BRiLSS Technical training manual for agro-ecological farming – 2nd Edition

About

BRiLSS Technical Training Manual for Agro-ecological Farming is a Trainer of Trainers (ToT) knowledge product utilized in the implementation of the Building Resilient Livelihoods in Southern Shan (BRiLSS) project supported by SWISSAID. The ToT is designed to build project partner capacity in agro-ecological farming practices. Covered are the fundamentals of a variety of agro-ecological farming technologies, e.g. conservation agriculture, organic farming, agroforestry, permaculture and many others applicable to smallholder farmers. From the building of soils to soil fertility and water management, to cash and food crop planning and management technologies, seeds to agroforestry and integrated-farming establishment; learning materials aim to provide simple and practical technologies for conventional farmers to transition to agro-ecological farming specific to their farming context.

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Session briefings

SESSION 1 Introduction to agro-ecological farming

1

Session content begins by explaining what agro-ecological farming is through a set of frequently asked questions. Other topics covered include defining the principles of agro-ecological farming and providing examples of common agro-ecological farming practices, e.g. conservation agriculture, organic farming, agroforestry, permaculture and others. The aim of the session is to provide BRiLSS project partners/ participants with introductory information on these agro-ecological farming practices, and to build their understanding as to how they fit with SWISSAID's support profile for ecological farming.

SESSION 2 Building and maintaining healthy soils

2

The session captures the base level of knowledge common to all forms of agro-ecological farming – soils. Beginning with building an understanding of soil structure and nutrient management, detail information is offered on how to build soil fertility and maintain nutrient balance through agro-ecological farming techniques. Also presented in session materials are 'how to' instruction on various forms of making and using compost and soil amendments, the use of green manures, mulch and soil cultivation techniques. The session has two main aims, 1) to provide BRiLSS project partners/ participants introductory information regarding soils as a living organism, and awareness on the importance of soil fertility and its management, and 2) building their understanding on how soil fertility can be rehabilitated, improved and managed through agro-ecological farming practices.

SESSION 3: Water management

3

The session presents a wealth of water retention and water conservation practices. Covered are ways to keep soil moisture in place, how to reduce soil evaporation, to practical technical application that aim to increase water infiltration, e.g. modes of trenching, contouring, and catchment configurations etc. Session materials also include an overview of the technical application of drip irrigation. In brief, the session aims to provide BRiLSS project partners with an overview of simple and accessible low cost agro-ecological farming water management practices.

SESSION 4: Cash and food crop planning and management

Session 4 is an extensive review of cash and food crop planning and management practices. Included in session materials are agro-ecological farming technologies such as crop rotation, intercropping, and the use of cover crops, system of rice intensification, to agro-ecological technologies in weed, pest and disease management. The session aims to provide BRiLSS project partners with practical 'how to' knowledge of featured agro-ecological farming activities, and a chance to analysis these from an 'implementation' perspective.

4

SESSION 5: Seed selection and management

The session stresses the importance of traditional seed varieties and seed conservation. Moving forward through the session handouts, practical guidance to seed evaluation and selection, to seed preparation, storage and treatment techniques prior to planting are explained in detail. The session also allows for hands on demonstrations of the aforementioned. Overall, the session aims to provide BRiLSS project partners with a solid understanding of seed and seed management practices.

5

SESSION 6: Agroforestry tree propagation, and nursery management

Session six (6) is a comprehensive review of agroforestry tree propagation and nursery management technologies. Covered are methodologies related to sexual and asexual tree propagation, seed sourcing and nursery management, to the production of vegetative tree planting materials. Included in the session materials is tree specific information regarding agro-ecological value, propagation and management techniques. The overall aim of the session is to provide BRiLSS project partners with the relevant theory regarding agroforestry tree propagation and nursery management, as well as hands on experience in propagation techniques.

6

Session 7 Integrating animal husbandry into agro-ecological farming

The session brings forward practical decision based knowledge regarding 'if' integrating animal husbandry into smallholder agro-ecological farms is possible and worthwhile vis-à-vis needed investments. Session handouts cover a variety of economical animal husband practices for smallholder farmers, e.g. food and fodder requirements vis-à-vis livestock numbers and farm capacities, to instructions on the making of silage, pasture management, and the use of cow, chicken and pig wastes as bio-fertilizers. Overall, the session aims to provide BRiLSS project partners with the relevant theory on integrating animal husbandry into agro-ecological farming; and an opportunity to develop mix-farming guidelines and a localized capacity building support profile for BRiLSS beneficiaries considering investment into mixed farming.

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Content

Session 1 Introduction to agro-ecological farming

1

Objective

- ✓ Provide BRiLSS project partners/ participants with introductory information on agro-ecological farming practices and how such fits with SWISSAID's support for ecological farming.

Session content begins by explaining what agro-ecological farming is through a set of frequently asked questions. Other topics covered include defining the principles of agro-ecological farming and providing examples of common agro-ecological farming practices, e.g. conservation agriculture, organic farming, agroforestry, permaculture and others. The aim of the session is to provide BRiLSS project partners/ participants with introductory information on these agro-ecological farming practices, and to build their understanding as to how they fit with SWISSAID's support profile for ecological farming.

Session 1 Introduction to agro-ecological farming

Facilitation guide (3+ hours)

STEP 1

Introduce Handout S1.1 – S1.4 through an organized PowerPoint presentation, including the session objectives, content, and the process the facilitator will take to deliver the session. Emphasize the importance of all participants having a common understanding of agro-ecological farming in the context of the BRiLSS project.

STEP 2

Begin by reviewing the frequently asked questions presented in Handout S1.1. Place emphasis on 'what agroecology is', and how it links to the practice of agro-ecological farming, i.e. agroecology is a 'form of study' based on understanding ecological processes that operate in agricultural production; the practice of agro-ecological farming is an attempt by the farmer to mimic ecological processes in agriculture. The practice includes protecting/ facilitating natural cycles of nutrient flows, internal waste management and recycling, to taking and more balanced approach to food production. This balanced approach considers ecology, culture, economics and society within food production operations occurring within a healthy environment.

STEP 3

Cover the learning point presented at the end of the handout. The following are key points to make:

- ☑ Agroecology represents a different way of farming. It's not necessarily organic, and it's not necessarily conventional. It is a practice that aims to ensure the sustainability of food production and crucial ecosystem services;
- ☑ Agroecology is one of many terms people use to describe an approach to farming – others being sustainable agriculture, ecological agriculture, low-external input agriculture or people-centered agriculture;
- ☑ Farms that focus on restoring and maintaining soil health are less dependent on chemical inputs, because plants grown in healthy soils can better access their natural defenses to ward off pests and disease; and
- ☑ Farmers that think ecologically tend to let their animals do a lot of the work for them. By allowing animals to perform their natural behaviors, farmers can use livestock to enhance the farmland ecosystem.

STEP 4

Move on to Handout S1.2 material. State that there are seven (7) core aims/ principles to agro-ecological farming. Cover each with the participants. In brief, they are:

1. Agro-ecological farming works to enhance the recycling of biomass and optimize and balance nutrient flows;
2. Agro-ecological farming focuses on enhancing soil biotic activity by managing organic matter;
3. Agro-ecological farming seeks to minimize crop losses through microclimate, soil and water management;

4. Agro-ecological farming aims to enhance species and genetic diversification;
5. Agro-ecological farming aims to enhance beneficial biological interactions among organisms;
6. Agro-ecological farming places emphasis on 'agro-biodiversity' to ensure farmer independence and food sovereignty; and
7. Agro-ecological farming garners the use of a variety of knowledge sources, scientific rigor, and participatory problem solving.

STEP 5

Handout 1.3 focuses on ecological farming and the parameters of such set out by SWISSAID. Emphasize that 'ecological farming' is one of the accepted forms of farming practices noted as agro-ecological farming. The main agro-ecological farming practices across Southeast Asia are presented in Handout S1.4.

Present the materials within the handout, i.e. ecological farming action principles, the eight (8) steps to ecological farming, and SWISSAID's support guidelines for the promotion of ecological farming.

STEP 6

Introduce Handout S1.4 to the participants. Note that there are many inter-related farming practices covered under 'agro-ecologic farming'; seven (7) of these are presented in brief in the handout:

- Conservation agriculture;
- Organic agriculture;
- Agroforestry;
- Systems of Rice Intensification;
- Permaculture home gardening;
- Integrated crop management; and
- Integrated farming.

Present the material, and focus participants on the **'common actions'** of each. These are noted with the ☑ symbol.

End the session by letting the participants know that in the following sessions, these common actions (and many others) will be broken-down and elaborated on in detail.

1.1 Frequently Asked Questions

What is the meaning of agroecology?

Agroecology is the study of ecological processes that are reflected in agricultural production systems. The prefix agro- refers to agriculture. Bringing ecological principles to bear in agro-ecosystems can suggest new management approaches that would not otherwise be considered.

What are the 3 main features of agroecology[1]?

- ✓ It is a scientific discipline involving the holistic study of agro-ecosystems, including human and environmental elements;
- ✓ It is a set of principles and practices used to enhance the resilience and the ecological, socio-economic and cultural sustainability of farming systems; and
- ✓ It is a movement seeking a new way of considering agriculture and its relationship to society.

What is the meaning of Agro-ecosystem?

An agro-ecosystem is an active association of crops, pastures, livestock, other flora and fauna, soils, water, and the atmosphere. Agro-ecosystems are contained within larger landscapes, which include uncultivated land, natural drainage networks, rural communities, and wildlife.

What is the meaning of agro-ecological zones[2]?

Agro-ecological zones are geographical areas that have similar climatic conditions that determine their ability to support rain fed agriculture. At a regional scale, they are influenced by latitude, elevation, and temperature, as well as seasonality, and rainfall amounts and distribution during the growing season.

What is Agro-ecological farming? Why does it work[3]?

Agroecology is a general term used to describe an approach to farming – others general terms used are sustainable agriculture, ecological agriculture, low-external input agriculture or people-centered agriculture. Agro-ecological farming is farming that “centers on food production that makes the best use of nature’s goods and services while not damaging these resources.” Agro-ecological farming uses a whole-systems approach to farming and food production by linking ecology, culture, economics and society together to create healthy environments, food production and communities.

Agroecology is not just “farming the traditional way,” but it is a constant process of farmer-led innovation as circumstances change, thus, determining constantly how to farm well and to improve life.

Agro-ecological Farming vs. Organic Farming - What’s the difference?

Although agro-ecological farming shares some of the same principals as organic farming, agroecology is not associated with a particular type of agriculture. Conventional and organic farms can take an agro-ecological approach to managing farmland. However, in practice, large organic farms don’t use synthetic chemicals, but they do little to manage

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[1] Source: http://nature.berkeley.edu/~miguel-alt/principles_and_strategies.html (July 1 2016)
[2] Source: http://www.agroecology.org/Principles_Def.html (July 1 2016)
[3] Source: Source: http://www.moreandbetter.org/en/news/a-viable-food-future (July 1 2016)

the ecosystem services provided by farmland. They rely heavily on fossil fuels, erode soils, pollute water supplies, destroy native wildlife habitat, and so forth. Intensive agriculture – even intensive organic agriculture – is generally an environmentally destructive practice. Comparing farming technologies, organic farming has a greater focus on the use of natural fertilizers and methods of pest control, whereas agro-ecological farming places focus on nutrient recycling, biological crop protection, and in some case does utilize chemical inputs.

Is organic food agro-ecological?

Not necessarily. Most of the organic food you see in the grocery store is from industrial operations that do not think ecologically. Instead of managing their farmland as an ecosystem, large-scale organic farms focus on producing as much food as possible. They don't use synthetic chemicals, but they do little to manage the ecosystem services provided by farmland.

Can conventional farms be agro-ecological?

Conventional and organic farms alike can also practice agroecology by setting aside a portion of their farmland for conservation. Restoring farmland to its natural state increases the number of native plant and animal species on farms, and can repair important ecosystem functions. Restored land can store atmospheric carbon dioxide, control erosion, detoxify soil, purify water, provide habitat for insect predators that keep pests at bay, and much more.

AGRO-ECOLOGICAL FARMING – THE EFFORT TO MIMIC ECOLOGICAL PROCESSES IN AGRICULTURE

LEARNING POINT: Farms that focus on restoring and maintaining soil health are less dependent on chemical inputs, because plants grown in healthy soil can better use their natural defenses to ward off pests and disease. Farmers that think ecologically also tend to let their animals do a lot of the work for them. By allowing animals to perform their natural behaviors, farmers can use livestock to enhance the farmland ecosystem. For example, chickens can be moved from field to field to clean up vegetable patches before a new crop is planted. In addition to clearing out old vegetation, chickens eat insect pests, aerate the soil as they scratch for food, and leave each patch with an ample dose of fertilizer. Pigs that are allowed to express their inherent 'piggy-ness' – namely, digging and wallowing – can be used to till a field or turn manure into compost. Rotating different species of farm animals across pastures can reduce disease-risk in livestock while keeping pastures rich in nutrients and forage.

In a way, agroecology represents a different way of farming. It's not necessarily organic, and it's not necessarily conventional. Given how much land use is agricultural and how environmentally destructive agriculture can be, agroecology seems like the best solution to ensure the sustainability of food production and crucial ecosystem services.

1.2 Principles of agro-ecological farming[4]

1

Agro-ecological farming works to enhance the *recycling of biomass* and balance nutrient flows. On an agricultural farm, a huge amount of biomass is produced year after year (cow dung, wheat and paddy hay, corn husk etc.). Farmers recycle this biomass to enhance nutrient levels in the soil. Agro-ecological practices enable a farmer to maximize the use of biomass available from all on-farm sources to increase productivity.

2

Agro-ecological farming focuses on *enhancing soil biotic activity* by managing organic matter. Organic matter helps to establish good soil conditions for better plant growth. Organic matter (both plant and animal residues), when decomposed, creates positive effects on soil properties and improves soil quality.

3

Agro-ecological farming seeks to *minimize crop losses through microclimate, soil and water management*. This is done through microclimate management, water harvesting and soil management by increasing soil cover. This allows the soil to absorb and retain moisture. Increase soil coverage with vegetation is also an important part of soil and water management, as it controls the evaporation of water into the air.

4

Agro-ecological farming aims to *enhance species and genetic diversification*. Selective breeding of plants leads to monocultures of genetically identical plants, which makes crops extremely susceptible to widespread diseases. In contrast, species and genetic diversity helps plants adapt to changing environments.

5

In the natural world, no organism exists in isolation, and every organism is connected to the environment and to other organisms. Agro-ecological farming aims to *enhance beneficial interactions among organisms*. An organism's interactions with its environment are fundamental to its survival and functioning of the ecosystem as a whole.

6

Agro-ecological farming *places emphasis on 'agro-biodiversity'* as an entry point for the re-conceptualization of agriculture and food systems to ensure farmer independence and food sovereignty.

7

Agro-ecological farming *garners knowledge diversity* (local/ traditional know-how and practices to expert knowledge), and participatory problem solving and solution finding driven by the needs of society and practitioners, while at the same time guaranteeing scientific rigor.

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[4] Varghese, Shiney & Karen Hansen-Kuhn, "Scaling Up Agroecology: Toward the Realization of the Right to Food," Institute for Agriculture and Trade Policy(IATP), Minnesota, USA.

1.3 SWISSAID and ecological farming

What is Ecological Farming?

Ecological farming aims to create globally sustainable land management systems through agro-ecology practices and principles, and encourages thinking of the importance of maintaining biodiversity in food production and farming end products. Ecological farming follows the principles of agro-ecology – ecological soundness, economic viability, and societal and cultural respect

Ecological farming action principles

Principle 1 Use natural ecosystems as models for understanding sustainable agriculture.

Principle 2 Maintain bio-diversity and water within the farming system and its surrounding environment.

Principle 3 Conserve and promote the use of local seed and plant varieties that can adapt to local environments.

Principle 4 Encourage biological pest control and pollination of crops by creating natural spaces.

Principle 5 Recycle materials and resources within the farm and its surrounding community as a strategy to create sustainable local nutrient and carbon cycles.

Principle 6 Maintain and enhance long-term soil fertility by ensuring soils are protected and stabilized, and continually provided with organic material inputs to encourage organic matter accumulation and soil biological activity.

Principle 7 Increase farm productivity by strengthening various components of the agro-ecological farming system: water conservation, nitrogen fixation, mineral cycling, soil organic matter formation, and the testing of more adapted plant materials.

Principle 8 Provide attentive care to the health and behavioral requirements of livestock.

Principle 9 Value and harness local/ traditional knowledge, and merge such with scientifically substantiated knowledge to develop and adopt new technologies in consideration of long-range social, economic and ecologic impact, including the reduction of workloads for women farmers.

Principle 10 Create linkages between ecological farming on the ground and advocacy activities at local and national levels in order to contribute to the development of a positive policy environment.

8 steps to ecological farming

1. **Emulate Nature:** Use ecological principles as the basis of farm planning.

2. **Diversify Your Crops:** Diversify to ensure your farm system is resistant to poor weather conditions, insects or disease outbreaks.

3. **Improve Your Soil:** Use compost to adjust nutrient levels to create a more balanced and regenerative soil.

4. **Select Suitable Species and Number of Livestock:** Chose appropriate species and numbers of livestock to suit your farm's special conditions and its carrying capacity, e.g. don't keep many cows if you do not have the hay and pasture.

5. **Be a Learner:** Be a good observer, talk with other farmers, visit their farms, and join farmer organizations.

6. **Start Small Scale:** Begin from a scale you can manage, and then make appropriate adjustments before expanding.

7. **Monitor Results:** Integrate your farm plan with good record keeping.

8. **Create a Sustainable Production System:** No matter where you are, you can still find ways to be sustainable by applying the principles of ecological farming.

SWISSAID ecological farming support profile

- ☑ Training in ecological farming techniques (compost preparation, intercropping techniques, application of manure, integrated pest management, agro forestry, etc.)
- ☑ Mutual learning and knowledge sharing
- ☑ Installation of farmer controlled seed banks and seed production centers (including training)
- ☑ The establishment of diverse agricultural farming systems (crops, livestock and aquaculture)
- ☑ Participatory and self-controlled certification processes if necessary or useful for market access
- ☑ Ecological producer marketing networks, cooperatives, organizations
- ☑ Microcredit to promote production and commercialization of ecologically produced products
- ☑ Advocacy at local and or national levels to promote favorable legal and economic conditions for ecological farming

SWISSAID does not support

- ☒ Purchase of chemical fertilizers
- ☒ Purchase and use of synthetic pesticides. Highly Hazardous Pesticides (HHP), such as Glyphosate, Endosulfan and Paraquat are to be avoided at all times
- ☒ Purchase and use of genetically modified seeds and animals
- ☒ Purchase of imported hybrid seed (except for vegetable seeds)
- ☒ Investments in monocultures
- ☒ Investments in agro fuel plants

The long-term aim is to phase out completely from synthetic pesticide use, therefore SWISSAID does not finance the purchase of pesticides. However SWISSAID understands that cases of emergency can occur, where farmers are lacking viable alternatives (for the moment) and have to apply pesticides to deal with mass infestation of pests.

SWISSAID is aware that criteria for ecological agriculture may conflict with immediate needs, practices of national and international agriculture extension services and policies of international development agencies. Thus, it is important that SWISSAID states clearly what its long-term vision, values, mission and policies are. This policy aims to clarify SWISSAID's position in supporting agriculture development activities. SWISSAID is part of an international movement that follows the same goals and strategies.

1.4 Core practices of agro-ecological farming

CONSERVATION AGRICULTURE is a set of soil management practices that minimize the disruption of the soil's structure, composition and natural biodiversity. Conservation agriculture has proven potential to improve crop yields, while improving the long-term environmental and financial sustainability of farming.

Principles

- Maintenance of permanent or semi-permanent soil cover (using either a previous crop residue or specifically growing a cover crop for this purpose);
- Minimum soil disturbance through tillage (just enough to get the seed into the ground); and
- Regular crop rotations to help combat biotic constraints.

Common Actions

☑ Utilization of green manures/cover crops to produce the residue cover;
☑ No burning of crop residues;
☑ Integrated disease and pest management; and
☑ Controlled/limited human and mechanical traffic over agricultural soils.

CAUTION! Conservation agriculture does allow farmers to apply synthetic chemical fertilizers, fungicides, pesticides and herbicides. Many farmers rely on using these to control weed and pest problems, particularly during the early transition years. As soil physical, chemical and biological health improves over time; the use of agrichemicals can be significantly reduced or, in some cases, phased out entirely.

ORGANIC AGRICULTURE is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and recycling of nutrients according to local conditions. Organic agriculture does not permit the use of synthetic chemicals to produce plant and animal products. Organic agriculture relies on the management of soil organic matter and biological processes.

Principles

- Combine scientific knowledge of ecology and modern technology with traditional farming practices based on naturally occurring biological processes;
- While conventional agriculture uses synthetic pesticides and water-soluble synthetically purified fertilizers, organic farmers are restricted by regulations to using natural pesticides and fertilizers.

Common Actions

- ☑ Use of crop rotation practices;
- ☑ Use of green manures and various forms of compost;
- ☑ Use of biological pest control; and
- ☑ Use of mechanical cultivation.

IMPORTANT NOTE: These measures use the natural environment to enhance agricultural productivity: legumes are planted to fix nitrogen into the soil, natural insect predators are encouraged, crops are rotated to confuse pests and renew soil, and natural materials such as potassium bicarbonate and mulches are used to control disease and weeds. Genetically modified seeds and animals are excluded.

AGROFORESTRY is a land use management system in which trees or shrubs are grown around or among crops or pastureland. It combines shrubs and trees in agricultural and forestry technologies to create a more diverse, productive, profitable, healthy, ecologically sound, and sustainable land-use systems. Agroforestry has a lot in common with intercropping. Both have two or more plant species (such as nitrogen-fixing plants) in close interaction, both provide multiple outputs, as a consequence, higher overall yields and, because a single application or input is shared, costs are reduced.

Common Actions

- ☑ Crops are purposely raised under tree canopies. For most uses, the understory crops are shade tolerant or the over-story trees have fairly open canopies. A visible example is shade-grown coffee. This practice reduces weeding costs and improves the quality and taste of the coffee.
- ☑ Crop strips alternate with rows of closely spaced tree or hedge species. Normally, the trees are pruned before planting the crop. The cut leafy material is spread over the crop area to provide nutrients for the crop.

IMPORTANT NOTE: Just because plants are grown under shade does not necessarily translate into lost or reduced yields. This is because the efficiency of photosynthesis drops off with increasing light, and the rate of photosynthesis hardly increases once the light intensity is over 10% of direct overhead sun. This means that plants under trees can still grow well even though they get less light.

SYSTEMS OF RICE INTENSIFICATION (SRI) is a methodology aimed at increasing the yield of rice produced in farming. It is a low water, labor-intensive, organic method that uses younger seedlings singly spaced and typically hand weeded with special tools. SRI concepts and practices have continued to evolve as they are being adapted to rain-fed (un-irrigated) conditions and at times transplanting being superseded by direct seeding.

Principles

- Rice field soils should be kept moist rather than continuously saturated, minimizing anaerobic conditions, as this improves root growth and supports the growth and diversity of aerobic soil organisms;
- Rice plants should be planted singly and spaced optimally widely to permit more growth of roots and canopy and to keep all leaves photo-synthetically active; and
- To avoid trauma to roots and to minimize transplant shock, seedlings should be transplanted when young.

Common Actions

☑ Transplant seedlings at the two (2) leaf stage, usually between 8 and12 days old;
☑ Reduced plant density to one plant per hill instead of 3-4 together to avoid root competition, and widely spaced (25cm X 25cm) to encourage greater root and canopy growth;
☑ Improved soil conditions by adding organic matter to improve soil structure, nutrient and water holding capacity.
☑ Apply a minimum of water during the vegetative growth period. A 1-2 cm layer of water is introduced into the paddy, followed by letting the plot dry until cracks become visible, at which time another thin layer of water is introduced. During flowering a thin layer of water is maintained, followed by alternate wetting and drying in the grain filling period, before draining the paddy 2-3 weeks before harvest.

PERMACULTURE HOME GARDENING is designed to recycle resources. Ecological relationships between different components of garden and household are manipulated in favor of human needs. Residues from crop processing are used as animal feed. Animal and human wastes are recycled into manure for garden fertilization. Floating aquatic plants are grown for pig feed. Pond water is used to irrigate the garden. Vegetation residues are used for animal and fish feed, and pond mud is used as a soil dressing.

Common Actions

- ☑ Conserve precious topsoil and retain fertility by terracing and planting across slopes and along contour lines of the same elevation;
- ☑ Use of nitrogen-fixing shrubs between vegetable beds and fruit trees to improve soil nutrient uptake and capture mobile soil when it rains;
- ☑ Cutting back of hedges regularly to reduce competition for light; their leafy branches mulch crop beds, conserving moisture and providing nutrients;
- ☑ Fixing of small cross-slope trenches to capture and direct surface run-off or fill with crop residues, which provide compost on-site;
- ☑ Placement of rocks to provide warmth, and leguminous creepers covering terrace walls provide soil fertility; and
- ☑ Placement of flowers and other plants to enhance the social function of the garden and to play a role as bio-filters in reducing pests.

IMPORTANT NOTE: Permaculture gardeners us a range of sustainable strategies to avoid having to pay for inputs, including saving what they have and recycling wastes. To provide vegetable seed for later crops, some plants are left to flower and seed. Such "land race" seed may not provide the vigor or the market benefits of commercial hybrid seed, but the gardener does not have to spend cash or rely on market access. Good gardeners select plants with the best production and market characteristics to be nurtured into strong seed.

INTEGRATED CROP MANAGEMENT: This is a holistic approach to sustainable agriculture. It considers the situation across the whole farm, including socio-economic and environmental factors, to deliver the most suitable and safe approach for long-term benefit. This means carefully considering site selection, soil management, seed & planting material, crop rotation, crop nutrition, pest management, water management and landscape management that fit the local conditions and climate. Overall, integrated crop management is a method of farming that balances the requirements of running a profitable business with environmental responsibility.

Common Actions

- ☑ Minimum tillage and soil conservation techniques to lower costs associated with maintenance of soil structure and fertility;
- ☑ Use of nitrogen-fixing plants, green manures and agro-forestry techniques to improve soil fertility;
- ☑ Use of biological methods of pest and disease control to lower costs and sustainable plant protection;
- ☑ Crop rotations to prevent build-up of pests, disease and weeds;
- ☑ Productive use and disposal of plant and animal residues to prevent damage to soil, water, human, plant and animal health;
- ☑ Maintenance and improvement of ecological diversity to avoid loss of biodiversity and damage to habitat; and
- ☑ Minimum use of purchased inputs and non-renewable fuel resources to reduce production costs and environmental damage.

IMPORTANT NOTE: Integrated crop management is not a quick fix that can be applied to one crop, or one field or one season. Although primarily concerned with crop production, livestock management is equally important on mixed farms because livestock are consumers of crops and providers of organic nutrients.

INTEGRATED FARMING – THE MIXED FARM: In an integrated agro-ecological system, livestock and crops are produced within a coordinated framework. The waste products of one component serve as a resource for the other. For example, manure is used to enhance crop production; crop residues and by-products feed the animals, supplementing often-inadequate feed supplies, thus contributing to improved animal nutrition and productivity.

Principles

- Utilizes an integrated agro-ecological systems approach - livestock and crops are produced within a coordinated framework;
- What counts is the yield of the total, not of the parts.

Common Actions

- ☑ Waste products of one component serve as a resource for the other;
- ☑ Provision of attentive care to the health and behavioral requirements of livestock;
- ☑ Production of fodder on-farm as grazing land or grass or tree crops used for cutting;
- ☑ Grazing and pasture management;
- ☑ Silage production;
- ☑ Utilization of cow dung and other animal waste as a fertilizer;
- ☑ Use of alternative animal composting practices.

IMPORTANT NOTE: The maintenance of an integrated farm is dependent on the availability of adequate nutrients to sustain animals and plants and to maintain soil fertility. Animal manure alone cannot meet crop requirements, nor can crop residues provide an adequate diet for livestock. Alternative sources for nutrients need to be found, e.g. growing fodder legumes and using them as a supplement to crop residue livestock feed.

Session 2 Building and maintaining healthy soils

Objectives

- ✓ Provide BRiLSS project partners/ participants introductory information regarding soils as a living organism, and awareness on the importance of soil fertility and its management respective of agro-ecological farming; and
- ✓ Build an understanding on how soil fertility can be improved through specific agro-ecological farming practices, e.g. on how to increase soil organic matter as part of soil rehabilitation and improvement processes to re-establish/ improve the function of the soil ecosystem and sustain farm productivity.

2

The session captures the base level of knowledge common to all forms of agro-ecological farming – soils. Beginning with building an understanding of soil structure and nutrient management, detail information is offered on how to build soil fertility and maintain nutrient balance through agro-ecological farming techniques. Also presented in session materials are 'how to' instruction on various forms of making and using compost and soil amendments, the use of green manures, mulch and soil cultivation techniques. The session has two main aims, 1) to provide BRiLSS project partners/ participants introductory information regarding soils as a living organism, and awareness on the importance of soil fertility and its management, and 2) building their understanding on how soil fertility can be rehabilitated, improved and managed through agro-ecological farming practices.

Facilitation guide (1 Day + time required for demonstrations)

STEP 1

Introduce Handout S2.1 – S2.6 through an organized PowerPoint presentation, including the session objectives, content, and the process the facilitator will take to deliver the session. Emphasize the importance of all participants having a common understanding of the content in the context of the BRiLSS project.

Note to participants that the session may take one (1) day to cover the written materials, with additional time needed for chosen field based practical exercises.

STEP 2a

Beginning with Handout S2.1 – soils & nutrient management, emphasis must be placed on setting a basic understanding that soils are alive, and that soil structure is most important to agricultural productivity. Note that aside from structure, the mineral content within the soil provides three (3) main elements needed for plant growth, 1) nitrogen (N), phosphorus (P), and potassium (K). Learning Aid S2.3 can be used to elaborate on this information.

Strongly note that soil contains smaller or larger quantities of **organic matter/ humus**, resulting from the decomposition of biomass, and is present in the top layer of the soil. The resulting structures can recombine themselves to form a very stable humus structure. A stable humus structure is key to soil water and nutrient retention and provision to plants.

STEP 2b

If possible, have ready several different soil samples for participants to conduct a 'soil testing' practicum. Follow instructions given within the handout. Following, focus participants on the purpose of soil microorganisms. Cover in detail the information given in Box 1.

STEP 3

Move on to Handout S2.2. Use Box 2 to facilitate learning around the key factors that influence soil fertility, and Figure 1 to discus the basics of the plant nutrient cycle. Highlight that the 'cycle' is not a true cycle because nutrients via plant mater are removed from the cycle due to off farm sales of harvested plants/ crops. Review 'nutrient balance and budgets' to emphasize this point.

STEP 4

Follow by using Box 3 to describe the functions of soil organic matter/ humus. The key message is that organic matter retains and releases nutrients. As organic matter consists of decomposing biomass, it provides a well-balanced mixture of all nutrients that plants require for their growth. And, while decomposing, it acts as a slow-release source of nutrients to the crops.

Review bullet points given in Box 4 as a re-cap.

STEP 5

Move on to the '5 practices to creating an agro-ecological soil-crop management system'. Present the five (5) agro-ecological farming practices used to manage soil nutrient cycling and use: 1) crop rotation, 2) soil and water conservation, 3) cover crops and green manures, 4) manure management, and 5) soil amendments. Note to participants that in later sessions they will learn in more detail these five (5) practices.

STEP 6

At this time it is useful to present the 'agro-ecological farming concept tree'. See Learning Aid S2.1. Note to participants that not all elements within the 'TREE' have been covered, but it is a good idea to see where key principles and actions discussed so far fit in the bigger agro-ecological farming picture. Highlight founding and technical principles, and general practices and common actions covered so far. As new elements are covered through the various sessions, point these out using the diagram.

Learning Aids S2.2 and S2.3 can be used to recap the handout.

STEP 7

Introduce Handout S2.3 – composting & organic soil amendments. Start with the advantages and disadvantages of composting before covering the basics to composting. Note to participants that there are many types of 'composting', e.g. static pile, thermal composting, worm composting, barn composting and many others. Participants may or may not be familiar with these methods, however, cover in detail the 'general steps to making a compost heap'. This will be the most applicable form of composting for the BRiLSS project area beneficiaries; others would include soil amendments covered in the handout.

STEP 8

Note to participants there are six (6) forms of soil amendments very applicable to the BRiLSS project area beneficiaries, 1) indigenous microorganisms (IMO), 2) fermented rice bran (FRB), 3) fish amino acids, 4) fermented plant juice (FPJ), 5) carbonized rice hull, and 6) bokashi. Detailed instructions are given on materials needed, the process of making the soil amendment, and applications. Each can be covered as per the written materials, and for those deemed most important, these can be demonstrated as a field-based practicum.

Following, provide a brief re-cap to the handout by noting the following learning points:

- Long-term use of inorganic fertilizers results in a soil that is impoverished in terms of organic matter content, microbial activities, and structure;
- Organic soil amendments described prove useful for jumpstarting the soil rehabilitation process on farms initiating a conversion from conventional to agro-ecological farming;
- The first years of agro-ecological cultivation are frequently characterized by lower yields and reduced farm income until the soil

has been restored; and

- Bokashi fermented organic fertilizer has been a particularly important tool for recruiting and energizing new agro-ecological farmers. Bokashi provides a powerful combination of beneficial microorganisms, abundant organic matter and essential nutrients and micronutrients to degraded soils. This stimulates the development of a healthy soil biota and good soil structure. Over time, once the soil structure has been rehabilitated it may no longer be necessary to re-apply bokashi as frequently.

STEP 9

Move on to Handout S2.4 – green manures. The first paragraph of the handout is most important for participants to understand. Set this understanding, and then review the benefits of using green manures and the process of doing so. Emphasize this process as a fundamental step in converting to agro-ecological farming practices, e.g. conservation agriculture and organic agriculture (see Handout S1.4 for a recap).

STEP 10

Move on to Handout S2.5 – mulching. The first paragraph of the handout is most important for participants to understand. Set this understanding, and then review the benefits of mulching and the process of doing so (see Box 6). Emphasize that mulching is an important water conservation technology used in many agro-ecological farming practices. For example: agroforestry, conservation agriculture, organic agriculture, and home gardening etc.

STEP 11

Move on to Handout S2.6 – soil cultivation and tillage. The first paragraph of the handout is most important for participants to understand. Set this understanding, and then focus on information provided in Figure 4. Follow by covering the different types of tillage practices used in agro-ecological farming; specifically the 'why' and 'when' to use the stated tillage practice.

2.1 Soils & nutrient management

Soil – A Living Organism

Soil is the most important production factor for crops and at the same time it is what the farmer has the most influence over. Soils are very diverse and have complex systems full of life. The soil itself can be viewed as a living organism because it is a habitat for plants, animals, and microorganisms that are all interlinked with each other.

Soil Structure – What Does it Mean?

Besides mineral particles and organic matter, soils also consist of minute pores (tiny hole) filled with air or water. The spatial arrangement of particles and pores is summarized as 'soil structure'. Small pores are good in preserving moisture while the larger pores allow for fast infiltration of rain or irrigation water, and also help to drain the soil and ensure aeration. In soils of good structure, mineral particles and organic matter form stable crumbles (aggregates). Organic matter works as a glue, sticking together soil particles. Soil organisms such as earthworms, bacteria and fungus support this process. Thus, soil structure can be improved by supplying organic matter to the soil. But wrong management can also ruin it, e.g. tilling the soil in wet conditions causes compaction.

Soils structure consists of 1) mineral particles, 2) organic matter, and 3) pores. It is the arrangement of the three (3) that determines how much air and water can be present, absorbed, or flows through the soil. Soils that contain more air spaces allow greater water infiltrating and root penetration.

Mineral particles originate from subsoil and rock, that gets crushed to smaller and smaller pieces through physical and chemical weathering processes. Mineral soil particles are divided into four groups according to their size:

- **Gravel and stones:** Particles larger than 2 millimeters;
- **Sand:** Particles from 0.05 to 2 millimeters - they can be felt between the fingers;
- **Silt:** Particles from 0.002 to 0.05 millimeters; and
- **Clay:** Particles smaller than 0.002 millimeters.

The difference between sand, silt and clay is not visible to the naked eye. Still it is important to distinguish between them, as the properties of the soil are very dependent on the composition of the different particle sizes. Soils having equal amounts of clay, silt and sand are ideal for agricultural use. Soil like this is called 'loam'.

Mineral particles contain nutrients that are slowly released in the process of weathering. Plant roots and some microorganisms can actively dissolve nutrients from mineral particles and use them for their growth. **Nitrogen** (N), **phosphorus** (P), and **potassium** (K) are the three (3) most important soil nutrients required for plant growth (see Learning Aid S2.3 for more detail). Besides mineral particles, soil contains smaller or larger quantities of organic matter resulting from the decomposition of biomass. Organic matter is mainly present in the top layer of the soil. Soil organisms can further decompose organic matter. The resulting structures can recombine themselves to form very stable soil.

Determining Your Soil Type

THE WATER TEST

Pour water onto your soil. If it drains quickly it is likely to be a sandy or gravelly soil, on clay soils the water will take longer to sink in.

The squeeze test

Grab a handful of soil and softly compress it in your fist.

- If the soil is sticky and slick to the touch and remains intact and in the same shape when you let go it will be clay soil;
- If the soil feels spongy it's peaty soil; sandy soil will feel gritty and crumble apart; and
- Loamy and silty soils will feel smooth textured and hold their shape for a short period of time.

THE SETTLE TEST

Add a handful of soil to a transparent container, add water, shake well and then leave to settle for 12 hours.

- Clay & silty soils will leave cloudy water with a layer of particles at the bottom;
- Sandy soils will leave the water mostly clear and most of the particles will fall, forming a layer on the base of the container;
- Peaty soils will see many particles floating on the surface; the water will be slightly cloudy with a thin layer at the bottom;
- Soils that are chalky will leave a layer of whitish, grit-like fragments on the bottom of the container and the water will be a shade of pale grey; and
- If the water is quite clear with layered particles on the bottom of the container with the finest particle at the top – this soil is likely to be a loamy one.

THE ACID TEST

The standard pH for soils usually ranges between 4.0 and 8.5. Plants favor soil that has a pH between 6.5 and 7 because this is the level where nutrients and minerals naturally thrive. You can buy a pH test kit here, or from a local garden center. As a general rule, in areas with soft water you will have acid soil and hard water areas will tend to have alkaline soil.

Source: http://learn.eartheasy.com/2013/06/how-to-make-the-most-of-your-soil-type/ (July 21 2016)

Soil organisms

Soil organisms vary greatly in size. Some can be seen easily, e.g. earthworms, mites, springtails or termites. However, most soil organisms are so small that they can only be seen with a microscope. These are called *microorganisms*. The most important microorganisms are bacteria, fungus and protozoa. Microorganisms are responsible for improving soil quality and fertility. The greater the variety of microorganism species and the higher their number, the greater is the natural fertility of the soil.

Microorganisms are Important

Many farmers consider microorganisms as pests and think, 'how can we kill them'? Actually, while some microorganisms in the soil can harm crops, the majority is of great use and importance for soil fertility.

Soil microorganisms are important because they:

- ✓ Help to decompose organic material and build up humus;
- ✓ Mingle organic matter with soil particles and thus help to build stable crumbs;
- ✓ Dig tunnels, which encourages deep rooting of plants and good aeration of the soil;
- ✓ Help to release nutrients from mineral particles; and
- ✓ Control pest and disease organisms affecting the roots of crops.

Most soil organisms are very sensitive to changes in soil moisture and temperature. As plant roots and soil organisms consume air, good air circulation within the soil is made and is crucial for plant development. Soil organism activity is generally low when soils are dry, very wet or too hot. Activity is the highest in warm, moist soils when food (biomass) is available.

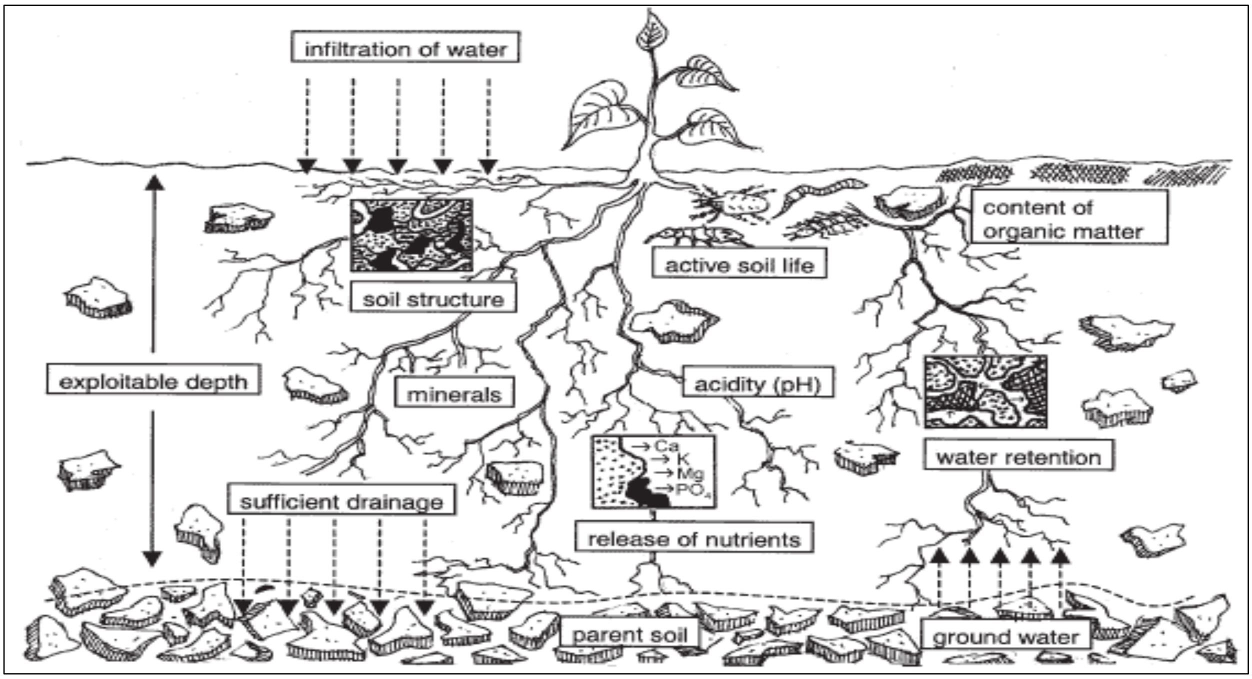
Box 1 Soil benefits derived from earthworms and fungus.

The earthworm – a valuable helper	Mycorrhiza – a beneficial fungus
Most farmers know that the presence of earthworms is a good sign their soil is fertile. Earthworms speed up decomposition of organic material by remove dead plant material from the soil surface. During digestion of the organic material, they mix this with mineral particles and build stable crumbs that help improve the soil structure. Their excrements contain 5x more nitrogen, 7x more phosphate, 11x more potash, and 2x more magnesia and calcium than normal soil. And their tunnels improve infiltration and drainage of rainwater and prevent soil erosion and water logging. Earthworms need a sufficient supply of organic matter, moderate temperature and sufficient humidity. Frequent tillage and the use of chemical pesticides decrease the number of earthworms in the soil. A large part of soil microorganisms are a fungus called 'mycorrhizae' and these live and work together with plant roots. The plant gets nutrients collected by the fungus and the fungus receives assimilates („food") from the plant in exchange.	Mycorrhizae are present in all types of soils, but not all crops can get into a partnership with the fungus. Mycorrhizae have several functions, which are of high interest to the farmer: ☑ They enlarge the rooting zone of plants and can enter into small soil pores; ☑ They dissolve nutrients such as phosphorus from mineral particles and carry them to the plant; ☑ They make soil aggregates more stable thus improving the soil structure; and ☑ They preserve moisture and improve the water supply to the plants. Mycorrhiza formation depends on the soil conditions, crops that are grown, and the management practices: ☑ Soil tillage and burning of biomass drastically harm the mycorrhizae; ☑ High nutrient levels (especially phosphorus) and chemical pesticides suppress the symbiosis; ☑ Mixed cropping, crop rotation and the cultivation of perennial plants encourage mycorrhiza; and ☑ Practice mulching to stabilize soil temperature and moisture.

