heights were conducted during the 1990s by Ramakrishna Mission Ashrama (RKM), a local NGO. More than 2,000 families have used the system. Results show, amongst other factors, that agricultural production of the land shaped area has risen by 40-50%. The number of crop harvest per year has increased; farmers are planting a wide range of crops, and families have more and better quality food. Moreover, food is available throughout the year. They even have a food surplus they can sell.

**Rainwater harvesting**

Increasing the productivity of rainfed agriculture is directly linked to the pattern and spatial distribution of rainfall.

Where rainfall is unevenly distributed or erratic it is necessary to make use of runoff, indeed to store the water.

There are various forms of rainwater harvesting which can be adapted in accordance with local conditions, particularly in accordance with the needs of the population, rainfall, soil type and topography, availability of materials and workforce, etc.

The methods presented here represent an overview of possible constructions. This is in no way an exhaustive study. There are many and various forms of rainwater harvesting, each appropriate to the corresponding site.

**Integrated programme for capacity building of vulnerable groups in Indonesia ACF, 2007-2010.**

The main objective of this programme was to reinforce the capacity of vulnerable communities to improve their diet and food security in the long term in the Nusa Tenggara Timur province. The project was launched in response to chronic food insecurity in drought affected areas of Timor and the TTS district.

This programme has taken part, along with others, in the organisation of small farmers in West Timor for sustainable production and food self-sufficiency. Various solutions were proposed to combat local constraints, particularly climate restraints in the form of very erratic rainfall.

ACF encouraged rainfall harvesting by distributing tarpaulins to certain beneficiaries.

**The “Teras”**

Ridges made of small stones or earth, are generally constructed along the contour of the watershed and act as an obstacle to water runoff. The ridge reduces the speed of the runoff and the water which seeps in behind it, increasing soil humidity and groundwater recharge.
“Teras” is the name given to plots with ridges on three sides, the fourth, the highest, is left open to catch the water runoff. The Teras technique consists of a base ridge which approximately follows the contour and retains the runoff waters. The two outside arms fulfill the same function but also serve to transport the water towards the cultivated plots.

Sometimes short arms are added to the interior to divide the plot into small pits and to improve the distribution of the water within the plot. Excess water is normally drained along the edges of the outside arms.

The aim of this technique is to increase crop yield. It is also appropriate for trees and grass, but does not allow for the recovery of water for consumption. It also makes it possible to provide water for much larger surfaces (up to 1 hectare) and to harvest greater amounts of runoff.

It requires a rainfall of 250 to 500 mm (arid and semi-arid areas), sufficiently clayey agricultural soils and a 0.25% to 1.5% slope with an optimum of 0.5%.

“Negarim” microcatchments

A “Negarim” microcatchment (from the Hebrew for “streaming/framework”) is a closed grid of diamond or open-ended “V” basins formed by small earth ridges with an infiltration pit in the lowest corner of the diamond, which is where the tree is planted.

This technique is mainly used for tree planting in arid and semi-arid regions and is performed manually.

It is appropriate where there is a minimum rainfall of 150 mm per year and at least 1.5 m, but preferably 2m, of soil depth to ensure adequate root development and a sufficient stock of harvested water. It can be carried out either on flat land or with a slope of up to 5%.

Source: Dijk J.A. van, 1995. Consult on:
http://www.fao.org/docrep/U3160E/u3160e1s.gif
Permeable stone barriers

Permeable barriers are used for floodplain cultivation. Runoff waters are distributed in the valleys to increase crop yields. This technique also assists in the struggle against the formation of ravines and even to "repair" the soil. The barrages are made up of long stone walls in valley bottoms.

This technique requires a minimum rainfall of 200-750 mm (arid and semi-arid areas, it is appropriate for all soil types and is best where there is a less than 2% slope. Finally, it needs to be adapted to each location and requires a large quantity of stones which will have to be transported to the site.

Improving rainfed production

Work in Burkina Faso, Kenya, Niger, Soudan and Tanzania has shown that rainwater harvesting can increase yields two to three times as compared with conventional dryland farming. Furthermore, rainwater harvesting often has double or triple benefits: not only does it provide more water for the crop but it also adds to the recharging of groundwater and helps reduce soil erosion.