2.2 Soil fertility & nutrient balance

As long as soil fertility is measured only by crop yields, awareness about soil will remain low. Soil in this context is just a medium where plants grow and a base to apply fertilizers. However, in agro-ecological farming, soil fertility has a totally different meaning. Improving and maintaining the fertility of the soil is a central focus, and feeding the crop means feeding the soil. Only a fertile soil can yield healthy crops. Therefore, it is very important for farmers to gain a very good understanding of the various factors that influence soil fertility (see Box 2 for details).

Box 2 Illustration and information on the key factors that influence soil fertility.



Factors influencing soil fertility	
▪ Soil depth - the exploitable volume for plant roots; ▪ Availability of water - moisture retention for continuous water supply; ▪ Drainage - most crops can't bear water logging; ▪ Aeration - necessary for a healthy root growth and a high activity of soil life; ▪ pH (range of acidity) - soil should neither be too acidic nor too alkaline; and ▪ Mineral composition - has an influence on the amount of nutrients released by weathering, nutrient capacity and the soil structure.	▪ Content of organic matter - has an influence on nutrients released by decomposition, the nutrient holding capacity, water retention, soil structure and soil life; ▪ Activity of soil organisms - crucial for nutrient availability, water retention, a good soil structure, decomposition of organic material and soil health; and ▪ Contamination - high concentration of salt, pesticides or heavy metals can inhibit plant growth.

Soil fertility can be maintained when nutrients are efficiently recycled through the soil food web and soil-plant-animal system. See Figure 1 for a simple illustration of this.

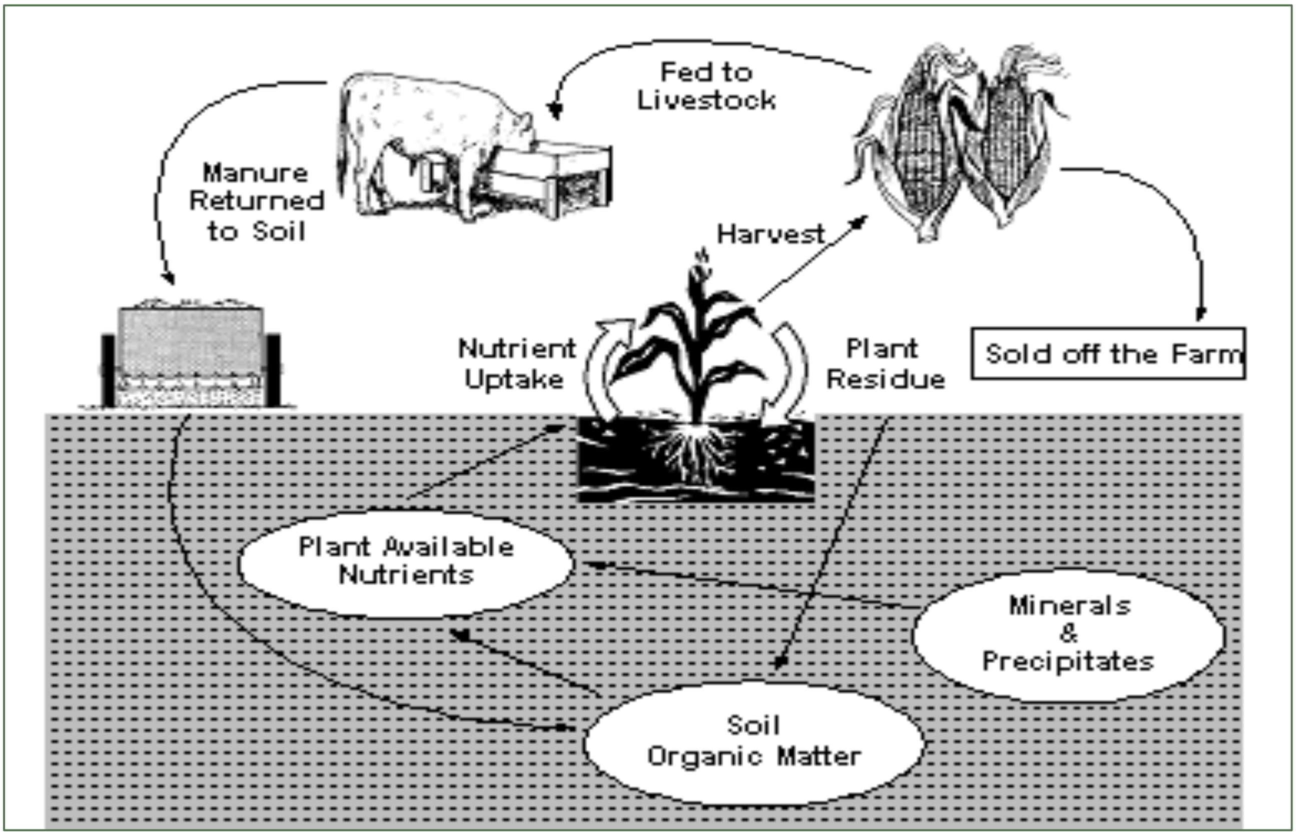


Figure 1 Basic plant nutrient cycle[5]

Nutrient balance & budgets

Nutrient cycling is not 100% efficient. There are always some losses or "leaks" from the cycles, even for natural ecosystems. In farming systems, where products are bought and sold, the balance between nutrient inputs and outputs is easily shifted in one direction or the other. When the balance between inputs and outputs is quantified, a nutrient budget can be calculated. Nutrient budgets describe the movement nutrient flows into and out of smaller a system, e.g. a farm field.

Cash crops nutrient budgets

Grain and vegetable farms that do not have livestock export large amounts of plant nutrients through off-farm sales. A 500-cwt/acre-potato crop, for example, removes about 215 lbs. of N, 30 lbs. of P, and 240 lbs. of K in the harvested tubers per year. A 150-bushel/acre-corn crop contains about 135 lbs. of N, 25 lbs. of P, and 35 lbs. of K in the grain. When corn plant residues/ waste or small grain straw is sold in addition to grain, nutrient losses from the farm are larger, especially for K. To maintain high yields, these nutrients must be replaced. Biologically fixed N from soybeans or other legumes rotated within the farm-crop plan can help replace N losses.

[5] Strictly speaking, a cycle is a circular, closed-loop pattern, so the nutrient cycle diagrammed in Figure 1 is not a true cycle.

Mixed crop & livestock nutrient budgets

Farms with crops and livestock have the potential to recycle a larger portion of the nutrients used by crops back into the soil because about 75% or more of the N-P-K consumed in animal feed is excreted in manure or urine. Depending upon the balance between crop and livestock enterprises, whole-farm nutrient budgets on mixed farms include different amounts of nutrient losses in milk, meat, or eggs, and different levels of nutrient inputs from purchased feed and fertilizer.

Concentrated livestock nutrient budgets

Concentrated animal-feeding operations import large amounts of plant nutrients in purchased grain, forage, and bedding. They are generally net nutrient importers because purchased inputs exceed nutrient losses from milk, meat, or egg sales. These excess nutrients accumulate in animal wastes that often create storage or disposal problems. High-density livestock operations frequently have not enough land to use properly all the manure they generate. Thus, there is the potential for increased risk of water contamination.

The importance of soil organic matter[6]

The content of organic matter in the soil is one of the most important factors for soil fertility. It has many functions that are crucial for the farmer's success. Understanding the different functions of organic matter can help to make the right decisions in soil management.

Plants are built up from water, air and nutrients. When plant material is decomposed with the help of animals and soil organisms, gases and nutrients are released and are available for new plant growth. In the process of decomposition, not all the plant material decomposes fully. These half rotten parts join together to build up dark brown or black soil organic matter. A part of this organic matter still contains visible structures of leaves, fibers, and wood etc., while most of it is shapeless and mixed into the soil layer. This is when organisms living on the top layer of the soil cut, chew, and eat and pull the organic material deeper into the soil where the microorganisms finish the decomposition.

Why is organic matter so important?

- Soil organic matter helps to build up a loose and soft soil structure with a lot of cavities (pores). This leads to better aeration, better infiltration of water and easier penetration of plant roots into the soil;
- The visible parts of organic matter act like tiny sponges that can hold water up to five times their own weight. Therefore in dry periods more water is available for the plants for a longer time;
- The non-visible parts of organic matter act like a glue, sticking soil particles together thus forming stable crumbs. Such aggregates improve the soil structure, especially

[6] IFOAM & FiBL – Undated. Basic Training Manual for Organic Agriculture in the Tropics. International Federation of Organic Agriculture Movements (IFOAM), Bonn (Germany) & Research Institute of Organic Agriculture (FiBL), Frick (Switzerland)
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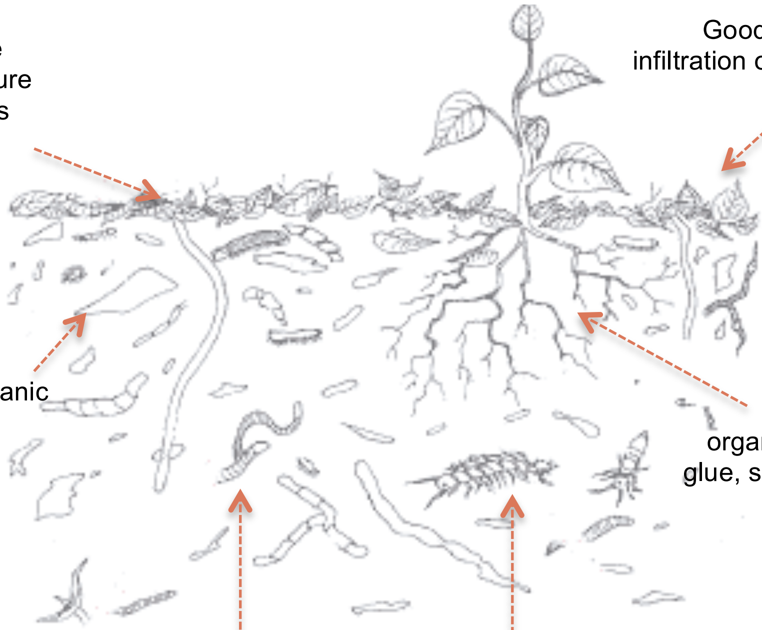
in clay and sandy soils;

- Beneficial microorganisms and other soil organisms such as earthworms also feed on organic material and help decompose it. As these organisms require sufficient humidity and aeration, soil organic matter provides a suitable environment for them;
- Organic matter has a great capacity to retain nutrients and release them continuously to the soil to supply plants with nutrients, and reduce nutrient losses though leaching; and
- Organic matter also prevents soils from becoming too acidic.



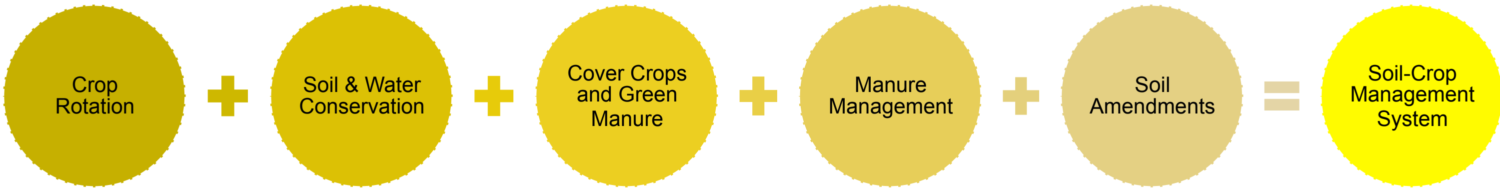
Box 3 Functions of soil organic matter.

Organic matter retains and releases nutrients. As organic matter consists of decomposing biomass, it provides a well-balanced mixture of all nutrients that plants require for their growth. While decomposing, it acts as a slow-release source of nutrients to crops.

What Exactly is Humus?

Humus is the main substance responsible for the fertility of the soil since it is an organic fertilizer that has a high content of microorganisms and enzyme activity that act to improve the soil by increasing its productivity. Humus is rich in organic matter and mineral salts that are easily absorbed by plants. It is an organic product that is stable, uniform and is dark in color.

5 practices to creating an agro-ecological soil-crop management system[7]



Farming practices that support the development of healthy, vigorous plant root systems result in the efficient uptake and use of available soil nutrients, i.e. maximizing nutrient cycling & nutrient-use. Common agro-ecological farming activities that help accomplish this are example:

- ✓ Establishing diverse crop rotations
- ✓ Reducing tillage
- ✓ Managing, maintaining, and recycling crop residues;
- ✓ Growing cover and green manure crops;
- ✓ Handling manure as a valuable nutrient source; and
- ✓ Using compost and natural soil amendments.

These beneficial farm-management activities have multiple effects on nutrient cycling and soil fertility, which make it important to integrate their use as a *complete soil-crop system*, rather than just a single stand-alone farm activity. Outlined are 5 practices to creating a robust agro-ecological soil-crop management system. Further details are given in subsequent handouts.

Practice 1 – Crop rotation

The term 'rotation effect' describes the observation that yields for a crop grown in rotation with other crops are usually 5% to 15% greater than for continuous monoculture of the same crop. The reason for increased yields is not always clear, and in most cases it is probably not due to a single cause, but growing a variety of crops in sequence has many positive effects on soil fertility.

In a diverse rotation, deep-rooted crops alternate with shallower, fibrous-rooted species to bring up nutrients from deeper in the soil. This captures nutrients that might otherwise be lost from the system. Differences in plant rooting patterns, including root density and root branching at different soil depths, also results in more efficient extraction of nutrients from all soil layers when a series of different crops is grown.

Including sod-forming crops in rotation with row crops decreases soil and nutrient losses from runoff and erosion, and increases soil organic matter. Growing legumes to fix atmospheric N reduces the need for purchased fertilizer and increases the supply of N stored in organic matter for future crops. Biologically fixed N is used most efficiently in rotations where legumes are followed by crops with high N requirements. Rotating crops

[7] Source: http://www.extension.umn.edu/garden/fruit-vegetable/nutrient-cycling-and-fertility/#nutrient-cycling (July 8 2016).

also increases soil biodiversity and in turn reduces the buildup and carryover of soil-borne disease organisms and insect pests.

Practice 2 – Soil & water conservation

Soil erosion removes topsoil, which is the richest layer of soil in both organic matter and nutrient value. Implementing soil and water conservation measures that restrict runoff and erosion minimizes nutrient losses and sustains soil productivity.

Tillage practices and crop residue cover, along with land slope, structure, and drainage, are major factors in soil erosion. Surface residues limit erosion by reducing 'wash out' of soil particles by wind or raindrop by restricting water movement across the soil. Tillage practices manage the amount of crop residue left on the soil surface. Reduced tillage or no-till maximizes residue coverage. Water moves rapidly and is more erosive on steep slopes, reducing tillage, maintaining surface residue, growing sod crops, and planting on the contour or in contour strips are recommended conservation practices.

Soils with good soil structure are less erodible than those with poor structure, and organic matter (including the activity of living soil organisms and fine roots) helps bind soil particles together into stable masses. Tillage breaks down soil masses, yet increases soil aeration (a good outcome), however, this accelerates organic matter decomposition. Drainage improvements on poorly drained soils reduce runoff, erosion, and soil compaction. Improving drainage also decreases N losses. This is done by allowing soil organisms to improving aeration in the plant-root zone - thus, promoting healthy root growth.

Practice 3 – Cover crops and green manures

Growing cover crops and green manure crops can be viewed as a type of crop rotation, where adding a non-revenue generating crop between annual cash crops extends the growing season. The terms cover crop and green manure are frequently used synonymously. Both perform many similar functions and many of the same plant species are used as both cover crops and green manure crops. The main difference between the two is that the primary purpose of growing a cover crop is to protect the soil surface from raindrop impact, runoff, and erosion. The main purpose of a green manure crop is to produce organic material for incorporation into the soil. Winter grains like cereal rye planted after potatoes are cover crops designed to hold soil in place until the next main crop is planted in the spring, but they also add organic matter to the soil when they are turned under. Rapidly growing summer annuals like niger seed are planted between short-season vegetable crops as green manures to add organic matter to the soil, but they also protect the soil from erosion between spring and fall vegetables.

Growing legume cover crops adds biologically fixed N. The additional plant diversity with cover crops stimulates a greater variety of soil microorganisms, enhances carbon and nutrient cycling, and promotes root health. The soil surface is covered for a longer period of time during the year, so nutrient losses from runoff and erosion are reduced. This longer period of plant growth substantially increases the amount of plant biomass produced, which in turn increases organic matter additions to the soil.

Disadvantages of growing cover and green manure crops:

- ☒ Large amounts of residue can make planting difficult and reduce crop stands;
- ☒ In wet springs, planting may be delayed if wet soil conditions delay killing of the cover crop;
- ☒ Soil warms more slowly in the spring under cover crops than for tilled soil and lower soil temperatures can slow seed germination;
- ☒ Spring cover crop growth uses water, which can adversely affect the following cash crop in a dry year;
- ☒ Some cover crops attract and/or harbor pests that can damage succeeding crops; and
- ☒ There are expenses and management time required to grow cover and green manure crops.

Cover crops have many benefits, but when you grow them you need to commit time to their selection and management to fully realize their benefits and avoid potential problems. Select cover crops with characteristics that will meet your objectives and fit your rotations, and then manage them with the same attention and skill you give any other crop.

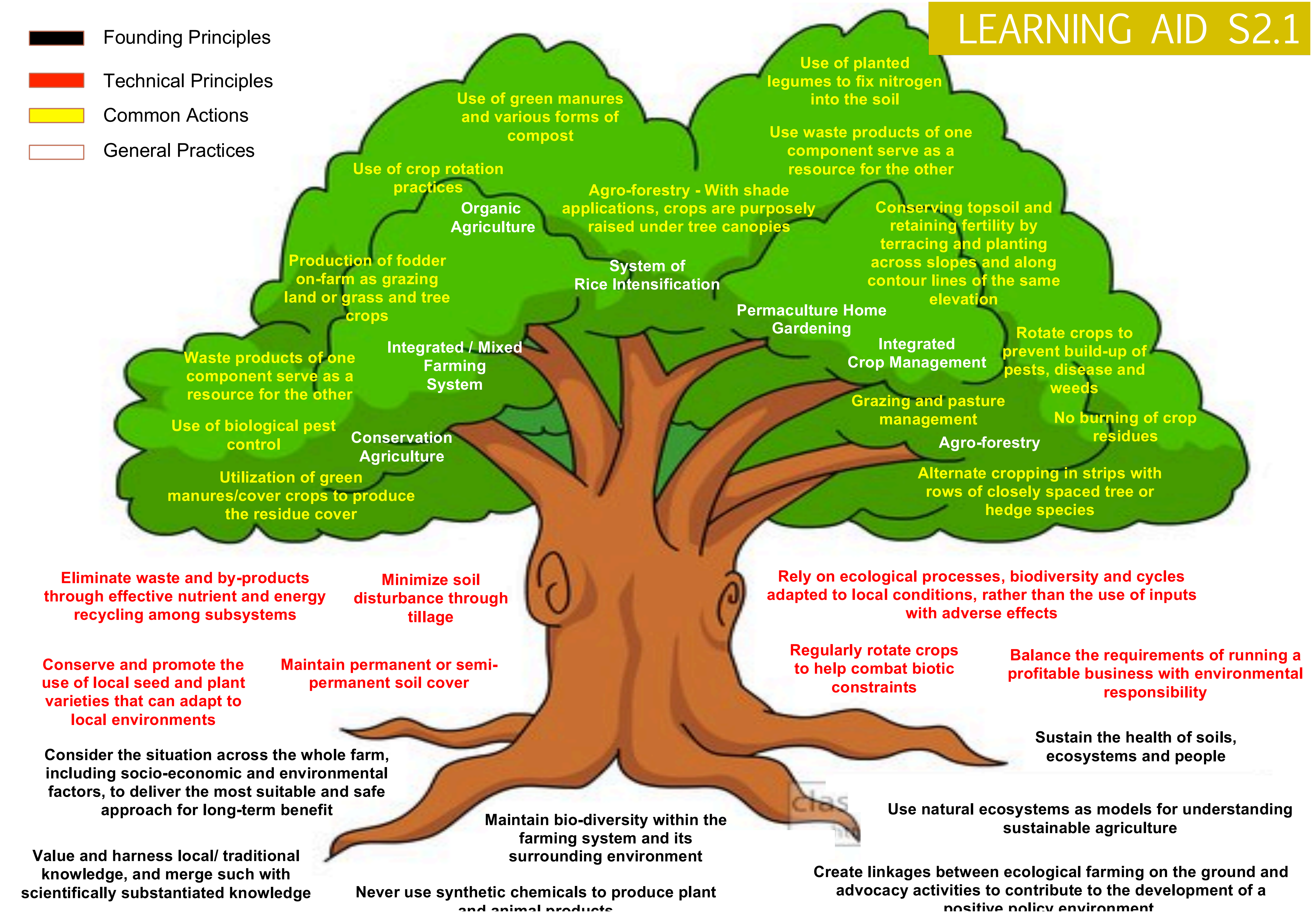
Practice 4 – Manure management

Returning manure to crop fields recycles a large portion of the plant nutrients removed in harvested crops. On farms where livestock are fed large amounts of off-farm purchased feeds, manure applied to crop fields is a substantial source of nutrient inputs to the whole farming system. However, just as nutrients can be lost from the soil, nutrient losses from manure during storage, handling, and application are both economically wasteful and a potential environmental problem. Soluble nutrients readily leach from manure, especially when it is unprotected from rainfall during storage. N is readily lost during storage. Nutrient losses from manure also occur when it is applied at rates exceeding crop nutrient requirements.

Analyze manure for its nutrient content and adjust application rates according to crop needs, soil tests, and frequency of manure applications. Avoid applying manure at rates that exceed crop requirements for any nutrient, but especially for N and P on fields that receive manure on a regular basis. Rates should be based on P requirements rather than N requirements. (see Learning Aid S2.2 for further information).

Practice 5 – Soil amendments

There are a variety of soil amendments, such as compost to the addition of microorganisms. Composting is a decomposition process similar to the natural organic matter breakdown that occurs in soil. Proper composting conserves N, and other mobile nutrients in waste products by incorporating them into organic forms where they are more stable and less readily lost. Most organic materials can be composted, nearly all organic materials contain plant-nutrient elements, and recycling all suitable wastes or byproducts through soil-crop systems by either composting or direct field application should be encouraged. These practices build up soil organic matter and provide a long-term, slow-release nutrient source. The addition of Indigenous Microorganisms (IMOs) strengthens the delivery of nutrients to crops. Handout S2.3 elaborates on their use.


LEARNING AID S2.1
Founding Principles
Technical Principles
Common Actions
General Practices
Use of green manures and various forms of compost
Use of planted legumes to fix nitrogen into the soil
Use waste products of one component serve as a resource for the other
Use of crop rotation practices
Organic Agriculture
Agro-forestry - With shade applications, crops are purposely raised under tree canopies
Conserving topsoil and retaining fertility by terracing and planting across slopes and along contour lines of the same elevation
Production of fodder on-farm as grazing land or grass and tree crops
System of Rice Intensification
Permaculture Home Gardening
Integrated / Mixed Farming System
Integrated Crop Management
Rotate crops to prevent build-up of pests, disease and weeds
Waste products of one component serve as a resource for the other
Grazing and pasture management
No burning of crop residues
Use of biological pest control
Conservation Agriculture
Agro-forestry
Utilization of green manures/cover crops to produce the residue cover
Alternate cropping in strips with rows of closely spaced tree or hedge species
Eliminate waste and by-products through effective nutrient and energy recycling among subsystems
Minimize soil disturbance through tillage
Rely on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects
Conserve and promote the use of local seed and plant varieties that can adapt to local environments
Maintain permanent or semi-permanent soil cover
Regularly rotate crops to help combat biotic constraints
Balance the requirements of running a profitable business with environmental responsibility
Sustain the health of soils, ecosystems and people
Consider the situation across the whole farm, including socio-economic and environmental factors, to deliver the most suitable and safe approach for long-term benefit
Maintain bio-diversity within the farming system and its surrounding environment
Use natural ecosystems as models for understanding sustainable agriculture
Value and harness local/ traditional knowledge, and merge such with scientifically substantiated knowledge
Never use synthetic chemicals to produce plant and animal products
Create linkages between ecological farming on the ground and advocacy activities to contribute to the development of a positive policy environment

Practical steps to improving soil fertility

Being a great gardener is to be an outstanding farmer of soil life. To grow healthy plants that are more resilient to drought stress and climate change you need fertile soil. Soil organisms are responsible for the movement of nutrients to the plant roots. Maintaining a large population of active soil organisms ensures that minerals and water are held in the soil and made available to plants.

Step 1

The first step to improve soil fertility is to TEST YOUR SOIL and understand what minerals are (or aren't) in the soil. Are there any imbalances? Is the soil too alkaline or acidic? How much (or little) organic matter is available?

Step 2

The next step is to dig your shovel into the soil. Notice if there is air space in the soil, how many earthworms are active? Are there white fungal strands, millipedes and beetles crawling about? Or is the soil hard and lifeless?

Step 3

Next, assess how well your soil drains. What is the soil texture? After irrigation or rain does the water lie on the surface?

After taking a close look at your soil characteristics, you are now more informed of what your soil needs. Too often people have over-applied water-soluble nitrogen fertilizers thinking that more is better. Sure, you may get instant green-up but you could be killing the beneficial soil organisms with excess nitrogen and salts, and thus, in the long run wasting your time and money. Plus, water-soluble nitrogen fertilizers often result in rapid plant growth that is weak, spindly and more prone to pests and disease.

Step 4

Eight Ways to Increase Soil Organic Matter and Nutrients

1. Leaving crop residues on the field, instead of burning or wasting them, as they are the major source of biomass;
2. Applying compost: this is very effective, as part of the organic matter in compost is al-ready stabilized and will remain in the soil for a longer time than fresh plant material;
3. Applying organic manures: as they contain organic material, they help to increase the content of organic matter; at the same time, they can speed up decomposition as they are rich in nitrogen and thus stimulate soil organisms;
4. Mulching with plant materials or agro-wastes: especially applying hardy material (rich in fibers or wood) will increase the organic matter and nutrient content;
5. Using green manures or cover crops: green manures grown on the same field will con-tribute biomass both from the leaves and roots; material grown on another site contributes only the leaves; the younger the plant material is, the faster will it decompose, thus releasing the nutrients faster;
6. Suitable crop rotation: including crops in the rotation that build up soil organic matter, especially perennials and crops with a dense root system are very beneficial;
7. Reducing soil tillage: each tillage will speed up the decomposition of organic material; and
8. Avoiding soil erosion: all methods listed before will be useless unless soils erosion is prevented – erosion carries away those parts of the soil that contain most humus and are most fertile.

Quick facts on manure use

Fresh vs. Composted Manure

Fresh, non-composted manure will generally have a higher N content than composted manure. However, the use of composted manure will contribute more to the organic matter content of the soil. Fresh manure is high in soluble forms of N, which can lead to salt build-up and leaching losses if over applied. Fresh manure may contain high amounts of viable weed seeds, which can lead to weed problems. In addition, various pathogens such as *E. coli* may be present in fresh manure and can cause illness to individuals eating fresh produce unless proper precautions are taken. Apply and incorporate raw manure at least three months before the crop will be harvested if the crop is intended for human consumption. Allow four months between application and harvest of root and leaf crops that come in contact with the soil. Do not surface apply raw manure under orchard trees where fallen fruit will be harvested.

Heat generated during the composting process will kill most weed seeds and pathogens, provided temperatures are maintained at or above 131°F for 15 days or more (and the compost is turned so that all material is exposed to this temperature for a minimum of 3 days). The microbial mediated composting process will lower the amount of soluble N forms by stabilizing the N in larger organic, humus-like compounds. A disadvantage of composting is that some of the ammonia-N will be lost as a gas. Compost alone may not be able to supply adequate available nutrients, particularly N, during rapid growth phases of crops with high nutrient demands.

Heat-dried Manure/ Compost

Drying manure or compost to low moisture content reduces their volume and weight, which lowers transportation costs, but it also requires energy inputs. Dried products can be easier to handle and apply uniformly to fields. Heat drying also reduces pathogens if temperatures exceed 150 to 175°F for at least one hour and water content is reduced to 10% to 12% or less.

Heat-dried composts vary widely in the degree to which they are composted before drying. Many are only partially composted and have higher amounts of soluble (inorganic) N forms than mature, stable compost. This readily available N gives these products some characteristics that are similar to soluble N fertilizers, such as ammonium nitrate. Heat drying of manure and immature compost may increase volatilization of ammonia-N and reduce the total N content of the finished product. In addition, composted or partially composted material that is dried at high temperature rather than going through a curing phase at ambient temperatures is not as biologically active as mature compost.

Quick notes: Soil fertility & N-P-K

How to improve and maintain soil fertility

- ☑ Protection of the soil from strong sunlight and heavy rain by means of plant cover: e.g. mulching with plant residues, green manure crops or cover crops, in order to prevent soil erosion and to preserve moisture;
- ☑ A balanced crop rotation or mixed cropping: a suitable sequence of annual crops grown on a field for preventing nutrient depletion;
- ☑ An appropriate tillage method: suitable for getting a good soil structure without causing erosion and compaction;
- ☑ A good nutrient management: application of manures and fertilizers according to the demands of the crops in their respective growth stages; and
- ☑ Balanced feeding and protection of soil organisms: enhancing the activity of beneficial soil microbes and organisms like earthworms by supplying organic material.

Table 2 N-P-K nutrient functions and deficiency symptoms.

Element	Function	Symptom of deficiency
Nitrogen (N)	▪ Essential for plant growth ▪ Necessary for protein production by the plant ▪ Necessary for may critical plant functions (photosynthesis, cell division and plant growth)	Adequate N produces a dark green color in the leaves, caused by a high concentration of chlorophyll. Nitrogen deficiency causes a yellowing of the leaves, and plants tend to be stunted, grow slowly, and produce fewer tillers than normal.
Phosphorus (P)	▪ Essential for plant growth and is especially vital to early growth ▪ Promotes early root formation and growth ▪ Improves the quality of many fruits, vegetable and grain crops	The first sign of P deficiency is an overall stunted plant. A purple or reddish color is often seen on young plants, especially at low temperatures. With sever P deficiency, dead areas may develop on the leaves, fruits and stems.
Potassium (K)	▪ Essential for protein synthesis and cell division ▪ Decreases water requirements of plants ▪ Important in fruit formation ▪ Helps plants survive cool weather ▪ Helps improve stalk strength and resistance to lodging	Potassium deficiency symptoms show up as scorching or firing along the margins of older leaves in most plants, and especially in grasses. The leaves may later turn brown. K deficient plants grow slowly and have poorly developed root systems. Stalks are weak, lodging is common and seed and fruits are small and shriveled. In grass/ legume forages the legume will not persist in the mixture when it is K deficient.

2.3 Composting & organic soil amendments

Composting is the controlled decomposition of organic wastes by a diverse number of microbes and invertebrates in a warm, moist aerobic (with oxygen) environment. Natural decomposition typically accelerated because of the rise in temperature that occurs from heaping wastes.

What are advantages of composting?

- ☑ Compost increases the level of organic matter in the soil, which has a positive effect on the soil organisms, soil structure, infiltration, water retention capacity and aggregate stability. Compost is rich in nutrients that are readily available to plants; and
- ☑ Through composting, diseases and pests, as well as weeds seeds are destroyed because the temperature in the compost heap is so high that they cannot survive.

What are disadvantages and limitations of composting?

- ☒ Composting is labor intensive. If labor is in short supply, this can be an important limiting factor. On the other hand, compost is such a valuable fertilizer that it makes the invested labor very cost-effective;
- ☒ Another limitation can be that organic material is scarce. Composting without manure is very difficult, but it is possible; and
- ☒ A compost heap can attract vermin, especially if kitchen scrapes are also used. It can also stink. This need not be a problem if the compost heap is kept in the field instead of the home yard.

A complex 'web of life' exists in the compost pile where various naturally occurring organisms feed on the organic materials or on other organisms in the pile. Aerobic organisms, those that require oxygen, are the primary organisms that cause decomposition on materials in compost. They provide rapid, complete composting. Certain mobile organisms, such as earthworms may move away from the excessive heat of the center of the pile than move back when the pile cools. Most harmful organisms, such as diseased organisms or persistent insect pest and weed seeds are killed or destroyed by the heat in the composting process.

Basics to Composting

Initially, wastes are heaped into a pile or bin, ensuring adequate proportions of nitrogen and carbon sources are present. Insects or microorganisms decompose the organic wastes, and temperatures rise – sometimes up to 160°F. When most of the material has been decomposed, the organisms no longer have an energy source and die. The temperature of the pile gradually lowers to ambient temperatures and the weight and volume of the compost pile decreases. Aeration and applying compost additives like perlite or lime are optional during this process. Generally, compost should be applied in the fall of the year previous to a heavy nutrient demanding crop at a rate of 8-12 tons/ acre, and incorporated into the soil no more than 6" deep. As a general rule, compost piles are built with:

- 40-50% carbonaceous materials (straw, leaves)
- 25-30% green organic matter (crop residues, hay)
- 20% high N material (manure, legume residues)
- 10% soil (for introducing microbial life)

Some composters like to keep things simple and use the terms brown (carbon) and green (nitrogen), and follow the general rule of 2 part brown for every 1 parts green.

Why mix manure compost with plant residues?

When you compost manure only, you end up with a product that is high in nitrogen and relatively low in carbon. It is for this reason that the nitrogen is lost relatively fast compared with mixing manure with plant residues. When you compost plant residues only (like straw, leaves, bran) you end up with a product high in carbon. This will release nutrients very slowly and greatly improve the structure of the soil, but does not provide enough nitrogen to the soil (not a problem when growing legumes or other nitrogen fixing pants). When you compost a mixture of manure and plant residues you end up with a balanced product that provides balanced nitrogen and carbon for the plants that is released in a timely manner and improves in soil structure.

Variations in Compost Making

- **Static pile method** – In static piles, materials are formed into a pile or windrow, inoculated with compost preparation, covered with straw, and left undisturbed for 6 months to one-year prior to use. A small amount (10%) of soil is commonly sprinkled onto the outside of the pile prior to covering with straw. Soil can also be added during the windrow construction process when brown (carbon) and green (nitrogen) feedstock materials are laid in alternating layers.

- **Turned/ Thermal compost method** – Thermal composting involves the rise in temperature produced by bacteria and fungi that kills weed seeds and kills, or reduces plant disease-causing organisms. Piles can be mixed or turned so the time to maturity is much shorter.

- **Worm composting (Vermicomposting)** – Worm-composting involves the use of earthworms, usually red worms or litter worms. Worms mix the organic material and enhance growth of organisms such as bacteria, fungi, protozoa, nematodes, and micro-arthropods.

- **Barn compost** – If your farm system includes animals, livestock bedding can be used as compost. For example, using a mixture of straw and rock phosphate for cattle bedding can produce good compost. This mix will reduce ammonia emissions and absorb urine.

- **Compost without manure** – Incorporating animals into the farm system is by no means necessary for making good compost. Compost can be made with 1/3-dry vegetation, 1/3-green vegetation, and 1/3 soil. Leave static for one year or turn every few days for fast results.

- **Mineralized compost** – The addition of rock powders (phosphate, greensand, granite dust) to compost piles is a long time practice known as mineralized compost. The dust adds mineral components to the compost and the organic acids are released during the decomposition process. This helps solubilize minerals in the rock powders to make the minerals easily available to plants.

General steps to making a compost heap

What to Consider When Planning a Compost Heap

- Location: The compost heap is ideally located near the source of the composting material and the fields to which the compost will be applied. The site should be shady and near a water source. Water logged sites should be avoided. The compost heap should not be placed too close to houses as the heap may attract rats, snakes and termites etc., and sometimes a bad odor can not be avoided;
- Composting materials: A compost heap should be set up when a lot of plant material is available. If the farm does not supply enough plant material, it may be collected from outside sources;
- Timing: It is easier to produce good compost during the wet season as the rain saves on labor for watering;
- Size: The compost heap should reach a size of at least $1m^3$ to allow for the correct composting process and to allow sufficient aeration the heap should not be more than 2.5 m wide and 1.5 m high; and
- Method: The chosen method should be appropriate to the climatic conditions.

Preparation

- Prepare the composting material properly: Chop coarse woody material to increase its surface area and encourage decomposition by fungi and bacteria;
- If dry, soak the composting material before mixing it;
- At the bottom of the heap, put twigs and branches to allow for good drainage of excess water;
- Pile up coarse carbon rich and nitrogen rich material in alternating layers;
- Manure or old compost applied to each layer enhances the composting process;
- Thin earth layers between the compost helps to prevent nitrogen loss;
- A 10 cm thick cover of straw or leaves in the initial stage, and an impermeable cover (sacks, plastic sheet etc.) in the final stage prevent potassium and nitrogen from being washed out of the heap. In dry climates, cover the heap with a 15 cm thick layer of mud; and
- If the heap is not moist enough, from time to time pour water or liquid manure over the compost.

Turning the Compost

- Two to three weeks after building up the compost heap, it will have decreased to about half its original size.
- This is the right time to turn it. Turning the compost helps to accelerate the process, but it is not essential. However, turning has a number of advantages:
    - It improves aeration and encourages the process of composting;
    - It ensures that material from the outside of the heap can decompose properly by being put into the center; and
    - It allows the quality of the composting process to be checked and for any non-ideal conditions to be improved.

What to Expect

The heating phase

- Within 3 days of setting up the compost heap, the temperature in the heap rises to 140-160°F and usually stays at this level for 2–3 weeks. Most of the decomposition occurs during the heating phase;
- In this phase, it is mainly bacteria that are active. The high temperature is a result of energy released during conversion of easily decomposable material by the bacteria. The warm temperature is a typical and important part of the composting process. The heat destroys diseases pests, weed roots and seeds;
- During this first phase of the composting process the bacteria have a very high oxygen demand due to the rapid development of their population. High temperatures in the heap signal that there is an adequate supply of oxygen for the bacteria. If there is not enough air in the heap, bacterial development will be hindered and the compost will develop an unpleasant odor;
- Humidity is also essential to the composting process, as bacteria require humid conditions for their work. The need for water is greatest during the heating phase because of high biological activity and strong evaporation that occurrs during this phase; and
- As the heat increases, the pH of the compost heap rises (i.e. acidity decreases).

The cooling phase

- Once the material which is easily digested by the bacteria has been converted, the temperature in the compost heap declines slowly and will remain at 75–110°F;
- With the decline in temperature, fungi settle and start the decomposition of straw, fibers and wooden material. As this decomposition process is slower, the temperature of the heap does not rise; and
- As the temperature drops, the pH of the composting material declines (i.e. acidity increases).

The maturing phase

- During the maturing phase nutrients are mineralized and humic acids and antibiotics are built up;
- Red compost worms and other soil organisms start to inhabit the heap during this phase;
- At the end of this phase the compost has lost about half of its original volume, has the color of dark, fertile soil and is ready to use;
- The longer it is stored from now on, the more it looses its quality as a fertilizer, while its capacity to improve soil structure increases; and
- In the maturing phase, the compost needs much less water than in the heating phase.

Time necessary for compost production

Animal manure mixed with rice straw takes 6-7 weeks, and with wheat straw, 8-10 weeks to complete the composting process. When saw dust or rice hull is mixed with animal wastes, it takes 4 – 6 months. When wood chips and bark is used, these materials must be left outdoors (under rain and sun) for 6 – 12 months. Then mix with nitrogen-rich materials, stacked and left for another 6 months.

Box 5 Possible problems & solutions in the composing process

Diagnosis	Problem	Possible reasons	Solutions
Temperature does not rise	Microorganisms can not develop	▪ Material too dry or too wet ▪ Lack of air or to much air ▪ C/N- ration is not correct ▪ Too much earth	▪ Wet with water or urine ▪ Pile looser ▪ Mix more fresh green material or dung to it
Sudden decrease of the temperature	Transformation process stopped	▪ Material has become too dry ▪ All available nitrogen used	▪ Wet with water or urine ▪ Add nitrogen rich material
Composting material gets dusty white	Too strong development of fungi	▪ Material too dry ▪ Material not mixed for a long time	▪ Mix and set up the pile again ▪ Wet with water or urine ▪ Add nitrogen rich material
Material turns a blackish-greenish color and is foul smelling	Composting material is fouling	▪ Lack of air and structure ▪ C/N-ratio too low ▪ Material too wet ▪ Material has not been mixed sufficiently	▪ Set up pile again adding bulky material with high C/N-ration ▪ Turn compost more often during heating process

Application of compost

There is no one definite stage of maturity. Compost ripens in an endless process. Compost can be used as soon as the original composting material is not recognizable anymore. The compost has then turned into a dark brown or blackish color and has a pleasant smell.

Compost is a scarce and valuable manure for most organic farmers. Usually it is not possible to produce sufficient amounts for fertilizing all fields. Therefore, farmers should think carefully about where compost applications would be most beneficial. High efficiency is achieved in nurseries and when planting seedlings or saplings.

Organic soil amendments[8]

Indigenous Microorganisms

Indigenous Microorganisms (IMO) are beneficial members of the soil biota (including filamentous fungi, yeasts and bacteria) collected from non-cultivated soil near the area where they will be applied. An IMO preparation can be used alone as a soil amendment but it is also the fundamental catalytic ingredient of other Nature Farming preparations such as bokashi fermented organic fertilizer. The critical element in the production of high quality IMO is to collect and culture the most appropriate population of soil microorganisms.

The IMO should be collected from healthy soil that is not currently under cultivation but is situated relatively near to the area where the preparation will eventually be applied. One of the best indications of soil with a high content of beneficial organisms is the presence of earthworm castings, which are often found under bamboo trees.

IMO materials

¬ 1Kg forest soil from an area with worm castings (under a bamboo or banana tree is a good place to look);
¬ 1Kg powdered rice bran;
¬ 2Kg brown sugar or molasses; and
¬ Water.

IMO procedure

1. Collect soil containing worm castings from beneath bamboo/ banana trees (Figure 2). Other types of soil may also be used.

2. Using your hands, break all the lumps in the soil to make a fine powder. Mix the forest soil together with the rice bran and add enough water to the mixture to achieve 60% moisture content. This is when the mixture is wet enough to form a ball that will crumble easily. The mixture will still appear to be quite dry.

3. Wrap the mixture in a dark cloth and place it in a cool dark place (e.g. in the branches of a mango tree), for 3 days. After this time open the cloth and inspect the molds formed. Desirable molds are white although orange and blue molds are also acceptable (Figure 2). Black molds are not desired although a few are acceptable as long as they are not predominant.

4. Break the ball into pieces approximately 1 inch in diameter using a clean stick. This stimulates the development of the IMO. If the mixture has dried out, sprinkle a small amount of water on the surface. Tie the cloth back up around the IMO culture.

5. Mix together 7L water and 2Kg brown sugar or molasses in a large container.

6. Hang the cloth above the water and sugar solution with about ½ of the bundle submerged in the solution. Cover the entire preparation with a cloth. This will help protect it from bees and other insect that may be attracted to the high sugar content of

[8] PABINHI-Pilipinas, February 2006. Nature Farming Manual. Pambansang Inisyatibo sa Binhi Likas-Kayang Pagsasaka sa Pilipinas (PABINHI-Pilipinas) - National Initiative on Seed and Sustainable Agriculture in the Philippines Batong Malake, Los Baños Laguna, The Philippines.

the solution.

7. Stir the solution for 10 minutes, 2 times per day, for 10-15 days.

8. Strain the solution through a fine cloth and retain the liquid containing the IMO.

9. The liquid IMO can be stored in a glass bottle for up to 6 months. It is important not to tighten the cap completely on the bottle to allow for aeration. Shake the bottle once a week to provide air to the microorganisms.

10. Once a month feed the IMO with 20% of its volume with sugar. The solution should be discarded when it begins to give off a foul odor.