L'eau source de sécurité alimentaire, Journée mondiale de l'alimentation: 16 octobre 2002, Archive de la FAO. http://www.fao.org/DOCREP/005/Y3918F/y391809.html#P0_0
**ADVANTAGES**

- Ensures better availability of water in sufficient time, and the durability of the resource;
- Permits better crop growth;
- Reduces the risks of leaching and flooding of soil;
- Prevents erosion caused by runoff and soil compacting;
- Reduces work time related to irrigation and consequently "liberates" work time for taking care of crops.

**LIMITATIONS**

- Certain simple and economic irrigation techniques are not appropriate for irrigating large areas;
- May generate supplementary installation costs and additional tasks (mulching, hoeing).

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**For more information:**


  [http://www.fao.org/docrep/005/y3918f/y3918f09.htm#p0_0](http://www.fao.org/docrep/005/y3918f/y3918f09.htm#p0_0)

- *Water harvesting*, 1991, Archives de la FAO.  
  [http://www.fao.org/docrep/U3160E/u3160e07.htm#5.2%20negarim%20microcatchments](http://www.fao.org/docrep/U3160E/u3160e07.htm#5.2%20negarim%20microcatchments)


- *Rainwater harvesting, Case-study, “Teras” (Sudan)*, International Groundwater Resources Assessment Centre.  
  [http://www.igrac.net/publications/205](http://www.igrac.net/publications/205)

- Capitalisation NGO Ramakrishna Mission Ashrama (RKM). *Landshaping in West Bengal, India.*  

- John Snow international. *Growing positively, a handbook on developing low-input gardens.*
Micro-irrigation, also known as “drip” irrigation is an irrigation method used particularly in arid regions since it reduces the use of water and fertiliser to a minimum.

It allows water under low pressure to drip slowly to the roots of each plant and to distribute it drop-by-drop either on the surface or underground through a network of tubes placed on top of or under the soil.

This method considerably reduces the consumption of water: it only humidifies that part of the soil situated near the roots, and it reduces loss by evaporation, runoff or deep infiltration.

Although the “modern” method of drip irrigation was developed in Israel in the 1960s, micro-irrigation has been in use since ancient times when clay pots filled with water were buried so that the water gradually filtered out into the soil.

These more traditional methods are still in existence today. Moreover, we should be reminded that a modern system, which has been tested in an industrialised commercial economy, will not necessarily be the most appropriate in the context of a precarious economy.

Systems built by farmers generally consist of tubing or other materials which have been pierced and connected to a water source situated on high to ensure low pressure on distribution.

Nowadays this method has become more and more popular, not only in arid regions and urban areas but also in sub-humid or humid areas where water supply is limited or the water has a high cost.

In irrigated agriculture micro-irrigation is widely used for row crops (mainly market garden and fruit crops), together with a vegetable cover crop (mulching etc.), and in greenhouses and nurseries.

It preferably requires filtered water to prevent blockage of the piping used for distribution.
Advantages

- Even distribution in the field;
- Water and fertiliser are delivered directly to where they are needed, to the root level;
- The amount and the duration of the irrigation are strictly controlled to maintain optimal levels of soil ventilation and humidity;
- Labour-saving, only one person is needed to water the whole plot;
- The cultivation period can be extended.

Limitations

- Investment costs may be high;
- Careful and regular maintenance of the equipment is required.

Low cost drip irrigation, Jhikhu Khola watershed, Nepal. International Centre for Mountain Development (ICIMOD)

Upland middle hill farming systems in Nepal are mostly of a rain-fed type, which remain fallow during dry seasons due to lack of irrigation water. In areas where water is scarce, drip irrigation provides the most efficient way to conserve irrigation water. Conventional drip irrigation systems, however, cost between $1,200 and $3,000 per hectare, which makes them inaccessible to small scale farmers in developing countries. The International Development Enterprise-Nepal (IDE-Nepal) has developed a variety of Low-Cost Drip Irrigation (LCDI) kits that are appropriately sized and affordable for smallholders. The PARDYP project was involved in the testing and promotion of these low cost systems.