Figure 2 Photographs of IMO production: Worm castings collected beneath a stand of bamboo trees (left), and white mold forming on the solid IMO culture after 3 days in a cool dark place (right).

IMPORTANT NOTE: IMO can be cultured from non-cultivated soil collected close to the area where the crop to be treated with the IMO is grown. It is also possible to culture 'mixed IMO' for use on the entire farm. This is achieved by collecting and combining soil from several non-cultivated areas on the farm including forest soil, soil from near a river or stream, soil from a bamboo stand, soil found under rocks and soil present near the cultivation areas of several different crops.

Once the molds have formed the preparation should no longer be touched with human hands to avoid contamination by human microorganisms. When stirring, stir steadily in one direction until a vortex is formed in the liquid and then reverse directions to form a new vortex. Never remove the bundle from the sugar solution, just move it to the side of the container while stirring.

IMO application guidelines

- ☑ **Concentration:** 1 Tbsp./ L
- ☑ **Application rate:** 1L/Ha
- ☑ **Instructions:** Spray the IMO on wet soil before the first plowing. Do not apply IMO to the soil during the dry season. The application should be a light spray only. If no

sprayer is available it is possible to mix the IMO with rice bran and ferment it to create fermented rice bran (see instructions for FRB in section 2.3). This preparation can then be hand-broadcast on the field.

Fermented Rice Bran

Fermented Rice Bran (FRB) is a solid preparation of IMO that can be applied to the soil without requiring the use of a sprayer as is necessary for liquid IMO. Because the rice bran provides the IMO with a stable substrate they have increased viability and are more effective. Furthermore, the addition of rice bran to the IMO increases the amount of organic matter that is added to the soil.

FRB materials

- 1 Tbsp. FAA;
- 1 Tbsp. IMO;
- 1 L water;
- 1 Kg rice bran;
- 1/2L alcohol (e.g. beer or rice wine); and
- Clay pot.

FRB procedure

1. Combine the FAA + IMO, alcohol (provides yeast to start the fermenting process) and water and stir for 5 minutes. If FAA is not available, double the amount of IMO.

2. Add the liquid mixture gradually to the rice bran while mixing. Continue until the moisture content of the rice bran is 60%. This is when the mixture is wet enough to be formed into a ball that will crumble easily.

3. Place the mixture in the clay pot and cover with a piece of paper or cloth. It is important to leave airspace in the top of the pot. Ferment for 7-10 days in the clay pot, stirring once per day.

4. When the mixture begins to dry out, add water to maintain the proper moisture level.

5. Use the FRB immediately, OR, store in the clay pot, maintaining the air circulation and moisture.

IMPORTANT NOTE: The rice bran can be replaced with powdered corn, powdered soy, or any other biomass material that is readily available and inexpensive. If the FRB is to be used as an animal feed ingredient, ferment for 3-4 days instead of 7-10 days. Air dry to stop the fermentation process before feeding to the animals.

Fish Amino Acids

Fish Amino Acids (FAA) are a good source of nitrogen for crop plants and may be used to supplement compost and manures in coastal regions that have a good supply of inexpensive fish byproducts. Fish trash may be purchased from fish vendors at the market.

FAA materials

- 1Kg uncooked fish trash (bones, head, guts). Avoid using fish that has been in cold storage; and
- 1Kg crude sugar.

FAA procedure

1. Mix the fish trash with the sugar.
2. Allow the fish juice to extract and fermentation to occur.
3. Filter out the solids and retain the liquid fish amino acids.
4. Store in glass bottles or empty mineral water bottles. Do not completely close the cap on the bottle. Shake the solution weekly and add sugar to it every month (20% of the volume) as is done for IMO.

FAA application guidelines

☑ **Concentration:** 1tbsp./L water
☑ **Instructions:** Apply to the soil as a source of nitrogen and amino acids

Fermented Plant Juice

Fermented Plant Juice (FPJ) is an ingredient in bokashi production and can also be used applied directly to soil and plants. FPJ is produced by the fermentation of plant leaves, grasses, thinned crop plants, auxiliary buds and/or young fruits. It contains plant growth hormones and micronutrients that stimulate the growth of beneficial microorganisms.

FPJ materials

- Plant materials: CHOPPED leaves, grass, buds, young fruits, etc.; and
- Crude sugar (1/2 to 1/3 of the weight of the plant material).

FPJ procedure

1. Without washing, mix the picked plants with the crude sugar.
2. Pack them in a pot until the pot is full.
3. Put a stone on top of the material for 1 day to lose remove air.
4. Upon removing the stone, materials should fill about 2/3rd of the pot.
5. Cover the pot with paper and string.

6. Keep in a cool dark place for 5-10 days. The plant juice will be extracted and fermentation will occur in the pot. The color of the juice will change from green to yellow or brown. The smell should be sweet and alcoholic.

7. Filter out and discard the plant residues and retain the juice.

8. The FPJ can be stored in a glass bottle in a cool, dark place for up to 6 months. It is important not to tighten the cap completely on the bottle to allow aeration. Shake the bottle once a week to provide air to the microorganisms.

9. Once a month feed the IMO with 20 % of its volume of sugar. The solution should be discarded when it begins to give off a foul odor.

FPJ application guidelines

- ☑ **Concentration:** 2tsp./5L water
- ☑ **Instructions:** Spray lightly on soil and plants

Carbonized Rice Hull

Carbonized Rice Hull (CRH) is a crucial ingredient of bokashi organic fertilizer and can also be used in composting toilets and animal bedding. CRH results from the incomplete combustion of rice hulls under high heat and low oxygen conditions (pyrolysis). Pyrolysis causes the decomposition of organic materials such as lignin and cellulose, leaving a residue of carbon and mineral nutrients. Breaking down the lignin accelerates decomposition of the rice hulls and the subsequent release of nutrients. When CRH is incorporated in bokashi organic fertilizer it provides a carbon source for microorganisms to balance the high nitrogen content of the manure. Carbonization conserves the physical structure of the rice hull, which provides a colonization site for beneficial microorganisms, contributes to soil permeability and water retention, and improves aeration of the soil. Carbonized rice hulls also contain nutrients such as potassium, phosphorous, calcium, magnesium and other microelements (see Figure 3).

Unprocessed rice hulls

Pyrolysis
(high heat, low oxygen)

Carbonized rice hulls: 43% fixed carbon, 33% ash, and nutrients (potassium, phosphorous, calcium, magnesium)

Figure 3 The physico-chemical transformation of rice hull through pyrolysis.

Rice hull carbonizer model for medium-large scale production (4-50 sacks)

CRH materials

- 18L metal can
- No. 24 galvanized iron (GI) sheet or other type of sheet metal (or 4” metal pipe)
- Hot coals from a fire
- Rice hull (as desired)
- Shovel, stirring stick, rake, water sprinkler/ can

CRH procedure

1. Use an 18 L can. The can used may be square or round. The instructions in this document refer to a square can approximately 12” X 12” X 18” in height.

2. Remove the bottom of the can.

3. Cut a hole for the chimney in the top using a knife (a 4” diameter for the hole is good).

4. Use a hammer and nail to make holes in the sides. The holes shouldn’t be too big or hulls may fall in and smother the fire. Approximately 12 rows of 10 holes per side – hole diameter 1/5”. Distance between each hole is approximately 1”.

5. Chimney instructions: The chimney should be at least 6’ tall. It should be taller than the people present so that smoke will be carried away from the users. If the chimney and the hole in the top of the base have different diameters (i.e. if the chimney is smaller) it is possible to place a skirt of sheet metal on the base of the chimney to adapt them to each other. A toxic creosote residue can build up at the bottom of the chimney so it is important not to make the chimney too narrow or the residue will block the flow of air. The chimney will need to be scraped clean of this residue periodically. The chimney should only extend a few inches down into the can, just enough for it to be stable, otherwise the fire won’t burn well. NOTE: do not increase the size of the can to carbonize a larger volume of rice hulls. This is a waste of space, it is better to combine several carbonizers to increase the power of the process (see Figure 4).

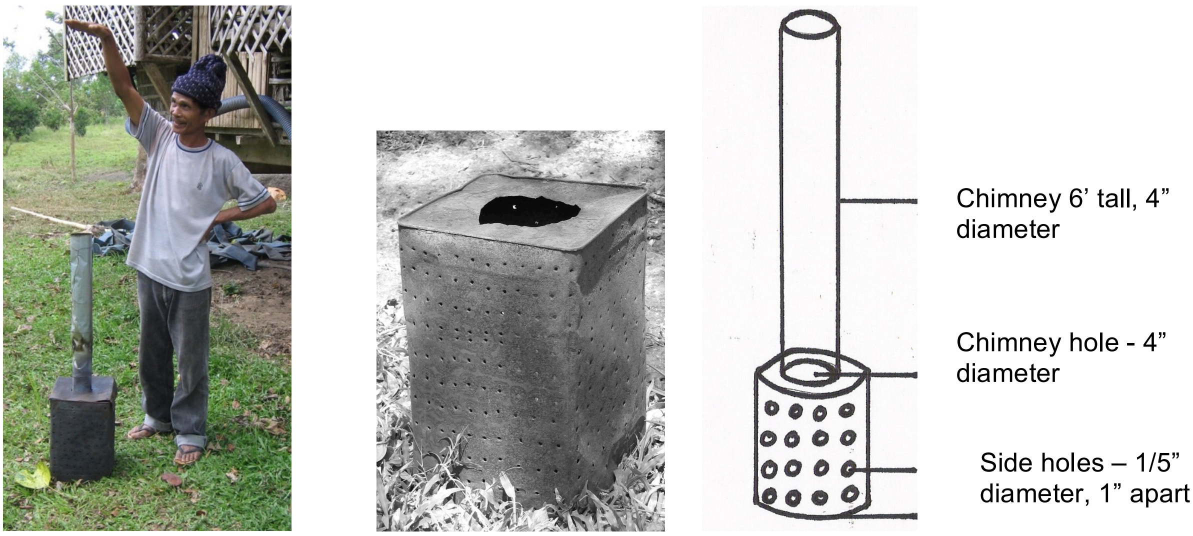


Figure 4 Medium-large scale rice hull carbonizer.

6. Starting the fire
   - Start the fire using a small amount of coals (equivalent to the content of ½ a coconut hull) and wood. Always use the same size of fire, regardless of the number of sacks to be carbonized.
   - Place the carbonizer can on top of the fire.

7. Adding the rice hulls to the carbonizer
   - Dry the rice hulls in the sun prior to use. This will reduce their moisture content and increase the speed of carbonization.
   - The base of the carbonizer needs to be entirely covered with hulls. The minimum quantity of rice hulls is 4 sacks because the size of the pile decreases with combustion. With less than 4 sacks the end of the carbonization process will expose the base.
   - The side of the pile that is facing the source of the wind will burn faster; the pile should be thicker on this side.
   - When the hulls start to burn the smoke will become denser and whiter.

8. Early stage of carbonization
   - It is easy to tell which parts of the pile are burning faster because smoke will start coming out of these areas and the hulls will begin to turn black.
   - When the hulls around the base of the chimney start to blacken cover them with rice hulls from the base.
   - When black spots of carbonized hulls appear on the outside of the pile, push the spot inwards by applying gentle pressure and then cover it with hulls from the base of the pile.
   - The bottom of the pile burns more slowly; this is why the hulls from the base are always moved upward to cover carbonized areas.
   - Always keep the sides of the pile as steep as possible.
   - Do not mix the pile during this initial stage of carbonization; just cover carbonized areas with non-carbonized hulls.
   - If it is necessary to speed up the carbonization process it is possible to remove the outer, non-carbonized layer of the pile at this stage for later carbonization.

9. Late stage of carbonization
   - At this point most of the center of the pile is black and large portions of the outer layer are also black.
   - Stirring the pile begins now. When one area on the outside looks mostly black insert a stick into the middle of the pile (at the base) in that area and lift the stick up and sideways at the top. Go methodically around the pile doing this, making sure to remake the steep-sided cone shape of the pile while stirring. Do not stir too much, this will cause the carbonization to take longer and the fire may go out. Once the pile has been mixed, wait for the outside to turn mostly black before mixing again.
   - Because the fire is stronger on the side of the source of the wind the pile can be rearranged to add more hulls to this side.

WARNING: A lot of dust (rice ash, mostly silica) comes out of the pile when stirring. This is a potential health hazard. Participants should wear dust masks/bandanas to cover mouth and nose during this stage and should ensure that they are upwind from the pile.

10. Halting the carbonization
    - The can in the center needs to be removed. Use a shovel to remove the can as well as the remaining charred wood from the pile of CRH.

- Do not remove the can until the outside of the pile is AT LEAST 90% black.
- Remake the cone shaped pile and wait for the remaining non-carbonized rice hulls to turn black.
- Spread the carbonized hulls in a long flat oval pile about 15-20 cm high (if the pile is round it is hard to pour water on the center part).
- Sprinkle water on the rice hulls and work it through the pile using a rake.
- Use about 4 gallons of water for every 2 sacks of rice hull that were carbonized.
- Make sure the fire is completely extinguished or else the combustion will continue.
- Do not bag the rice hulls until the excess water has drained out.

11. Storage of the CRH

- The yield of CRH is about 60% of the original volume of rice hull. During the dry months this climbs to 70% because there is less moisture in the hulls.
- It is better not to store the CRH in feed sacks because experience has shown that it will destroy the sacks after one month. Plastic fertilizer bags will work for storage.
- The best storage option for the CRH is to keep it in a pile under a shelter.
- After the CRH has been in a pile for at least 1 month it can be stored in feed sacks without destroying them.

Troubleshooting and notes

- If the fire seems to go out and no more smoke is coming from the chimney it may have become blocked with creosote. Use a long stick to unblock it. Otherwise, hulls may be falling in and smothering the fire, in this case use a can with smaller holes.
- Even if the carbonization is interrupted by rain the fire can keep going. Just wait until the rain stops and then the fire will rekindle and dry out the hulls. This will take longer because the moisture content of the hulls will be very high. It is best to carbonize during the dry season.
- A cement surface is the best option for carbonizing and makes it possible to achieve 100% carbonization.

Figure 5a The steps of rice hull carbonization: starting the fire and installing the carbonizer (a), adding hulls to the carbonizer (b), the appearance of carbonized areas on the rice hull pile (arrow) (c).

Figure 5b The steps of rice hull carbonization: the progression of carbonization (d), the appearance of the pile when approximately 90% of the carbonization has occurred (e), stirring the rice hulls during the final stage of carbonization (f) and spreading out the carbonized rice hulls and halting the carbonization (g).

CRH application guidelines

- ☑ **Concentration:** 4-8 sacks of rice hull carbonized / hectare
- ☑ **Instructions:** Spread lightly on soil/ base of plants

Bokashi

Bokashi is an organic soil amendment originally formulated in Japan where it is widely used. It is a fermented organic fertilizer containing indigenous microorganisms and nutrients that are beneficial to soil and plants. Practical advantages associated with the use of bokashi include the rapid preparation time (only 2-4 weeks) relative to traditional compost (6 months) and the reduced cost compared to commercial fertilizers because it is manufactured from low-cost, locally available materials. Moreover, it is easily substituted for chemical fertilizers without requiring much additional training. As such, it is an appropriate tool for farmers who are in the process of making the transition from conventional to agro-ecological farming methods.

BOK materials for small-scale bokashi production

- ¬ 3 sacks chicken dung or other animal manure;
- ¬ 2 sacks carbonized rice hull;

- 2 sacks garden soil, forest soil or soil collected from under a bamboo tree;
- 1.5 sacks rice bran;
- 1 kg sugar;
- 1/2 gallon local coconut/ rice wine, OR 5tbsp. FPJ; and
- 5 tbsp. indigenous microorganisms (IMO).

BOK materials for large-scale bokashi production (3.5 tones)

- 32 sacks chicken dung or other animal manure;
- 30 sacks carbonized rice hull;
- 20 sacks garden soil, forest soil or soil collected from under a bamboo tree;
- 10 sacks rice bran;
- 10 Kg sugar;
- 8 1/2 L local coconut/ rice wine OR 1/3L FPJ; and
- 1/3 L indigenous microorganisms (IMO).

BOK procedure

1. Select a good site for bokashi production (e.g. under a tree). The site should have a roof to protect the bokashi from sunlight and the surrounding area should have good drainage to protect the bokashi from heavy rains. It is much better if the area is cemented and located near the house so that it is safe from heavy rains and easy to monitor. During the dry season, the bokashi can be produced under a tree. In this case it is important to ensure that the area does not have any stray animals.

2. Prepare all materials needed. Chicken dung should be dried.

3. Slowly mix the materials together one at a time and add water (for every 1 sprinkler can of water mix 1 glass of coconut/ rice wine) until the mixture is saturated but not too wet. Estimate the moisture content; it should not be more than 60% (mixture can be formed into a ball that crumbles easily, if you squeeze the ball you shouldn't see any water come out). Avoid adding too much water because moisture content above 60% can result in a foul odor being produced, that means that the bokashi is not good.

4. Mix the materials thoroughly, form the mixture like a pyramid and cover with sacks.

5. Check and mix everyday. Temperature should be less than 70 centigrade. Record the temperature before mixing. Mixing should be done in the morning and afternoon for 1 week. If it is not possible to measure temperature with a thermometer, check temperature by burying your hand in the pile. In general, if you can't resist the heat after a few seconds, then your pile needs to be mixed twice a day. After 1 week, if the bokashi is too dry, sprinkle with water to moisten.

6. From 8-14 days, mix the bokashi once a day, in either the morning or afternoon. As well, record the temperature. If the temperature is below 30 centigrade (i.e., feels cool to lukewarm on the hand), there is no need to mix. Starting on the 8th day, if the form is not pyramiding, just level it on the ground flat and cover with sacks. After 14 days, it is ready to use and should have a smell similar to silage.

7. After 2 weeks of fermentation, leave the sacks on the bokashi and store it in a dry place away from direct sunlight.

8. Mix with an equal volume of local soil and apply to fields during soil preparation (see Table 3 for further application advice).

Table 3 Guidelines for applying bokashi organic fertilizer to different crops (BOK)

Crop	Application type	Application rate*	Method
Vegetables & rice	Basal application	20 - 30 sacks/Ha	Mix with the soil by spreading on the topsoil before plowing. In the case of lowland rice drain the water first. Follow up by spraying IMO or spreading FRB.
Corn, millet & upland rice	Basal application	30 sacks/Ha	Apply on furrows before planting the seeds.
Lowland rice	Top dress (only if basal application was inadequate)	1 Kg/m^2	Drain water and spread bokashi
Corn, millet & upland rice	Top dress (only if basal application was inadequate)	20 sacks/Ha	Apply before on bearing or hilling up.
Squash, bitter gourd, etc.	Top dress (only if basal application was inadequate)	2 Kg/plant	Dig a trench around the plant (5-10 cm from the base), put bokashi in it and cover with topsoil.
Tomatoes, eggplants, etc.	Top dress (only if basal application was inadequate)	1 Kg/plant	Dig a trench around the plant (5-10 cm from the base), put bokashi in it and cover with topsoil.

*1 sac = 50kg bokashi

LEARNING POINT: The organic soil amendments described prove useful for jumpstarting the soil rehabilitation process on farms initiating a conversion from conventional to agro-ecological farming. The long-term use of inorganic fertilizers results in a soil that is impoverished in terms of organic matter content, microbial activities and structure. The first years of agro-ecological cultivation are frequently characterized by lower yields and reduced farm income until the soil has been restored. This is a particularly serious concern on small-scale farms whose primary function is to provide for the nutritional needs of a family. Funds are not always available to supplement nutritional shortfalls engendered by short-term yield decreases. It is therefore important to accelerate the restoration of the soil so as to render the conversion to organic agriculture feasible for small landowners by reducing the associated risk.

Organic crop amendments produced from native materials have a much lower cost than commercial amendments. This is especially true when farmer's organizations undertake large-scale production of some amendments that can be distributed to other members. During these activities group members donate materials and labor in return for an allotment of the output. This practice has additional positive impact of increasing cooperation and communication between farmer-members of the organizations. The most important long-term impact of these organic agriculture practices is the reinforcement of self-reliance and creativity among farmers.

2.4 Green manures[9]

Green manures are plants grown to accumulate nutrients for the main crop. When they have built up maximum biomass, they are worked into the surface soil. As they are usually cut before flowering, growing a green manure is thus different from growing a legume crop in the rotation. Once worked into the soil the fresh plant material releases nutrients quickly and will be fully decomposed within a short period of time. Old or coarse material (e.g. straw, twigs) will decompose at a slower rate than fine material and will therefore contribute more to the build up of soil organic matter than to fertilizing the crop.

An alternative to sowing a green manure crop in the field is to collect fresh plant material from elsewhere and work it into the soil. For example, tree and/or shrub leaves and grasses growing alongside crops in an agroforestry system may provide large quantities of green material that can be used as green manure or for mulching.

Benefits of Green Manures

- ☑ They penetrate the soil with their roots, make it more friable and bind nutrients, which would otherwise be washed away;
- ☑ They suppress weeds and protect the soil from erosion and direct sunlight;
- ☑ If legume plants are used, nitrogen is fixed from the air into the soil;
- ☑ Some green manures can be used as fodder plants or even to provide food for human consumption (e.g. beans and peas);
- ☑ By decomposing, green manures release all kinds of nutrients in the correct mixture for the main crops to utilize thus improving their yield;
- ☑ The incorporated plant material encourages the activity of soil organisms, and builds up organic matter in the soil. This improves soil structure and water holding capacity; and
- ☑ Green manure is an inexpensive way to improve soil fertility and nutrient balance.

Before growing green manures – considered the following:

- Labor is required for tillage, sowing, cutting and incorporation of plants into the soil, and is most intensive where the amount of helpful equipment available is small;
- If green manures are intercropped with the main crops, they compete for nutrients, water and light. When old or coarse plant material is incorporated into the soil, nitrogen may be temporarily immobilized and therefore unavailable for plant growth. If food and space are in short supply it may be more appropriate to grow a food crop rather than a green manure and recycle the crop residues, or to intercrop a green manure crop with the main crop; and
- The benefits of green manures occur over the long term and are not always visible immediately.

Green manure & nitrogen fixation

Air is the only primary source of nitrogen (secondary sources are rainwater, organic matter and animal manures). Air consists mainly of nitrogen (N^2), approximately 78% and thus offers potentially endless amounts of this valuable plant nutrient. However, in most cases nitrogen is the limiting plant nutrient as most plants are unable to take up nitrogen directly

9 IFOAM & FiBL – Undated. Basic Training Manual for Organic Agriculture in the Tropics. International Federation of Organic Agriculture Movements (IFOAM), Bonn (Germany) & Research Institute of Organic Agriculture (FiBL), Frick (Switzerland)

from the air, instead needing it in a modified form. Some plants, especially those of the legume family, but also some from the mimosa family, are capable of fixing nitrogen from the air via their roots. Legumes do this by living in association (symbiosis) with bacteria called rhizobium, which are hosted in visible nodules growing on the roots. These bacteria take up nitrogen from the air, transform it and make it available for the host plant.

Sowing the green manure

- If grown within a crop rotation, the time of sowing must be chosen such that the green manure can be cut down and worked into the soil before the next crop is sown;
- Green manures need water for germination and growth;
- The ideal seed density must be tested for each individual situation. It depends on the species chosen; and
- In general no additional fertilization is necessary. If legumes are grown in a field for the first time, inoculation of the seeds with the specific rhizobia may be necessary to profit from nitrogen fixation of the legume.

Working the green manure into the soil

- Timing: The time gap between digging in the green manure and planting the next crop should not be longer than 2 to 3 weeks so as to prevent nutrient losses from the decomposing green manure;
- Crushing: Green manures are worked in most easily when the plants are still young and fresh. If the green manure plants are tall or contain bulky and hard plant parts, it is preferable to chop the plants into pieces to allow easier decomposition. The older the plants, the longer decomposition will take. The best time to dig in green manure plants is just before they flower; and
- Depth of incorporation: Green manures should not be ploughed deeply into the soil. Instead they should only be worked in to the surface soil (in heavy soils only 2-6 inches deep, in light soils 4-8 inches deep). In warm and humid climates the material can also be left on the soil surface as a mulch layer.

How to integrate green manures into the crop rotation

Between two crops (for a short period)

As a cover crop into an annual crop

Between two crops (for a long period)

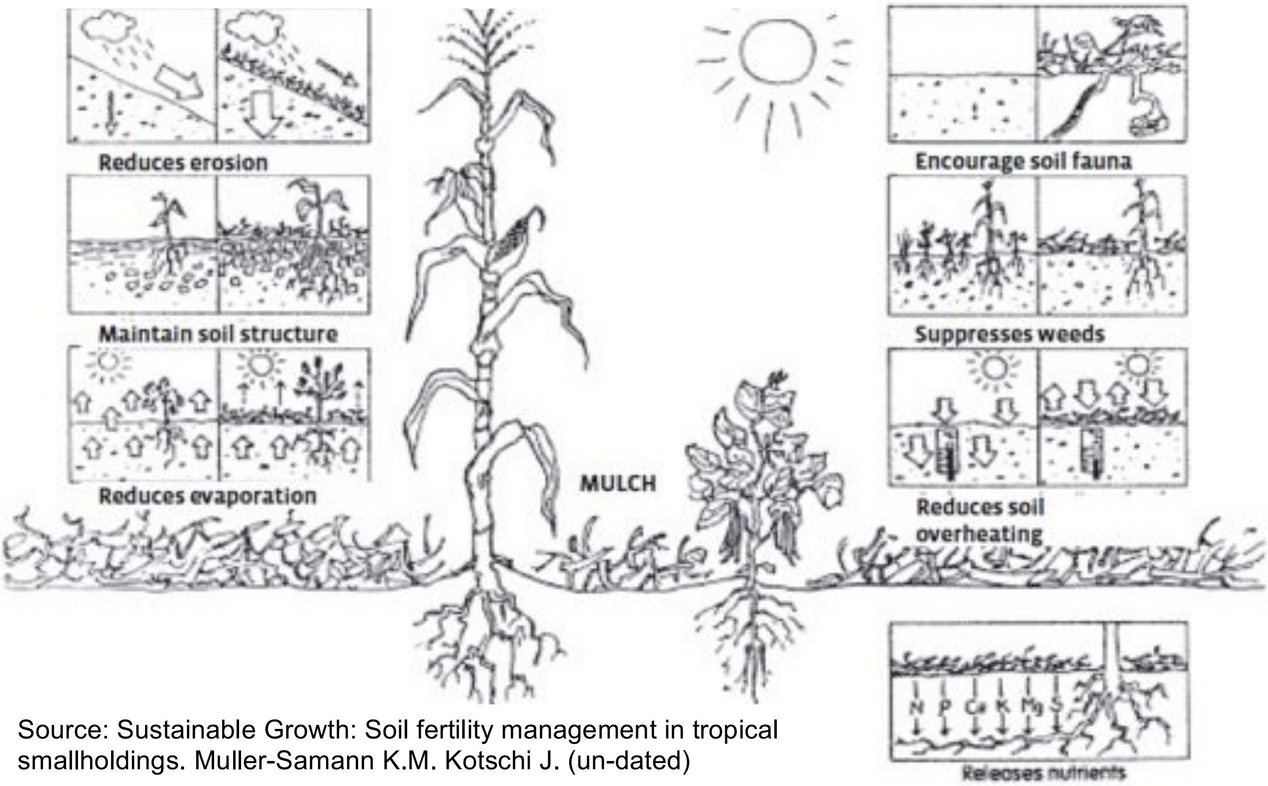
2.5 Mulching[10]

Mulching is the process of covering the topsoil with plant material such as leaves, grass, twigs, crop residues, straw etc. A mulch cover enhances the activity of soil organisms such as earthworms. They help to create a soil structure with plenty of smaller and larger pores through which rainwater can easily infiltrate into the soil, thus reducing surface runoff. As the mulch material decomposes, it increases the content of organic matter in the soil. Soil organic matter helps to create a good soil with a stable crumb structure. Thus the soil particles will not be easily carried away by water. Therefore, mulching plays a crucial role in preventing soil erosion.

What is the Use of Mulching?

¬ Protecting the soil from wind and water erosion: soil particles cannot be washed or blown away;
¬ Improving the infiltration of rain and irrigation water by maintaining a good soil structure: no crust is formed, the pores are kept open;
¬ Keeping the soil moist by reducing evaporation: plants need less irrigation or can use the available rain more efficiently in dry areas or seasons;
¬ Feeding and protecting soil organisms: organic mulch material is an excellent food for soil organisms and provides suitable conditions for their growth;
¬ Suppressing weed growth: with a sufficient mulch layer, weeds will find it difficult to grow through it;
¬ Preventing the soil from heating up too much: mulch provides shade to the soil and the retained moisture keeps it cool;
¬ Providing nutrients to the crops: while decomposing, organic mulch material continuously releases its nutrients, thus fertilizing the soil; and
¬ Increasing the content of soil organic matter: part of the mulch material will be trans-formed to humus.

Box 6 Illustration depicting the benefits and use of mulching



Source: Sustainable Growth: Soil fertility management in tropical smallholdings. Muller-Samann K.M. Kotschi J. (un-dated)

Selection of mulch materials

The kind of material used for mulching will greatly influence its effect. Material that easily decomposes will protect the soil only for a rather short time but will provide nutrients to the crops while decomposing. Hardy materials will decompose more slowly and therefore cover the soil for a longer time. If the decomposition of the mulch material should be accelerated, organic manures such as animal dung may be spread on top of the mulch, thus increasing the nitrogen content.

Sources of mulching material: Weeds or cover crops, crop residues, grass, pruning material from trees, cuttings from hedges; and waste from agricultural processing.

Cautions when using mulches

- Some organisms can proliferate too much in the moist and protected conditions of the mulch layer. Slugs and snails can multiply very quickly under a mulch layer. Ants or termites that may cause damage to the crops also may find ideal conditions for living;
- When crop residues are used for mulching, in some cases there is an increased risk of sustaining pests and diseases. Damaging organisms such as stem borers may survive in the stalks of crops like cotton, corn or sugar cane. Plant material infected with viral or fungal diseases should not be used if there is a risk that the disease might spread to the next crop. Crop rotation is very important to overcome these risks; and
- When carbon rich materials such as straw or stalks are used for mulching, microorganisms for decomposing the material may use nitrogen from the soil. Thus, nitrogen may be temporary not available for plant growth.

Application of mulch

If possible, the mulch should be applied before the onset of the rainy season, as then the soil is most vulnerable. Apply a thin layer only. If the layer of mulch is not too thick, seeds or seedlings can be directly sown or planted in between the mulching material. On vegetable plots it is best to apply mulch only **after** the young plants have become somewhat hardier, as the products of decomposition from fresh mulch material may harm them (see Figure 3 for example).

Figure 3 Mulch being used on raised vegetable bed.

2.6 Soil cultivation and tillage

Soil cultivation includes all mechanical measures to loosen, turn or mix the soil, such as plowing, tilling, digging, hoeing, harrowing etc. Careful soil cultivation can improve the soil's capacity to retain water, its aeration, capacity of infiltration, warming up, to water evaporation etc. But soil cultivation can also harm the soil fertility as it accelerates erosion and the decomposition of humus (see Figure 4). There is no 'one right way' to cultivate soil, rather a range of options should be considered. Depending on the cropping system and the soil type, appropriate soil cultivation patterns must be developed.

There are many reasons for cultivating the soil…

- Loosen the soil to facilitate the penetration of plant roots;
- Improve the aeration (nitrogen and oxygen from the air);
- Encourage the activity of the soil organisms;
- Increase infiltration of water;
- Reduce evaporation;
- Destroy or control weeds and soil pests;
- Incorporate crop residues and manures into the soil;
- Prepare the site for seeds and seedlings; and
- Repair soil compaction caused by previous activities.

BUT there are MORE reasons for NOT cultivating the soil…

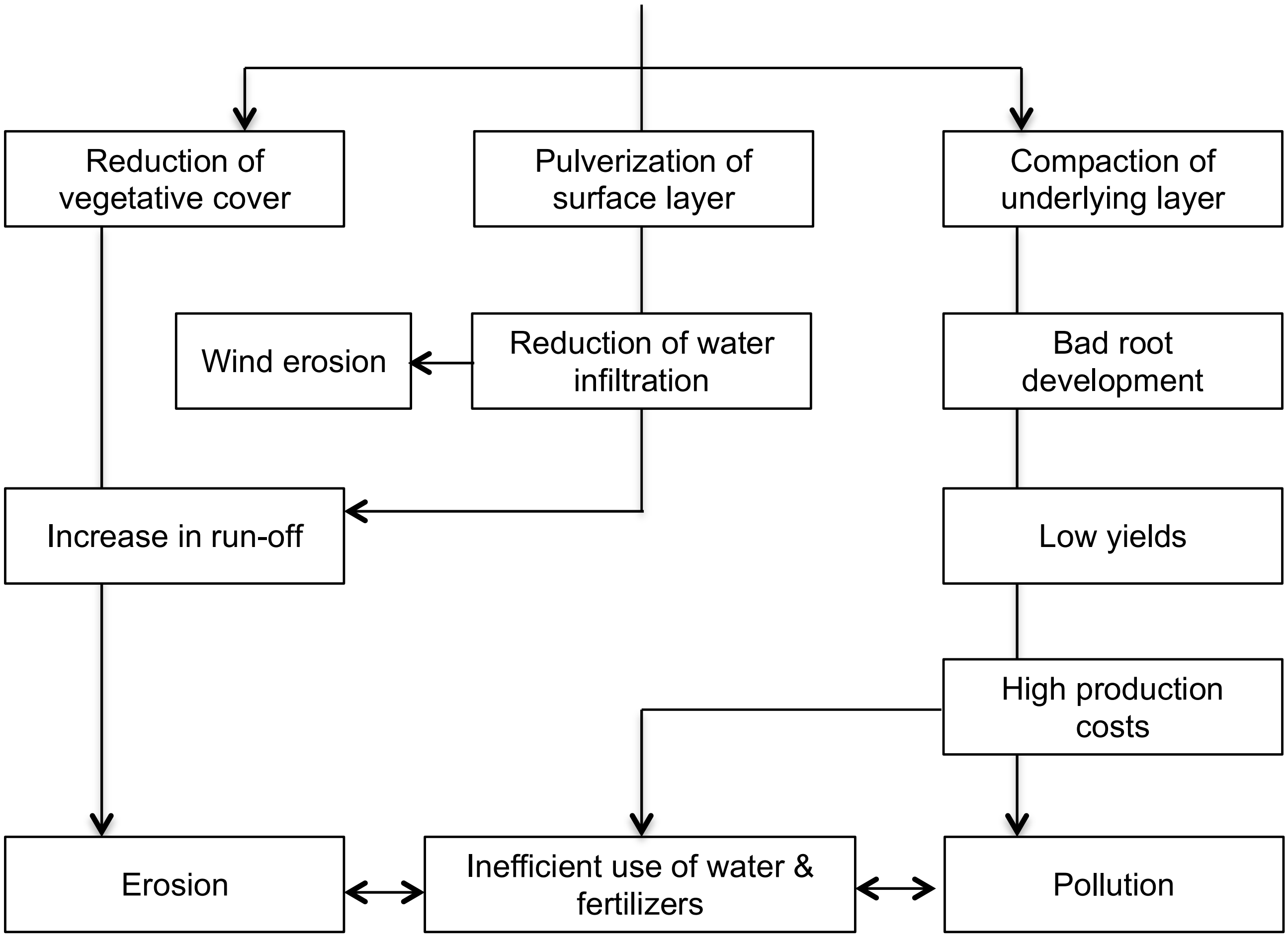


Figure 4 Harmful effects of soil cultivation and associated linkages.

TO TILL or NOT to TILL

Advantages of tillage: Improves aeration, incorporates crop residues, facilitates root penetration, and suppresses weeds.

Advantages of zero-tillage: Improves soil structure, maintains soil organic matter, supports soil organisms, and prevents soil erosion.

Minimum disturbance tillage

Any soil cultivation activity has a more or less destructive impact on soil structure. Regular tillage accelerates the decomposition of organic matter that can lead to nutrient losses. The mixing of soil layers can severely harm certain soil organisms. After tillage, soils are very prone to erosion if left uncovered before the onset of heavy rains.

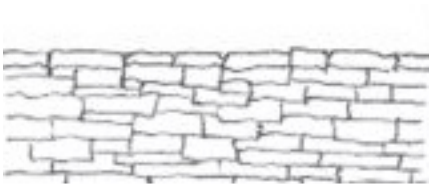
Conversely, minimum tillage systems help to build up a natural soil structure with crumbly topsoil rich in organic matter and full of soil organisms. Nutrient losses are reduced to a minimum as there is no sudden decomposition of organic matter, and a dense network of plant roots catch nutrients. Soil erosion won‘t be a problem as long as there is a permanent plant cover or sufficient input of organic material. Last but not least, farmers can save a lot of labor.

To minimize the negative impacts of soil cultivation while benefiting from its advantages, the farmer should aim to reduce the number of cultivations to the minimum and choose methods that conserve the natural qualities of the soil.

Soil compaction

If soils are cultivated in wet conditions or burdened with heavy machinery, there is a risk of soil compaction that results in suppressed root growth, reduced aeration and water logging. Where soil compaction is a potential problem, farmers should be aware of the following aspects:

- The risk of soil compaction is highest when the soil structure is disturbed in wet conditions;
- High content of soil organic matter reduces the risk of soil compaction; and
- It is very difficult to restore a good soil structure once soil compaction takes place.



How to avoid soil compaction:

- ✗ Do not cultivate in wet conditions;
- ✗ Do not use heavy vehicles on sensitive soils; and
- ✗ Maintain plant cover and a high organic matter content.

How to repair soil compaction:

- ✓ Deep tillage in dry conditions encouraged by earthworms;
- ✓ Apply organic matter; and
- ✓ Grow deep rooting plants (e.g. green manure).

Types of soil cultivation

Depending on the aim of the soil cultivation, different cultivation practices are implemented during different stages of the cropping cycle: after harvesting, before sowing or planting or while the crop stands.

Post-harvest: In order to accelerate decomposition, the residues of the previous crop are incorporated into the soil before preparing the seedbed for the next crop. Crop residues, green manure crops and farmyard manure should be worked only into the topsoil layer (5-8 inches), as decomposition in deeper soil layers is incomplete, producing growth-inhibiting substances that can harm the next crop.

Primary tillage: In annual crops or new plantations, primary tillage is usually done with a plough or a similar instrument. As a principle, soil cultivation should achieve a flat turning of the topsoil and a loosening of the medium deep soil. Deep turning soil cultivation mixes the soil layers; harms soil organisms and disturbs the natural structure of the soil.

Seedbed preparation: Before sowing or planting, secondary soil cultivation is done to crush and smoothen the ploughed surface. Seedbed preparation has the purpose to provide enough loose soil of appropriate clod size. If weed pressure is high, seedbeds can be prepared early thus allowing weed seeds to germinate before the crop is sown. Shallow soil cultivation after some days is sufficient to eliminate the young weed seedlings. Where water logging is a problem, seedbeds can be established as mounds or ridges.

In-between the crop: Once the crop is established, shallow soil cultivation (e.g. by hoeing) helps to suppress weeds. It also enhances the aeration of the soil and at the same time reduces the evaporation of soil moisture from the deeper soil layers. When crops are temporarily lacking nutrients, shallow soil cultivation can stimulate the decomposition of organic matter, thus making nutrients available.

Farmers in Honduras are practicing minimum tillage

- First, the vegetation is cut down to the soil level;
- Then the soil is opened along contour lines at plant row distance;
- Organic manure is applied into the rows;
- The crop is sown into these rows;
- The vegetation in between is cut regularly and used as a mulch; and
- This system can be combined with leguminous plants that act as cover crops.

Farmers in Honduras practicing zero tillage (sowing maize and corn directly into the residues of the previous crop)

- Corn is sown into the mulch layer;
- 1-2 months later beans are sown;
- After the corn is harvested, the residues are left on the field and the beans grow over them;
- The beans offer suitable conditions for a direct sowing of the following corn crop; and
- With this method, two corn crops and two bean crops per year are grown with satisfying yields.

Session 3 Water management

3

Objective

- ✓ Provide BRiLSS project partners with an overview of simple and accessible low cost agro-ecological farming water management practices.

The session presents a wealth of water retention and water conservation practices. Covered are ways to keep soil moisture in place, how to reduce soil evaporation, to practical technical application that aim to increase water infiltration, e.g. modes of trenching, contouring, and catchment configurations etc. Session materials also include an overview of the technical application of drip irrigation. In brief, the session aims to provide BRiLSS project partners with an overview of simple and accessible low cost agro-ecological farming water management practices

Session 3 Water management

Facilitation guide (3+ hours)

STEP 1

Introduce Handout S3.1 – S3.2 through an organized PowerPoint presentation, including the session objectives, content, and the process the facilitator will take to deliver the session. Emphasize the importance of all participants having a common understanding of the content in the context of the BRiLSS project.

Before starting a review of the session handout materials, note that agro-ecological farming aims at optimizing the use of on-farm resources, active water retention, and water harvesting and storage; each become an integral part of the process. Note that this starts with improving the water retention and infiltration of water into the soil.

STEP 2

Present Handout S3.1 learning materials. Note that the focus of the sub-session is on water retention and conservation practices (WRCP). Present Figure 5 in conjunction with the first three (3) core WRCP, 1) keeping soil moisture in the ground, 2) taking preventive measure to reduce water evaporation from the soil, and 3) making better use of seasonal rainfall.

Follow by presenting the remaining 8 WRCPs. Present each in conjunction with its associated illustrations.

STEP 3

Check with the participants as to who has experience using an A-Frame to develop farm contours (also known as swales). If participants are not well experienced in the technique, it is advisable to undertake the technique as a practical exercise following the six (6) point guide given in the handout. If some participants have good experience in developing farm contours, then review the six (6) point guide and ask participants to share their experience in developing the contours in detail.

STEP 4

Using Handout S3.2 – irrigation technologies, begin by pointing out the potential harms irrigation can cause. Advise that if irrigation is a choice there are general rules to follow in order to mitigate these harms. Table 4 is a useful guide to follow with regards to minimizing irrigation applications.

Present ‘drip irrigation’ through the use of the figures given. If there is a keen interest in learning more, e.g. a planned effort supported by the BRiLSS project, then download the recommended technical manual and plan for the needed technical training.

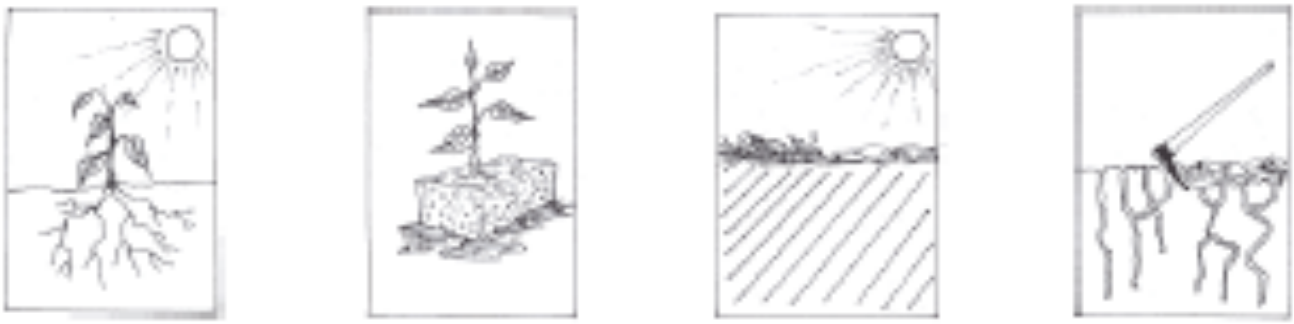
3.1 Water retention and conservation practices (WRCP)

In conventional agriculture, the first idea to overcome a shortage of water usually is to install irrigation facilities. However, agro-ecological farmers know that it is more important to first improve the water retention and infiltration of the soil - FIRST.