Results show that, amongst other economies, 50-60% per cent of water was saved compared to the traditional bucket irrigation system. Water loss through evaporation was reduced, thereby conserving soil moisture. Fertile soil loss from the surface of the land due to run off was also reduced. Dry season vegetable production became possible due to the more efficient irrigation system. Due to the labour saving technology, the cost of production has been reduced and farmers are able to spend more time in other income generating activities and home management. Drip irrigation farmers had a comparative advantage as crops matured earlier than those irrigated using traditional bucket methods. This resulted in better market prices and additional household income for participating farmers.
For more information:


- Water as a source of food security, World Food Day. 16 October 2002, FAO archives. [http://www.fao.org/DOCREP/005/Y3918F/y3918f09.htm#P0_0](http://www.fao.org/DOCREP/005/Y3918F/y3918f09.htm#P0_0)

Technical documents/implementation of projects:


- Practical Action. Micro irrigation.
Hedging is an agroforestry technique consisting of the planting of bushes and trees around and within cultivation plots. These bush hedges can line the borders of the plots or be used to compartmentalise large plots.

The density, the layout and the nature of these hedgerows may be very variable and adaptable. Nevertheless, a windbreak hedge should always be wind permeable to avoid the formation of whirlwinds which may cause crop damage.

There are 3 types of hedge in function of their recommended use:

- **Windbreak hedge**: hedge perpendicular to prevailing winds; its function is to “break” the wind and protect crops. Examples of varieties: Jatropha, Acacia, Azadirachta (neem tree), Parkinsonia, Tephrosia etc. to be planted in combination.

- **Protective hedge**: generally planted as a complement to fences (barbwire and wire mesh), it is made up of thorny varieties or those not eaten by animals, for example: Euphorbia, Gum, Prosopis, Jujube, Cactus, Sisal etc.

- **Hedge for biomass production**: generally planted near the composter or the plots, it is regularly pruned; the trimmings are used to make compost or for mulching. Examples of varieties: leguminous bushes, Tephrosia, Leucaena, Flemingia, Glyricidia, Acacias etc.

**Hedging at Anjouan in the Comoros Islands: Technical Innovation and its results. Implemented by CEFADER (Comoros) and the NGO, GRET, between 1985 and 1995**

On the island of Anjouan in the Comoros, in an area of high demographic pressure and with strong physical constraints (soil erosion, low fertility), farmers enclose some plots with live hedges and intensify the crop systems within them by penning livestock. Hedging practically leads to the abandonment of the traditional crop system, rice – maize – pigeon peas. The newly implemented crop systems are much more productive: gross yield has currently increased by a factor of from 2 (associated cultivation of peanuts and maize) to 10 (market gardening). But these new systems are much more work intensive (4 hours of work per day to transport feed for the livestock tied to revolving stakes).

In addition to the direct advantages related to the actual function of the hedges, the farmer can also reap the benefits of the complementarities between the crops and the trees. Different types of trees can be planted: leguminous shrubs for their role in fixing nitrogen, fruit trees for consumption and sale or forage trees as a complement for livestock breeding etc.

- **Moringa** (*Moringa oleifera*) is particularly useful for its edible leaves as it can be regularly cut back and because of its numerous other properties;

- **Neem** (*Azadirachta indica*) can be used for the production of biopesticides (Flier n°23), timber and firewood.

### ADVANTAGES

- Protection of crops against wind erosion;
- Reduces renewal and deterioration of fences for livestock;
- Ventilation and maintenance of soil humidity by providing shade and windbreak and as a result of its root system which absorbs and recycles mineral elements which have migrated to deep layers of the soil;
- An increase in the production of biomass for organic fertilisation and mulching of the market garden beds or for consumption;
- Provides a variety of resources (fruit, wood, bio-pesticides etc.);
- Makes a longer growing season possible and increases yields.

### LIMITATIONS

- Requires a relatively long time to become established 1 to 2 seasons);
- Requires regular upkeep and considerable labour;
- Takes up considerable space;
- It may require ownership of the property.

**For more information:**

Natural pesticides and fungicides

In nature, certain plants or minerals have the capacity to repel or eliminate parasites because of the natural molecules which they contain. They can be used by the farmer to prepare solutions denominated “biopesticides”. They can be both preventive and remedial.

These biopesticides have comparative advantages over synthetic chemical products. Phytosanitary treatments make use of active agents generally of low toxicity. They facilitate the control of parasite invasion without destroying natural fauna in its entirety.

Their effectiveness has been proved and they are more affordable for the farmers who can find solutions with locally available materials. They present an interesting alternative to the difficulties stemming from the supply of synthetic chemical inputs and help to significantly reduce operational costs.

Numerous plants have anti-parasitical properties, amongst the most common to be found are flowers and aromatic plants such as lemon grass, basil, or even shrubs such as the neem tree (Azadirachta indica), palm tree, moringa (Moringa oleifera), as well as garlic, chili, tobacco, rice etc. These latter can be used in solutions or simply as plant associations (Flier n°19).

How to prepare a biopesticide

In the preparation of the product all or part of the plant is used depending on the case. There are a number of different recipes for biopesticides depending on the plants used, but generally the principle for production is similar.

The harvested plants should be cut into small pieces and placed in a large bucket or barrel. Add water and leave in soak for several days. Soap can also be added to increase the adhesive effect of the product or even ashes or animal droppings to encourage the production of microorganisms. In some cases the solution will need to be diluted before applying with a spray, or failing that, with a brush or a cloth.

Preparation of a chili and soap based pesticide against caterpillars, aphids and ants, Bangladesh 2008-2009.

For the first time, an environmentally friendly biopesticide against desert locusts has been successfully tested under large-scale field conditions. 28 June 2005, FAO Rome.

During a field trial organized jointly by the plant protection authorities of Algeria and FAO near El Oued in eastern Algeria, a biopesticide, formulated with Metarhizium anisoplae, was sprayed on more than 1,400 hectares of land infested by Desert Locust larvae. The locusts were clearly weakened and started moving slowly after four days and were then eaten by birds, lizards and ants.

Natural herbicides

As there are chemical phenomena of repulsion and attraction between different plants (called allelopathy), the best natural weed control methods are doubtlessly plant cover (mulching, cover crops (Flier n°11), plant associations with so-called “smother” crops, crop rotation (Flier n°18), even manually pulling up the weeds or with the help of tools providing it is light work.

### ADVANTAGES

- Easily carried out with local resources and numerous treatment possibilities;
- Low costs (locally available materials);
- Has little effect on the environment;
- Maintains the balance between conflicting and destructive populations.

### LIMITATIONS

- Not devoid of pollution risk due to the toxicity of some materials (nicotine in tobacco) and protection is recommended during preparing and whilst carrying out the treatment;
- Requires knowledge of plants, minerals and their properties;
- Generally requires several successive applications.

Mrs Durgi Gharti from the village of Ratadada, Surkhet district Gumi – 5, Nepal, relates her experiences preparing and using biopesticides

“It has been very useful for me. Different local spices such as mugwort (armoise), neem, Adhatoda vasica etc. can be used and the preparation can be used on legumes. We were attacked by aphids, so I sprayed the plants and they never came back! The biopesticide is easy to use; it requires very little work to prepare and costs nothing. The method of preparation is also easy to learn and to teach to others”.

What is liquid manure? The Farmers’ Handbook - "Near The House 1", Chapter 10 - Liquid Manure
For more information:

- Capitalisation ACF: Preparation of Biopesticides. Livelihood support to vulnerable and flood affected population in the District of Shariatpur, Division of Dhaka, Bangladesh March 08-March 09.


- Numerous recipes and links on the website of the NGO Biovision Foundation, Natural Pest Control section. http://www.infonet-biovision.org/default/ovvImg/-1/recipesForOrganicPesticides

- World Agroforestry Centre. Natural pesticides recipes.