Keeping water in the soil

During dry periods, some soils are more and some are less in a position to supply crops with water. The ability of a soil to absorb and store water largely depends on the soil composition and on the organic matter content, e.g. soils rich in clay can store up to three times more water than sandy soils. Soil organic matter acts as a water storage – similar to a sponge. Therefore, soils rich in organic matter will preserve their moisture for a longer time. For increasing the organic matter content, the application of organic manures, compost, mulch or green manures can be used as described in Section 2.

A thin layer of mulch can considerably reduce the evaporation of water from the soil. It shades the soil from direct sunlight and prevents the soil from getting too warm. Shallow digging of the dry topsoil can help to reduce the drying up of the soil layers beneath (it breaks the capillary vessels)(see Figure 5 for further information). A better retention of water within the soil saves on irrigation costs.



During dry periods, crops are depending on the moisture supply of the soil. Soil organic mater acts as a storage of water

Organic matter

Mulching

Apply mulch or plant cover to reduce evaporation and increase infiltration. Shallow digging of the dry topsoil helps to reduce the drying up of the soil layers beneath water

Figure 5 Simple smallholder farm water retention and conservation practices.

Practice 1
Keep Soil Moisture

During dry periods, some soils are more and some are less in a position to supply crops with water. The ability of a soil to absorb and store water largely depends on the soil composition and on the content of organic matter. Soils rich in clay can store up to three times more water than sandy soils. Soil organic matter acts as storage of water, just like a sponge. Therefore, crop residue or a cover crop protects the soil, prevents crusting on the surface, and slows runoff. Roots, earthworms and other soil life maintain cracks and pores in the soil. Less water runs off, and more sinks into the soil.

Practices 2 & 3
Reduce Evaporations and Use Rainfall Better

Reduce evaporation: A thin layer of mulch can considerably reduce the evaporation of water from the soil. It shades the soil from direct sunlight and prevents the soil from getting too warm. Shallow digging of the dry topsoil can help to reduce the drying up of the soil layers beneath (it breaks the capillary vessels). A better retention of water within the soil saves costs on irrigation.

Better use of seasonal rainfall: Ripping during the dry season allows farmers to plant earlier – right at the start of the rains.

ATTENTION: A green manure or cover crop is not always a suitable way of reducing evaporation from the soil. While a plant cover provides shade and thus reduces sunshine directly reaching the soil, they are themselves evaporating water through their leaves even more efficiently than mere soil. When soil moisture gets scarce, plants competing for water with the main crop can be pruned or cut down, thus serving as mulch.

Increasing water infiltration

During strong rains, only some of the water infiltrates into the soil. A considerable part flows away as surface runoff, thus not available for crop growth. In order to get as much water into the soil, the infiltration of rainwater needs to be increased. Most important for achieving a high infiltration is to maintain a topsoil with a good soil structure containing many cavities and pores, e.g. those made from earthworms.

Cover crops and mulch application are suitable to create such a favorable topsoil structure, and the establishment of a good population of earthworms. To further improve water infiltration, practical applications are, 1) trench establishment, 2) semi-circular bund establishment, and 3, the planting of pits (see Figure 6 for illustrations).

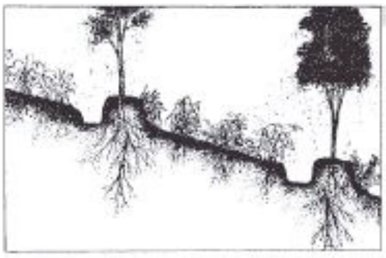
Practices 4, 5 & 6

Use Trenches, Semi-circular Bunds and Pits

Trenches: On slopes, the infiltration of rainwater can additionally be encouraged through trenches dug along contour lines. Surface runoff is caught in the trench where it can slowly infiltrate into the soil.

Semi-circular bunds: Semi-circular bunds around tree crops collect water flowing down the slope and encourage its infiltration near the root zone of the crop.

Planting pits: On level fields, plant pits can be used. The effect of these ‘water traps’ can be increased if a layer of mulch is also integrated. Planting pits are hand-dug circular holes that collect water and store it for use by the crop. Each pit is about 20 cm across and 20 cm deep. After planting, the holes are left partly open so they collect water. Planting pits take a lot of work to dig when the soil is dry. But they produce good yields in areas where otherwise crops might die because of a lack of water. Once made, the pits can be used again, season after season. Leave the soil covered, and add compost or fertilizer to the pits to increase their fertility.



Contour trenches

Semi-circular bunds

Planting pits

Figure 6 Illustrations of WRCPs.

Practice 7 Soil Contouring

Most people know about terracing as a way to capture water and reduce soil erosion, but soil contouring can also be an effective tool to conserve water in the soil. Created are ditches along the contour line to capture water.

A contour line is a line made up of points of the same elevation. They act to capture water so that it can drain deep into the soil and replenish the water table under your garden/ crop. This will increase the moisture on the land and make it more productive.

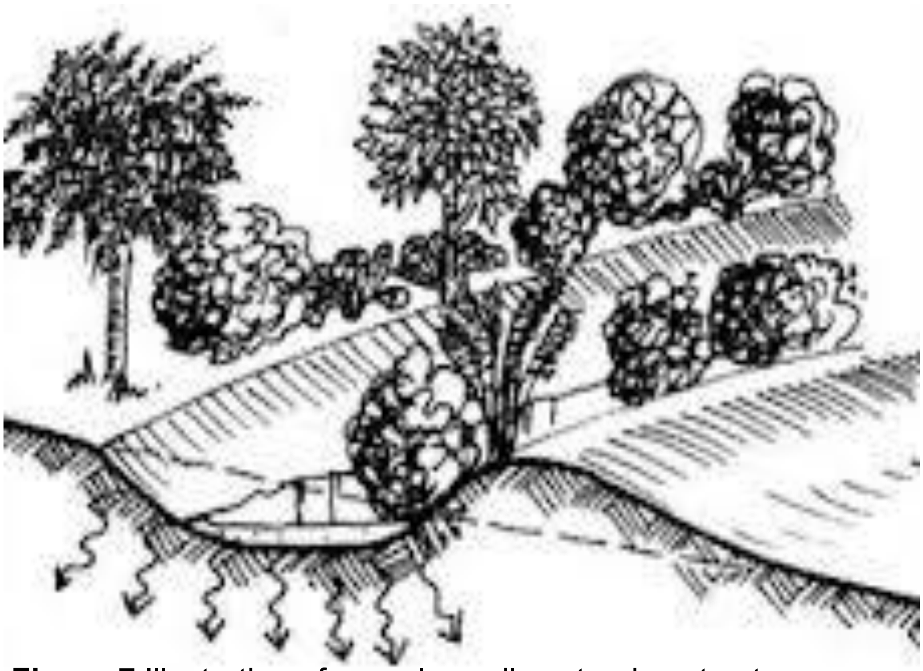


Figure 7 Illustration of a swales soil contouring structure.

The ditch should be placed along the contour line so that it can hold the water. If it is slightly downhill or uphill the water will be lost. The lower side of the ditch walls can be planted with shrubs, pigeon peas, or trees to secure the wall during heavy rains. The inside of the ditch walls can also be planted with fast growing trees to act as wind breaks for the crops, e.g. bananas. The ditches/ contours can be placed 30 feet apart. On steep slopes, place the ditches/ contours closer together, or on slopes that have heavy, compacted soils where it is more difficult for water to infiltrate (Figure 7).

Practice 8 Contour Bunds and Catchment Strips

In areas with low rainfall, there may not be enough water to grow a crop over the whole area. On gentle slopes (less than 3%), one possibility is to use contour bunds and catchment strips. Catchment strips are areas where no crops are planted. When rain falls on this ground, it runs down the slope and is trapped by the contour bund. Plant rows of crops behind the bund so they can use this water (Figure 8). This can produce a good yield even with very little rain. Mulch the cultivated areas with crop residues to prevent erosion, help water sink in, and slow evaporation.

Figure 8 sketch shows an example of a farmer who made their cropped strips 0.8–1m (32-39 inches) wide a 3.3m (approximately 10 feet) apart. The land between the strips is shaped - sloped towards the cropped strips - so rainwater will flow towards the crop. Planted are two rows of maize in each strip, and a cover crop, e.g. cowpeas, is sown between the strips. The strips are permanent: they can be used to grow crops season after season. The soil in the strips gradually improves in fertility as crop residues accumulate there. Rotating maize with a legume crop will improve the soil fertility further.

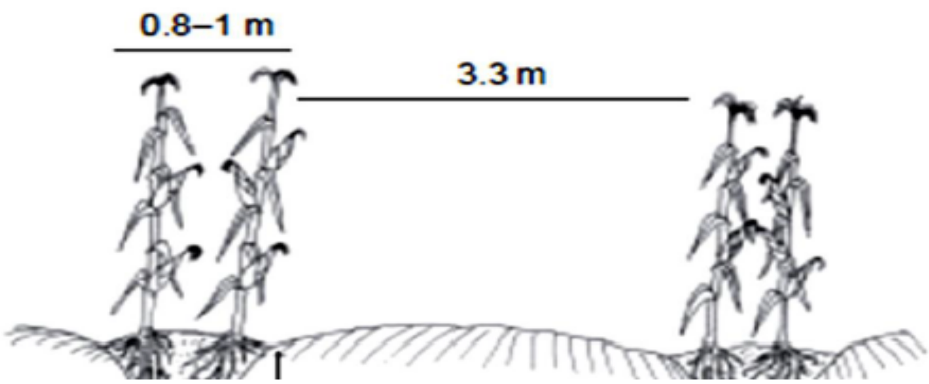
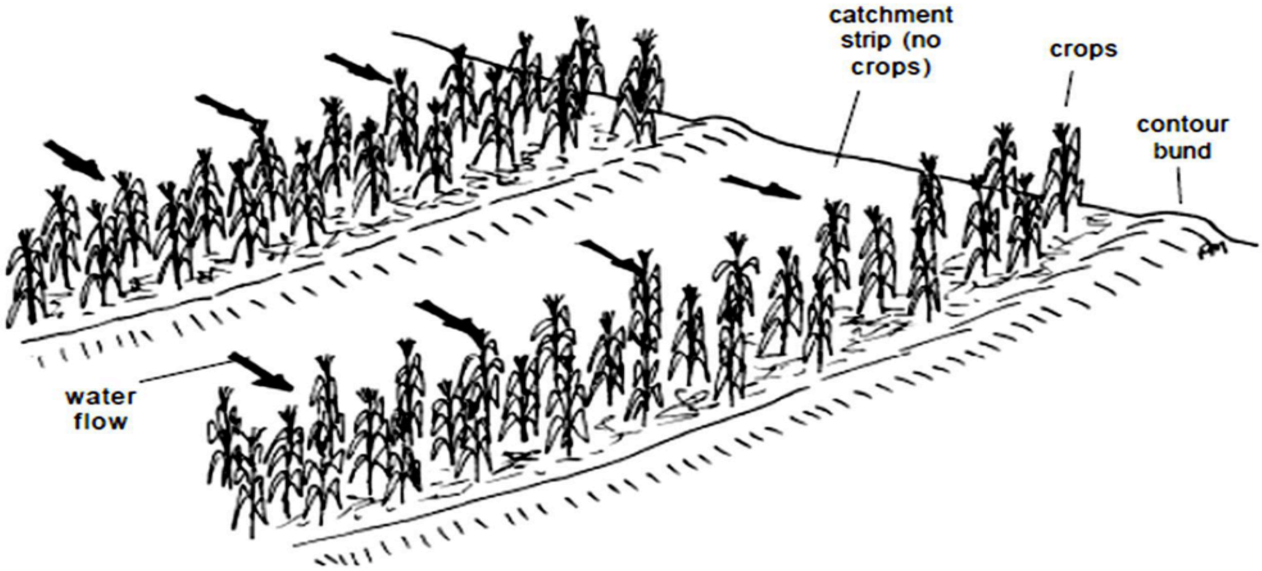


Figure 8 Maize crop grown in a permanent contour catchment strip (above) and overall construction and placement of the catchment (below).[11]



[11] IIRR & ACT. 2005. Conservation Agriculture: A manual for farmers and extension workers in Africa. International Institute of Rural Reconstruction (IIRR), African Conservation Tillage Network (ACT). Nairobi, Kenya

Practice 9 Road Catchments

Water from roads – and from other unproductive areas such as paths and homestead compounds – can be channeled onto fields. It may be possible to divert water from structures that already exist, such as the ditches below terraces. Or special bunds can be built around fields close to the road. Another possibility is to direct the water into a pond, which can be used to irrigate crops (see Figure 9[12] for details).

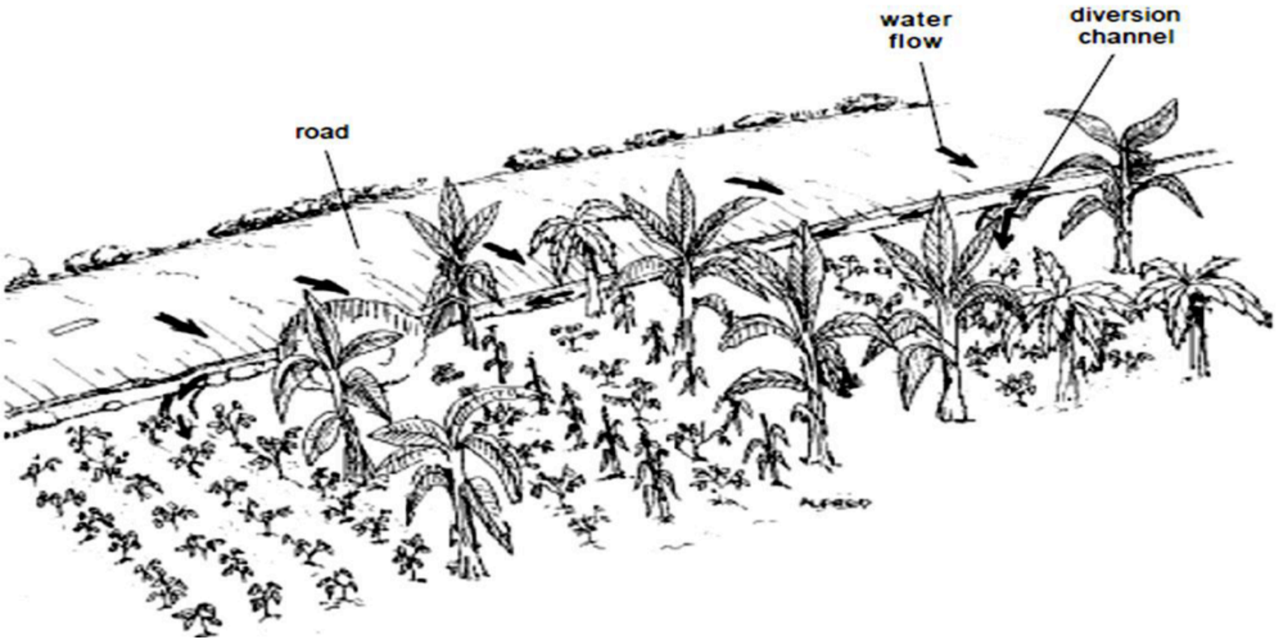


Figure 9 Illustration of contour bunds and road catchment strip.

Practice 10 Half-moon Micro Catchments

Half-moon micro-catchments are small, semicircular earth bunds. The half-moons catch water flowing down a slope. Crops such as sorghum, millet and cowpeas can be planted in the lower portion of the half-moons. Half-moons are also helpful to rehabilitate degraded land (see Figure 10 for illustration).

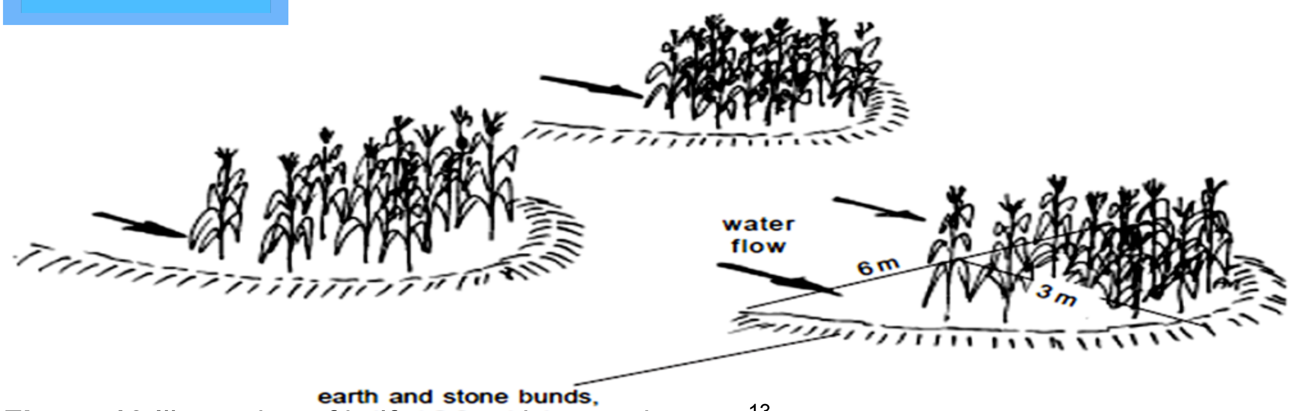


Figure 10 Illustration of half-moon micro-catchments[13]

[12] IIRR & ACT. 2005. Conservation Agriculture: A manual for farmers and extension workers in Africa. International Institute of Rural Reconstruction (IIRR), African Conservation Tillage Network (ACT). Nairobi,

[13] IIRR & ACT. 2005. Conservation Agriculture: A manual for farmers and extension workers in Africa. International Institute of Rural Reconstruction (IIRR), African Conservation Tillage Network (ACT). Nairobi, Kenya

Practice 11
Water Storage

Excess water in the rainy season may be made use of during dry periods. There are many possibilities of storing rainwater for irrigation, but most of them are labor intensive or costly. Storing water in ponds has the advantage that fish may be grown, but water is likely to be lost through infiltration and evaporation. The construction of water tanks may avoid these losses, but need appropriate construction materials. To decide whether or not to build water storage infrastructure, the benefits should be weighed against the costs, including the loss of arable land.

How to make a contour ditch[14]

Find the contour line by using an A-frame. A-frames are very simple to make:

1. Take two-piece of wood (or other material) that are of equal length and attach them with some nails. The feet of the A frame should be at least 60 inches wide.

2. Put a crosspiece to form an 'A'.

3. Place a string with a weight that comes just below the crossbar. The weight can be a stone, a bottle with water, or something else. The weight must be heavy enough to pull down the string and not waver on a windy day.

4. To find the center of the A-frame (or where the A-frame is level), place the A-frame upright and mark on the crossbeam where the string crosses. Then reverse the A-frame, placing each foot where the opposite foot was before. Mark on the crossbeam again where the string crosses. The center is halfway between the two marks (Figure 11).

Figure 11 A-frame with wide base and a water bottle as a weight.

[14] Flint, 2012: Ecological Farming Manual. Agahozo Shalom Youth Village Agricultural Professional Skills Program. Kenya.

5. Choose the starting point of the ditch/ trench. Move the A-frame across the land by reversing the feet and balancing the weight to determine the contour. Keep the A-frame upright while finding the center. It is important to reverse the feet because one side of the A-frame will measure the elevation slightly different than the other (Figure 12). When you reverse the feet every time it averages along the line. Mark the contour line with sticks or rocks.

Figure 12 Agriculture students finding a contour line using an A-frame.

6. Dig the contour trench 12 inches deep and 18 inches wide. Put the soil on the down slope side of the hill. You can check the bottom of the ditch with the A-frame to make sure it is level. You can also dig pits and/or plant water loving plants in these pits along the length of the ditch. Sometimes you will need to clean out the ditch if it starts collecting sediment from runoff.

In general, the more water (from rainfall), the bigger, and more numerous the ditches/ contour lines are needed. After digging, you can plant the berm (down slope hill) to make it more stable and multifunctional.

3.2 Irrigation technologies

Potential harms of irrigation

Even in organic agriculture, large areas of land nowadays are under irrigation. While the opportunity for irrigation may help farmers to improve their income and livelihood, there are also some potential negative impacts of irrigated agriculture which should be considered:

- When the amount of water extracted from a lake, river or groundwater table exceeds its replenishment rate, depletion of the water resource can be the result and impact severely the eco-system;
- Excessive irrigation in dry or semi-arid areas can cause salinization of the soil, which in the worst case can make the soil unsuitable for agriculture;
- Intense irrigation can cause soil erosion;
- Irrigation by sprinkling or flooding can harm the structure of the topsoil. The crumb structure of the soil may get destroyed and soil particles may accumulate in the pores, resulting in the formation of a hard crust. This will reduce the aeration of the soil and harm soil organisms;
- Improper irrigation may cause stress to the crops, making them more vulnerable to pests and diseases; and
- Application of irrigation water during the hot period of the day can cause a shock to plants.

General rules to irrigation

- ✓ During the flowering and fruit setting stages of crop development, plants are most sensitive to drought/water stress – thus, try to limit irrigation to these growth periods;
- ✓ Irrigation when the soil moisture in the root zone of the plant has decreased to ~50% of field capacity;
- ✓ Seedbeds containing small-seeded, directly sown crops require light and frequent water applications. Irrigate when 50% of the surface soil has dried down/ showing discoloration; and
- ✓ Seedbeds containing large-seeded, directly sown crops require less frequent water applications. Irrigate when soil at the 'seed depth' has dried to 50% of its holding capacity/ field capacity moisture. Use Table 4 as a guide to estimating soil field moisture by feel.

IMPORTANT: Crop – irrigation exceptions to the general rules

- ☑ Potatoes: Planting and maturation stages require full soil moisture fluctuation between 50% and 100% of thee field capacity. Tuber initiation and enlargement demand less of a fluctuation, responding favorably to a moisture swing between 75% and 100% of field capacity;
- ☑ Other Solanaceae family crops (e.g., tomatoes, peppers, eggplant), these respond favorably to a full swing between 50% and 100% of field capacity;
- ☑ Leafy greens: Hold at 50% of field capacity minimum; and
- ☑ Established fresh beans and peas: Hold at 50% of field capacity minimum.

Table 4 Guide to estimating soil moisture by feel – general rules.

Soil moisture level (% of field capacity)	**Coarse soil** (sand)	**Light soil** (loamy sand, sandy loam)	**Medium soil** (fine, sandy loam, silt loam)	**Heavy soil** (clay loam, clay)
0 –25% field capacity No available soil moisture. Plants wilt. Irrigation required. **(1st range)**	Dry, loose, single grained, flows through fingers. No stain or smear on fingers.	Dry, loose, clods easily crushed and will flow through fingers. No stain or smear on fingers.	Crumbly, dry, powdery, will barely maintain shape. Clods, breaks down easily. May leave slight smear or stain when worked with hands or fingers.	Hard, firm baked, cracked. Usually too stiff or tough to work or ribbon* by squeezing between thumb or forefinger. May leave slight smear or stain.
25 –50% field capacity Moisture is available, but level is low. Irrigation is needed. **(2nd range)**	Appears dry; will not retain shape when squeezed in hand.	Appears dry, may tend to make a cast** when squeezed in hand, but seldom will hold together.	May form a weak ball under pressure but will still be crumbly. Color is pale with no obvious moisture.	Pliable, forms a ball, will ribbon but usually breaks or is crumbly. May leave slight stain or smear.
50 –75% field capacity Moisture is available. Level is high. Irrigation not yet needed. **(3rd range)**	Color is darkened with obvious moisture. Soil may stick together in very weak cast or ball.	Color is darkened with obvious moisture. Soil forms weak ball or cast under pressure. Slight finger stain, but no ribbon when squeezed between thumb and forefinger.	Color is darkened from obvious moisture. Forms a ball. Works easily, clods are soft with mellow feel. Will stain finger and have slick feel when squeezed.	Color is darkened with obvious moisture. Forms good ball. Ribbons easily, has slick feel. Leaves stain on fingers.
75% - 100% field capacity Soil moisture level following irrigation. **(4th range)**	Appears and feels moist. Color is darkened. May form weak cast or ball. Will leave wet outline or slight smear on hand.	Appears and feels moist. Color is darkened. Forms cast or ball. Will not ribbon, but will show smear or stain and leave wet outline on hand.	Appears and feels moist. Color is darkened. Has a smooth, mellow feel. Forms ball and will ribbon when squeezed. Stains and smears. Leaves wet outline on hand.	Color is darkened. Appears moist; may feel sticky. Ribbons out easily, smear and stains hand, leaves wet outline. Forms good ball.

*Ribbon is formed by squeezing and working soil between thumb and forefinger.
**Cast or ball is formed by squeezing soil in hand.

Drip irrigation

The major factors that determine the necessity of irrigation are the selection of crops and an appropriate cropping system. Obviously, not all crops (and not even all varieties of the same crop) require the same amount of water, and not all need water over the same period of time. Some crops are very resistant to drought while others are highly susceptible. Deep rooting crops can extract water from deeper layers of soil and hence they are less sensitive to temporary droughts.

Figure 13 Illustrations of drip irrigation piping system (above) and filed application (below).

With the help of drip irrigation (see Figure 13), many crops can nowadays be grown outside their typical agro-climatic region. This may cause not only the aforementioned negative impacts, but also bring about some advantages. It may make it possible to cultivate land that would otherwise be unsuitable for agriculture without irrigation. Or the cultivation of sensitive crops can be shifted into areas with less pest or disease pressure.

There are irrigation systems of higher or lower efficiency and with more or less negative impact. If irrigation is necessary, agro-ecological farmers should carefully select a system which does not overexploit the water source, does not harm the soil and has no negative impact on plant health. One promising option are *drip irrigation systems*. From a central tank, water is distributed through thin perforated pipes directly to crop plants – one by one. There is a continuous but very light flow of water, thus allowing sufficient time to infiltrate into the root zone of the plant. In this way, a minimum of water is lost and the soil is not negatively affected.

Benefits of drip irrigation

- ☑ Slow and regular application of water directly to the root zone of plants through a network of small plastic pipes and low discharge emitters;
- ☑ Regular application of water and nutrients improves product quality and increases yield;
- ☑ Water savings at 50% compared to traditional irrigation methods. This means a farmer can irrigate more crop area per unit of water used; and
- ☑ A number of different crops can be irrigated, e.g. vegetable crops, fruit crops, commercial cash crops, flowers, etc.

For complete details, download a detailed manual at:
http://www.ideorg.org/ourtechnologies/ideal_drip_technical_manual.pdf

Session 4 Cash and food crop planning and management

4

Objective

- ✓ Provide BRiLSS project partners/ participants practical information regarding agro-ecological farming management practices: 1) crop rotation, 2) inter-cropping, 3) the use of cover crops, and 4) weed, pest and disease control.

Session 4 is an extensive review of cash and food crop planning and management practices. Included in session materials are agro-ecological farming technologies such as crop rotation, intercropping, and the use of cover crops, system of rice intensification, to agro-ecological technologies in weed, pest and disease management. The session aims to provide BRiLSS project partners with practical 'how to' knowledge of featured agro-ecological farming activities, and a chance to analysis these from an 'implementation' perspective.

Session 4 Cash and food crop planning and management

Facilitation guide (8 hours)

STEP 1

Introduce Handouts S4.1 – S4.6 through an organized PowerPoint presentation, including the session objectives, content, and the process the facilitator will take to deliver the session. Emphasize the importance of all participants having a common understanding of the content in the context of the BRiLSS project.

STEP 2

Beginning with Handout S4.1 – crop rotation, emphasize the meaning of 'crop rotation', e.g. the changing of the type of crops grown in the field each season or each year. Note that crop rotation is a critical feature of all agro-ecological cropping systems because it provides the foundation for the building healthy soils, the control of pests and weeds, and a means to maintaining soil organic matter. Follow by reviewing the five (5) stated benefits of crop rotation.

STEP 3

Note to participants that 'crop rotation' is a planned process that requires knowledge of plant types, their compatibility with each other and that of the soil. The planning process takes into consideration the overall purpose of 'rotation', e.g. are plants to be rotated part of a cover crop application, specifically used to facilitate soil fertility improvements, or to limit pest and disease problems etc. Presented in the handout materials is a series of questions to facilitate the planning process, and information on companion planting for crop rotation and mixed crop agro-ecological farming (Table 5). A step process to crop rotation (basic 5-step crop rotation process) is provided and should be reviewed through practical examples that look at the farmland use over a minimum of 12 months, what will be planted and why. Recommended is to cover handouts 4.1 to 4.3, then use the following as a facilitation guide for developing practical examples:

1. Market – have participants name a main crop grown for cash income.
2. Family check – have participants identify a probable crop for planting after the main crop is harvested.
3. Companion check – have participants identify other crops that can be integrated with the selected main crop. This is relevant if the farmer will intercrop.
4. Root & nutrient demand check – have participants think about root structure of selected crops, e.g. if I intercrop, will the crops make use of soil nutrients in upper and lower layers of the soil, within my rotation, do crops selected have similar nutrient demands etc.
5. Six (6) question check – have participants look at their '12 month' cropping plan in comparison to the 6 question check list. Make adjustments to the cropping plan if needed.

STEP 4

Move on to Handout S4.2 – intercropping. The first paragraph of the handout is most important for participants to understand. Set this understanding, and then review the four (4) intercropping arrangements. Use the associated figures to demonstrate each arrangement.

STEP 5

Move on to Handout S4.3 – cover crops. The first paragraph of the handout is most important for participants to understand. Set this understanding, and then review information given on the 'ideal cover crop' and highlight the 'caution' given.

STEP 6

Provide further detail on cover crop interactions. The following statements about cover crops can be helpful:

- Besides building soil fertility and suppressing weeds, they can affect a farm's insect community. Attention given to the effects of cover crops on insect populations can result in improvements in insect management;
- A given cover crop can be attractive to either pest insects or their predators;
- They can be a supplemental food source to insects in the form of nectar from their flowers, and they can also provide shelter for insects; and
- They can have positive and negative crop-insect interactions.

Note that both beneficial and pest insect populations can be managed through planting cover crops and other plants attractive to insects. Maintaining a healthy diversity of flowering plants throughout the farm and throughout the season can be a successful way to reduce insect pest problems.

STEP 7

Move on to Handout S4.4 –System of Rice Intensification. Cover the basic step process in brief. If participants require more in-depth information, guide them to the following web link:

http://siteresources.worldbank.org/WBIWATER/Resources/SRIbrochure.pdf.

STEP 8

Move on to Handout S4.5 – agro-ecological weed management. The first paragraph of the handout is most important for participants to understand. Set this understanding, and then review the four (4) common strategies used in agro-ecological farming regarding soil cultivation practices to control weed growth when preparing for the planting season. Follow by reviewing the cultivation strategies to control weeds during the cultivation period.

STEP 9

Move on to Handout S4.6 – agro-ecological pest and disease management. Stress from the onset that a healthy plant is less vulnerable to pest and disease infestation. Therefore, a major aim for an agro-ecological farmer is to create conditions that keep a plant healthy. State that within the handout learning materials there are many natural pest and disease control techniques presented. These techniques won't be covered in detail during the session, however, they have been included in the materials as 'reference materials' to be used when needed.

Important is to focus participants on the typical signs of pest attacks on crop plants, e.g. pest damage, mites and nematodes. There are the three (3) major issues farmer deal with. Note how agro-ecological farmers manage these 'attacks' through natural and mechanical means.

STEP 10

Follow in brief with the various natural pesticides that farmers can make as part of their pest control tools, e.g. Agniastra and Neemastra. Materials needs, process procedures, and application instructions are given in the handout.

Note that being proactive in identifying pest attacks and taking action before the problem becomes critical is very, very important. And, as important is to be able to identify disease attacks on crop plants (also know as pathogen attacks). Present the three (3) major signs to look for, and the following nine (9) mitigation strategies to address pathogen attacks.

STEP 11

Present information on 'controlling other organisms'. Note that many control strategies and directly linked to broader agro-ecological farming practices, e.g. encouraging beneficial microorganisms growth within soils, the use of cover crops, to the establishment of natural plant-pest barriers such as growing chrysanthemum flowers or making an extract from flower to be used as a natural insecticide.

STEP 12

Presenting the exercise 'Placing agro-ecological farming practices in context'. Follow the facilitation guide sheet (Exercise S4.1) to complete the exercise.

STEP 13

Close the session by covering Learning Aid S4.1 – preventative crop protection measures of pest and disease management as a recap to the session. Link each prevention measure to the specific learning materials covered in Session 4. Learning Aid S4.2 – challenges in transitioning to agro-ecological farming can be use as information material or as a guide to a focus group discussion contextualizing Sessions 1-4 collectively.

4.1 Crop rotation[15]

Crop rotation means changing the type of crops grown in the field each season or each year. It is a critical feature of all agro-ecological cropping system, because it provides the principal mechanisms for building healthy soils, a major way to control pests, weeds, and to maintain soil organic matter. Crop rotation brings the following benefits:

Benefit 1
Improves Soil Structure

Some crops have strong, deep roots. They can break up hardpans, and tap moisture and nutrients from deep in the soil. Others have many fine, shallow roots. They tap nutrients near the surface and bind the soil. They form many tiny holes so that air and water can get into the soil (see Figure 14)

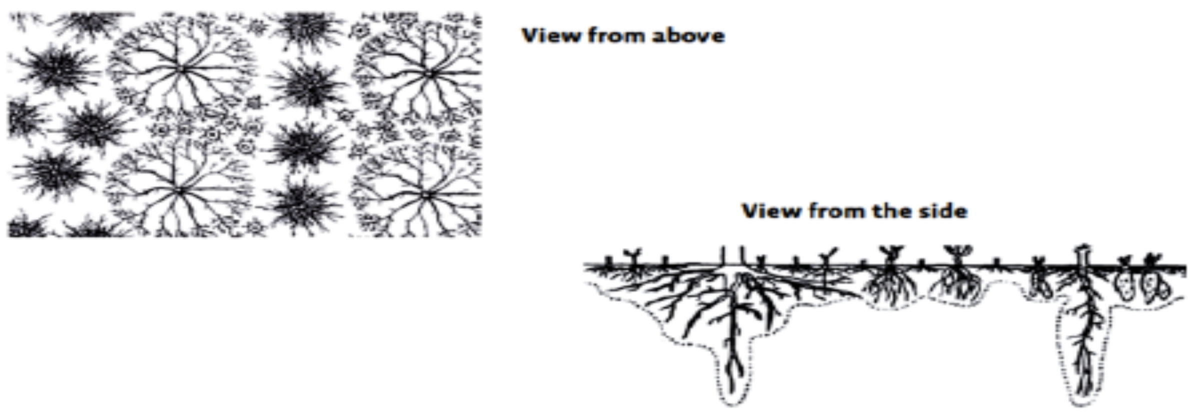


Figure 14 View of roots of intercropped coffee, maize, and cocoyam demonstrating better use of root space in associated crops.

Benefit 2
Increases Soil Fertility

Legumes (such as groundnuts and beans) fix nitrogen in the soil. When their green parts and roots rot, other crops such as maize can use this nitrogen. The result is higher, more stable yields, without the need to apply expensive inorganic fertilizer.

Benefit 3
Controls Weed, Pests & Diseases

Planting the same crop season after season encourages certain weeds, insects and diseases. Planting different crops breaks their life cycle and prevents them from multiplying.

Benefit 4
Mixed Outputs

Growing a mix of grain, beans, vegetables and fodder means a more varied diet and more types of produce to sell.

[15] FAO 2015 Training manual for Organic Agriculture. Climate, Energy and Tenure Division (NRC) and the Technologies and practices for smallholder farmers (TECA) Team from the Research and Extension Division (DDNR) of FAO Headquarters in Rome, Italy.

Benefit 5 Reduces Tillage Need

In some ways, crop rotation takes the place of ploughing/ tilling the soil. It helps aerate the soil, recycles nutrients, and helps control weeds, pests and diseases. Intercropping, strip cropping and relay cropping bring many of the same advantages as rotation.

Crop rotation selection – 6 questions to answer

Question 1

What should I produce? Crops produce many different things: food, fodder, firewood, fence poles, thatch and medicines. Farmers grow some crops (such as cotton) only for cash. For other crops, such as cereals or vegetables, you may be able to sell what you do not use yourself. If your objective is marketing, make sure that there is a market of your main output or rotation crop.

Question 2

Will my selection grow well? This depends on many factors: the amount of rain or moisture in the soil, the season (some crops and varieties do not grow well at certain times of year), and soil fertility among others.

Question 3

What are the roots like? Tall cereals (millet, maize, sorghum, etc.), finger millets and some legumes (e.g., pigeon pea and sun hemp) have strong roots that penetrate deep into the soil – up to 4 feet tall cereals. Their roots improve the soil structure and porosity, and are a good choice if the soil is compacted (see Figure 15)

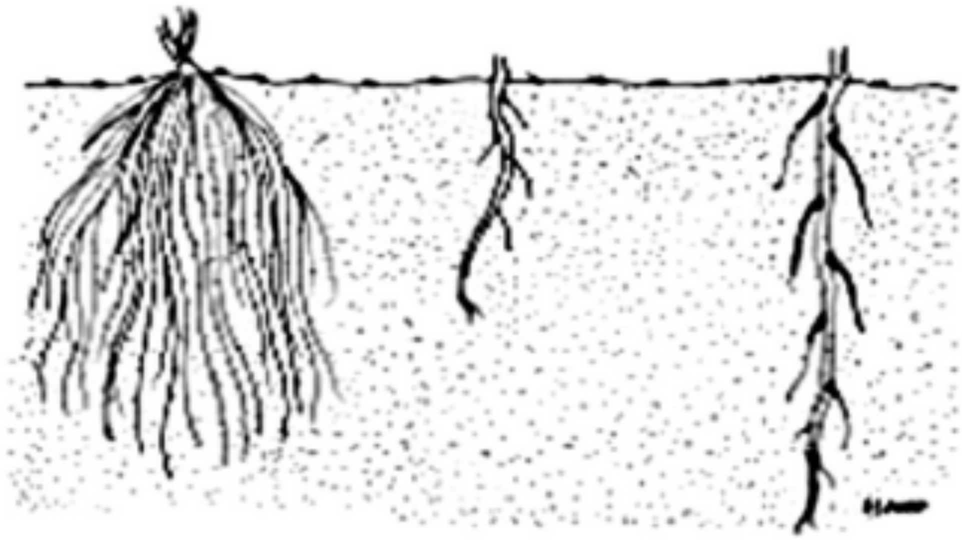


Figure 15 Illustration of differing root systems vis-à-vis differing crops.

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Question 4

Will my selection improve soil fertility? Legumes improve the soil fertility by fixing nitrogen from the air. They use part of it for their own needs, and leave the rest in the soil. Cereals and other plants can use this nitrogen if they are intercropped with the legume, or if they are grown as the next crop in the rotation.

Question 5

Will my selection cover the soil well? Tall cereals do not cover the soil well because they have upright leaves and they are planted far apart. Short grasses (Brachiaria, Cenchrus, Andropogon) and many legumes (lablab, groundnut, cowpea, beans) cover the ground very quickly after they are planted. When their main use is indeed to provide cover, we call them cover crops. If their main use is to provide food, we call them food legumes (beans, groundnuts).

Question 6

Will my selection grow well with other crops? Try to find combinations of crops that complement each other well (see Table 5). For example, cereals grow well with legumes (either food legumes or cover crops): the cereals benefit from the nitrogen fixed by the legume. Two different legumes or two different cereals do not usually work well together.

Table 5 Companion planting for crop rotation and mixed crop agro-ecological farming[16]

Family	Good companions	Bad companions
Asparagus	Tomato, Parsley, Basil	Unknown
Beans	Most Vegetable And Herbs	Onion, Garlic, Gladiolus
Beans, Bush	Potatoes, Cucumber, Corn, Strawberry, Celery, Summer Savory	Onion
Beans, Pole	Corn, Summer Savory, Celery	Onion, Beets, Kohlrabi, Sunflower
Beets	Cabbage And Onion Families, Lettuce	Pole Beans
Cabbage Family	Aromatic Herbs, Celery, Beets, Onion Family, Chamomile, Spinach, Chard	Dill, Strawberry, Pole Beans, Tomatoes
Carrots	Peas, Lettuce, Rosemary, Onion Family, Sage, Tomato, Leeks	Dill
Celery	Onion And Cabbage Families, Tomato, Bush Beans, Nasturtium, Leeks	Unknown
Corn	Potatoes, Beans, Peas, Cucumber, Pumpkin, Squash	Tomatoes
Cucumber	Beans, Corn, Peas, Sunflower, Radish	Potatoes And Aromatic Herbs
Eggplant	Beans, Marigolds	Unknown
Ginger	Chili Pepper, Cilantro, Lemon Grass	Unknown
Leeks	Onions, Celery And Carrots	Unknown
Lettuce	Carrots, Radish, Strawberry, Cucumber, Onions	Unknown
Onion Family	Beets, Carrots, Lettuce, Cabbage Family, Summer Savory, Leeks	Beans And Peas
Parsley	Tomato And Asparagus	Unknown
Peas	Carrots, Radish, Turnip, Cucumber, Corn, Beans	Onion Family, Gladiolus, Potatoes

[16] Kuepper G. and Dodson M. 2001. Companion planting: basic concepts & resources. Horticultural technical notes from the Appropriate Technology Transfer for Rural Areas (ATTRA). National Center for Appropriate Technology (NCAT).

Table 5 Cont'

Family	Good companions	Bad companions
Potatoes	Beans, Corn, Cabbage Family, Marigolds, Horseradish	Pumpkin, Squash, Tomato, Cucumber, Sunflower
Pumpkin	Corn, Marigold	Potato
Radish	Peas, Nasturtium, Lettuce, Cucumber	Hyssop
Saffron	Lettuce, Cucumber, Radish	Unknown
Spinach	Strawberry, Faba Beans	Unknown
Squash	Nasturtium, Corn, Marigold	Potatoes
Strawberry	Bush Beans, Spinach, Lettuce, Onion Family	Cabbage
Sunflower	Cucumber	Potatoes
Tomato	Onion Family, Nasturtium, Marigold, Asparagus, Carrot, Parsley, Cucumber	Potatoes, Fennel, Cabbage Family
Turnip	Peas	Potatoes

Basic 5-step crop rotation process

What crops should you plant next season or next year, and the year after that will depend on many factors. Outlined is a basic crop rotation system for smallholder farmers.

Market Check

Crops produce many different things: food, fodder, firewood, fence poles, thatch and medicines. Farmers grow some crops (such as cotton) only for cash. For other crops, such as cereals or vegetables, you may be able to sell what you do not use yourself. If your objective is marketing, make sure that there is a market for your main output or rotation crop.

Family Check

Knowing the family name where your crops belong to helps you to decide what to plant on the next cropping season, by planting a crop that belongs to a different family to the previous one. Table 6 provides various crop families and their common names.

Companion Check

Try to find combinations of crops that complement each other well (see Table 5).

Table 6 Cash and food crop scientific family and common names.

Family	Common Names
Allium	Chive, Garlic, Leek, Onion, Shallot
Cucurbit (Gourd Family)	Bitter Gourd, Bottle Gourd, Chayote, Cucumber, Ivy Gourd, Luffa Gourd, Melons Pumpkins, Snake Gourd, Squash, Wax Gourd
Crucifer (Brassica)	Bok Choy (Petchay), Broccoli, Brussels Sprouts, Cabbage, Chinese Cabbage, Cauliflower, Collard, Kale, Kohlrabi, Mustard, Radish, Turnip, Watercress
Legume	Common Beans, Black Bean, Broad Bean (Faba), Clover, Cowpea, Garbanzo, Hyacinth Bean, Kidney Bean, Lima Bean, Lintel, Mung Bean, Peanut, Pigeon Pea, Pinto Bean, Runner Bean, Snap Pea, Snow Pea, Soybean, String Bean, White Bean
Aster	Lettuce, Artichoke
Solanaceous (Nightshade Family)	Potato, Tomato, Pepper, Eggplant
Grains And Cereals	Corn, Rice, Sorghum, Wheat, Oat, Barley, Millet
Carrot Family	Carrot, Celery, Dill, Parsnip, Parsley
Root Crops	Cassava, Sweet Potato, Taro, Yam, Water Chestnut
Mallow Family	Cotton, Okra

Root & Nutrient Demand Check

Consider plant root types. For example, rotating two crops with shallow roots may not work well because the first crop has depleted the available nutrient in that soil layer – the topsoil. However, following a shallow rooted crop with a deep rooting crop will allow the crop to access available nutrients, and allow for the recover of the top layer of soil.