- IFOAM. Natural pesticides, Training Manual on Organic Agriculture in the Tropics.


- http://www.neemfoundation.org/

- http://www.moringa.com/
**Before storage**

**Drying of cereals**

After harvesting it may be necessary to carry out pre-drying of the grain, in order to undergo the next operation of threshing or shellling. The grain must then undergo the processes of cleaning and drying so that they can be stored or subjected to further transformations.

In fact after threshing, the moisture content of most grain is too high for good conservation (13-14%). The aim of this desiccation is to lower the moisture content of the grain in order to guarantee conditions favourable for storage or for further processing of the product. It permits a reduction of the risks of premature germination of the grain, the development of moulds and the proliferation of insects.

The natural drying method consists of spreading the grain in thin layers on a drying-floor (plastic sheet, raised terrace etc.) where it is exposed to the air, in sun or in shade, for a maximum of 10 – 15 days. To encourage uniform drying the grain must be stirred frequently.

**Cleaning bulbs, tubers and other legumes and fruits**

These crops should be harvested preferably early in the morning or in the evening, when respiration and transpiration rates are lower, in order to maintain water levels and the freshness of the foods. They should also be handled with care after harvesting to reduce damage and promote the development of microbes.

After harvesting, legumes should be washed as soil remains may harbour pathogens. However, bulbs and tubers should be dried immediately after washing to prevent germination. Finally, fruits should be wiped clean rather than washed. Any parts which are damaged, attacked by disease or discoloured should be removed.

The right conditions for the conservation of these crops are a cool temperature and a high level of humidity. Some legumes such as onions or garlic can however be dried.

**Various storage techniques**

There are, in general terms, two storage techniques: storage in sacks, which is carried out in the open air or in stores and bulk storage in bins or silos of varying capacity. The majority of traditional storage systems used by small farmers in the rural communities of many developing countries are home-made from local materials.

Whatever the type of structure used for storage it is essential to follow certain fundamental rules, amongst others:

- store the crops only when they are completely dry and free from all impurities
- control the state of conservation of the crop both before and during storage.
**Underground storage**

One of the most effective techniques for storing small quantities is to use a container (barrel, box etc.) and to bury it in the soil, protecting it with insulating materials (straw etc.)

Crops can also simply be stored in holes dug in the soil and “closed” by an insulating system (a plastic or glass covered frame). The merchandise stays cool, almost completely air-free with no temperature change, thus maintaining its quality.

In areas where the climate is sufficiently dry, an underground store (cellar etc.) offers a very appropriate alternative solution compared with other closed storage systems. This system can be used for all types of crops (market garden crops, cereals etc.)

**Granaries and improved traditional silos**

They are only appropriate for very limited amounts of grain where most of the crop is for home consumption. There are a number of different types of traditional storage structures, each one adapted to the climate proper to the country. In dry regions there will be earth-enclosed granaries and in humid regions aerated granaries made of vegetable fibre and wood.

**Improved plaited granaries or baskets**

Crop storage in plaited baskets can be improved by covering the walls with mud. Rounded, cylindrical or rectangular granaries can be constructed. They can be made of loam, of clay (sometimes reinforced by mixing with straw) or baked bricks.

These granaries are usually elevated or separated from the ground by wooden or clay posts or large stone plinths. They provide good protection against the rain, are more solid and help to prevent the dry crops absorbing moisture. Small capacity silos (1 to 2 tons) made of bricks or stabilised earth blocks, or even of mud or raw blocks are equally effective.

The addition of a small amount of cement to the loam or the mud reinforces the protection of the structure. Cow dung, which is equally useful for its insect-repellent properties, can also be added. In some regions neem leaves (*Azadirachta indica*) or small quantities of palm or groundnut are added to the stored grain for better protection.
Storage in cribs

In some countries of the Sahel (Burkina, Benin etc.) maize is stored on elevated structures called cribs, where it can be kept for 5 or 6 months without running any risks of importance. Large-scale farmers use cribs with a 10 to 15 ton capacity and with a sheet metal roof. The cribs may or may not be completely enclosed and can be constructed with bamboo or wood.

![Maize in cribs, Cameroon.](http://old.iita.org/medialib/albums/userpics/10005/normal_Maize_4-_Cameroon.jpg)

![Yams in open cribs](http://farm6.static.flickr.com/5018/5473627906_ed9231663_z.jpg)


Metal or cement silos

New structures such as cement or metal silos, generally requiring non-traditional construction techniques and materials, can also be introduced. The metal silo is a simple structure that allows grain to be kept for long periods and prevents attack from pests (rodents, insects, birds etc.)

Metal silos can hold between 100 and 3,000 kilos of grain. A silo with a capacity of 1,000 kilos can conserve the grain needed to feed a family of five for one year.

Furthermore a small or medium farmer can store surpluses for off-season sale when prices are more attractive, thus increasing the household income.
Storage in sacks

The method consists of keeping previously dried and cleaned grain in sacks (vegetable fibre or plastic), and stacking them orderly in properly adapted spaces. There are a number of ways to store grain in sacks. The sacks of grain can be stacked in the open air, under tarpaulin or, when the infrastructure is available, kept inside a store, a hangar or a warehouse.

For example, in dry areas and for short term storage, the sacks can be stacked pyramid style on platforms, if possible protected against bad weather and termites. The platforms also serve to prevent re-humidification of the grain by damp rising from the ground.

Horticultural produce (bulbs, tubers etc.) can also be kept in plastic sacks which have been perforated to ensure ventilation.

ADVANTAGES

✓ Protection of harvests for the short or long term, increasing food availability for the future and maintaining its quality;
✓ Possibility of low-cost storage using local materials;
✓ Enclosed storage is usually effective against pest invasion;
✓ Clay constructions in particular lead to the formation of a cool, dry micro-climate;
✓ In the case of prolonged airtight storage the oxygen is consumed by possible pests and in fact by the respiration of the crop itself which leads to the death of the pests. The remaining oxygen is sufficient to ensure the ability of the stored grain to germinate.

LIMITATIONS

✗ Clay constructions do not withstand the rain very well, whereas in dry periods cracks may appear making frequent repairs necessary or even the construction of a new installation;
✗ The cracks also provide an ideal refuge for insects;
✗ Furthermore there is a danger of condensation especially in the case of metal containers ;
✗ The most successful structures (except underground) may be too costly, whilst the materials (metal, wood) may not always be available in sufficient quantities or may be too expensive.
Storage and conservation of seeds

After the production and harvest of the seeds it is important to ensure their survival for future use. It is therefore indispensable not only to know the best conditions for protection against disease or pests but also how to preserve the seeds’ ability to germinate.

Care should be taken on storing seeds to note down the name of the germ line or variety, year of production and any other relevant information.

“Grain” seeds (cereals, vegetables etc.)

Humidity: Recently harvested seed should not be immediately placed in hermetic containers, as their moisture content is still high and there is a risk of spoilage. The optimal conditions for conservation are: low humidity level and a low temperature.

It is therefore vital to dry the seeds well before storage, so that they reach the correct moisture content (generally 7-8%).

They will also absorb moisture from the environment where they are stored. Therefore it is best to keep them in a hermetic container, either a screw top jar or a metal box.

Darkness: The life expectancy of seeds is shortened by exposure to sunlight. It is best to use dark coloured or non-transparent jars for protection. Failing this they can be placed in paper bags inside the jars.

Temperature: A temperature below 15°C is ideal for storing most vegetable seeds. The seeds can be placed in a hermetic container and kept in the refrigerator when such infrastructure is available.

For short term storage seeds should be kept in a cool dry place sheltered from the light.

Most market garden seeds can be kept for at least 3 to 5 years.

Seed bulbs and tubers

Bulbs and tubers are the reserve organs of the plants, that is, they are the equivalent of a grain. They ensure the multiplication of the plant, usually by vegetative propagation. The vegetative multiplication of tubers, the edible part of the plant (potato, sweet potato, yam etc.), is normally carried out by planting tubers, or even fragments of tubers or sprouts produced by tubers put to germinate.