6 Question Check

After outlining your crop rotation plan, review/ assess your plan one more time. Use the 'Crop rotation selection – 6 questions to answer' to aid the assessment.

Extra Crop Rotation Advice: Tomatoes, potatoes, peppers, and eggplants:

- Grow tomatoes AFTER peas, lettuce, or spinach, because tomatoes need a considerable amount of nutrients;
- Grow lettuce BEFORE potatoes, because it is a light feeder and an aboveground crop;
- Grow legume cover crops BEFORE potatoes or corn, so that they can feed the crops;
- Grow potatoes BEFORE crops that are poor competitors, because potato production involves aggressive cultivation and further working of the soil during harvest, both of which reduce weed pressure;
- AVOID growing potatoes before corn, because both are heavy feeders;
- BE CAUTIOUS when growing bell pepper before another vegetable crop, because of diseases; and
- AVOID planting potatoes after corn, because of wireworm problems.

4.2 Intercropping

Intercropping refers to the practice of growing two or more crops in close proximity. For example: growing two or more cash crops together, growing a cash crop with a cover crop, or other non-cash crop that provide benefits to the primary crop. This practice requires additional management to keep competition between intercropped species in balance. When two or more crops are growing together, *each must have adequate space to maximize cooperation and minimize competition between them.* This can be accomplished by 1) ensuring selected crops are good companions, 2) ensuring cops are rotated properly, and 3) establishing a spatial arrangement that is favorable.

Intercropping spatial arrangements

Row Intercropping

Growing two or more crops at the same time with at least one crop planted in rows. This can be beneficial in situations when using tall crops to reduce drought or heat stress of shorter crops by providing shade and reducing wind speed (see Figure 15).

Figure 15 Row intercropping with alternate rows of maize and beans (left) and row intercropping with alternate rows of cereal and grass cover crop (right).

Relay Intercropping

Planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting (e.g. transplanting lettuce next to tomatoes plants). The lettuce will use the space that is not yet occupied by the tomatoes and is harvested about the time the tomatoes are branching out to cover the width of the bed.

Mixed Intercropping

Growing two or more crops together in no distinct row arrangement (for further details of possible combinations see Table 5 & 6). Some crops may also be sown as a border crop or as a trap crops at the hedges of the main crop to reduce pests. Pest arriving in the field from the edges encounters the trap crop (which is strongly preferred than the main crop) and stops. The trap crop may be sprayed with natural insecticide to control the pest, before it moves to the main crop (see Figure 16).

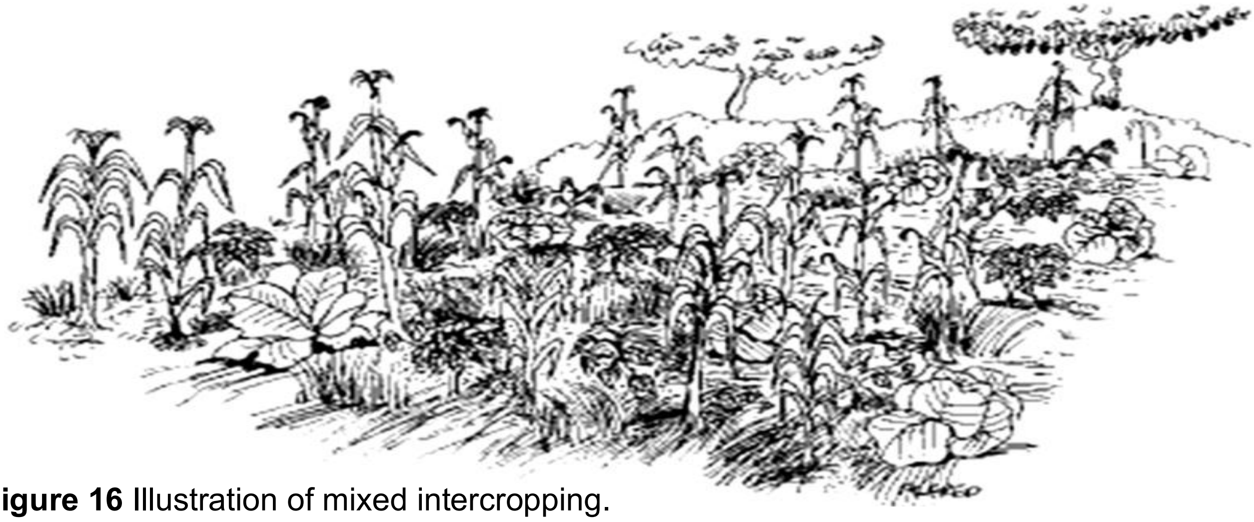

Figure 16 Illustration of mixed intercropping.

Strip Intercropping

Growing two or more crops together in strips wide enough to permit separate crop production using machines but close enough for the crops to interact. For example, intercropping beans and maize. Legumes have a nitrogen-fixing bacteria associated with their roots. Consequently they compete slightly with non-legumes for nutrients, and in some cases even supply nitrogen to adjacent plants (see Figure 17).

Figure 17 Illustration of strip intercropping.

A crop mixture with different **growth forms or development** may make cultivation and use of mulches more difficult and less effective. Therefore planting crops in alternate rows greatly simplifies management. Intercropping may also present a problem for crop rotation, e.g. the separation of plant families in time. Replanting two families mixed in the same field may be difficult.

4.3 Cover crops

Every plant that covers the soil and improves soil fertility can be a cover crop. It could be a leguminous plant with other beneficial effects, or it could be a weed characterized by its rapid growth and enormous production of biomass. The most important property of cover crops is that they are fast growing and have the capacity to cover the soil.

The ideal cover crop

- ☑ The seeds are cheap, easy to get, to harvest, to store and to propagate;
- ☑ Grow fast, and able to cover the soil in a short time;
- ☑ Resistant to pests and diseases;
- ☑ Produce large amounts of organic matter and dry material;
- ☑ Fix nitrogen from the air and provide it to the soil;
- ☑ Have a de-compacting root system and can regenerate degraded soils;
- ☑ Easy to sow and manage as single crop or is association with other crops; and
- ☑ Can be used as fodder, and grains as food.

AND

- ☑ Can or has a market demands;
- ☑ Supplies enough fodder for farm animals;
- ☑ Maintains soil fertility;
- ☑ Is well adapted to local climate and soil conditions;
- ☑ Uses the climatic growing conditions of different seasons in the best possible way;
- ☑ Avoids a build up of soil born pests and diseases; and
- ☑ Effectively suppresses weeds.

Cowpea as a Cover Crop

Cowpea (*Vigna unguiculata*, French: Niébé) is an important grain legume throughout the tropics and subtropics. It has some properties which make it an ideal cover crop:

- It is drought tolerant and can grow with very little water;
- It can fix nitrogen and grows even in very poor soils;
- It is shade-tolerant and therefore compatible as an intercrop;
- It yields eatable grains and can be used as an animal fodder rich in protein; and
- It is quite resistant to pest attack.

Other legumes used as cover crops are alfalfa (*Medicago sativa*), crimson clover (*Trifolium incarnatum*), Faba beans (*Vicia faba*) and hairy vetch (*Vicia vellosa*).

Cover crops are an integral part of a sustainable vegetable system. Besides building soil fertility and suppressing weeds, they can affect a farm's insect community. Attention to the effects of cover crops on insect populations can result in improvements in insect management.

CAUTION: Manipulation of cover crops for insect pest control is a complicated proposition. It is never as simple as attracting beneficial insects and repelling pest insects. A given cover crop can be attractive to either pest insects or their predators for several reasons. Many cover crops provide a supplemental food source to insects in the form of nectar from their flowers. Cover crops can also provide shelter for insects. Insects that obtain food or shelter from a cover crop can in turn act as a supplemental food source to predatory insects. Thus, insect interactions with cover crops can result in either positive or negative effects on the crop plant.

Positive cover crop–insect interactions

- ✓ Cover crops are more attractive to pests than cash crops; and
- ✓ Cover crops make cash crops more difficult to locate and cover crops are attractive to predators of insect pests.

Negative cover crop–insect interactions

- × Cover crops provide habitat or food source for pest insect at a time when cash crop cannot support pest population; and
- × Cover crops attract predator insects away from cash crop.

A cover crop that attracts pest insects away from a cash crop can cause a disaster if mowed or plowed at the wrong time. This can cause the pests living in that field to be released into a neighboring crop field. Not mowing can be just as disastrous if the cover crop flowers and then seeds. Hence, always cut cover crops before they seed.

In spite of the complicating factors, some general strategies can be recommended. The simplest strategy is to provide a diverse array of vegetation so that the habitat for insects is as varied as possible. This can include selecting a set of cover and cash crops so that something is always flowering on the farm. Using more than one type of cover crop is a good way to increase diversity. Another strategy is to plan cover crops so that they flower sequentially. Table 7 lists beneficial and pest insects that are attracted to or harbored by common cover crop types.

Table 7 Insects attracted to common cover crop species.

Cover Crop	Beneficial Insects	Pest Insects
Buckwheat	Extra floral nectaries attract parasitic wasps; ladybugs; tachinid and hover flies; and lacewings	Tarnished plant bugs and aphids
Clovers	Parasitic wasps, big-eyed bugs, minute pirate bugs; ladybugs; tachinid flies and aphid midges	Spider mites and flower thrips
Hairy vetch	Minute pirate bugs; ladybugs; predatory and parasitic wasps	Tarnished plant bugs
Cereals	Ladybugs	Aphids

Insect Associations

Insect associations with cover crop plants provide yet another opportunity for a grower to manage pests through careful observation and attention to the details of pest populations. The simplest strategy is to plant cover crops that favor more beneficial insects than pest insects. More complicated schemes put specific cover crops next to cash crops that are benefitted by their insect associates. A high diversity of cover crop species can also help assure that there is habitat for predatory insects at all times.

4.4 System of Rice Intensification[17]

The System of Rice Intensification, known as SRI, is a set of farming practices developed to increase the productivity of land and water, as well as other resources. SRI is based on the principle of developing healthy, large and deep root systems that can better resist drought, water logging and wind damage. It consists of six key elements to better manage inputs, utilize new ways to transplant seedlings, and to manage water and fertilizer application. Reports from thousands of SRI farmers and practitioners around the world indicate that SRI plants develop stronger roots and stalks, and more tillers, with higher yields and even better flavor qualities.

The SRI process

1 Seedlings get transplanted at a much younger age.

2 Only single seedlings, instead of a handful of seedlings get planted in each hill.

3 Plants are spaced wider apart, and in a square pattern, e.g. 12 inches X 12 inches.

4 Intermittent water application to create wet and dry soil conditions, instead of continuous flood irrigation.

5 Rotary weeding to control weeds and promote soil aeration.

6 Increased use of organic fertilizer to enhance soil fertility.

[17] Adapted from: SRI Achieving More with Less – A New Way of Rice Cultivation. World Bank Institute, Water Program. Washington, DC, USA.

4.5 Agro-ecological weed management[18]

Agro-ecological weed management promotes weed suppression, rather than weed elimination by enhancing crop competition and phytotoxic effects on weeds. Farmers integrate cultural, biological, mechanical, physical and chemical tactics to manage weeds without synthetic herbicides. Standard practices require rotation of annual crops, meaning that a single crop cannot be grown in the same location without a different, intervening crop. Crop rotations frequently include weed-suppressive cover crops and crops with dissimilar life cycles to discourage weeds associated with a particular crop.

Farm Management Practices that Contribute to Weed Problems

- Poor soil management, i.e. improper management of soil fertility;
- Excessive use of soluble N and P fertilizers. Fertilizers like urea 64-0-0 provides nitrogen in a highly available form that can be easily and rapidly taken up by weeds (even before the crop has had a chance to use it);
- Excessive use of manures; and
- Poor crop rotations using crops with similar seasonal growth patterns that have similar weed species associated with them.

Common Mechanical and Physical Weed Control Practices

- ✓ Tillage - Turning the soil between crops to incorporate crop residues and soil amendments; remove existing weed growth and prepare a seedbed for planting; turning soil after seeding to kill weeds, including cultivation of row crops;
- ✓ Mowing and cutting - Removing top growth of weeds;
- ✓ Flame weeding and thermal weeding - Using heat to kill weeds;
- ✓ Mulching - Blocking weed emergence with organic materials, plastic films, or landscape fabric; and
- ✓ Grazing - Weeds can be controlled by grazing. For example, geese have been used successfully to weed a range of crops including cotton, strawberries, tobacco, and corn. Similarly, some rice farmers introduce ducks and fish to wet paddy fields to eat both weeds and insects.

4 Soil cultivation strategies to control WEEDS when planting crops[19]

Strategy 1
Spring Tillage

Spring tillage is done prior to planting. If a number of spring tillage operations are planned, the first should be the deepest (6-8 inches) with each successive till shallower (3 inches). The first operation should be to aerate and warm the soil. The following tills should destroy weed growth while conserving as much moisture as possible. The loss of soil moisture due to tillage can be a critical problem, hindering successful crop establishment. It is important to balance the loss of soil moisture with weed control benefits of spring cultivation.

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[18] [18] FAO 2015 Training manual for Organic Agriculture. Climate, Energy and Tenure Division (NRC) and the Technologies and practices for smallholder farmers (TECA) Team from the Research and Extension Division (DDNR) of FAO Headquarters in Rome, Italy.

[19] Source: http://www.reap-canada.com/online_library/IntDev/id_china/19j%20Weed%20Control%20(English).pdf (retrieved July 15 2016)

Strategy 2
False Seedbed

The false seedbed technique is an effective technique to control weeds by fooling the early weeds to grow early, i.e. creating a false seedbed but then not planting it. After 5-7 days the soil should be shallowly tilled (3 inches maximum) to destroy the first generation of weeds. Seeds can then be planted. This technique can reduce weed pressure by 50%

Strategy 3
Blind Harrowing

Blind harrowing is a commonly used method to control weed in cereal and grain legume crops like peas. A diamond tooth harrow of flexible tine can be dragged over the crop just prior to the crop emerging (or at emergence). Usually this is about 5 days after planting.

Strategy 4
Summer Tillage

Summer tillage should be as shallow as possible to avoid bringing new weeds to the surface. The initial till should be the deepest (3 inches maximum) with each till after progressively shallower. Tillage is most effective when the soil surface is dry, air temperature is high and the sun is shining. Summer tillage can be most effective against hard to control perennial grass weeds and thistles.

Soil cultivation strategies to control WEEDS during cultivation[20]

☑ Remove weeds from your tillage devices between fields;
☑ Pay special attention to problem weed patches to make sure they don't spread;
☑ Control weeds with hoeing at a very early stage - it is much easier and prevents weed problems later;
☑ Prevent weed reproduction after harvest by clipping weeds or through tillage;
☑ Practice tillage following harvests. This is effective at destroying weeds that set seed after harvest, preventing winter annual weeds from establishing and helping to control perennial weeds. Tillage for control of annual weeds should be shallow (less then 4 inches) to avoid burying weeds in the soil. Let the seeds stay near the surface where then can germinate and die, or be eaten by earthworms and ground feeding insects; and
☑ Plant in straight rows so you can hoe/ till more precisely near the row to avoid so much labor of hand pulling weeds; and
☑ When weeds are small, surface scratch the soil with a stirrup hoe as it takes little effort to remove them.

[20] Source: http://www.reap-canada.com/online_library/IntDev/id_china/19j%20Weed%20Control%20(English).pdf (retrieved July 15 2016)

4.6 Agro-ecological pest & disease management

A healthy plant is less vulnerable to pest and disease infestation. Therefore, a major aim for an agro-ecological farmer is to create conditions that keep a plant healthy. The interaction between living organisms and their environment is crucial for a plant‘s health. In favorable conditions, the plants own protection mechanisms to fight infections are sufficient. This is why a well-managed ecosystem can be a successful way of reducing the level of pest or disease problems.

The health condition of a plant depends to a large extend on the fertility of the soil. When nutrition is well balanced, the plant becomes stronger and is therefore less vulnerable to infection. Climatic conditions, such as suitable temperatures and sufficient water supply, are further factors crucial for growing healthy plants. If one of these conditions is not suitable, the plants can become stressed. Stress weakens the defense mechanisms of plants and makes them easy targets for pests and diseases.

Pest and disease management consists of a range of activities that support each other. Most management practices are long-term activities. *Management* focuses on keeping existing pest populations and diseases low. *Control* on the other hand is a short-term activity and focuses on killing pests and diseases. The general approach in agro-ecological farming is to deal with the causes of a problem rather than treating the symptoms. This also applies to pest and disease management, i.e. management is of a higher priority than control.

Typical signs of PEST attacks on crop plants

Pest Damage

Pest damage is often species-specific: leaves with holes or missing parts is an indication of caterpillar or weevil damage; curled leaves is an indication of aphids; damaged or rotten fruits are often caused by larvae of fruit flies; withering plants can also be caused by larvae of noctuids or the stem borer; and branches or trunks with holes may be an attack by lignivorous insects.

Mite Damage

Mites are very small and cannot be seen with the naked eye. However, some mite species (spider mites) weave a typical tissue on attacked plant parts and can, therefore, easily be detected. If mites are present on plants, leaves and fruits become yellowish.

Nematode Damage

Nematodes are also very small and therefore, they are not easy to observe with the naked eye. They mostly attack plant roots; plants become yellow, wither and die.

Promoting and managing natural enemies of PESTS

The natural enemies of pests are other organisms (fungi, bacteria, viruses, insect predators, and insect parasitoids) that kill pest. Therefore, the agro-ecological farmer should try to conserve natural enemies already present in the crop environment and enhance their impact. This can be achieved with the following methods:

- ✓ Minimizing the application of natural pesticides (chemical pesticides should be avoided);
- ✓ Allowing some pests to live in the field that will serve as food or host for natural enemies;
- ✓ Establishing a diverse cropping system (e.g. mixed cropping); and
- ✓ Include host plants providing food or shelter for natural enemies (e.g. flowers which beneficial insects feed on).

There are many possibilities to enhance floral diversity within and along the boundaries of crop fields:

- ✓ **Hedges** - Use indigenous shrubs known to attract pest predators and parasitoids by offering nectar, pollen, alternative hosts and/or preys. Most flowering shrub species have this property. However, care should be taken to not use plant species known to be alternative hosts (a second home) to pests or diseases.

- ✓ **Beetle banks** - Strips of grass in the neighborhood of crop fields harbor different natural pest enemy groups like carabids, staphylinid beetles and spiders. In order to lower the risk of weeds and plants known as host plants of crop pests and diseases, one to three native grass species can be sown in strips of 3 to 9 feet.

- ✓ **Flower strips** - Use indigenous flowering plant species known to attract predators and parasitoids by offering nectar, pollen, alternative hosts and/or preys. Most flowering plant species have this property. However, care should be taken to not use plant species known to be alternative hosts (a second home) to pests or diseases. Three to five native flowering plant species can be sown in well-prepared seed beds, arranged in strips of 3 to 9 feet on the boundary of the crop field.

- ✓ **Companion plants** - companion plants within a crop can also attract natural pest enemies. Companion plant species can be the same as used in the flower strips. A few (1 or 2 per 100 feet square) flowering companion plants within a crop serve as a 'service station' for natural pest enemies.

Mechanical control of PESTS

Mass trapping of pests is an additional control measure. They often can easily be built with cheap material. Some examples include:

Light Traps

Light traps can be used to catch moths such as armyworms, cutworms, stem borers and other night flying insects. Light traps are more efficient when placed soon after the adult moths start to emerge but before they start laying eggs. However, light traps have the disadvantage of attracting a wide range of insect species. Many insects that are attracted to the area around the light traps (sometimes from considerable distances) do not actually fly into the trap. Instead, they remain nearby, actually increasing the total number of insects in the immediate area.

Colored Sticky & Water Traps

Colored sticky traps can be used to monitor adult thrips. In some cases thrips can even be reduced by mass trapping with colored (blue, yellow or white) sticky traps in the nursery or field. The color spectrum of the boards is important for the efficacy of the sticky traps. Bright colors attract more thrips than darker ones. Sticky traps with cylindrical surfaces are more efficient that flat surfaces. They are best-placed 4 feet above crop level. Traps should not be placed near the borders of fields or near shelterbelts.

Water traps should be at least 2 inches deep with a surface area of 10 to 20 inches square, and preferably round, with the water level about 1 inch below the rim. A few drops of detergent added to the water ensure that thrips sink and do not drift to the edges and escape. Replace or add water regularly.

Yellow Sticky Traps

Yellow sticky traps can be used to control whiteflies, aphids and leaf mining flies. Yellow plastic gallon containers mounted upside down on sticks coated with transparent car grease or used motor oil, is one such trap. These should be placed in and around the field at about 4 inches above the foliage. Clean and re-oil when traps are covered with flies. Yellow sticky boards have a similar effect. To use, place 2 to 5 yellow sticky cards per 5000 feet square of field area. Replace traps at least once a week. To make your own sticky trap, spread petroleum jelly or used motor oil on yellow painted plywood (size 12 inches X 12 inches). Place traps near the plants, but far enough away to prevent the leaves from sticking to the board. Note that the yellow color attracts many insects including beneficial insects - so use yellow traps only when necessary.

Fruit Bagging

Fruit bagging prevents fruit flies from laying eggs on the fruits. In addition, the bag provides physical protection from mechanical injuries (scars and scratches). Although laborious, it is cheap, safe and gives a more reliable estimate of the projected harvest. Bagging works well with melon, bitter gourd, mango, guava, star fruit, avocado and banana.

Recommendations to Farmers Regarding Fruit Bagging

Cut old newspapers to fruit size and double the layers, as single layers break apart easily. Fold and sew or staple the sides and bottom of the sheets to make a rectangular bag. Blow in the bag to inflate it. Insert one fruit per bag then close the bag and firmly tie the top end of the bag with string, wire and plant fiber. Push the bottom of the bag upwards to prevent fruit from touching the bag. For example, start bagging the mango fruit 55 to 60 days from flower bloom or when the fruits are about the size of a chicken egg. When using plastic bags (e.g. with bananas), open the bottom or cut a few small holes to allow moisture to dry up. Moisture trapped in the plastic bags damages and/or promotes fungal and bacterial growth that causes diseased fruits. Plastic also overheats the fruit. Bags made of dried plant leaves are good alternatives to plastic.

Agniastra

Agniastra's main ingredient is cow urine and is used for preparing organic mixtures and pest control solutions. Other natural herbs used in this are tobacco leaves, garlic, pepper, jaggery, green chili and water (see Figure 19). This natural pesticide can be applied on vegetables, fruits, flowers and other agricultural crops. It is effective on leaf rollers, stem borers, fruit borers and pod borers. Agniastra also acts as manure for soils and plants, removes all kinds of pests and insects, and improves the richness of the soil and greenery of the plant. Yield increases are also associated with its application.

Figure 19 Agniastra ingredients

Agniastra materials

- 10 liters cow urine;
- 1kg. crushed tobacco leaves;
- 500g. green chili;
- 500g. garlic; and
- 5kg. neem leaves pulp.

Agniastra procedure

- Make a thick paste of all the ingredients and mix it thoroughly with cow urine;
- Heat the contents and allow it to boil 5 times (boil – cool – boil – cool etc.);
- Leave the mixture to ferment for 24 hours; and
- Extra the liquid by filtering the contents through a cloth into a container and let sit for 21 days before use.

Agniastra application

Agniastra needs at least 21 days to be prepared and it should be used once every 4 days for the 1st and 2nd applications, and once in a week for subsequent applications. The best time for application is either in the early morning or evening hours. 1 liter of Agniastra can be mixed with 50 liters of water and can be sprayed directly on the crops.

Neemastra

Neemastra is effective on removing pests and mealy bugs (Figure 20).

Neemastra materials

- 100 liters water;
- 5 liters Desi cow urine;
- 5Kg. Desi cow dung; and
- 5kg. crushed neem leaves.

Neemastra procedure

- Add cow urine to 100 liters of water;
- To this liquid mixture, add 5kg. of cow dung and crushed neem leaves and its pulp;
- Let the solution ferment for 24hours;
- Stir the solution twice in a day with a stick; and
- Extra the liquid by filtering the contents through a cloth into a container.

Figure 20 Neemastra materials & ingredients.

Neemastra application

Mix 2 liters of the Neemastra with 100 liters of water and spray on the crops. It should be used once every 4 days for the 1st and 2nd applications, and once in a week for subsequent applications.

Typical signs of DISEASE attacks on crop plants

Fungal Diseases

Fungi cause the great majority, estimated at two-thirds, of infectious plant diseases. They include all white and true rusts, smuts, needle casts, leaf curls, mildew, sooty molds and anthracnose. In addition, they are responsible for most leaf, fruit, and flower spots, cankers, blights, wilts, scabs, and root, stem, fruit, wood rots among many others. Parts of plants or the total crop plant can wither and die.

Bacterial Diseases

Bacteria cause any of the four following main problems. Some bacteria produce enzymes that breakdown the cell walls of plants anywhere in the plant. This causes parts of the plant to start rotting (known as ‘rot’). Some bacteria produce toxins that are generally damaging to plant tissues, usually causing early death of the plant. Others produce large amounts of very sticky sugars; as they travel through the plant, they block the narrow channels preventing water getting from the plant roots up to the shoots and leaves, again causing rapid death of the plant. Finally, other bacteria produce proteins that mimic plant hormones. These lead to overgrowth of plant tissue and form tumors.

Viruses

Viruses mostly cause systemic diseases. Generally, leaves show chlorosis or change in color of leaves and other green parts. Light green or yellow patches of various shades, shapes and sizes appear in affected leaves. These patches may form characteristic mosaic patterns, resulting in general reduction in growth and vigor of the plant.

Reducing the presence of infectious pathogens on farms

Mitigation 1
Crop Rotation

Practicing crop rotation is one of the easiest ways to manage soil and crop residue borne diseases, i.e. it cuts off the food source of the disease causing organisms by diversifying and planting unrelated crops. If this is done, the number of disease organisms will decline rapidly. Some pathogens, e.g. Sclerotinia, can live for longer periods (3-4 years); therefore some diseases will need longer rotation periods to prevent them from reoccurring. As a general rule, it is good to alternate a grass crop (wheat, millet, oats, corn) with broadleaf crops (peas, potatoes, buckwheat, lentils, mustard, flax). This however does not apply in every case. A nitrogen fixing and low water using pea crop can make a good prior crop to potatoes if the pea field is free of diseases.

Mitigation 2
Use Clean Seed & Tubers

Always use clean seed and tubers. Many pathogens are seed-borne, thus, it is important to save your own seed or tubers from healthy disease free fields that are managed under a good crop rotation. For potatoes, it is best if you buy first class seed and multiply it up on clean fields for larger field plantings the next year. Pull out any diseased plants from areas where you are saving tubers. Many hybrid seeds cannot be produced by farmers themselves. When buying tubers or seeds, you must make sure that the seeds come from a reliable supplier, such as big seed companies and research institutes. Soaking seeds in compost tea can help suppress some diseases. Compost tea is made by putting compost in a barrel and adding water.

Mitigation 3
Use Composted Manure

Use composted manure only on fields. The composting process kills diseases found in manure. Composting also encourages higher populations of soil microorganisms that compete with or destroy soil pathogens. Some farmers even spray teas made from compost on their crop leaves to establish populations of beneficial microorganisms. These prevent disease causing microorganisms from getting established on the leaf surfaces and adding nutrients directly to the leaves. Compost can therefore work both in the soil and on the plant to prevent diseases! The best disease suppression results using compost occur when it is at least 4 months old and applied to the field several months before planting.

Mitigation 4
Use Green Manures

Green manures also increase soil microbial activity and create a healthy soil environment. The soil's capacity to suppress disease is typically related to the total level of microbial activity, so use green manure where possible.

Practices to make field environments less conducive to diseases

- **Create a healthy soil environment for the crop.** When plants grow in productive and fertile soils they have an enhanced ability to ward off plant diseases. Soils with good aeration and drainage are especially important to prevent root diseases.

- **Avoid dense crop canopies.** Seeding crops too thickly or applying excessive rates of nitrogen fertilizer makes lush canopies that can create conditions for diseases to flourish. A dense canopy creates greater leaf surface area for pathogens to become established on, and can make for wetter canopy and surface soil conditions.

- **Increase air circulation.** Plant crops in an east-west direction if you have the option; this allows for better air circulation and sunlight penetration into the canopy. Some disease susceptible crops can also be planted in wider rows. Fruit trees can be heavily pruned to promote air circulation.

- **Develop diversity in the field.** Having less canopy of any one crop in a field helps prevent the spread of disease. The use of strip cropping and development of multiple cropping systems with mixed seedlings can be quite helpful in this regard. Planting field buffer areas with plants and trees that attract beneficial insects and birds that can help control disease transmitting insect pests.

Controlling other ORGANISMS

Organisms aside from weeds that cause problems on farms include arthropods (e.g., insects, mites), nematodes, fungi and bacteria. Agro-ecological practices for managing these include, but are not limited to:

- ✓ Encouraging predatory beneficial insects to control pests by serving them nursery plants and/or an alternative habitat, usually in a form of a shelterbelt, hedgerow, or beetle bank;
- ✓ Encouraging beneficial microorganisms;
- ✓ Rotating crops to different locations from year to year to interrupt pest reproduction cycles;
- ✓ Planting companion crops and pest-repelling plants that discourage or divert pests;
- ✓ Using row covers to protect crops during pest migration periods;
- ✓ Using biologic pesticides and herbicides;
- ✓ Using insect traps to monitor and control insect populations; and
- ✓ Using physical barriers, such as row covers.

Examples of predatory beneficial insects include minute pirate bugs, big-eyed bugs, and to a lesser extent, ladybugs (which tend to fly away), all of which eat a wide range of pests. Lacewings are also effective, but tend to fly away. Praying mantis tend to move more slowly and eat less heavily.

Naturally derived insecticides allowed for use on organic farms use include *Bacillus thuringiensis* (a bacterial toxin), pyrethrum (a chrysanthemum extract), spinosad (a bacterial metabolite), neem (a tree extract) and rotenone (a legume root extract – but very toxic to fish populations).

Exercise: Placing agro-ecological farming practices in context

Objectives

- ✓ Provide BRiLSS project partners/ participants with an opportunity to take a first look into planning for the application of agro-ecological farming practices; and
- ✓ Provision of an interactive session review of key agro-ecological principle and practices.

Facilitation guide (2+ hours)

STEP 1

Worksheet S4.1 is provided to help organize the exercise. Introduce the exercise and it's purpose. Highlight that the objectives of the exercise is to take a first look into planning for the application of agro-ecological farming practices and to provide a basis for further discussion.

In groups, participants are to complete the worksheet. Encourage participants to use the session handouts as a source of information, as well as bring forward their own knowledge as relevant. Groups are to present their work for discussion. A key is provided below to the first row of questions.

Why practice minimum soil disturbance?

- Reduces destruction of the soil structure;
- Does not expose soil to wind and water erosion;
- Improves water infiltration rates;
- Slows the rate at which organic matter is mineralized and oxidized, so organic matter build-up occurs;
- Causes little disruption to the organisms that live in the soil;
- Saves time, energy, and money because less land is tilled; and
- Reduces soil compaction because the crop plant roots are left undisturbed.

Why practice permanent soil cover?

- Helps reduce direct raindrop impact and so reduces soil erosion;
- Helps reduce runoff and helps water to seep into the soil;
- Reduces evaporation and so conserves moisture for the crop;
- Suppresses weeds emergence;
- The organic residues improve organic matter content and soil nutrient status;
- Provides a beneficial environment for soil organisms, such as worms and millipedes, that are important for biological tillage;
- Moderates soil temperatures.

Why practice mixing and rotating crops?

- Replenishes soil fertility: intercropping with nitrogen-fixing legumes adds 'top-dressing fertilizer' to the soil;
- Enables crops to use the nutrients in the soil more effectively:
- Helps to control weeds, diseases and pests by breaking their life cycles through the introduction of a new crop;
- Reducing the risk of total crop failure in cases of drought and disease outbreaks.

WORKSHEET S4.1

Agro-ecological Farming Practices		
Why practice minimum soil disturbance?	Why practice permanent soil cover?	Why practice mixing and rotating crops?
•	•	•
How will I apply this ‘practice’ across BRiLSS project area sites?		
•	•	•
Do I need special resources? What would these be?		
•	•	•
What challenges will I encounter?		
•	•	•
What actions will I take to overcome the challenges?		
•	•	•

Preventative crop protection measures for pest & disease management

Measure 1

Selection of adapted and resistant varieties: Choose varieties that are well adapted to local environmental conditions (temperature, nutrient supply, pests and disease pressures etc.), as it allows them to grow healthy and makes them stronger against infections of pests and diseases.

Measure 2

Selection of clean seed and planting material: Use safe seeds that have been inspected for pathogens and weeds at all stages of production, and use planting material from safe sources.

Measure 3

Use suitable cropping systems:

- Mixed cropping can limit pest and disease pressure as the pest has less host plants to feed on and more beneficial insect life;
- Crop rotation reduces the chances of soil borne diseases and increases soil fertility; and
- Green manuring and cover crops increase the biological activity in the soil and can enhance the presence of beneficial organisms (but also of pests; therefore a careful selection of the proper species is needed).

Measure 4

Use of balanced nutrient management:

- Moderate fertilization because steady growth makes a plant less vulnerable to infection. Too much fertilization may result in salt damage to roots, opening the way for secondary infections; and
- Balanced potassium inputs as this contributes to the prevention of fungi and bacterial infections.

Measure 5

Input organic matter:

- Increases microorganism density and activity in the soil, and in turn this will help to decrease population densities of pathogenic and soil borne fungi; and
- Stabilize soil structure and improves aeration and infiltration of water.

Measure 6

Apply suitable soil cultivation methods:

- Facilitate the decomposition of infected plant parts;
- Regulate weeds that serve as hosts for pests and diseases; and
- Protect the microorganisms that regulate soil borne diseases.

Measure 7

Apply water management practices:

- Prevent water logging to limit stress on the plant – stress encourages pathogen infections; and
- Avoid water on the foliage, as water borne disease spread with droplets and fungal diseases germinate in water.

Measure 8

Conserve and promote natural enemies:

- Provide an ideal habitat for natural enemies to grow and reproduce; and
- Avoid using products that harm natural enemies.

Measure 9

Select optimum planting time and spacing:

- Most pests or diseases attack the plant only in a certain life stage, therefore it's crucial that this vulnerable life stage doesn't correspond with a period of high pest density;
- Ensure sufficient distances between the plants to reduce the spread of a disease; and
- Ensure good aeration of the plants to allow leaves to dry off faster, which hinders pathogen development and infection.

Measure 10

Use of proper sanitation measures:

- Remove infected plant parts (leaves, fruits) from the ground to prevent the disease from spreading; and
- Eliminate residues of infected plants after harvesting.

Challenges in transitioning to agro-ecological farming

Farms with High External Inputs

Farms with high external inputs rely strongly on external inputs, usually grow a few annual or perennial cash crops, and apply heavily commercial fertilizers, pesticides and herbicides. On such farms, crops are often grown without a planned rotation and farm animals are not integrated into the nutrient cycle. Diversification is usually low on these farms. Trees and bushes are mostly removed to facilitate extensive mechanization, and mono cropping is common.

Transition challenges

¬ Establishing a diverse and balanced farming system with a natural ability to regulate itself takes several years;
¬ Major efforts may be necessary to restore natural soil fertility by providing a considerable amount of organic matter to the soil; and
¬ Abandoning high input external fertilizers results in lower yields in the first years of conversion, i.e. before soil fertility is re-established and yields rise again.

Transition tips

¬ Diversify the farm: Select appropriate annual crops for the area and rotate them in a planned sequence. Include legume crops such as beans or leguminous feed crops in the rotation to provide nitrogen to the subsequent crops. Plant hedges and flower strips to encourage natural enemies and to control pests;
¬ Start recycling valuable farm by-products. Establish on-farm compost production based on harvest residues and manure, if available, and mix the compost with the topsoil. This will bring stable organic matter into the soil and improve its structure and its capacity to feed the plants and store water. Green manures can provide plenty of plant material to feed soil organisms and build up soil fertility;
¬ Introduce farm animals into the system. Farm animals provide valuable manure and diversify farm income through additional animal products; and
¬ Grow cover crops or lay out mulches in perennial crops provide protection to the soil.

Farms with Low External Inputs

Farmers working with little external inputs are often based on traditional practices and may grow many different crops in a densely mixed system on the same piece of land. A few livestock such as chickens, pigs, cattle and/or goats may be kept, which scatter the manure in their feeding places, hence providing very little manure for the gardens. The trees may be extensively cut for firewood and charcoal burning. Bush and trash burning may be a common practice especially during land preparation. Harvests are probably low and increasingly becoming difficult due to unreliable and insufficient rains. The harvests may just be sufficient for feeding the family and little may be left to sell for income.

Traditional farmers practice some principles of agro-ecological farming already, e.g. by relying on farm-own resources, growing different crops simultaneously and raising livestock. However, there are still practices, which clearly distinguish such farms from agro-ecological farms.

Potential challenges in transiting

- Establish a well-organized diversification systems including a ‘planned’ crop rotation and intercropping systems;
- Accumulating knowledge and practice regarding efficient use of farm owned resources, especially for compost production to manage and improve soil fertility;
- Avoiding indiscriminate tree cutting for firewood and charcoal burning;
- Establishing a system to collect animal manure for composting;
- Paying special attention to satisfy feed and health requirements of farm animals;
- Avoid seeds infected diseases; gain knowledge on disease cycles and preventive measures; and
- Avoiding harvest and storage losses.

Transition tips

- Avoid burning of crop residues after harvest, as this is in most cases not a viable solution since it destroys valuable organic material and damages soil organisms;
- Apply measures to prevent loss of soil through erosion, and protect it from drying out;
- Implement planned crop rotation and intercropping systems. A combination of annual and perennial crops including leguminous green manure cover crops is needed. Combined with properly selected or improved crop varieties with good resistance to plant pests and diseases, will facilitate the crop and soil management;
- Proper integration of animals into the farming system, as well as planting rows of nitrogen fixing trees between annual crops will improve the growing conditions for the crops and encourage better growth, while providing additional feed for the ruminant animals. Better housing is also needed to facilitate collection of animal manure for field use; and
- Improving the fertility of the soils, for example, through the application of high quality compost. Compost is a highly valuable fertilizer in organic farming. Instead of burning the crop residues after harvest, collect them for compost production, or work them into the soil. The animal manures and plant materials should be regularly collected for compost making.

SESSION 5: Seed selection and management

5

Objective

- ✓ Provide BRiLSS project partners with an overview of seed selection and management, e.g. importance of local varieties of seeds, and seed preparation, storage and treatment processes.

The session stresses the importance of traditional seed varieties and seed conservation. Moving forward through the session handouts, practical guidance to seed evaluation and selection, to seed preparation, storage and treatment techniques prior to planting are explained in detail. The session also allows for hands on demonstrations of the aforementioned. Overall, the session aims to provide BRiLSS project partners with a solid understanding of seed and seed management practices.

Session 5 Seed selection and management

Facilitation guide (3+ hours)

STEP 1

Introduce Handout S5.1 – S5.4 through an organized PowerPoint presentation, including the session objectives, content, and the process the facilitator will take to deliver the session. Emphasize the importance of all participants having a common understanding of the content in the context of the BRiLSS project.

STEP 2

Begin the session with Handout S5.1 – importance of traditional seed varieties and seed conservation. Note that seeds are a controversial topic, and that there are two waves of thinking:

- Agro-ecological methods and traditional farming, while often more resilient than conventional monocultures, have limits to the amount of food they can produce per unit of labor; and
- When locked into a low input farming system, particularly one that only produces low outputs, there is little chance of improving livelihoods and breaking the poverty cycle.

and;

- Seed biodiversity and the wealth of information and characteristics they contains is particularly important to global challenges, e.g. from food insecurity to climate change; and
- There are crops and crop varieties that can withstand extreme conditions – conditions that would decimate many of the commercialized crops.

Through discussion, ensure that participants understand that through agro-ecological farming practices, farmers can improve their resilience and adaptive capacity to global challenges, including poverty reduction.

STEP 3

Following by presenting the bullet points listed under 'seed resilience and adaptive capacity'. End by reviewing the three (3) forms of seeds: 1) hybrid seeds, 2) heirloom seeds (often referred to as open pollinated), and 3) GM seeds.

STEP 4

Move on to Handout S5.2 – seed evaluation and selection criteria. Present the four (4) parameters of seed quality.

STEP 5

Move on to Handout S5.3 – seed harvesting and processing. Note that there are two (2) ways of processing seeds, a dry and a wet method, depending on the origin of the seed. Note the following specifics for the dry seed process; 1) when to collect, and 2) how to harvest and store seeds going through the drying process and afterward.

Follow by presenting the three (3) step process for wet seed preparation, and the 'principles of seed drying'.

STEP 6

Move on to Handout S5.4 – seed storage and treatment. Note that the parameters important to seed storage are temperature, humidity, and seed moisture content. Present the handout content. Ensure the following points are clear to all participants:

- Short term storage of seeds: temperature (in degrees F), plus the relative humidity should not exceed a total of 100;
- Long term storage: temperature must not exceed 50°F, and humidity must not exceed 50%;
- Seed moisture has a greater effect on seed longevity than temperature;
- Above 13% seed moisture content, seed storage fungi and increased heating due to respiration cause seed longevity to dramatically decline; and
- Bacteria do not have a significant role in seed deterioration because free water is required for bacterial growth. If the moisture content of the seed is high enough to support bacteria, the seed is more likely to succumb to deterioration due to other causes such as fungi, respiration, heating or premature sprouting.

Ensure that participants know how to determine seed moisture content.

STEP 7

Discus packing materials and containers used for seed storage, then cover **seed treatment,** specifically the hot water treatment method. Use Table 8 to support learning. Ensure that participants understand that the treatment is applied prior to storage.

5.1 Importance of traditional seed varieties

Cycles of seed saving and the maintenance of agricultural biodiversity have been challenged by the introduction of higher-yielding hybrid seeds/ crops that can lose their vitality after the first season. Whereas, traditional seed varieties contain a wealth of information and traits, retain their vitality, and resilience vis-à-vis a variety of changing conditions. This is particularly important given global challenges of food insecurity to those related to climate change. There are crops and crop varieties that can withstand extremes that would decimate many of the crops we regularly eat. Pearl millet for example, a crop grown annually on more than 29 million hectares in the arid and semi-arid tropical regions of Asia, Africa and Latin America, can survive the most hot and hostile conditions. Thus conserving seed diversity in situ is imperative.

Seeds & Food Sovereignty

For many the concept of saving seeds is firmly entrenched in the ideals of food sovereignty, which is about the right of people to define their own food systems. Few would argue against increasing food production in developing countries and reducing huge amounts of food imports that can leave poor consumers at the mercy of volatile global food prices. At the extreme, food sovereignty espouses the restriction of all food trade and corporate involvement that raises a couple of issues:

- Agro-ecological methods and traditional farming, while often more resilient than conventional monocultures, have limits to the amount of food they can produce per unit of labor; and
- When locked into a low input farming system, particularly one that in turn only produces low outputs, there is little chance of improving livelihoods and breaking the poverty cycle.

Seed resilience and adaptive capacity

Traditional seeds are locally available because farmers collect good seeds from their own plots and keep them for the next season. The benefit of doing so are:

- ✓ Farmers either buy or exchange their seed with other farmers or grow their own seeds. Therefore the cost of seeds is minimal;
- ✓ Native seeds are geared to a subsistence economy as the farmers first grow food for their subsistence and/or stock seed for the next season and market the surplus;
- ✓ Native seeds embody indigenous knowledge. A farmer who uses native seeds use their traditional knowledge, skills and wisdom to grow them, thus, promoting self-reliance;
- ✓ An outstanding feature of native seeds is diversity;
- ✓ Native seeds are hardy, as they have over the years developed resistance to pests and diseases; and
- ✓ Traditional seeds have high levels of tolerance to conditions of stress and are adapted to local agro-climatic conditions.