To prevent precocious germination of tubers they should be kept at a cool temperature and a high level of moisture until they are replanted or destined for consumption.

Underground storage is one of the simplest and most effective solutions (see above).

The bulbs or tubers selected for planting should be of good quality in order to achieve a maximum crop yield. Choose those that are of a good size and weight.
For more information:

Cereals


Market garden and horticultural products

- Traditional yam and manioc storage and its improvement, Jochen Knoth, GTZ-Postharvest Project, République Fédéral d'Allemagne, 1993. [Archives de la FAO](http://www.fao.org/inpho/content/documents/vlibrary/gtzhtml/x0066f/X0066F05.htm#4.6.1)


- Home-based fruit and vegetable processing : a manual for field workers and trainers, Book 1, Principles of post-harvest handling, storage and processing of fruits and vegetables, Susan Azam Ali, Edited by Charlotte Dufour, Published by arrangement with the Food and Agriculture Organization of the United Nations by the Ministry of Agriculture, Irrigation and Livestock, Government of Afghanistan, 2008.

Silos en métal


- Keeping weevils at bay with metal silos, Compiled by Dancan Muhindi, Maendeleo Agricultural Technology Fund (MATF)

Seed conservation

- AVRDC - The World Vegetable Centre. How to produce and conserve your own legume seeds. A guide for farmers.
Raw agricultural products as the basis of human nutrition are usually seasonal and spoil quite quickly once harvested, particularly if they are not preserved correctly. In the developed countries such methods as refrigeration and freezing, together with the addition of chemical preservatives have been perfected for prolonging food preservation. These methods, with high energy consumption and questionable from the point of view of health, are difficult, when not impossible, to implement in the poor communities of the developing countries.

Apart from the different possibilities for storage (Flier n°24), which are not appropriate for all agricultural products, it is also possible to preserve foodstuffs for a long time by processing them.

Different processes such as conserves, drying or even frying give foodstuffs a longer life whilst maintaining the better part of their nutritional value (vitamins, minerals etc.)

**Heat treatment**

**Preserves and jars**

Heat treatment is one of the most common and effective ways to preserve foodstuffs. It consists of preparing them and placing them in air-tight containers (glass jars, tins etc.), which are then heated up in order to destroy, by pasteurisation or sterilisation, the microorganisms and enzymes which damage the products.

The duration and the temperature of the heating up will depend on the type of product (fruits, vegetables etc.) It should also be noted that the boiling point varies according to altitude.

This method of preservation is that which best maintains the nutritional qualities and the taste of the foodstuffs.

The products can not only be preserved whole or in pieces but also in sauces, as chutney or pâtés. Fruits can be preserved as jams, compotes and juices or even crystallised.
The basic ingredients for sauces and chutney are tomatoes, onions, carrots, peppers and citrus fruits, as well as many other vegetables and spices.

The basic principles of the method are the addition of a combination of sugar or salt and acid (acetic acid or vinegar) to the concentrated mixture and heating to reduce water content.

The production of jams requires a large quantity of sugar (equal quantities of fruit and sugar), citric acid (or lemon juice) and pectin. The fruit (apricots, plums, citrus fruit, carrots, pumpkin, red fruits, mangos etc.) is washed, chopped and cooked in a casserole with a little water and then crushed. Sugar and lemon juice is added and then it is heated until the volume is reduced by 2/3.

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
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<tbody>
<tr>
<td>✔ Can be carried out with relatively simple equipment;</td>
<td>✗ Requires a large amount of sugar and fuel for heating which may be expensive;</td>
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<tr>
<td>✔ The products are very safe and have quite a long life-span;</td>
<td>✗ The glass jars for packaging may be difficult to find;</td>
</tr>
<tr>
<td>✔ Can be prepared from a wide range of fruits.</td>
<td>✗ Vinegar is not always readily available.</td>
</tr>
</tbody>
</table>

**Frying / chips**

**Tubers** (potatoes, sweet potatoes, parsnips, beetroot, carrot, plantain, manioc etc.) lend themselves quite well to being transformed into chips, i.e. fried in oil.