Relevant characteristics of adaptation to local conditions are:

- **Length of the growth cycle:** This is critical for rain-fed crops in particular to enable them to mature while there is sufficient water in the soil for grain filling. When conditions are good, a late maturing (long-cycle) variety typically gives a higher yield than other varieties. However, in drought conditions, farmers may be interested in early-maturing (short-cycle) varieties that can be planted late in the season or harvested before the end of the season to reduce the risk of damage by drought;

- **Climate requirements:** Temperature and rain regimes, the amount of rainfall, risk of drought, solar radiation and day length should be taken into consideration;
- **Soil requirements:** Tolerance to acidity or salinity and the availability of water and nutrients must be considered; and
- **Resistance to damage by diseases, insects and other pests:** The ability of plants to live with these organisms without significant loss of yield and quality must be considered.

As a general rule, traditional varieties are well adapted to the local conditions of the area where they have grown and developed. However, they may not be adapted to other areas. Traditional and agro-ecological farmers recognize the differences among the traditional varieties they grow, and know which of them are suitable for planting at particular locations and times. With regard to improved varieties, some were developed to do well in particular zones, but in many cases breeding programmes aim at producing varieties with adaptation characteristics to a wide range of agro-ecological conditions. It is difficult to anticipate how a variety (either traditional or improved) will respond to a specific agro-ecological zone until it is actually grown there. Therefore, before recommending the use of a seed variety in a zone, it is important to obtain precise and comprehensive information on its adaptive characteristics, and if possible, the results of a variety trials over several years.

Need to Know

Hybrid seeds: These are seeds produced by artificially crossing two different inbred parent plants that makes a hybrid offspring that has good qualities like high yield, disease resistant, uniformity, color, fast maturity, etc. These are often marked as F1 (first generation) or hybrid seeds. You cannot save seeds from hybrid plants because they will not be the same as their parents. Many types of corn, squash, zucchini, broccoli, and cauliflower are hybrids.

Open pollinated or Heirloom seeds: These are seeds that come from plants that are bred over generations to be stable. You can save seeds from these plants because their offspring will be the same as the parents. Open pollinated seeds are often more variable in how they grow than hybrid seeds (day to maturity, yields, disease resistance). However, you can save the seeds from these plants, many have richer flavors than hybrid plants, they provide food security to farmers, and they increase the genetic diversity of the farm ecosystem.

GM seeds: These are seeds that have been genetically modified (GM) to include genetic material of other organisms. This material is inserted into the seed to give the plant a trait like disease or drought resistance quality. GM seeds have recently been developed and there is a big question on whether they are safe for the environment or for people to eat. Additionally, they must be purchased each year from a large corporation. These seeds are expensive and take away the food sovereignty rights of the farmer. You cannot save seeds from GM plants, in fact it is illegal to do so because the seeds have been patented as intellectual property.

5.2 Seed evaluation & selection criteria[1]

Quality seed is critical to agricultural production: poor seed limits the potential yield and reduces the productivity of the farmer's labor and other production inputs. There are four basic parameters for seed quality:

Quality 1
Physical

Good physical quality of the seed in a seed lot is characterized by the following:

- Minimal damage to seed. Damaged (broken, cracked or shriveled) seed may not germinate and is more likely to be attacked by insects or microorganisms. It is possible to eliminate most of the damaged seed during seed processing/ conditioning.
- A minimal amount of weed seed or inert matter. Good quality seed should be free of weed seeds (particularly noxious types), chaff, stones, dirt and seed of other crops. Almost all these impurities can be discarded during processing/conditioning.
- Minimal diseased seed. Discoloration and staining are symptoms of seed that may carry microorganisms that have already attacked the seed or will attack it when it starts to grow. The plant may live and spread the disease to other plants.
- Near-uniform seed size. Mature medium and large seed will generally have higher germination rates and vigor than small and immature seed. After harvest, undersized and light seeds are normally eliminated. Physical quality parameters such as seed uniformity, extent of inert material content and discolored seed can be detected by visually examining seed samples. Closely examining handfuls of seed is the first step to a better understanding of the quality of seed.

Quality 2
Viability & Vigor

Viability is a basic requirement of seed in that it must germinate at the right time. The germination rate (percentage of seed germinating within a seed lot) is an indicator of the seed's ability to emerge from the soil to produce a plant under normal conditions. And, seed vigor is its capacity to emerge from the soil and survive under potentially stressful field conditions, and to grow rapidly under favorable conditions.

In hot and humid conditions, seed may quickly lose its ability to germinate; the rate of deterioration varies among crop types. Starchy seeds, for instance those of cereals like maize, generally have a slower rate of deterioration compared with those of legumes like groundnut and soybean, which are oily and have high protein content. *The moisture content of the seed and the temperature of the building where it is stored are the most critical factors affecting the rate of deterioration.* The lower the temperature and relative humidity, the longer the seeds can be safely stored. The importance of physiological quality cannot be undervalued. Seed can only fulfill its biological role if it is viable. Therefore, physically uniform seed of an adapted variety will be

[1] FAO 2014. Appropriate Seed Varieties for Small-scale Farmers: Key Practices for DRR Implementers. Food and Agriculture Organization of the United Nations (FAO). Rome Italy.

useless if it has a low in germination rate and vigor.

Quality 3
Genetics

Genetic uniformity is very important, both when crops are produced for the market and for agronomic reasons. A mixture of varieties may mature at different times, which can lead to problems in harvesting and post-harvest handling, and result in lower yields.

Seed of different varieties of the same crop is often difficult or even impossible to distinguish once harvested and therefore varietal purity has to be determined in specialized seed laboratories. However, traditional varieties (or landraces), particularly of cross-pollinated varieties used by subsistence farmers are often not very uniform. This heterogeneity can be an advantage in some circumstances such as farmers cultivating is areas of low rainfall, low fertility and pest and disease pressure are high.

Quality 4
Health

Seed health refers to the presence or absence of disease causing organisms such as fungi, bacteria and viruses, as well as animal pests, including nematodes and insects. Seed health testing can be carried out in seed laboratories to assess the quality of seed sanitation. Ensuring seed health is important because *diseases initially present in the seed may give rise to progressive disease development in the field* and reduce the commercial value of the crop.

Imported seed lots may introduce diseases or pests into regions where they were not present before. For this reason, countries have legislation on plant and seed health, specifying cases where seed must be held in quarantine at the point of arrival into the country. The best way to avoid seed contamination by pests and diseases is to use proper seed production practices, i.e. to control pests and diseases during the seed production process. However, if a seed becomes infested with insects it can be fumigated. Special precautions need to be taken when treated seed is distributed to farmers, and farmers should receive instructions on the appropriate way to handle these seeds, and be warned about the danger of its use for human consumption.

5.3 Seed harvesting & processing

The basic rule of seed harvesting is to allow the seed to mature as long as possible on the plant without the seed or fruit becoming diseased, or overly ripe. Each type of plant has an optimum time for collecting the seed, but factors such as climate, weather, disease, insects, birds, or predatory mammals may require that the seed be collected at less than the optimum time. Humidity may play a large role in determining how and when seed is ready for harvesting. For example, in dry climates, beans can normally be left to mature and dry in the field, but during wet humid weather, it is best to harvest early and allow the beans to continue maturing and drying under cover.

Seed processing and cleaning methods can be divided into two: 1) dry processing, and 2) wet processing. Dry processing involves harvesting seed that has already matured and dried within the seed-bearing portion of the plant. Examples of dry processed seed plants include beans, broccoli, corn, lettuce, okra, onions, sunflower, and turnips. Wet processing is used when the mature seed is enclosed within a fleshy fruit or berry. Examples of wet processed seed plants include cucumbers, melons, and tomatoes. Some vegetables can be either dry processed or wet processed, for example, peppers, and squash.

Dry seed processing

When seeds are ready to be processed the entire seedpod, capsule, or seed head will become brown and dry. During the maturation process, the ripening pods and capsules change color from green, to yellow-green, to yellow, to light brown, to a darker brown, or dark gray. Ripening and maturation may be uneven within the pod or capsule, uneven on the plant, and uneven within the stand of plants. For that reason, the pods of many plants are harvested individually. Seeds of legumes and brassicas often develop a split along one side of the pod. This is the best time to collect the seed, before the pods start to open and scatter their seed. Most flower seed heads are not ready to harvest until the flower head has dried completely to the base, including a short section of the supporting stem. Some plant families, such as the Asteraceae (Aster family) have a smaller percentage of viable seed in the head, and the seeds continue to mature after collection. For this reason it is best not to be too hasty in harvesting the seed. Examples include lettuce and sunflower.

Some seed may mature in a capsule or pod, and at times even before the pod has turned completely brown. Most seeds turn a darker color as they mature. Seeds may initially be white, turning green or tan, and then brown or black. Once the seedpod, capsule, and or seed heads start to mature, it is important to check the crop on a daily basis. Rain or seed predators can ruin a good seed crop in a short period of time. Plants that produce umbels (members of the carrot family, or Umbelliferae) can usually be left in the field to harvest until the umbels are dry. Some members of this family mature their seed unevenly causing seed to scatter, while other seeds in the umbel continue to mature. One method of dealing with crops that mature their seed unevenly is to pull the plants and hang them upside down to dry under cover. This allows the seed to continue to mature on the plant while the plant dries. This procedure is often used for lettuce. Confidence in knowing when to harvest comes both with experience and familiarity with different species and crops.

After harvest, seeds are threshed to remove the seed from the surrounding plant material. A period of air-drying is important before seeds are threshed. Plant material should be spread out in thin layers until all plant material is dry; otherwise, mold, decay, and heat from decay will cause damage to the seeds. As the plant material dries, seed pods may split open or shed seed. Harvested material should be stored in a well-ventilated room with low humidity. During this time you should be aware of insects, especially weevils that feed on seeds. Plant material that is ready to be threshed should be brittle. Threshing is best done outside on a dry day.

Wet seed processing

Wet seed processing is used with seed crops that have seeds in fleshy fruits or berries. There are three steps to the process:

Step 1
Extracting the Seed

The type of extraction process depends on the species. Soft fruits such as tomatoes are cut up, mashed, and then fermented. Cucumbers and melons are cut in half, the seed scraped out along with the fruit pulp surrounding the seed, and then fermented. In watermelons, the entire fleshy fruit is fermented along with the extracted seed. These types of fruits have a gel surrounding the seed that contains germination inhibitors. The presence of the gel also makes handling and drying of the seed difficult.

Fermentation is a natural process that occurs to a small extent as fruits decompose. When fermentation is done in a controlled manner, the microorganisms, principally yeast break down the gel thus releasing the seed while killing bacteria and fungi that cause most seed-borne diseases. The temperature and length of fermentation are important. If the mash is not fermented long enough, seed-borne diseases will not be eliminated, but if fermented too long, the seeds may sprout prematurely. The length of the fermentation is dependent on temperature and typically last three days at a temperature of 70 to 75^{o}F (21^{o}C to 24^{o}C).

Length of fermentation may also depend on the variety itself. For example, varieties with high sugar content may take longer to ferment, up to four days. *With few exceptions, fermentation periods longer than three days risk damaging the seed.* There are different fermentation techniques for different crops, for example, pepper seeds are extracted from the fruits by mashing, but the fermentation process may last only 24 to 48 hours. Though eggplant isn't a watery fruit, it can be mashed and fermented for about 48 hours.

There are some differences of opinion about adding water to the fermenting mixture, the concern being that water slows the fermentation process causing premature sprouting. As long as the ferment is not diluted more than perhaps 10 to 20 percent by volume, this isn't a concern. The issue of whether to add water depends on how thick the mash is and it depends on the variety. Some varieties make a very thick mash that is hard to stir, and others make a watery mash that stirs easily. The mash should be stirred three times a day, once in the morning, once in mid-day, and once in the evening. If the mash is too thick to stir easily, the nutrients are not going to circulate easily. Stirring is also important for better control of seed-borne diseases. When the mash is not stirred, a foul-smelling, white mold forms on top of the mash. This mold can discolor (darken) and damage seeds at the top of the mash. These seeds will later have to be hand picked out of the dried seed. A properly fermenting mash should not have a foul smell, and there should be little or no white mold on the top. A small amount of white mold is not harmful and can be stirred back into the mash, but a heavy overgrowth should be removed.

Step 2 Washing the Seed

After fermentation is complete, the seeds are washed to remove pulp, pieces of fruit and debris, and low quality seed. Before washing the seed, it is useful (especially for washing tomato seed) to first scoop out pieces of pulp floating on top of the mash. This is done by straining the mash with your fingers and pulling out the larger chunks. Whether or not there is floating pulp depends on the variety or how thoroughly the fruit was processed. Add a volume of water at least equal to twice the volume of mash. It is important to dilute the mash sufficiently because the more dissolved solids there are in the mash, the higher the specific gravity. If the specific gravity is high (lots of soluble solids) it will be more difficult to wash the seeds properly. As a general rule, good seeds are heavy and sink to the bottom, whereas poor quality seeds are light and tend to float.

The washing process is repeated until the wash water becomes clear. Although most good seeds sink to the bottom, some vegetables have very light seed, do not sink, and require extra care during the washing process. For example, it is common for a significant amount of good pepper seed to float rather than sink during the washing process. Adding wash water slowly, so as not to create tiny air bubbles that adhere to the seeds and making them buoyant can avoid this. Even with this precaution, there are a few varieties of watermelon for example, where the good seeds tend to float rather than sink, thereby requiring special care in washing. In this case, the best way to wash the seed is to pour the wash through a cloth screen, and then use a hose to force pulp through the screen.

Step 3 Drying the Seed

Seeds should be dried fairly quickly after washing. Slow drying may result in mold growth or premature sprouting of the seed. *Seeds should not be dried in the sun, nor should they be dried anywhere where the temperature exceeds 95^{o}F (35^{o}C).* Dark colored seeds are especially vulnerable to damage when sun dried. Instead, seeds should be dried in a climate-controlled environment using fan ventilation. A combination of ceiling fans and air conditioning dries seed safely and very quickly. Seed should be spread out in thin layers and then stirred several times a day until dry. Once the seeds feel dry, they should cure for another two to three weeks. Curing is the final stage in the drying process. As the seed moisture content declines it comes into equilibrium with the relative humidity. After the seeds are cured they can be placed in a container for storage.

When drying seeds, choose plywood, window screen, or any hard, non-stick surface. Avoid using paper towels, newspaper, cardboard, or cloth because seeds will tend to stick to the surface making them difficult to remove. Beginner growers often make the mistake of drying squash seed on newspaper, which adheres permanently to the seed coat. No one wants to read the daily news on the surface of squash seed.

Principles of Seed Drying

Drying is a normal part of the seed maturation process. Some seeds must dry down to minimum moisture content before they can germinate. Low seed moisture content is a pre-requisite for long-term storage, and is the most important factor affecting longevity. Seeds lose viability and vigor during processing and storage mainly because of high seed moisture content (seed moisture greater than 18%).

High seed moisture causes a number of problems:

- Moisture increases the respiration rate of seeds, which in turn raises seed temperature. For example, in large-scale commercial seed storage, respiring seeds may generate enough heat to kill the seeds quickly, or to even start a fire if not dried sufficiently. Small-scale growers are not likely to have such an extreme condition, but seed longevity will, nevertheless be affected;
- Mold growth will be encouraged by moisture, damaging the seeds either slowly or quickly, depending on the moisture content of the seeds. Some molds that don't grow well at room temperature may grow well at low temperatures causing damage to refrigerated seeds. In such a case there may be no visual sign of damage; and
- Unless seed moisture is at least eight percent or below, insects such as weevils can breed causing rapid destruction of seeds in a short period of time.

5.4 Seed storage and treatment[2]

Seed storage[3]

Seed storage has certain requirements that include protection from water, contamination, rodents, and fungi etc. However, *relative humidity and temperature are the most critical aspects to keep in mind during storage*. The two are actually interrelated. In short term storage their relationship can be expressed by a simple rule of thumb. Storage temperature (in degrees F) plus relative humidity (in %) should not exceed a total of 100. For example: 60°F at 40% relative humidity (RH) or 55°F at 45% RH or 65°F at 35% RH.

For long-term storage, the temperature and relative humidity considerations are slightly different. Moreover, seeds stored for germplasm preservation must be stored under very controlled conditions. If the storage temperature does not exceed 50°F and the RH is not higher than 50%, most species of seeds will retain their viability for a few years. Many seeds will retain good viability for 20 years or more when stored at 35-40°F and 40% RH.

Effect of temperature on seed longevity

The general effect of temperature on seed longevity is that longevity increases as temperature decreases. This is true of "orthodox" seeds: that is, most seeds that follow the general rules of storage life. The relationship between temperature and seed longevity is that for each 10°F (5.6°C) decrease in temperature, longevity doubles (Harrington, 1972). This rule applies to seeds stored between temperatures of 32°F (0°C) and 122°F (50°C). This rule assumes that the moisture content is a constant. This is a general guideline; in reality the longevity of some vegetable species declines more rapidly than suggested by the rule, while the longevity of others declines more slowly in relation to storage temperature.

Subfreezing temperatures do generally not affect the longevity of seeds provided the moisture content is less than 14%. For a variety of vegetable, flower, and herb seeds, dried to approximately 5% percent moisture content is ideal for long-term storage. Note: seed taken in and out of the freezer too many times without re-drying may cause degradation of germination

Effect of seed moisture and humidity on seed longevity

Seed moisture has a greater effect than temperature on seed longevity. Most seeds also follow some general rules regarding moisture and longevity. The general relationship is that for each 1% increase in seed moisture, longevity decreases by half. This rule applies to seed with moisture content between 5% and 13%. Above 13% moisture content, seed storage fungi and increased heating due to respiration cause longevity to decline at a faster rate. Once seed moisture reaches 18% to 20%, increased respiration, and the activity of microorganisms cause rapid deterioration of the seed. At 30% moisture content, most non-dormant seeds germinate.

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[2] McCormack, J.,H., 2004. Seed Processing and Storage: Principles and practices. VA, USA.

[3] Source: http://bry-air.com/casestudies/desiccant-dehumidification-for-seed-drying-and-storage/ (June 16 2016)

Relationship between relative humidity and seed moisture content

Commercial seed is usually packaged for short or long-term storage under conditions of ambient humidity (unless special equipment is used). Because relative humidity has a significant effect on seed moisture content, it is important to understand the relationship between humidity and seed moisture.

Regardless of the type of storage conditions, the moisture content of a seed eventually comes into equilibrium with the moisture in the surrounding air. The relationship between atmospheric relative humidity and seed moisture content is shown in Figure 21.

The curve was derived from measurements of the average seed moisture content of ten vegetable species stored at different relative humidity. Because the curve represents an average of ten different vegetable crop species, the response of individual species may vary. For example, grain seeds (which contain relatively high percentages of carbohydrate) will have a moisture content of 13% to 15% at 75% relative humidity, whereas seeds rich in oils (such as peanuts) can have a moisture content of 9% to 11% at 75% relative humidity.

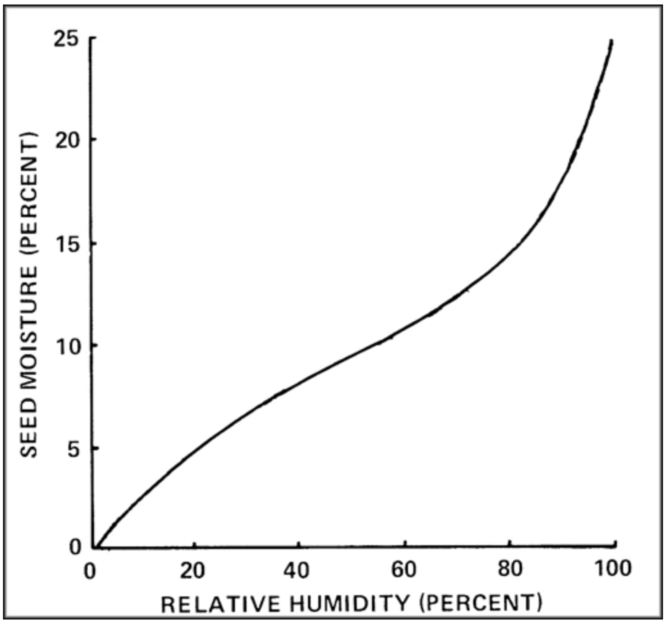


Figure 21 Relationship of vegetable seed moisture content on relative humidity

Note that once the relative humidity reaches 70%, the moisture content of the seed has reached approximately 13%, the point at which increased respiration and seed storage fungi become a significant problem. Above 70% relative humidity the moisture content rises dramatically. If the seed is stored in an open barn, or outbuilding, the relative humidity surrounding the seeds will be higher than that of a climate-controlled building. By using the values above, and referring to the chart above, it is possible to get an estimate of the moisture content of stored seed. It is clear from looking at the chart, that it is important to store seeds in a climate-controlled environment, especially during the summer.

Determining Seed Moisture Content

$$\text{Seed moisture content (\%)} = \frac{\text{fresh seed weight} - \text{dry seed weight}}{\text{dry seed weight}} \times 100$$

Relationship between temperature and moisture on seed longevity

The effects of temperature, moisture, and relative humidity were discussed previously as separate factors that affect the longevity of stored seed. In reality, the effects of temperature and relative humidity are highly interdependent in their effect on stored seed. There is a simple method for calculating the combined effects of relative humidity and temperature on seed longevity, which is as follows: the sum of the storage temperature (in degrees F), plus the relative humidity (in percent) should not exceed 100. Since seed moisture is the most important concern, the rule stipulates that *the temperature should contribute to no more than half of the sum.*

The majority of crop seeds lose viability quickly when the humidity approaches 80% at temperatures of 77oF (25^{o}C) to 86 F (30^{o}C), but when stored at a relative humidity of 50% or less, and a temperature below 41^{o}F (5^{o}C), seeds will remain viable for at least ten years. If seeds are taken from a cold or frozen storage and transferred to room temperate, care must be taken to prevent condensation on the seeds. If the seeds are in a sealed container, allow them to sit until they reach room temperature before opening the container. If they are stored in paper, place the seeds into a plastic bag with the excess air sucked out, seal the bag, and wait for the temperature to stabilize before unsealing.

Effects of respiration and heating on seed storage

The largest factor affecting respiration and heating is moisture content, and therefore, at a minimum, seeds need to be kept dry. Respiration in seed storage has three effects:

1. Depletion of food reserves. Over the life of properly stored seed, depletion of food reserves within the seed is inconsequential.
2. Release and accumulation of gasses that may affect viability of seeds in storage. The accumulation of respiratory gases such as carbon dioxide is an advantage of storing seeds in sealed containers - increases longevity.
3. Release of energy, mostly in the form of heat. When seeds are stored under favorable conditions, respiration is of little consequence. *When moisture is high, respiration increases, which in turn increases the production of heat thereby decreasing longevity.*

Effects of fungi, bacteria, and pests on seed storage

The process of seed harvest and cleaning removes most debris and insects, but certain fungi, bacteria, and insects make their way into stored seed. Fortunately, the same conditions that are favorable to seed preservation inhibit fungi and bacteria and kill insects.

Bacteria	Bacteria do not have a significant role in seed deterioration because free water is required for bacterial growth, and if the moisture content of the seed is high enough to support bacteria, the seed is more likely to succumb to deterioration due to other causes such as fungi, respiration, heating or premature sprouting.

Fungi

Most seed storage fungi are inhibited when the relative humidity is kept below 65%. At this relative humidity the moisture content of starchy seeds is about 13%, and oily seeds, about 7%. The major effects of fungi are:

- Decreased viability;
- Production of toxins that negatively affect seed viability and germination;
- Increased heat production – especially important in large seed lots; and,
- Causes discoloration, mustiness, and caking.

Insects

In hot, humid climates mites, weevils, flour beetles, and borers can be a serious problem to stored seed, but if the seed is dried to 8% moisture content and the storage temperature reduced to (64^{o}F to 68^{o}F (18^{o}C to 20^{o}C), insects should not be a problem. At a moisture content of 15% and a temperature of 86^{o}F to 95^{o}F (30^{o}C to 35^{o}C), they can become very destructive. Mites will not survive when the relative humidity is below 60%.

Seed moisture levels required for long-term sealed storage

Seed can be stored for the long-term under sealed storage conditions provided that the seed moisture content is less than 8%, which means that the relative humidity must be kept below 35% (as shown in Figure 22).

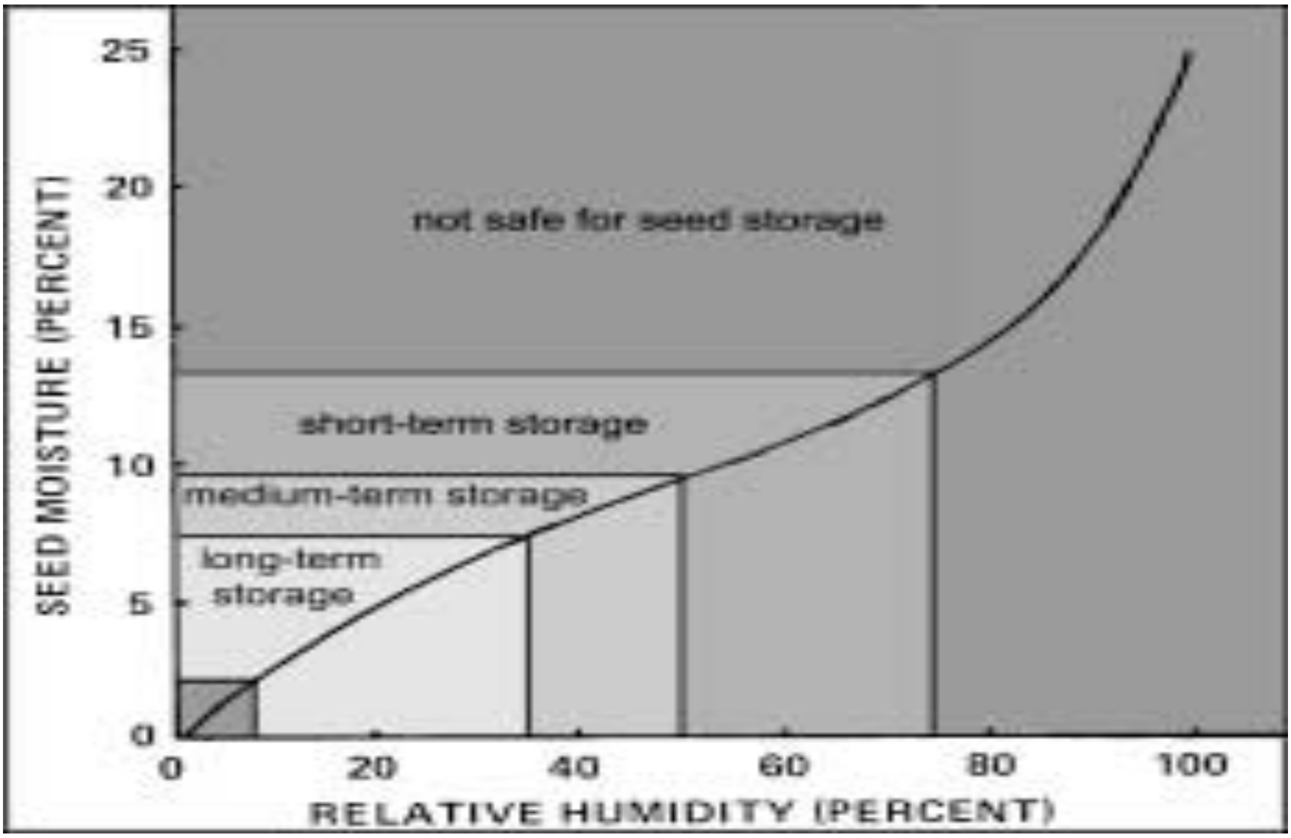


Figure 22 Length of seed storage in relation to seed moisture content and relative humidity.

The diagram above is based on averages of different vegetable seed crops. Note that grain crops have higher seed moisture content than do oily seed crops.

Packaging materials and containers for seed storage

Materials for Short-term Storage

There are a wide variety of materials that can be used to store seed for short-term storage. Most of these are non-rigid materials such as cotton, burlap, paper, and composite materials such as multi-wall paper and plastic film, or polyethylene bags. Materials used for short-term storage are generally porous. They adequately contain and protect the seeds from mixing, but *do not provide protection from moisture or loss of seed viability*. Such materials are usually used for mechanically separating seed lots, and for transporting and shipping seed until the seed can be placed in environmentally controlled conditions for longer-term storage. Each type of packaging material has its own advantages and disadvantages:

- ✓ Burlap bags have the greatest strength, can be re-used many times, and can be stacked high without slipping of the stack;
- ✓ Cotton bags can often be re-used, depending on the quality of the fabric;
- ✓ The strength of cotton bags is dependent on the thickness of the weave and thread, and the quality of the seams; and
- ✓ Cardboard boxes and cans, though expensive, are re-usable, good for stacking, and provide some protection against mechanical injury to seeds and protection from seed storage insects.

- × Bags made of woven plastic material are fairly strong but tend to slip when piled high and are harder to close securely after the bag has been opened; and
- × Flexible packaging that has a weave, whether it is burlap, cotton, or plastic offers little protection against seed storage pests such as grain moths. Seed storage insects are very good at locating small openings in bags or containers that are not well sealed.

For small lots of seed, paper bags such as lunch bags are inexpensive and adequate for storing seed, but the seams are not always reliable, and when used, the bags should be double or triple bagged to ensure they do not burst. Other materials such cellophane, acetate, and 2- to 4-mil polyethylene zip lock bags may be used (provided the seeds have dried adequately). If using polyethylene, it is best to use the 4-mil thickness, especially for heavy seeds. Plastics and thin films are NOT reliable moisture barriers, though such materials offer better moisture protection than paper.

Materials for Long-term Storage

Metal and glass containers, properly sealed to prevent the exchange of moisture and gas, are the most commonly used containers. They are the only reliable means of protecting seeds against humidity, insects, rodents, floods, and mechanical damage. Plastic should not be used for long-term storage. For storing large quantities of seed, metal cans fitted with a rubber gasket lid and pressure ring are ideal for storing large seeds such as peas, beans, and corn.

Glass jars are also excellent, provided that the lid has a gasket seal. Gaskets can be cut from sheets of rubber (available at hardware stores) or used automobile inner tubes.

Seed treatment

Seeds can be treated to control germs attached to the seed (seed-borne diseases), and/or to protect against pests and diseases in the soil that can attack seeds, emerging roots or young seedlings (soil-borne diseases).

There are three main methods for seed treatment in agro-ecological farming:

1. Physical: sterilizing by soaking seed in hot water (typically 50–60ºC),
2. Botanical: by coating seeds with a layer of plant extract, such as crushed garlic, and
3. Biological: by coating seeds with a layer of antagonistic fungi.

When seeds are bought from seed companies, attention should be paid to the type of treatment they underwent, as chemical treatment is discouraged in agro-ecological farming – prohibited in organic farming.

Hot Water Treatment Method

Though not as easy as chemical treatments, hot water treatment can be more effective and is non-toxic. The purpose of the hot water treatment method is to submerse seed in water hot enough to kill the pathogen without damaging the seed embryo. When properly done the procedure is very effective, but there are some precautions to follow:

- ✓ Use only new, vigorous, high germination seed;
- ✓ Control the temperature of the process very carefully, since this is fundamental to success;
- ✓ Test the germination of the seed lot before and after treating the seeds; and
- ✓ Practice first on a small sample before treating a large batch of seeds.

Although the germination of properly treated seed will not be significantly affected, the storage life of the seed may be shorter.

Hot water treatment materials

- 1 large metal pot and several smaller containers;
- Bags for seed made of muslin, cotton, or nylon (panty hose will do);
- An accurate thermometer from a science supply house; and
- Sieve, colander, vegetable steamer, or hardware cloth cut in the same diameter as the inside of the pot.

Hot water treatment procedure

1. Place the seeds loosely in a fabric bag, filling no more than half full, and then tie securely. Add a small weight, such as a small rock or bolt to help sink the seeds.
2. Set up the treatment container so that the bag of seed doesn't touch the bottom of the pot – at least ½" off the bottom. There are several ways to keep the bag off the bottom: (a) suspend the seed bag on a vegetable steamer, (b) set the bag in a colander, or (c), cut a circle of hardware cloth and suspend it at least ½" off the bottom by using small stones.
3. Fill the treatment container about half full of water, and using an accurate

thermometer, slowly bring the water to the treatment temperature.

4. Pre-soak the seeds in water, between 100-105°F (38-41°C) for five to ten minutes to pre-warm the seeds – use a separate container.
5. Once the temperature in the treatment container is constant, add the bag of seed. While treating the seed, stir the water slowly and constantly, while keeping an eye on the temperature and the clock. An accurate thermometer is essential because temperatures of 1 or 2 degrees too high can injure the seed, and 1 or 2 degrees too low will fail to kill pathogens. To help adjust the temperature, cold or hot water can be added while stirring.
6. Remove the seed, and cool by dipping the bag briefly in lukewarm water, and then in cool water.
7. Open the bag and spread out the seed to dry on a hard surface or fine screen. Dry at room temperature using a fan for supplemental ventilation, and stir the seeds several times daily until dry.

For hot water treatment times for vegetable seed, see Table 8.

Table 8 Hot water treatment times (in minutes) for vegetable seed.

Vegetable	Temperature (F)			
	118	**120**	**122**	**125**
Broccoli			20	
Brussel sprouts			25	
Cabbage			25	
Chinese cabbage			20	
Carrot			15 – 20	
Cauliflower			20	
Celery, celeriac	30			
Collard			20	
Cucumber			20	
Eggplant			25	
Garlic		20		
Kale			20	
Kohlrabi			20	
Lettuce	30			
Mustard			15	
Pepper				30
Radish			15	
Rutabaga			20	
Spinach			25	
Tomato			25	
Turnip			20	

Seed treatment with biological agents

Seeds can be coated with a layer of biological agents. These agents are usually antagonistic fungi or bacteria that work against soil-borne pathogens. An example is the bacterium *Bacillus subtilis*, used as a seed treatment for the control of a range of pathogens such as *Fusarium spp.*, Pythium spp. and *Rhizoctonia spp.* that cause damping-off and root rot in young seedlings. It is effective in a wide range of crops including soybeans, peanuts, wheat, cotton and leguminous food crops. The antagonistic organisms grow and multiply in the area around the seedling‘s roots. They compete with pathogens that attack the new emerging roots, and thus reduce the risk of infestation.

SESSION 6: Agroforestry tree propagation, and nursery management

6

Objective

- ✓ Provide BRiLSS project partners with the relevant theory regarding agroforestry tree propagation and nursery management, as well as hands on experience in propagation techniques.

Session six (6) is a comprehensive review of agroforestry tree propagation and nursery management technologies. Covered are methodologies related to sexual and asexual tree propagation, seed sourcing and nursery management, to the production of vegetative tree planting materials. Included in the session materials is tree specific information regarding agro-ecological value, propagation and management techniques. The overall aim of the session is to provide BRiLSS project partners with the relevant theory regarding agroforestry tree propagation and nursery management, as well as hands on experience in propagation techniques.

Session 6 Agroforestry tree propagation, and nursery management

Facilitation guide (1 day)

STEP 1

Introduce Handout S6.1 – S6.5 through an organized PowerPoint presentation, including the session objectives, content, and the process the facilitator will take to deliver the session. Emphasize the importance of all participants having a common understanding of the content in the context of the BRiLSS project.

STEP 2

Start the session with Handout S6.1 – tree propagation. A definition of tree propagation is given. Note that tree propagation is done through a variety of techniques. Use Figure 23 to outline the techniques, specifically separating the techniques between sexual and asexual propagation.

STEP 3

Place focus on sexual tree propagation, i.e. through the use of seeds. Review the 'seed viability text'. Important to note is that not all seeds will pass the 'floating test' method because some seeds naturally float. If resources are available, conduct a demonstration using a variety of seeds, including those that would naturally float and those most applicable to the floating water method.

STEP 4

Move on to Handout S6.2 – seed sources and nursery management practices. Review bullet points presented for seed collection and sowing, followed by a demonstration on determining seed moisture content. Note that the process is a general test and to only be used in the absence of NOT being able to determine seed moisture content mathematically (see Session 5 – Handout S5.4).

STEP 5

Present handout content on 'management practice of germination beds'. If possible, demonstrate the setting up of a germination seedbed. Use information in Box 7 to help guide participants in the application of proper seed planting techniques. Follow by presenting handout content on 'practices in seed handling for germination'. It is advisable to present this learning content as a practical exercise.

STEP 6

Move on to Handout S6.3 – establishment and management of a seedling nursery. Begin with 'nursery site selection', reviewing each consideration noted. Express clearly that if just one (1) consideration cannot be met, adjustments to the selected site must be made, or a new site identified.

Follow by presenting handout content on 'nursery design and construction'. If possible, it is recommended to visit a professional nursery for 1st hand experience/ learning, and the opportunity to discus sexual and asexual tree propagation and management techniques.

STEP 7

Continue with handout content on 'weed control in nurseries'. Emphasize that agro-ecological farming principles and practices extend to nursery management techniques. Thus, this DOES NOT allow for the use of 'Highly Hazardous Pesticides' for weed, disease and pest control.

STEP 8

Move on to Handout S6.4 – production of vegetative/ tree planting materials. Note that this sub-section will require hands on grafting demonstrations. Prepare accordingly for both 'cleft grafting and T-Budding'. Present the theory during the conduct of demonstration/s. Each participant should have the opportunity to try both techniques twice.

STEP 9

Following the demonstration, present handout content on the 'concepts and principles of cuttings'. For effective learning, participants are to be given the opportunity to start the soil propagation process. At the very least, prepare a variety of 'propagation environments' prior to delivering the session. See Figure 32 for guidance. The practicum should also include 'procedures for rooting stem cuttings'.

PRACTICUM ADVICE: Handout S6.4 content should NOT be delivered via a PowerPoint presentation if possible. Rather, content should be given interactively through hands on demonstrations. The best place to conduct the activity is within an established tree nursery.

STEP 10

Move on to Handout S6.5 – management of agroforestry tree species. Present the eight (8) concepts given; supported through the illustrations provided. Content delivery on 'agroforestry trees of interest – propagation and management' and 'pest and diseases' is optional. Content is to be considered as 'reference material'. Note that within, for each tree species, information includes its agro-ecological value, propagation and management notes.

6.1 Tree propagation

What is Tree Propagation?

Plant propagation is the process of creating new plants from a variety of sources: seeds, cuttings, bulbs and other plant parts. Plant propagation can also refer to the artificial or natural dispersal of plants. The simplest method of propagating a tree vegetatively (non-sexually) is by rooting or taking cuttings. The most common method of propagating fruit trees, suitable for nearly all species, is grafting or budding a desired variety onto suitable rootstocks.

Tree propagation can either be sexual (through seeds/seedlings) or asexual (vegetative through cuttings or grating)(Figure 23). Propagation through seeds is the most common practice and will be discussed in detail in this section including basic tree nursery management practices.

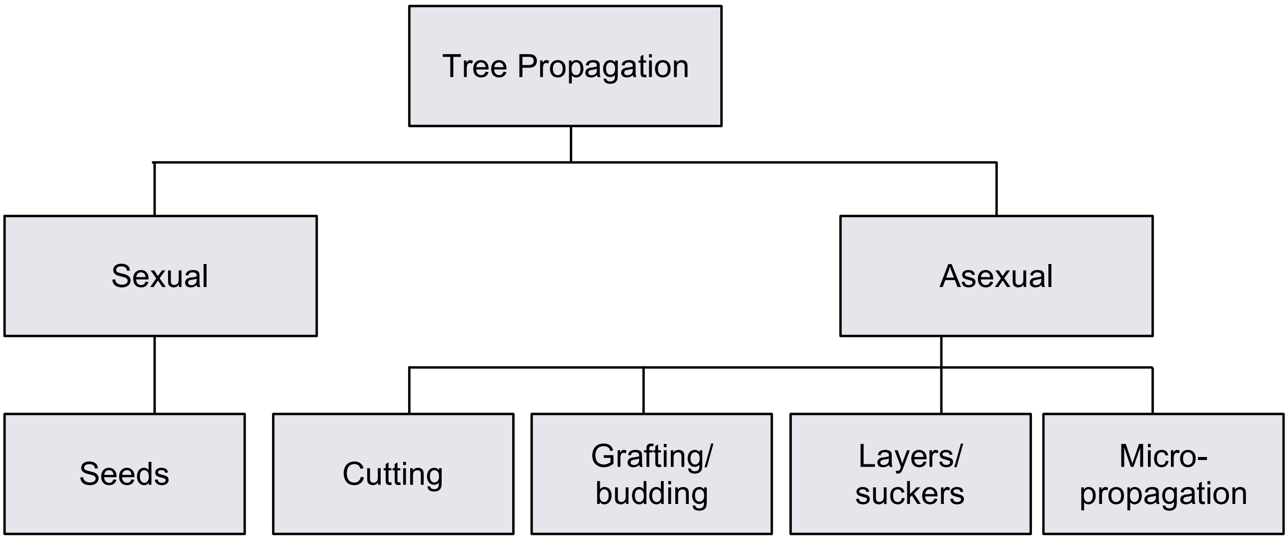


Figure 23 Tree propagation methods.

Types of tree propagation[4]

Sexual Propagation

In sexual propagation, seeds are used and provide opportunity for variation and genetic improvement that leads to production of varieties that perform better in the field and/or produce better quality of products, e.g. fruits.

Asexual Propagation

In asexual propagation, an exact copy of the variety and genetic material of a mother plant is made and continued in new individuals. This is possible because unlike animals or humans,

[4] ICRAF, 2014. Conservation Agriculture with Trees: Principles and practices. World Agroforestry Centre, (ICRAF) Nairobi, Kenya.

plants have meristematic cells (undifferentiated cells) that can grown into various plant parts necessary to form a whole new plant. A piece of plant shoot, root or leaf can grow to form a new plant that contains the exact genetic information of its source plant. Compared to trees planted from seed, trees from stem cuttings grow faster but develop a shallow root system that makes them more susceptible to moisture stress and wind damage.

Seed types

Orthodox Seeds	Orthodox seeds are those which do not lose viability quickly and hence can be stored at subzero temperatures without damage. Some of them stay dormant for some time hence there is a need to break their dormancy before sowing. Examples include *Tephrosia candida*, *Gliricidia sepium* and *Faidherbia albida*;
Recalcitrant Seeds	Recalcitrant seeds are those that lose viability quickly (less than 1 month) and cannot be stored under conventional conditions. Some of these seeds even suffer chilling damage. Examples are seeds of cocoa, rubber, Warbugia, avocado and mango.
Intermediate Seeds	Intermediate seeds are those that can be stored under sub-zero temperatures but for a period not exceeding 6 months. Examples include *Prunus africana*, *Azandirachta indica*, *Dovyalis caffra*.

Seed viability test

Step 1	Open the seeds and check for pests and disease attack.
Step 2	Check also whether the embryo is alive. It should be firm, and mostly white. Grey, black or soft embryo is an indication that the seed is dead.
Step 3	Examine the shape of seeds. Deformed seeds and those with bad coloration are likely to be unviable.
Step 4	Floatation in water is also used to check for dead/unviable seeds that normally do not float. Note that only naturally heavy seeds can be used for this procedure because light seeds will all float.

Viability Test Using Floating Method

- ☑ Fill a jar about three-quarter way with water;
- ☑ Pour seeds into the water-filled jar;
- ☑ Seed separation takes place: some will float while others will sink; and
- ☑ Sinkers are viable while floaters are not.

6.2 Seed sources & nursery management practices[5]

Seed sourcing, collection and selection for rootstocks production

Identification of seed sourcing, collection and selection is crucial in achieving healthy and uniform-sized seedlings. For fruit rootstocks, optimum yield cannot be attained even with a favorable environment if the rootstocks used are not well adapted to environmental conditions. The concept of proper selection is based on the following principles:

- A parent tree with desired qualities is capable of producing offspring with similar performance; and
- The performance of the seedlings may be predicted based on the performance of the parent materials.

Seed collection and sowing:

- ☑ Always collect seeds from superior trees;
- ☑ A chart should be prepared in each nursery indicating the seed collection period of local or preferred tree species along with the location of the tree. Seedlings developed from poor or abnormal trees will never produce good trees;
- ☑ After collection, seeds should be processed carefully otherwise they may become damaged and lose viability;
- ☑ Each species requires different processing after seed collection, i.e., seeds with pulp are processed differently compared to the pods, drupes and capsules; and
- ☑ Most of the seeds have short viability; therefore, sowing should be done immediately after collection and processing.

How to determining moisture content before storing seeds:

- ☑ Fill one quarter of the jar with salt and then add the seed sample;
- ☑ Close the lid tightly and shake the jar well; and
- ☑ Allow the seeds to settle for about 10 minutes.

If damp salt sticks on the sides of the jar, then the seeds are too moist for storage (moisture is above 13-15%). On the other hand, if the jar is still dry and no salt is stuck on its sides then the seeds have less than 13 per cent moisture content and can be stored safely (Figure 24).

Figure 24 Moisture content cheek in seeds using the salt test.

[5] Munjuga MR, Gachuiri AN, Ofori DA, Mpanda MM, Muriuki JK, Jamnadass RH, Mowo JG. 2013.Nursery management, tree propagation and marketing: A training manual for smallholder farmers and nursery operators. Nairobi: World Agroforestry Centre

Management practices of germination beds

Seeds are first germinated in the germination bed before they are planted in polybags. A well-drained area with moderate shade is an ideal site for a germination bed. The germination bed should be established on a flat or level area near a water source within the nursery site. The best kind of germination medium is sand or light soil because the germination of seeds will be faster due to aeration, and seedlings can be easily pulled out during uprooting with less damage to the roots. With pure garden soil, the germination of seeds tends to be slower because the soil is too heavy and less aerated.

Sow large seeds ¾” to 1 ¼” (2-3cm) deep in the soil. Sow small seeds about ¼” to ½” (0.5-1cm) deep or broadcast and cover them with a small amount of fine soil. *The beds can also be covered with thatch or a plastic sheet till the seeds germinate.*

Germination bed materials

- Machete;
- Garden tools (fork, shovel or mattock);
- Sand or light soil;
- Hollow blocks or planks; and
- Shade nets, grass or banana leaves.

Germination bed preparation process

Prepare a germination bed at most 39” (1m) wide, raised 6” (15cm) above the ground. Its length will depend on the number of seeds to be sown, size of seeds and available space. Use wooden planks to protect the bed from erosion (Figure 25).

Use any of the following materials as a germination medium:

- Fine river sand;
- Decomposed sawdust (dried for at least 6 months); and
- Coir dust.

You can use a combination of coir dust and garden soil or sawdust and garden soil. A depth of at least 5” (10cm) is recommended.

Figure 25 Germination bed using wood planks as siding materials

Box 7 Common mistakes in seed propagation.

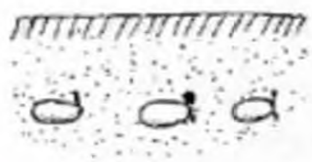
Correct Sowing Density
(crop dependent)

Wrong Density – Too Dense
- × Weak seedling & competition;
- × Risk of damping off; and
- × Diffficult to separate.

Wrong Density – Too Thin
- × Weak sprout; and
- × Loss of space.

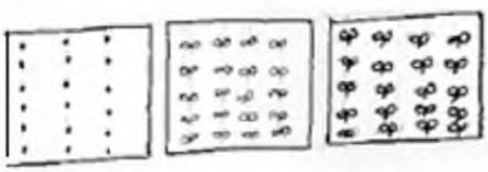
Correct Sowing Depth

Wrong Depth – Too Deep
- × Seed may die;
- × Seed does not germenate; and
- × Germenation takes too long.



Wrong Depth – Too Shallow
- × Seed has weak root system;
- × Seed is exposed to the sun; and
- × Bird and insect dmage.

Correct Sowing Planning: Fewer sees in several batches, ease of management.



Wrong Sowing Planning: Too many seeds at once
- × High workload;
- × Lack of planting space; and
- × Lack of market to sell excess.

Practices in seed handling for germination

Most leguminous seeds such as *Calliandra calothyrsus, Gliricidia sepium, Leucaena trichandra, Sesbania sesban* and *Faidherbia albida* have thick, hard seed coats. To hasten the germination, a mechanical means of breaking the thick seed coat before soaking in water and sowing in the seedbed must be instituted.

Germination materials

- Seeds;
- Nail clipper or mechanical pliers;
- Cotton bag/sack;
- Hose/sprinkler;
- Mulching materials; and
- Clean water.

Germination process

- Partially crack the seed coat of seeds using mechanical pliers (Figure 26);
- Soak the seeds in clean water overnight (Figure 27) to enhance germination;
- Sow the seeds closely on the bed surface; arrange the seeds in a single layer with the flat groove side facing downward. (Note: avoid overcrowding to prevent root distortion that may lead to difficulty in removing the seedlings);
- Press the seeds firmly into the seedbed until they are at the same level as the surface of the germination medium.
- Mulch the bed surface with dried grass to retain seed moisture for rapid germination;
- Water the seeds/ seedlings at least once a day; and
- Observe the development of the seeds in the germination bed. The seeds will start germinating within a week after sowing in case of legumes.

Figure 26 Nicking or partially cracking the seed coat of Leucaena seeds using a nail clipper

Figure 27 Treated seeds soaked in water overnight for optimum germination.

Selecting out and transplanting of germinated seeds to polythene pots

To attain uniform growth and a high survival rate in the field, select and uproot the germinated seeds carefully by hand using a hand trowel.

Transplanting materials

- Sprinkler;
- Container with water;
- Clean water;
- Potted poly-tubes; and
- Watering can.

Transplanting process

1. Water the germination bed first;
2. Uproot the seedlings with two leaves one by one;
3. Place the uprooted seedlings in a container half-filled with water to maintain turgidity and to avoid damage before transplanting to the poly pots;
4. Discard retarded, deformed or diseased seedlings because they have less chances of survival; and
5. Bring to the area to be planted in polythene bags.

Watering

¬ Keep the seedbed moist, not wet.
¬ Do not water at a fixed time each day. Water when the plants need it.
¬ Small seedlings require less amount of water. Large seedlings require more water more often.
¬ Seedlings require more water more often on windy and sunny days. Water less often when seedlings are kept in a shade.
¬ Moss and algae growth is an indication of excess watering. Always use clean water; dirty water may cause diseases.
¬ Over-watering results in weak plants and causes diseases such as root-rot and damping-off of seedlings.

Transplanting

¬ Water the seedling bed well before starting the transplantation process.
¬ Always use some tools (e.g. bamboo sticks) to loosen the soil before pulling out seedlings from the seedling bed.
¬ Make a deep and wide hole in the polythene bag or container for transplanting the seedlings. Hold the seedling at the base of the stem and pull it out gently from the seedling bed.
¬ Never bend the roots and do not force the seedlings into the hole. Keep transplanted seedlings under proper shade until they have recovered.

Hardening of seedlings

In a nursery, seedlings are kept under ideal conditions; therefore hardening is essential to make them strong enough to tolerate the harsh conditions of the planting site. It is generally done by reducing the amount of watering about one month before the date of planting into its permanent location.

6.3 Establishment & management of a seedling nursery[6]

Nursery site selection

The selection of an appropriate nursery site is the most important decision for efficient production of good quality plants. The selection needs to be agreed upon at least six months before the first seed is sown. It must start from a well-defined statement of the objectives of the nursery, which must include details such as:

- Number of plants to be produced each year;
- Species;
- Type and size of plants;
- Location of the plantations and villages to be supplied; and
- Expected life of the nursery.

Some of the technical factors that need to be considered when establishing a nursery are discussed.

Consideration 1
Land Availability

It is important that the site selected for the nursery has enough land to raise the number of seedlings needed, and if possible, room for expansion. A small nursery raising 20,000 plants in 4" to 6" pots, and keeping the plants in the nursery for a year could require about 1500 square feet (approx. 500m^2) of land; this includes seedling beds, potting beds, and 20% extra for losses and damage, paths between the beds, soil storage, and a compost-making area. But for sloping sites the land requirement may need to be double the size. Overall, the size of the nursery depends on the number of plants to be produced, the time they will remain in the nursery, as well as the quality and slope of the site.

It is also important to learn who owns the land. If it is institutional or privately owned land it is important to formalize the use of the land by obtaining a letter from the owner agreeing to its use as a tree nursery for a defined period of time.

Consideration 2
Water Supply

A reliable and adequate water supply is always a requisite in nursery establishment. The nursery site should be located near the source of water either from a running stream or main pipe water supply to sustain rapid and healthy growth of the seedlings. The ideal situation is where there is a perennial stream at a higher level than the nursery, and fairly close to it, so that water can be diverted from the stream to the nursery in high-density plastic pipes (which should be buried at least 6" (15cm) deep. Alternatively, a water storage tank can be installed to ensure a sustainable water supply.

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[6] [6] Munjuga MR, Gachuiri AN, Ofori DA, Mpanda MM, Muriuki JK, Jamnadass RH, Mowo JG. 2013.Nursery management, tree propagation and marketing: A training manual for smallholder farmers and nursery operators. Nairobi: World Agroforestry Centre

Consideration 3 **Topography**	The area for tree nursery establishment is preferably flat with a gentle slope to allow for drainage. Contour terracing should be done if the slope is in excess of 2%.
Consideration 4 **Land Size**	The size of the area must be large enough to accommodate any possible expansion of the nursery.
Consideration 5 **Site Location**	The nursery site should be located near the planting site to minimize injury to the plants in handling and during transportation. It must be easily accessible to facilitate nursery field operations and supervision. Access roads should be usable during all seasons of the year.
Consideration 6 **Soil**	Deep, good-structured, easily pulverized soil is desirable. Avoid shallow soils with a hard sandstone band near the surface. A very sandy-structured soil should also be avoided because of poor moisture retention characteristics and faster leaching of plant nutrients. Soil containing too much clay has poor drainage characteristics and should not be considered in site selection.
Consideration 7 **Media** **Preparation**	Most of the plants are multiplied on nursery beds. Solarization is an effective and eco-friendly method of soil sterilization and it involves trapping of heat from the sun through a polythene covering. This raises the temperature of the soil media to the level where it becomes lethal to soil microorganisms.
Consideration 8 **Exposure to** **Extreme Weather**	At high altitudes, sites that are particularly vulnerable to frost damage should be avoided. Such areas include valley bottoms and other sides where the downward flow of cold night air is common due to a dense belt of trees or shrubs below the site. Other natural hazards should also be avoided, e.g. areas threatened by landslides, subject to flooding or strong winds must be avoided.
Consideration 9 **Labor Availability**	A lot of labor is required for the construction of a nursery and subsequent nursery activities. Hence nurseries should be located where labor is available. Siting a nursery on a main trail near a village will also increase awareness and enhance patronage.

Nursery design and construction

Design

The nursery design will vary according to the type of plants to be raised and topography of the land. Before construction begins, draw a sketch plan. Measurements should preferably be made with a measuring tape. The plan should include:

- ☑ Fence or wall;
- ☑ Internal paths;
- ☑ Water tanks and distribution system;
- ☑ Seedbeds;
- ☑ Soil storage shelter;
- ☑ Working area; and
- ☑ Compost-making area.

Construction

The land must first be cleared of all rocks, stumps, trees and shrubs.

Fence

It is necessary that all animals be totally excluded from the nursery, so a fence or wall must be built. It should be about 2 feet (60cm) below ground and 4 feet (120cm) above.

Nursery beds

Ideal size of the bed is 39” (1m) to 48” (1.2m) wide. It should not be wider because of the difficulty in reaching the center when weeding, watering or manuring. Seedbeds that are narrower than 39” (1m) are a waste of land. The length of the bed is relatively less important. If possible, the beds should be oriented from east to west to provide better shade against the midday sun. Paths should be provide adequate working space. When the area for the beds has been leveled, protect the corners and the edges (See Figures 28, 29, & 30 for illustrations).

Other structures

A waterproof soil storage shelter is needed to store the potting mixture and to provide some working space.

Nursery construction & operations materials

- Seeds, soil, sand, compost;
- Poly-pots: 4”, 6”, 8” and 10” in diameter and the same in height;
- Heavy gauge polybags for seed storage;
- Wire, strings, mesh wire, nails soap;
- Pens, pencils, waterproof markers;
- Registers: nursery, seed and visitors;
- Machete, knife, scissors, secateurs, germination trays, plant-carrying trays, soil and sand sieves, hammer; and
- Watering can with hoses.

Setting up the polybag nursery

- ☑ Clean the area and remove all plant debris, weeds and other unwanted plants;
- ☑ Prepare polybags from the polybag sheet roll or buy the preferred size; and
- ☑ Fill the perforated bags with loamy soil (compost, fine sand, top soil in a ratio of 1:1:1) or forest soil, collected from the top layer below the litter layer;
- ☑ Arrange the polybags in single rows; and

☑ Fence the perimeters properly to ensure safety of the plants against stray animals or intruders.

Setting up the ground nursery beds

- Plough the area when there is enough moisture;
- Cultivate the land thoroughly to produce fine soil tilt and to kill existing and germinating weed seeds;
- Establish straight lines indicating planting points at a distance of plants; and
- Make small holes using a dibble stick enough to accommodate the germinated seeds.

Figure 28 Illustration of seedling arrangement in the nursery bed.

Figure 29 A nursery layout showing beds with seedlings.

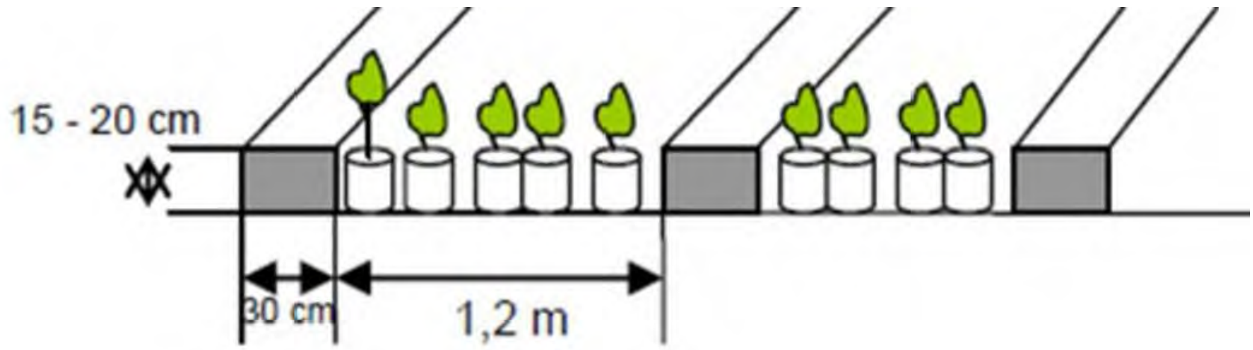

Figure 30 Ground nursery field layout illustrating the distance of planting, paths and beds.

Planting and maintenance of germinated seeds and seedlings

Planting materials

- Germinated seeds;
- Polybags;
- Sprinklers/hose; and
- Topsoil.

Planting process

- Carefully plant the germinated seeds in each hole for ground nursery or each bag for the polybag nursery with the radicles pointing downward;
- Cover the entire root system including the cotyledon with fine soil. Press the soil lightly to compact it around the plant; and
- Water the plant as often as necessary during the dry season.

Maintenance of seedlings in the nursery

The natural fertility of the soil is continuously getting depleted with repeated cropping. Replenishing the soil supply of nutrients through fertilizer application is needed. Sound fertilization of seedlings provides the following advantages:

- ✓ Healthy plants;
- ✓ Uniform growth of plants;
- ✓ Fast growth of seedlings; and
- ✓ High rate of survival after field planting.

The fertilizer must be applied when the plants need it and must not be in direct contact with plants.

Maintenance materials

- Compost fertilizer;
- Garden tools; and
- Weighing scale.

Weed control in nurseries

Weed control in the nursery aims to minimize competition from weeds for light, water and nutrients.

Weed control materials

- Knapsack sprayer;
- Natural herbicides, or those not on the PAN HHP[7] list; and
- Mulching materials.

Weed control process

- Remove the weeds by hand, weeding at monthly intervals. Reduce the frequency of weeding as the plants grow older;
- Spray glyphosate herbicides between rows taking care not to spray other green parts of the plants; and
- Use rice straw, rice hull, and sawdust as mulching materials to control weeds.

Nursery hygiene and seedling disease control

Diseased seedlings grow and develop slowly. Plants may die under severe infections. Most of the microorganisms, insects and pests that cause diseases in the nursery live in weeds, trash and puddles. Therefore, keeping a nursery neat and clean reduces the chances of attack of common diseases. All trash, waste, polythene bags and diseased plants should immediately be removed and burnt far from the nursery.

Hygiene and disease control materials

- Knapsack sprayer; and
- Fungicides such as Benlate, Captan, Dithane M-45.

Hygiene and disease control process

- Monitor and check the occurrence of the diseases; and
- Spray fungicides.

Dealing with insect pests

- **Termites:** Termites form colonies at the base of the trunk. Their feeding habits are diverse. Some species prefer living in trees while others feed on dead tissues. Newly budded plants are highly susceptible to termite attack. Affected young trees show deficiency symptoms. Termites are difficult to control when the colonies are fully developed.

- **Root-feeding grubs:** Grubs live entirely in the soil. They are voracious feeders and may consume the roots of tree and cover crops. Affected young trees have yellow leaves and dying shoots, and in severe cases the trees may die.

- **Sucking insects** (scales, mealy bugs and aphids): The adult female of scales and

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[7] (HHP – Highly Hazardous Pesticides): See http://www.pan-germany.org/download/PAN_HHP_List_150602_F.pdf. for listing.

mealy bugs the nymphs and adults of aphids are destructive to plants. The insects excrete honeydew, which attracts ants and sooty molds. In heavy infestations, the shoots may die.

Insect pest prevention materials needed

- Knapsack sprayer;
- Insecticides (those not on the PAN HHP[8] list); and
- Garden tools.

Insect pest prevention process

- Monitor the presence and occurrence of the insect pests in the area;
- Practice proper sanitation in the area to control termites and sucking insects; Destroy early colonization of termites; and
- Propagate seedlings using polybags to control root feeding and sucking insects.

Natural Insecticides Using Neem Seeds

Make powder of 500g dried neem seeds and soak overnight in 15 liters of tap water. Sieve twice and spray. Besides this, chili powder and tobacco leaf powder can also be used. They generally take a little longer to repel or kill the insects, therefore, apply them as soon as the insect problem is discovered. The main advantage is that they are natural, hence safe and biodegradable. Remember the following tips while using them:

- ✓ Proper doses should be prepared by carefully reading the label or guidelines;
- ✓ Always provide protective clothing, masks, gloves and goggles to the person spraying the pesticide;
- ✓ Never mix insecticides and fungicides together in the same sprayer;
- ✓ Never eat, drink or smoke while spraying;
- ✓ Never use pesticide containers to store other things; and
- ✓ Extra pesticides should be disposed of by burying them in a hole far from rivers and wells.

Planning and record keeping

Planning of a nursery should be done at community level. First visit the planting sites and discuss the reason for planting, and the species to be planted. Begin by growing local species with which the people are familiar with.

Time of seed collection and sowing

One of the main constraints on nursery plans is the availability of seed. Each and every type of seed has different collecting seasons. The plan of seed collection is very essential. For every activity conducted, for instance, fruit or seed collection, sowing, seedlings transplanting; keep a record file, a signboard or tag placed in front of each bed or bag/ container with seeds, with the following information:

[8] (HHP – Highly Hazardous Pesticides): See http://www.pan-germany.org/download/PAN_HHP_List_150602_F.pdf. for listing.

- Name of variety/type;
- Place the seeds were harvested;
- Date when seeds or nuts are harvested, if available or sowing;
- Number of seeds or nuts sown; and
- Seedbed number.

Planning seed supplies

- The quantity of seed required must be calculated, the sources identified, arrangements made for collection and the cost estimated;
- Prepare a table listing the number of healthy plants of acceptable size required at the planting site;
- In the absence of germination test results, assume that for every four seeds sown, only one seedling will be produced; this means 4 times the amount of seeds are required;
- Find the number of seeds per gram; and
- Calculate the weight of seeds to be sown in grams.

Calendar of operations

By making a comprehensive calendar that includes all activities for all species, it is easy to see how much labor and materials are needed each season. This calendar forms the basis of the budget. It also indicates when extra labor is needed and materials that cannot be obtained locally must be ordered/ purchased.

6.4 Production of vegetative/ tree planting materials[9]

Vegetative propagation is a form of asexual reproduction in plants. Asexual propagation or reproduction from vegetative parts of the original plant is possible because every cell of the plant contains the genetic information necessary to regenerate the entire plant. Reproduction can occur through the formation of roots and shoots or through the uniting of vegetative parts by grafting or budding. Stem cuttings and layers have the ability to form roots, and root cuttings can regenerate a new shoot system. It is also possible for leaves to regenerate both new roots and new shoots while a stem and a root can be grafted together to form a single plant.

Concepts and principles of grafting

Grafting is a technique used to untie 'parts' of different plants by bringing the cambium of each into contact to grow together as one plant. The technique involves two important stages: the preparation of the grafting surfaces and the procedures for aftercare. The advantages of grafting include:

- ✓ Reduced height for easy picking;
- ✓ Good quality fruit from selected varieties; and
- ✓ Early fruiting after only a few years.

There are several types of grafting namely: cleft, side-veneer, bark, splice, whip, tongue, saddle and approach grafting. One of the simplest and most popular forms of grafting is described in this handout, i.e. cleft grafting.

Raising Rootstocks

Raising rootstocks requires allowing a single stem to grow for 6 to18 months depending on the species. The technique involves formation of a union between scions taken from desirable mother tree and rootstocks that are normally young and healthy seedlings established in the nursery. If grafting is done with the right plant material, it can shorten the period between field establishment and when a tree flowers and fruits. This is important for fruit trees, since early maturity means revenues can be realized more quickly by farmers.

To achieve a successful graft, it is important to have healthy, actively growing rootstocks that grow well in the area they will eventually be established, as well as scions with active (swollen) buds that have not yet opened. Normally, scions and rootstocks should be of the same diameter in order to align the cambium layers. This is required for the formation of the graft union, to allow the effective movement of the nutrients and water needed for plant growth between roots and shoots.

Selecting and Handling the Scion

The best quality scion usually comes from shoots grown the previous season. Scions should be severed with a sharp, clean knife and placed immediately in moistened plastic

[9] Munjuga MR, Gachuiri AN, Ofori DA, Mpanda MM, Muriuki JK, Jamnadass RH, Mowo JG. 2013.Nursery management, tree propagation and marketing: A training manual for smallholder farmers and nursery operators. Nairobi: World Agroforestry Centre

bags or tissue paper. It is a good practice during the harvesting of scions and the making of grafts to clean the cutting tools regularly. Immersing them in a sterilizing solution such as alcohol or methylated spirit to do this. An alternative sterilizing solution may be prepared by mixing one part household bleach with nine parts water (by volume). However, this bleach solution can be highly corrosive to certain metals.

For best results, harvest only as much scions as can be used for grafting during the same day. Select only healthy scions that are free from insects, disease or damage. Be sure the stock plants are of good quality, healthy and true to type. If large quantities of scion wood must be harvested at one time, follow these steps:

- Cut all scions to a uniform length, keep their basal ends together, and tie them in bundles of known quantity (for example, 50 scions per bundle);
- Label them, recording the cultivar, date of harvest, and location of the stock plant;
- Wrap the base of the bundles in moistened tissue paper or cotton wool, place them in polythene bags and seal the bags; and
- Store the bundles for short periods in a cool box.

It should be noted that grafting, as well as budding, the vascular cambium of the scion or bud must be aligned with the vascular cambium of the rootstock. In woody plants the cambium is a very thin ribbon of actively dividing cells located just below the bark. The cambium produces conductive tissue for the actively growing plant. This vascular cambium initiates callus tissue at the graft or bud unions to stimulate tissue growth and healing.

Cleft Grafting

1. Harvest scions from the desired mother tree and cut them about 15cm long; Remove all the leaves carefully. The scions should be the same thickness as the rootstock stem;
2. With a very sharp knife cut the bottom of the scions with two sloping cuts 3.cm long (A);
3. Cut off the top of the rootstock about 30cm above the soil. Make one straight cut about 3cm deep in the top of the rootstock (B) to form a wedge;
4. Push the scions firmly into the rootstock cut. Leave .cm of the cut scions outside the rootstock as shown;
5. Use clear plastic tape to wrap firmly around the graft. Do not remove the tape until the scion begins to grow – showing the graft has been successful;
6. Remove any buds that have grown below the graft; and
7. If the graft dies, you must allow one bud to grow below the graft and wait several months before trying again.

See Figure 31 for illustrated details.

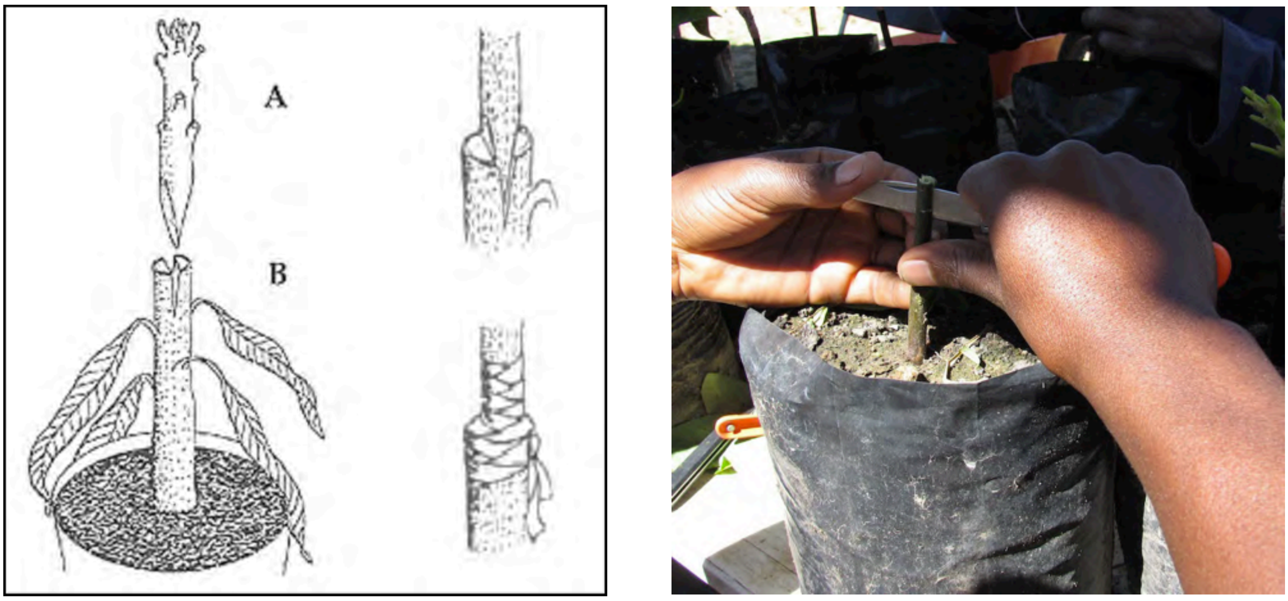


Figure 31 Cleft grafting – matching the 'rootstock' with the scions.

Concepts and principles of budding

This is a method of asexual propagation that involves inserting of a strip of bark with a bud from the branch of the desired plant/ clone into the stem of the seedling stock. Budding is a form of grafting and is based on the same principles and requirements for a successful union graft. Similar to grafting, it uses vigorous and disease-free rootstocks and scions. There are two commonly used budding techniques in tree propagation. These are T-budding and patch budding.

The principle involved in budding is the replacement of the shoot system of a plant with that of another more desirable plant. In this process, a patch of bark of the seedling plant (stock) is replaced by a patch of bark with a dormant bud (bud patch) taken from the clone to be multiplied. The bud patch gets attached to the stock permanently and becomes part of it. The stock is then cut off above the budded portion and the grafted bud develops into a shoot exhibiting the characters of the plant from which it was taken. The new tree is a two-part tree, comprising a root system belonging to the stock plant and a shoot system contributed by the donor of the bud.

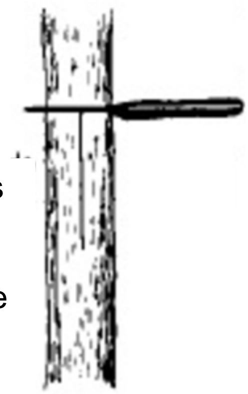
Steps in T-Budding

'T'- or Shield Budding

'T' or Shield Budding is a budding method in which incisions are made in the bark of the rootstock to form the shape of a letter '**T**' with one horizontal cut and another downward cut that originates from the center of the first cut. A *bud piece* or *shield piece* containing a bud is prepared with an upward cut that includes a thin layer of wood from about ½ inch (1.25 cm) below the bud. A horizontal cut is then made about ¾ inch (2 cm) above the bud to remove the shield piece from the *budstick*. This piece of bark has the shape of an ancient elongated shield, with a curved lower end and a horizontal top. The shield piece, generally with the thin piece of wood attached, is inserted into the T-cut from the horizontal cut down.

Preparing the stock:

STEP 1: A vertical cut about 1” (2.5cm) long is made in the stock.



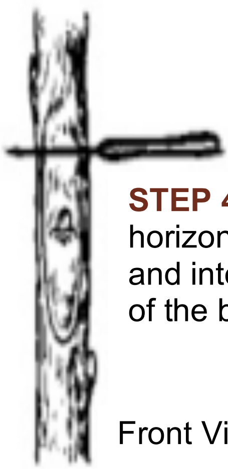
STEP 2: A horizontal cut is made through the bark about 1/3 the distance around the stock. The knife is given a slight twist to open the two flaps of the bark.

Preparing the bud:

STEP 3: Starting about ½” (1.2cm) below the bud, a slicing cut is made under and about1” (2.5cm) beyond the bud.

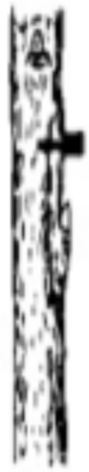
Front View

Side View



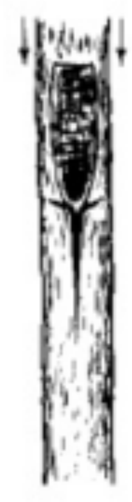
STEP 4: About ¾” (2cm) above the bud a horizontal cut is made through the bark and into the wood, permitting the removal of the bud piece.

Front View



Side View

Inserting the bud into the stock:



STEP 5: The shield piece is inserted by pushing it downward under the two flaps of the bark…

… until the horizontal cuts on the shield and the stock are even

STEP 6: The bud union is then tightly tied with some wrapping material

T-budding grafting materials

- Budding knife;
- Clean wiping cloth;
- Budding tape wax;
- Bud sticks;
- Rootstocks; and
- Pruning shear.

T-budding grafting process

1. Wipe the base of the seedling stock with 75% ethanol;
2. Make 2 vertical parallel incisions at ¼” (6mm) apart, 2” (5cm) long and 1” – 2” (2.5cm to 5cm) from the ground level;
3. Connect the top or bottom portion of the parallel incisions with a horizontal cut. Open the flap and cut the lower or upper portion leaving one half of the flap;
4. Get a bud patch from a bud stick, making a similar but smaller incision on the flap of the stock;
5. Slowly strip the flap having the bud eye on the middle;
6. After removing the bud patch from the bud-stick, carefully examine the inner side for the presence of the core of the bud. Discard the bud patch, if the core of the bud is not present;
7. Handle the bud patch with care so as to avoid any damage to the cambium. Always hold the edges of the bud patch without touching the cambium;
8. Lift the flap and insert the bud patch immediately and hold firmly;
9. After inserting the bud patch, place back the flap over it;
10. Wrap the incisions with plastic tape or budding tape with starting from the lower cut

going upward. Make sure that the edges of the tape overlap each other. During the first few turnings of the wrapping, the lower end of the flap should be kept gently pressed over the bud patch, to prevent it from slipping. Tighten the wrapping to keep the cambium tissues of the seedling stocks and the bud patch in intimate contact with each other;

11. Open the tape after 21 days. The budding is successful if the cambium of the seedling stocks and that of the bud patch unite. A green bud patch seen through the tape indicates successful budding. If the patch is black, then it was not successful;

12. Cutback (slide cutting) the stem of the budded plants at 1" – 2" (2.5cm to 5cm) from the bud eye three weeks after budding. Apply wax to the wound of the newly cut seedlings. The buds often bear shoots at 7 to 10 days from cutting and are ready for transplanting in the field.

Concepts and principles of cuttings

This is a plant cloning technique where bare plant parts are removed from the parent tree and induced to form roots and shoots that later grow to form new plants. The plant part that is removed is called a cutting. This cutting may be referred to by the location from which it is taken. Plants can be propagated from root cuttings, leaf cuttings or stem cuttings. Typically, stem cuttings of tree species are more difficult to root. Cutting propagation is often the preferred method for plant propagation because it is the easiest and most cost effective way to produce a clone of a particular parent plant.

Stock Plant Management

The conditions frequently chosen to root stem cuttings are warm, moist and shaded or at least away from dry air movement. It is important to choose cuttings that are pest and disease free. If appropriate, use proper and prescribed pest management tools prior to cutting.

Stock plants should be at a stage of growth most likely to have root stem cuttings. Old or mature plants are often more difficult to root than young, vigorously growing plants. Therefore, established blocks of trees and shrubs used for parent plants, known as stock blocks, will need to be replanted every 5 to 10 years. The less mature a plant, the easier it is to root a cutting from it.

Stock plants should receive balanced nutrition, usually at a moderate level for average or more difficult to root plants. When applying fertilizer to stock plants, avoid too much available nitrogen or too great an imbalance of essential nutrients. Field grown blocks of stock plants are often fertilized only once a year. However, taking cuttings from field stock is relatively easier than from root container grown plants that may require many applications of fertilizer in a year.

Propagation Substrates

Stability of components with minimal decomposition during propagation is necessary as changes in particle size also change the air and water balance in the substrate. The most common components used by professional propagators are combinations of pine bark, peat moss, coir, and horticultural grade perlite and washed sand. Moistening components prior to mixing and filling propagation trays or benches is a very important step in preparation of substrates. Mixing dry components creates a mixture with low aeration and poor drainage characteristics as particles fit tightly together and seal capillary channels. The effects are long lasting and have definite influence on root development and growth.

Coir (pronunciation: /ˈkɔɪər/), or coconut fiber, is a natural fiber extracted from the husk of coconut and used in products such as floor mats, doormats, brushes, and mattresses. **Coir** is the fibrous material found between the hard, internal shell and the outer coat of a coconut.

Cutting Types

Cutting types can be described by their origin such as leaf, root or stem cuttings. They can also be described by their location on the stem such as the cuttings from the ends of stems being called terminal or tip cuttings. Cuttings from further down the stem are called secondary cuttings. Terminal cuttings often root in higher percentages than those located further down the stem due to changes in natural hormone concentrations and hardiness.

Rooting Environment

The desire is to keep cuttings alive until they can root and support themselves, and this has prompted plant propagators to develop many creative ways to provide an environment that favors rooting. Light, temperature and moisture are usually the environmental factors most often manipulated.

Light

Light can keep a stem cutting from rooting by either being too bright or too dark. Inadequate light cause defoliation of cuttings and reduces rooting percentages. More frequently, cuttings are exposed to excessive light intensities that can cause heat damage during propagation. For this reason it is common to root plants under 25 – 70% shade with 50% being the most common shading provided for rooting stem cuttings.

Temperature

The most effective environment for rooting different plants may vary somewhat. Most often, normal cool to warm greenhouse temperatures are maintained, depending on the needs of the individual plant, with cooler air temperatures at night than during the day. Shading is used to reduce heat build-up during bright, sunny days. Excessive high temperature causes excessive shoot growth in advance of root development and thus leads to increased water loss and death of cuttings.

Moisture

High humidity around the leaves and stems of softwood and semi-hardwood cuttings keeps the cuttings from drying out and allows normal plant functions like photosynthesis and respiration to take place without the plant wilting while new roots are forming. Under most propagation systems, roots are formed in a medium that has the proper balance of moisture and air space to allow for the development of healthy roots.

Propagating Environment

Maintenance of high humidity, optimum temperature and light around the cutting is critical. High humidity may be provided by placing a flowerpot, plastic bag or glass jar over the cuttings or by misting the cuttings with water several times a day. Cuttings can also be placed in plastic trays covered with clear plastic stretched over wooden hoops or wire frame (Figures 32, 33, & 34). The plastic will help keep the humidity high and reduce water loss from the cuttings. Shade and temperature can also be manipulated by using shade net or local materials such as palm fronds, leaves or grass over the cuttings.

Figure 32 Small-scale rooting/ cutting humidity enhancement structures - pot, polybags, vase and small bed covered tightly with transparent polythene sheet.

Figure 33 Low tunneling structure/ environment.

Figure 34 A modified low-tunneling structure with planted stem cuttings.

Plants with thicker or waxy leaves suffer less from low humidity than thin-leaved plants. Plants in sealed containers may require a fungicide spray to deter harmful pathogens. If you need more elaborate facilities, you can construct a small hoop frame or use an intermittent mist system.

Procedures for rooting stem cuttings

Cuttings should generally consist of the current or past season’s growth. Avoid material with flower buds if possible. Remove any flowers and flower buds when preparing cuttings so that the energy can be used in producing new roots rather than flowers. Take cuttings from healthy, disease-free plants, preferably from the upper part of the plant.

The fertility status of the stock (parent) plant can influence rooting. Avoid taking cuttings from plants that show symptoms of mineral nutrient deficiency. Conversely, plants that have been fertilized heavily, particularly with nitrogen, may not root well. The stock plant should not be under moisture stress. In general, cuttings taken from young plants root better than cuttings taken from older, more mature plants.

Early morning is the best time to take cuttings, because the plant is fully turgid. It is important to keep the cuttings cool and moist until they are inserted in the rooting medium. An ice chest or dark plastic bag with wet paper towels may be used to store cuttings.

While terminal parts of the stem are best, a long shoot can be divided into several cuttings. Cuttings are generally 3” to 5” (5cm to10cm) long depending on the species. Use a sharp, thin-bladed pocketknife for the preparation of cutting. If necessary, dip the cutting tool in rubbing alcohol to prevent contamination or infections.

Remove the leaves from the lower one-third to one-half of the cutting (Figure 35). On large-leafed plants, the remaining leaves may be cut in half to reduce water loss and conserve space. Wounds may be created at the base of cuttings of difficult to root species.

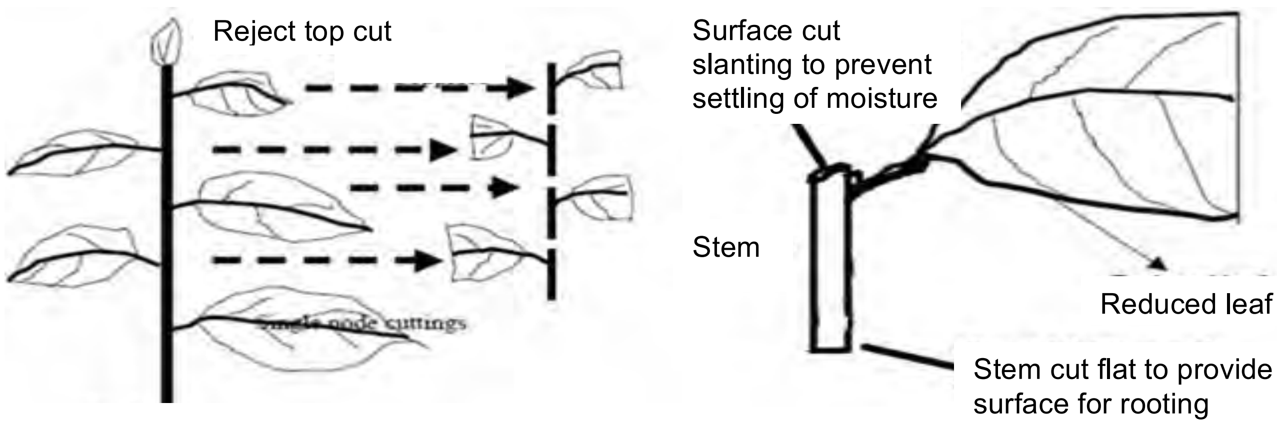


Figure 35 Schematic drawing showing shoots as cutting source and cutting the right single node cuttings (left), and stem cutting showing the slanting cut at the end of the stem with the leaf cut into half (right).

Treating cuttings with root-promoting compounds can stimulate rooting of some plants that might otherwise be difficult to root. Prevent possible contamination or damage to the entire supply of rooting hormone by taking small quantities from storage whenever required. Any material that remains after treatment should be discarded and not returned to the original container. Be sure to tap the cuttings to remove excess hormone when using a powder formulation.

The rooting medium should be sterile, low in fertility and well-drained to provide sufficient aeration. It should also retain enough moisture so that watering does not have to be done frequently. Materials commonly used are coarse sand, sawdust, a mixture of one part peat and one part perlite (by volume), or one part peat and one part sand (by volume).

Insert the cuttings ⅓ to ½ their length into the medium. Maintain the vertical orientation of the stem (do not insert the cuttings upside down). Make sure the buds are pointed up. Space cuttings just far enough apart to allow all leaves to receive sunlight. Water the container or set-up again after setting or inserting the cuttings. Cover the cuttings with plastic and place in shaded area to avoid exposure to direct sun. Keep the medium moist until the cuttings have rooted. Rooting will be improved if the cuttings are misted on a regular basis.

Transplanting the Cuttings

Newly rooted cuttings should not be transplanted directly into the landscape. They should instead be transplanted into pots. Growing them to a larger size before transplanting to a permanent location will increase the chances for survival. Handle rooted cuttings by the root-ball or pot, not the stem.

6.5 Management of agroforestry tree species[10]

Concept 1

Watering/Irrigating: This is crucial for young seedlings especially those that are newly transplanted.

Concept 2

Fertilizing/Manuring: Fertilization is important for nursery seedlings or if plants are planted in infertile soils. This practice is however critical when the tree is young because mature trees have deep roots which can reach into the nutrients deposited deeper in the soil through leaching. However, for tree species where huge volumes of products are harvested annually such as fruit it is prudent to apply fertilizers or manures every once in a while even when mature to sustain the productivity.

Concept 3

Controlling weeds: This is done to reduce competition between the trees and other unwanted plants through activities such as spot weeding, herbicides, mulching around the base of each young tree. For trees intercropped with annual crops, the weed control is done when weeding is done for the crops.

Concept 4

Mulching: Placing dry leafy material at the base of the trees to conserve soil moisture by reducing loss of water through evaporation. This is critical in the first few months after planting the trees in the field before full establishment - if the rains are not adequate.

Concept 5

Gapping: Filling gaps of trees that do not establish well or those that age with others. This ensures that the available land is used effectively. There are three ways in which a farmer can do this. A farmer can either add trees of different species if the new species are more superior (substitution), or add more trees of the same species if the species is satisfactory (addition) and replace a poorer variety of the same species with a better variety (replacement).

Concept 6

Thinning: This happens when the trees grow big on the farm and occupy too much space that they compete among themselves and other farm components. It involves removal of some trees that are too slender for the desired size/economic value and using the wood from the removed trees as building material, firewood or even sale.

Concept 7

Pruning: This practice is conducted when the tree crowns are too huge and involves removal of branches from the lower part of the crown. In this practice, branches are cut near the stem to reduce shade for intercropped cereals, to increase yields because lower branches respire more than they photosynthesize implying less productivity from these branches than in the upper parts of the crown.

[10] ICRAF, 2014. Conservation Agriculture with Trees: Principles and practices. World Agroforestry Centre, (ICRAF) Nairobi, Kenya.