The oil should always be changed after being used 3 or 4 times otherwise it becomes rancid. Moreover any excess of fat should be drained off or absorbed on a cloth.

Finally, the chips should be consumed quickly or packaged in air-tight bags after they have properly cooled down.

**Drying**

Drying is one of the oldest techniques for the preservation of fruits and vegetables. Most fruits and vegetables can be dried and they can be preserved for quite a long time in this way.

The products most frequently dried are tomatoes, onions, okra, aubergines, garlic, peppers, apricots, grapes, plums, dates, green vegetables such as spinach, beans and aromatic plants such as mint etc.

In order to correctly preserve dried fruits or vegetables they should first be washed and cut into more or less fine slices. These slices can then be blanched in boiling water for several minutes and then spread out on a raised stand in the sun or on the rooftop.

In fact, sun drying is the most widespread and the least costly technique. However it is limited to dry climate regions. In cold or damp climates drying becomes more difficult.

Finally the dry products must be packaged or preserved in air-tight containers.
Pickling

Vegetables can be preserved in **brine, that is, by adding salt or vinegar and leaving them to ferment for several days.** During fermentation, lactic acid (with salt) or acetic acid (with vinegar) is produced which reduces the pH of the product and contributes to preservation by preventing the growth of "bad" bacteria.

**Strict attention should be paid to hygiene to ensure that only the bacteria necessary for fermentation are present.** Vegetables can be preserved in brine for several months in a cool, dry place, away from direct sunlight.

Contrary to preservation in the cold (freezing, deep-freezing) or by heat (sterilisation, pasteurisation), **lacto-fermentation does not require any energy input and does not destroy the nutrients.** It produces a highly nutritious foodstuff at a minimal financial and ecological cost.

The majority of vegetables can be lacto-fermented (garlic, chard stalk, beetroot, carrot, celery, mushrooms, all kinds of coles, cucumber, courgette, broad bean, green bean, turnip, onion, pea, peppers, pumpkin, radish, scarole, tomato etc.).

The vegetables are **washed and cut into pieces,** they can be **boiled or blanched** but it is not obligatory. They are then **placed in brine** (water and 300 grams of salt per 10 kilos of vegetables) and left to ferment in a **sealed container;** they should be tightly packed into the container.

Vinegar can also be used providing that a sufficient quantity is locally available. Pickling takes an average of from 1 to 4 weeks.

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ One of the least costly preservation techniques, and requires very little equipment;</td>
<td>✗ Not appropriate in cold and humid climates;</td>
</tr>
<tr>
<td>✓ The majority of fruits and vegetables can be dried;</td>
<td>✗ Products may not dry properly and so may spoil during storage.</td>
</tr>
<tr>
<td>✓ Dried foodstuffs have a long lifespan and can be used in a number of ways;</td>
<td></td>
</tr>
<tr>
<td>✓ Particularly appropriate in warm and dry climates.</td>
<td></td>
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For more information:

- Home-based fruit and vegetable processing : a manual for field workers and trainers, Book 1, Principles of post-harvest handling, storage and processing of fruits and vegetables, Susan Azam Ali, Edited by Charlotte Dufour, Published by arrangement with the Food and Agriculture Organization of the United Nations by the Ministry of Agriculture, Irrigation and Livestock, Government of Afghanistan, 2008.
- The conservation of fruits and legumes, Ife Fitz James, Bas Kuipers, Fondation Agromisa, Wageningen, 2003.

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<tbody>
<tr>
<td>✓ Pickled vegetables can be produced with relatively little material;</td>
<td>✓ The availability of vinegar may be a problem in some regions;</td>
</tr>
<tr>
<td>✓ The product has quite a long lifespan due to the combination of high acidity, high salt content and low humidity;</td>
<td>✓ The conditions for fermentation must be strictly adhered to.</td>
</tr>
<tr>
<td>✓ They can be produced from a wide variety of fruits and vegetables.</td>
<td></td>
</tr>
</tbody>
</table>
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