Concept 8

Coppicing: This is a practice that is desirable when trees are planted in alleys in cropland and competition with crops needs to be minimized. It works best with species that are able to grow back after cutting and involves cutting a tree at or near the base so that it grows new shoots. The practice is also done for trees planted away from crop alleys if the species has the ability to re-establish after cutting – this replaces the task of planting a new tree after a mature one is felled (Figure 36).

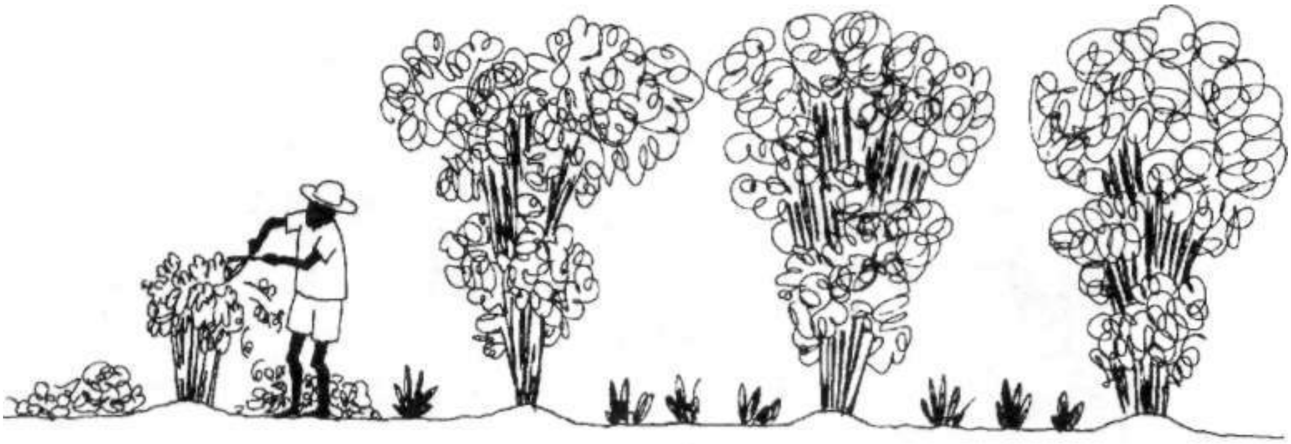


Figure 36 Illustration depicting of coppicing.

Concept 9

Pollarding: Cutting the tree at the top to control apical dominance and encourage side growth mainly for forage materials while reducing shading of crops underneath. The practice also works best with species that re-grow easily after cutting (Figure 37).

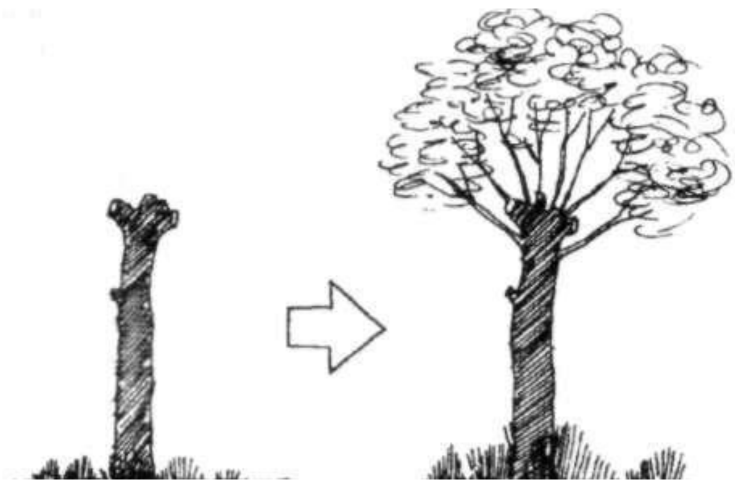


Figure 37 Illustration depicting pollarding - branches harvested and the leafy re-growth remains out of reach of browsing animals

Carica papaya L. (Common name: papaya)

Agro-ecological value: Carica papaya is a widely cultivated fruit tree in the tropics and subtropics. The fruit is consumed fresh and processed into fruit salads, refreshing drinks, jam and jelly. Unripe fruits are pickled or cooked as a vegetable. They are commercially used to produce papain, an enzyme that finds uses in the beverage, food and pharmaceutical industries. It is also used in treating hides, degumming silk and softening wool. Carpaine, an alkaloid present in papaya, can be used as a heart depressant, amoebicide and diuretic.

Propagation: Papaya is propagated by seed. To reproduce the desired characteristics seeds are produced through controlled pollination. The fleshy outer layer of the seed coat (sarcotesta) enveloping the seed is removed by rubbing the seed together against a fine-meshed screen under running water because it inhibits germination.

Dried seeds stored in airtight containers remain viable for several years. Seeds are sown in small containers (tin cans, plastic bags or paper cups) at the rate of 3-4 seeds per container. Use of sterilized soil minimizes losses resulting from nematodes and damping-off fungi. Germination takes 2-3 weeks. Another practice is to sow the seeds in sterilized nursery beds and to prick out at the 2-3-leaf stage, transferring 3-4 seedlings to each container.

Seedlings are transplanted about 2 months after sowing when they reach the 3-4 leaf-stage or 8” (20cm) height, preferably at the onset of the rainy season. Transplants must be watered regularly until they are established. Vegetative propagation of desirable clones is preferred while tissue culture is fast gaining popularity especially as it facilitates rapid production of disease free plants.

Management: Planting holes of 24” X 24” X 20” depth (60cm x 60cm x 50cm depth) are prepared with 1 bucket of compost and a handful of rock phosphate are mixed in with the soil. It can be intercropped with coconut, other fruit trees such as mango or citrus or annual crops such as capsicums, beans, onions and cabbages. Irrigation is needed to minimize the abortion of flowers and maintain growth during the dry season.

Papaya requires a lot of nutrients for growth; use of manure and mulch balances the release of nutrients. Calcium deficiency depresses growth and fruit set, and results in fruit drop. Hence liming is recommended to a pH of about 6. The tree can be productive for over 10 years but the economic period is only the first 3-4 years.

Pests and Diseases: Fruit flies have been recorded from papaya in East Africa, namely Bactrocera invadens and Ceratitis rosa. Spider mites and the broad mite, the cotton aphid and the green peach aphid are the most important aphids in papaya growing.

Citrus (Common names: orange & lemon)

Agro-ecological value: Citrus species are native to the subtropical and tropical regions of Asia and have been cultivated since ancient times for their edible fruits, spreading to other regions of the world.

Propagation: The most common method of citrus propagation is by budding. When old trees are top-worked, bark grafting is used. Citrus varieties grown from seed have numerous problems like late bearing, uneven performance due to their genetic variability and susceptibility to drought, root invading fungi, nematodes and salinity. Rootstocks are therefore used to meet all citrus requirements (tolerance / resistance to pests and diseases, suitability to soil and water conditions, in compatibility with the scion variety selected). Rootstocks also improve the vigor and fruiting ability of the tree, as well as the quality, size, color, flavor and rind-thickness of the fruit.

Pests and Diseases: Citrus spp. are susceptible to mites, insects and nematodes including citrus rust and bud mites, mealybugs, the citrus nematodes, woolly whitefly, blackflies, aphids, leafminer, African citrus psyllid, thrips, false codling moth and fruit flies. Citrus diseases caused by bacteria, mycoplasma, fungi and viruses include damping-off, greening disease, citrus tristeza virus (CTV), phaeoramularia fruit and leaf spot, gummosis and anthracnose.

Mangifera indica L. (Common name: mango)

Agro-ecological value: Mangifera indica is an economically important horticultural tree native to India, but naturalized in the tropics. It is cultivated for its fruit that is consumed fresh or processed into various products such as juice, chutney, pickles, jam, jelly, canned and dried fruit. In addition to income opportunities, the mango is noted for nutritional and food provision especially during the dry season. The wood is used as timber, carving and fuel wood while various parts of the tree are used in medicine and as animal feed.

Propagation: Mangos are propagated either vegetatively or by seed. Seeds must be taken from ripe fruits and should be fresh at the time of planting. Freshly sown seeds should be protected from high temperatures and desiccation by providing shade. Once seedlings emerge the shade is removed to harden the plants and produce a sturdy stem for grafting. Seedlings are grown sometimes to produce new cultivars but mainly for use as rootstocks or to reproduce known poly-embryonic cultivars. Mono-embryonic types, however, require vegetative propagation to retain all of the desired characteristics.

Trees grafted on selected rootstocks remain smaller than the rootstock, and bear better and earlier. In the dry zones of Kenya, mango generally flowers from July to November and the fruit is harvested from December to March.Grafted mango trees can begin fruit production after 3-4 years though optimal yields are achieved between 10 and 15 years.

Management: Mango trees require pruning in order to shape young trees: in the first year, cap the seedling at 39” (1m) height in order to produce a spreading framework of branches. In the second year, prune to leave 4 to 5 well-spaced branches to be the future main branches. Structural pruning should be done after fruit harvest so that the canopy is over 39” (1m) above the ground and, to remove dead and sucker branches from the main structural branches.

Pests and Diseases: The worst pests for mangoes include fruit flies, cotton scales, mealy-bugs, cicadas and black flies that create honeydew. Diseases caused by fungi and bacteria include anthracnose, powdery mildew and leaf spot.

Persea americana Mill (Common name: avocado)

Agro-ecological value: Perse a americana is native to tropical America and is an important horticultural crop in East Africa. The nutritious high protein and oil content edible fruit has multiple uses including cosmetics, healthcare products, lubricant or fuel oil. The wood is used as fuel wood while various parts are used as medicine.

Propagation: Avocado seeds are recalcitrant; they germinate readily and can be raised in a nursery. Commercial planting is mostly based on grafting high-yielding material onto hardy rootstock. Grafting should be carried out when the seedling reaches pencil thickness. The ‘wedge’ grafting method is most successful. Grafting should be done at the point where rootstock is soft. The scion should be dormant at the time of grafting and should match the size of the stock.

Pests and Diseases: Major pests include fruit fly, thrips, aphids, mites, and scales, false codling moth and the Mediterranean fruit fly. Diseases recorded include Phytophthora root rot, anthracnose, scab and Cercospora leaf spot.

Azadirachta indica A. Juss. (Common name: neem)

Agro-ecological value: The neem tree is native to India and Southeast Asia, but it is now grown in the warm lowland tropics and in arid and semi-arid areas of the world. Seeds, leaves and bark extracts are used in medical, cosmetic and insecticidal products. The wood is used as timber and when planted on slopes, the tree helps to combat erosion. It is planted for amenity, windbreak and shade purposes.

Propagation: Neem trees are propagated by seed. Fresh seed should be sown within two weeks while stored seed should be soaked in water for 24 hours. Fresh seed germinates readily at the rate of 85%. Seeds are commonly sown in polybags in the nursery, although direct sowing is successful where there is adequate rainfall. Vegetative propagation methods employed include grafting, root cuttings, stem cuttings and stump cuttings.

Management: Lack of zinc or potassium drastically reduces growth. Trees affected by zinc deficiency show chlorosis of the leaf tips and leaf margins, shoots exude resin, and older leaves fall off. Those with potassium deficiency show leaf tip and marginal chlorosis and die back (necrosis).

Pests and Diseases: In some parts of Africa, scale insects, mistletoes and semi parasitic plants have been reported to infest neem in Africa. Many diseases of neem are caused by fungi that affect its leaves, stems or roots, and are a particular problem for seedlings in plant nurseries.

Coffea robusta & Coffea Arabica (Common name: Coffee)

Agro-ecological value: There are more than 20 species within the genus Coffea but only two, Coffea arabica and Coffea canephora (commonly know as robusta) are produced in vast amounts to produce the worlds coffee demands. Both species of coffee are very different from each other in taste, caffeine content, cultivation conditions and disease resistance. The arabica bean is typically grown at heights between 1500 feet and 6000 ft and requires better soils to grow. Due to this and also the fact that the bean is considered tastier, the price of arabica beans is far higher against robusta beans. The Robusta beans being more easily farmed and more resilient to disease, cheaper, and used to produce both the instant coffee and the mass-produced ground coffees.

Propagation: Cuttings are a favored method for producing new plants, using short 5” or 6” tip cuttings. Take off all but the last 2-4 leaves at the tip. Dip the slanted cut in a high quality rooting compound. Cloning machines have a fine mist that constantly bathes these cuttings in a highly oxygenated environment. Rooting is faster and more reliable with this technique. Yet, the propagator can carefully pack the treated cutting in damp soil with a humidity dome as one would for any softwood cutting. Take care to remove the dome periodically. This prevents pathogenic fungus from establishing; the cutting will benefit from the exchange of new air too.

Gardeners should make cuttings in the spring after berries have ripened and before flowering begins. This is the time when the tree is preparing to grow new leaves in its annual cycle. Even though this is an evergreen, periodic leaf drop will happen. Expect the greatest loss to happen about the time the berries ripen. The plant is preparing for a new season.

From seed, green berries that have not been roasted will germinate. The rate will be low because of how processors cleaned the berries in preparation for shipment. There is also a significant decrease in germination with age. Gardeners should keep seed as fresh as possible because even a half-year from picking means that one can expect poor germination rates. Each berry contains two beans. Both are capable of sprouting. Beans at the grocer have had their fruit pulp removed. You will need to remove the fruit pulp should you have access to berries instead of seed. Soaking the dried berry in water for a day softens the pulp as well as hydrates the beans for planting. Simply plant your beans in a damp rich sterile potting media. Coffee is slow to germinate. Expect germination to begin in about 2 months or more. Continue to water and begin mild fertilization once true leaves emerge.

Management: Once the cutting has rooted or the seedling has emerged, provide plenty of light. Hopefully this will be in the summer when you can place your container in as much sunlight as the young leaves will tolerate without burning. A safe rule is morning sun with afternoon light shade.

After the first winter/ cold season you will find a hardy dark green plant that encourages closer inspection each time you pass by it. The tree is inviting. A 6-foot tree will be your result after 5 or 6 years. Some guides suggest that berries will begin to set in 3 years from sprouting. Realistically, allow a few extra years. Once the tree reaches 5 to 7 feet tall, you will begin to see flowering and fruit set.

Be sure to raise the soil level so the tree is at or above the soil line (not a depression in the ground). This encourages excess water to flow away from the tree. This is the best time to prune the tree.

Pests and diseases[11]

Black Twig Borer (*Xylosandrus compactus*)

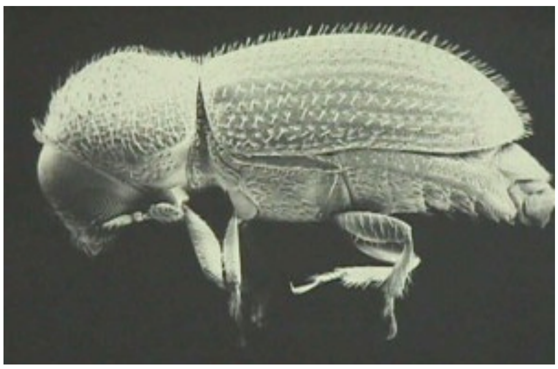
The black twig borer is native to Asia where it is a serious pest of Robusta coffee, and has spread to coffee growing regions throughout the world where it attacks Arabica coffee as well. Females bore into branches, twigs, and suckers, leaving a pin-hole sized entry.

The plant is destroyed through tunneling as well as pathogens introduced by the borer. The black twig borer thrives in humid conditions since humidity facilitates the ambrosia fungus upon which the borer feeds in its younger stages. Infestations can be controlled by pruning (specifically removing unwanted suckers) and shade reduction.

Cicadas (*Quesada gigas, Dorisiana drewseni, Carineta fascicuata, Carineta spoliata, Carineta matura*)

Cicadas are often called locusts, though they are actually unrelated. Females lay eggs by cutting into the bark of tree branches and depositing eggs. After hatching, the nymph falls to the ground where they burrow into the ground and feed from the sap of the taproot and other larger roots. This can cause chlorosis in the outermost leaves of the plant, as well as premature falling of leaves, flowers, and fruits. These systems are more predominant in dry periods.

Coffee Borer Beetle (*Hypothenemus hampei*)



The coffee borer beetle is a small black beetle that bores into the lower portion of the coffee fruit and lays eggs in the seed endosperm. The coffee borer beetle thrives in humid conditions and dense crop spacing. The best means to limit infestations are through proper plant pruning and ensuring that all coffee is harvested and no coffee fruit is left in the fields between harvests.

[11] Source: http://www.casabrasilcoffees.com/learn/pests-and-diseases/ (June 17 2016)

Nematodes *(Meloidogyne incognita, M. javanica, M. caffeicola, M. arenaria, M. hapla, M. exigua)*

Nematodes are worm-like organisms that are 0.1-5mm in length. They attack the root system of plants, feeding on the sap. They can form knots in the roots that inhibit the plant from properly feeding. Symptoms of a nematode infestation are galls, splits, scales and decreased mass in the root system, and chlorosis and defoliation in the upper plant. C. *canephora* is more resistant to nematode infestations, and thus using seedlings engrafted in C. *canephora* rootstock is a means of limiting outbreaks.

Bacterial Blight (*Pseudomonas syringae pv garcae*):

Bacterial Blight, also called Elgon Die-back, was first identified in Garca, Sao Paulo, Brazil, thus its name "garcae." It normally occurs in seedling nurseries and affects plant leaves and tissue. Leaves initially appear to be water-soaked, followed by the appearance of necrotic brown lesions surrounded by yellow rings. The leaves eventually dry, curl up, blacken and die; however, they do not fall from the tree.

Coffee Berry Disease – CBD (*Colletotrichum kahawae*)

Coffee Berry Disease (CBD) is caused by the fungus *Colletotrichum kahawae*. CBD was first documented in 1922 in Kenya. It attacks coffee berries at any point in their maturation; however, only symptoms detected on young berries can be clearly diagnosed The disease can appear in "active" form and "scab" form. In the "active" form, dark- colored indented spots appear on the coffee bean and are followed by a pale pink crust as the spores develop. The berry is destroyed in a matter of days and reduced to an empty, blackened and dried out pouch. The "scab" form is a much milder attack where several small concave spots form on the berry.

Coffee Rust (Hemileia vastatrix)

Coffee rust is fungus that attacks coffee plants. Its color can range from yellow to orange. First documented in Kenya in 1861, it is now known to be in nearly every coffee-producing region in the world. Spores set in on the underside of leaves and can cause severe defoliation, impaired photosynthesis, and a decrease in crop production. Copper-based chemicals have been somewhat effective in combating coffee rust, as have fungicides such as Triadimefon, Cyproconazole and Hexaconazole.

Due to the historical significance of its destruction, much research has been conducted in genetic resistance to coffee leaf rust resulting in the development of such varieties as Catimor, Colombia, Ruiru 11, and Icatu.

Session 7 Integrating animal husbandry into agro-ecological farming

Objectives

- ✓ Provide BRiLSS project partners with the relevant theory on integrating animal husbandry into agro-ecological farming; and
- ✓ Provide project partners with an opportunity an opportunity to develop mix-farming guidelines and a localized capacity building support profile for BRiLSS beneficiaries considering investment into mixed farming.

7

The session brings forward practical decision based knowledge regarding 'if' integrating animal husbandry into smallholder agro-ecological farms is possible and worthwhile vis-à-vis needed investments. Session handouts cover a variety of economical animal husband practices for smallholder farmers, e.g. food and fodder requirements vis-à-vis livestock numbers and farm capacities, to instructions on the making of silage, pasture management, and the use of cow, chicken and pig wastes as bio-fertilizers. Overall, the session aims to provide BRiLSS project partners with the relevant theory on integrating animal husbandry into agro-ecological farming; and an opportunity to develop mix-farming guidelines and a localized capacity building support profile for BRiLSS beneficiaries considering investment into mixed farming.

Session 7 Integrating animal husbandry into agro-ecological farming

Facilitation guide (5+ hours)

STEP 1

Introduce Handouts S7.1 – S7.6 through an organized PowerPoint presentation, including the session objectives, content, and the process the facilitator will take to deliver the session. Emphasize the importance of all participants having a common understanding of the content in the context of the BRiLSS project.

STEP 2

Begin the session with Handout S7.1 – integrating animal husbandry – the mixed farming system. The first paragraph of the handout is most important for participants to understand. Use Figure 38 to build this understanding. Follow by presenting handout information on the advantages of animal integration and associated constraints.

STEP 3

Ensure that participants understand that integrating animals into the agro-ecological farming system is not always a win-win situation. It is recommended that participants explore this in a focus group discussion in the context of the BRiLSS project support profile for farmer debt relief and investment.

Follow by reviewing 'lessons learned and recommendations', and see if key statements in the FGD have any commonalities. Ask participants how they could work recommendations made into their BRiLSS activity plans to better support livestock integration.

STEP 4

Move on to Handout S7.2 – making the decision to integrate livestock. Review the six (6) questions posed. Have participants answer these questions in the context of the BRiLSS project. Follow by presenting the tabled information on general food requirements for pigs and chickens. Stress to participants that the smallholder farm will need to produce the carbohydrate and protein base feed, thus, the number of animals a farmer chooses to raise depends on the farms ability to feed the livestock. Note that this is a key concept that separates conventional animal husbandry practices vs. agro-ecological integrated farming.

STEP 5

Move on to Handout S7.3 – food and fodder. Present the content, focusing on Table 11. Ensure that participant have a good understanding of the following statement:

Unlike conventional livestock raising, agro-ecological integrated farming and husbandry should be mainly based on the fodder produced on the farm itself, as there is a direct link between the quantity and composition of the food and the health status of the animals.

STEP 6

Move on to Handout S7.4 – silage. Begin with the definition of silage to set a base understanding amongst participants. Focus participants on the advantages and disadvantages of silage feeding. Follow by presenting the 'silage production process'.

STEP 7

Move on to Handout S7.5 – pasture management. Ensure that participants understand that overgrazing is probably the most significant threat to grass land. Once the protective grass cover is destroyed, the topsoil is prone to erosion. Degraded pastures or land with little plant cover is difficult to re-cultivate. Therefore, it is important that the use of pastureland aligns with the pastures production capacity. This is the purpose of pasture management.

STEP 8

Cover material given on 'how grazing affects root growth'. Focus participants on Figure 42, noting that when grass plants are continuously grazed short, the root mass decreases to what the leaf area can support. This eventually equates to less available food for livestock and the degradation of the land. Follow by stressing the golden rule to grazing – 'graze when the grazing forage is 8 to 12 inches tall, and stop grazing when the average height is 4 to 6 inches.

Follow by presenting the five (5) steps to small pasture management.

STEP 9

Move on to Handout S7.6 – cow dung and other animal dung as fertilizer. Cover material on composting cow dung and how to make use of cow urine as a bio-fertilizer and pesticide. Follow by presenting the diagrams on alternative animal composting practices – chicken & pig bokashi production. (Refer to Session 2, Handout S2.3 for further information on bokashi production).

7.1 Integrating animal husbandry – the mixed farming system

In an integrated agro-ecological system, livestock and crops are produced within a coordinated framework. The waste products of one component serve as a resource for the other. For example, manure is used to enhance crop production; crop residues and by-products feed the animals, supplementing often-inadequate feed supplies, thus contributing to improved animal nutrition and productivity (see Figure 38).

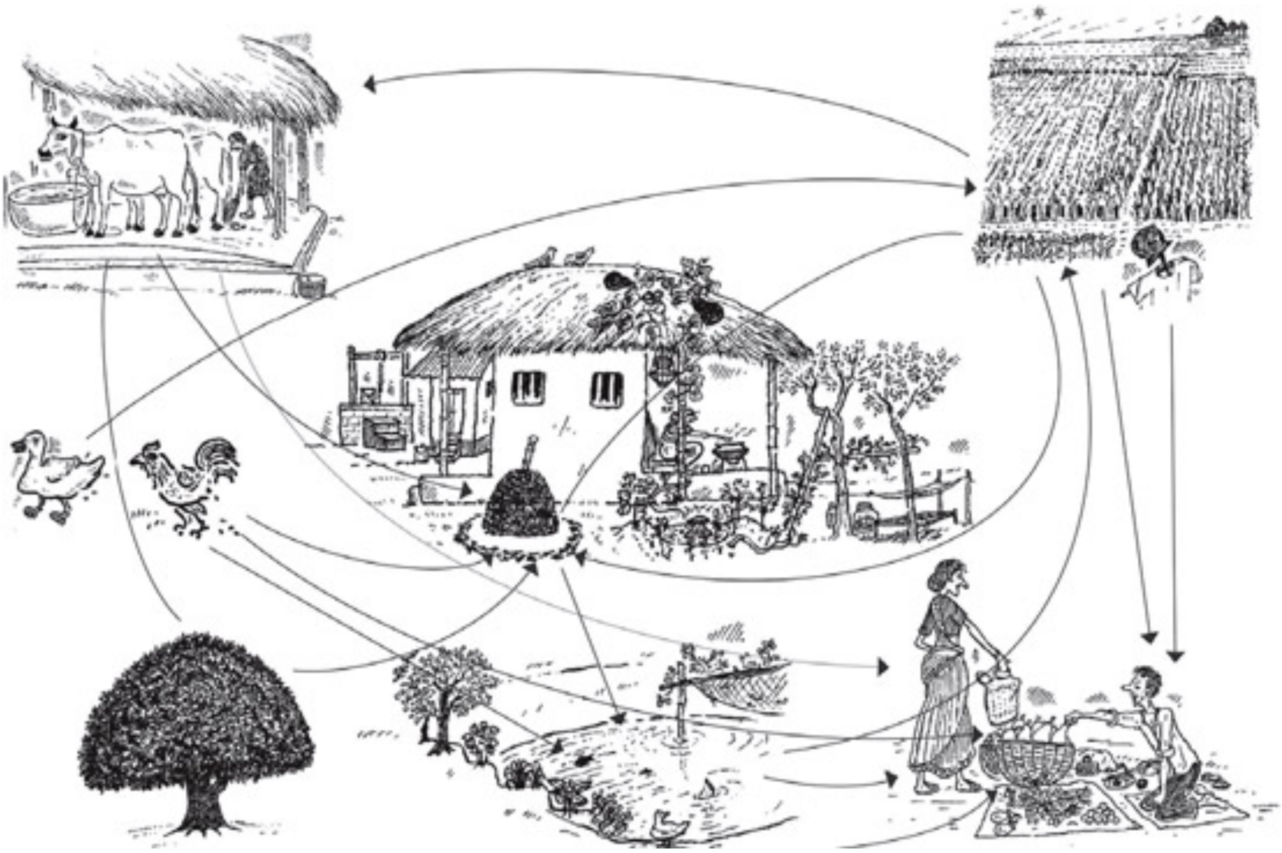


Figure 38 Sketch of 'connectivity' between production and waste recycling across an integrated crop-livestock farming system.

Advantages of animal integration

The result of this cyclical combination is the mixed farming system, which exists in many forms and represents the largest category of livestock systems in the world in terms of animal numbers, productivity and the number of people it serves.

Animals play key and multiple roles in the functioning of the farm, and not only because they provide livestock products (meat, milk, eggs, wool, hides etc.) or can be converted into prompt cash in times of need. Animals transform plant energy into useful work: animal power is used for ploughing, transport and in activities such as milling, logging, road construction, marketing, and water lifting for irrigation. Animals also provide manure and other types of animal waste. Animal waste has two crucial roles in the overall sustainability of the system:

Role 1
Improving Nutrient Cycling

Animal waste contains several nutrients (including nitrogen, phosphorus and potassium) and organic matter, which are important for maintaining soil structure and fertility. Through its use, crop production is increased while the risk of soil degradation is reduced.

Role 2
Energy Provision

Animal waste is the basis for the production of biogas and energy for household use (e.g. cooking, lighting) or for rural industries (e.g. powering mills and water pumps). Fuel in the form of biogas or dung cakes can replace charcoal and wood.

Crop residues represent the other pillar on which the equilibrium of this system rests. They are fibrous by-products that result from the cultivation of cereals, pulses, oil plants, roots and tubers. They are a valuable, low-cost feed resource for animal production, and are consequently the major source of nutrients for livestock in developing countries.

The overall benefits of crop-livestock integration (mix farming system) can be summarized as follows:

- ☑ Agronomic, through the revival and maintenance of the soil productive capacity;
- ☑ Economic, through product diversification and higher yields and quality at less cost;
- ☑ Ecological, through the reduction of crop pests (less pesticide use) and better soil erosion control; and
- ☑ Social, through the reduction of rural-urban migration and the creation of new job opportunities in rural areas.

The mix farming system has other specific advantages:

- ✓ It helps improve and conserve the productive capacities of soils, with physical, chemical and biological soil recuperation. Animals play an important role in harvesting and relocating nutrients, significantly improving soil fertility and crop yields;
- ✓ It is quick, efficient and economically viable because grain crops can be produced in four to six months, and pasture formation after cropping is rapid and inexpensive;
- ✓ It helps increase profits by reducing production costs. Poor farmers can use fertilizer from livestock operations, especially when rising petroleum prices make chemical fertilizers unaffordable;
- ✓ It results in greater soil water storage capacity, mainly because of biological aeration and the increase in the level of organic matter; and
- ✓ It provides diversified income sources, guaranteeing a buffer against trade, price and climate fluctuations.

Constraints of animal integration

- × Nutritional values of crop residues are generally low in digestibility and protein content. Improving intake and digestibility of crop residues by physical and chemical treatments is technically possible but not feasible for poor small farmers because they require machinery and chemicals that are expensive or not readily available;
- × Crop residues are primarily soil regenerators, but too often they are either disregarded or misapplied;

- Intensive recycling can cause nutrient losses;
- If manure nutrient use efficiencies are not improved or properly applied, the import of nutrients from feeds and fertilizers will remain high, as will the costs and energy needs for production and transportation; and surpluses lost in the environment;
- Farmers prefer to use chemical fertilizers instead of manure because it acts faster and is easier to use; and
- Resource investments are required to improve intake and digestibility of crop residues.

Lessons learned and recommendations for integrated farming[12]

1

The maintenance of an integrated crop-livestock (mix farm) system is dependent on the availability of adequate nutrients to sustain animals and plants and to maintain soil fertility. *Animal manure alone cannot meet crop requirements*, even if it does contain the kind of nutrients needed. This is because of its relatively low nutrient density and the limited quantity available to small-scale farmers. Alternative sources for the nutrients need to be found.

2

Growing fodder legumes and using them as a supplement to crop residue is the most practical and cost-effective method for improving the nutritional value of crop residues. This combination is also effective in reducing weight loss in animals, particularly during dry periods.

3

Given their traditional knowledge and experience, local farmers are perfectly able to apply an integrated system. However, relatively few adopt this system, mainly because they have limited access to credit, technology and knowledge. The crop-pasture rotation system is complex and requires a substantial capital outlay for machinery and implements.

4

Veterinary services are generally unable to reach poor small farmers in remote areas. Therefore, for livestock production to be improved, more attention needs to be paid to making veterinary care accessible, particularly in terms of prevention.

5

Better livestock management is needed to safeguard water. Livestock water demand includes water for drinking and for feed production and processing. Livestock also have an impact on water, contaminating it with manure and urine. All of these aspects need to be given due consideration.

6

Intensification of agriculture through appropriate incorporation of small livestock has the potential to decrease the land needed for agricultural production and relieves the pressure on forests.

[12] Source: www.ifad.org/lrkm/index.htm (July 18 2016)

7.2 Making the decision to integrate livestock[13]

There are several reasons for taking up animal husbandry as a part of farming activities or even as the main one. There are also a number of critical aspects to be taken into consideration. In order to make a decision on if, and how to get involved in animal husbandry, farmers need to ask themselves a number of questions.

Q1

Is my farm suitable?
Do I have sufficient space for shedding and grazing, sufficient fodder or by-products to feed animals, sufficient know-how on keeping, feeding, and treating specific kinds of animals?

Q2

Will the animals benefit my farm?
Can I use the dung in a suitable way? Will I get products for my own consumption or sales? Will the animals somehow affect my crops?

Q3

Can I get the necessary inputs?
Is sufficient labor available within or outside my farm? Is enough fodder and water of good quality available throughout the year? Will remedies and veterinary support be available, if needed? Can I get suitable breeds of animals?

Q4

Will I find a market for the products?
Does anyone want to buy my milk, eggs, meat etc.? Is the price worth the effort? Am I able to compete with other farmers?

Q5

What do animals need?
Agro-ecological farmers try to achieve healthy farm animals that can produce satisfyingly over a long period of time. To achieve this goal, various needs of farm animals have to be considered:

- Fodder in adequate quality and quantity; for non-ruminants: diversity in fodder is usually required;
- Sufficient access to clean drinking water;
- Clean sheds of sufficient size and with adequate light and fresh air;
- Sufficient freedom to move around and perform their natural behaviors;
- Healthy conditions and veterinary follow-ups, when needed;
- Sufficient contact with other animals, but no stress due to overcrowding; and
- For herd animals: an appropriate age and sex distribution within the herd.

Ecological animal husbandry means not only feeding organic food and avoiding synthetic food additives and synthetic medicines (e.g. antibiotics, growth hormones), but also focusing on satisfying the various needs of the farm animals. Good health and welfare of the animals are among the main objectives. Suffering due to mutilations, permanent tethering or isolation of herd animals must be avoided as much as possible. For various reasons, landless animal husbandry (i.e. fodder purchased from outside the farm, no grazing land) is not permitted in organic farming, nor considered in the realm of ecological farming.

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[13] FAO 2015 Training manual for Organic Agriculture. Climate, Energy and Tenure Division (NRC) and the Technologies and practices for smallholder farmers (TECA) Team from the Research and Extension Division (DDNR) of FAO Headquarters in Rome, Italy

Q6

How many animals to keep?

In order to identify the appropriate number for a specific kind of animal on a farm, the following points should be considered:

- Availability of fodder on the farm, especially in periods of scarcity (e.g. dry season);
- Carrying capacity of pastures;
- Size of existing or planned sheds;
- Maximum amount of manure the fields can bear; and
- Availability of labor for looking after the animals.

In tropical countries, farm animals are frequently found underfed. When defining the number of farm animals, keep in mind that the economic benefit will be higher when fewer animals are kept, but fed well. Not only the amount, but also the quality of the available food must be taken into consideration.

General Pig Feed Requirements

<table>
<tr><th>Age</th><th>Water (L/Day)</th><th>Protein Base (% of diet)</th><th>Carbohydrate Base (% of diet)</th><th>Vitamins</th><th>Minerals</th><th>Salt</th></tr>
<tr><td>Suckling Piglets (1 month)</td><td>1.0 – 1.5</td><td>22</td><td>78</td><td colspan="3" rowspan="6">IMPORTANT: A pig has a single stomach, so it cannot digest fibrous feed like cows, goats, etc. Fibrous feeds such as jungle forages, pasture grass & green leaves should not exceed 20% of the total diet.

Vitamins: A, D, E, K, B-complex and C. Deficiency causes poor growth, weakness, anemia, and low production of milk. Vet mixes are available – 1-2 teaspoons/ day/ pig.

Minerals: Essential – especially during pregnancy to stimulate normal growth in piglets. Increase milk yield, and prevent milk fever disease. Use agrimin, milkmin or kelmin - 1-2 teaspoons/ day/ pig

Salt: An essential item – 5gm/ day/ pig.</td></tr>
<tr><td>Weaner (2-4 months)</td><td>1.5 – 2.0</td><td>18 - 20</td><td>80 - 82</td></tr>
<tr><td>Growers (5-6 months)</td><td>2.0 – 5.0</td><td rowspan="4">15</td><td rowspan="4">85</td></tr>
<tr><td>Adults (7-10 months)</td><td>5.0 – 6.0</td></tr>
<tr><td>Sows & Boars</td><td>5 - 8</td></tr>
<tr><td>Lactating Sows</td><td>15 - 30</td></tr>
<tr><td colspan="7">1Kg = 2.2 pounds</td></tr>
<tr><td colspan="3" rowspan="2">OVERALL FOOD REQUIREMENTS</td><td>Weaner (up to 20Kg.)</td><td>Growers (20 to 40 Kg.)</td><td>Adults (up to 100Kg.)</td><td>Lactating Sows</td></tr>
<tr><td>0.25 – 0.75Kg</td><td>0.75 – 1.5Kg</td><td>1.5 – 2.5Kg</td><td>2.0 – 3.5Kg</td></tr>
</table>

General Chicken Feed Requirements

In general, poultry, as other animals, need feed containing energy and protein, as well as vitamins and minerals. The need for feed will change, depending on the age and status of the bird (chicken, grower, egg layer, broody hen). The cheapest – and also often the best way to supplement the diet of poultry is to use local resources. However, many vitamins and nutrients are destroyed if stored too long or under sub-optimal conditions, e.g. high humidity and heat. Knowledge of the quality and source of different feedstuffs is important to reduce the risk of bad feeding. If production is based on improved breeds for egg production, different types of commercial diets may be used: usually they are divided into three distinct categories, with decreasing amount sof protein:

1) A starters' diet: high in protein (30% of total); from hatch up to 4 to 6 weeks of age;
2) A growers' diet: medium in protein (20% of total); up to 20 weeks;
3) A layers' diet: lower in protein (10-20% of total); hens from 20 weeks.

Protein sources: Oil cake for groundnut or sesame, soybean, meat, fishmeal.
Carbohydrate sources: Rice bran, millet bran, sweet potato, cowpea, chick pea

How much feed do free-range chickens need?

Limit the quantity of feed given to local birds to no more than 30% - 50% of their full intake as an adult (see Table 9 & 10 for suggested feed levels and needs). In general this means giving maximum 30-40 g/bird/day from week 4-6 and onwards, gradually reducing the supplementary feeding. At age 0-4 weeks, the small chicks will receive feed according to their needs. As the birds grow, they will gradually get a smaller portion of what they need, until they only get between 1/3 and half of their needs as adults.

Table 9 Supplemental feed requirement for free-range chickens/ day.

Age - Weeks	1	2	3	4-6	8	16-27	28 - forward
Viss/ day (dry weight)	0.016 – 0.24	0.24 – 0.32	0.34 – 0.05	0.05 – 0.06	0.06 – 0.07	0.07 – 0.08	0.07 – 0.08
Grams/ day (dry weight)	10-15	15-20	21-30	30-40	30-40	30-50	30-50

1 Viss = 1.6Kg.

Table 10 Feed requirement for caged chickens/ day.

Age - Weeks	1	2	3	4-6	8	16-27	28 - forward
Viss/ day (dry weight)	0.02 – 0.24	0.24 – 0.32	0.32 – 0.056	0.056 – 0.08	0.09 – 0.1	0.11 – 0.13	0.16
Grams/ day (dry weight)	12-15	15-21	21-35	35-50	55-60	65-80	100

1 Viss = 1.6Kg.

7.3 Food and fodder

The availability of fodder is one of the limiting factors in animal husbandry. Unlike conventional livestock raising, agro-ecological integrated farming and husbandry should be mainly based on the fodder produced on the farm itself.

Grazing vs. shed feeding

In many regions of the tropics, favorable periods with abundant fodder alternate with less favorable periods when there is almost nothing to feed animals. However, keeping animals means providing fodder throughout the year. Fodder can be produced on the farm as grazing land or as grass or tree crops cuttings.

While grazing requires less labor than shed feeding, more land is needed and appropriate measures to keep the animals away from other crops must be undertaken. Grazing may lead to lower productivity (milk, meat) but usually it is the more favorable option concerning the health and welfare of the animals (see Table 11 for further information).

Table 11 Grazing vs. shed feeding.

	Grazing	▪ Less labor; ▪ More land require; ▪ Lower productivity; ▪ More move/ exercise; and ▪ Dung is spread on the pastures.
Combining grazing & shed feeding may be an idea solution.		
	Shed feeding	▪ More labor; ▪ Less land required; ▪ Higher productivity; ▪ Less move/ exercise; and ▪ Dung collected easily.

How much hay and forage do animals need?		How much hay & forage can a pasture produce?	
Average Animal Feed Requirements		Average forage production of pasture in 1 year	
Animal	**'Hay' (Viss/month)**	**Fertile Soils (non-irrigated)**	**Poor Soils (non-irrigated)**
1 Horse	312	625-1250 Viss Hay/ Acre	312 Tones Hay/ Acre
1 Cow	750		
1 Sheep	125		
1 Goat	125		

Shed keeping, however, has the advantage in that the dung can be easily collected, stored, or composted and applied to the crops. Whether grazing or shed feeding is the more suitable option will mainly depend on the agro-climatic conditions, the cropping system, and the availability of land. A combination of shed feeding and grazing in a fenced area may be an ideal combination of high productivity and animal friendly husbandry. However, in extensive grasslands of semi-arid areas, grazing may be the only suitable option.

7.4 Silage[14]

What is silage?
Silage consists of green forage preserved by fermentation in a silo for use as succulent fodder during periods of feed scarcity. Silage is the product of controlled fermentation of green fodder retaining high moisture content. The material is normally stored in drums under anaerobic conditions. Naturally produced organic acids, mainly lactic acid, preserve the fodder.

Why silage and not hay?
Forages can be made into hay to conserve the nutrients, especially protein, before they decline in the plant. However it is often too wet to dry the successfully and special machinery, has to be used to assist the forage to dry quickly. Forage crops such as maize, are too thick-stemmed to dry successfully as hay.

Silage is considered the better way to conserve forage crops. A forage crop can be cut early and only has to have 30% dry matter to be ensiled successfully. There is no need to dry out the plant material any more than that, so wet weather is not such a constraint as it is with making hay.

Silage making is long practiced by the larger agricultural sector, but the production method relies on heavy equipment and large production, in order to dig or build storage pits and to compress the green mass, putting it beyond the reach of smallholder farmers.

Advantages

- ☑ Plants can be harvested at optimal phase of development and are efficiently used by livestock;
- ☑ Reduction of nutrient loses which in standard in hay production may amount to 30% of the dry matter (in silage is usually below 10%);
- ☑ More economical use of plants with high yield of green mass;
- ☑ Better use of the land with 2-3 crops annually;
- ☑ Silage is produced in both cold and cloudy weather;
- ☑ The fermentation in silage reduces harmful nitrates accumulated in plants during droughts and in over-fertilized crops;
- ☑ Allows by-products (from sugar beat processing, maize straw, etc.) to be optimally used;
- ☑ Requires 10 times less storage space compared to hay;
- ☑ Maize silage has 30-50% higher nutritive value compared to maize grain and maize straw; and
- ☑ 2 kg of silage (70% moisture) has the equal nutritive value of 1 kg of hay.

Disadvantages

- ☒ Silage is not interesting for marketing as its value is difficult to be determined.
- ☒ It does not allow longer transportation;
- ☒ The weight increases manipulation costs;
- ☒ Has considerably lower vitamin D content compared to hay

[14] Portions of this material have been adopted from the Food and Agriculture Organization of the United Nations (FAO) (un-dated): Silage Making for Small Scale Farmers.

Silage production process

Stage 1
Forage Harvesting

- The material to be conserved must have a high nutritive value;
- The forage must not be contaminated with soil; and
- The forage should be chopped into pieces no longer than about 2 cm in length to facilitate good compaction and reduce the amount of air in the silage.

What can be used for Silage?

- Corn (whole or residue)
- Sugarcane
- Mulberry – Nacedero – Taiwan grass
- Lab lab – Hay molasses – Madre cacao
- Leucaena- Rejected banana – Cassava
- Leaves – Napier grass – Elephant grass

Stage 2
Forage Processing

1” (3cm) long cuttings of the ‘green organic mass/ silage mix’ is stored in large, clean, plastic drums. The material is pressed into the drum, thus removing the air and thereby preventing decomposition once the drum has been filled and shut. The feed can be stored in this way, without losing the nutritive quality, for up to a year. This allows farmers to maintain feed levels through dry or winter seasons.

The purpose of chopping and compacting forage for silage is:

- To release as much plant sugar as possible for fermentation, and
- To ensure that all the air is pushed out of the plant material so that when the silo is sealed, the plant material is free of air. This is when fermentation works best to produce lactic acid.

It is important to time the cutting of the forage so that the cut forage is not sitting for more than a day waiting to be chopped and ensiled, otherwise it will become moldy or to dry. It is also important that once the forage has been chopped, it is placed in the silos/ drums and compacted as much as possible to get the air out before the silo is sealed.

Stage 3
Silage Compaction

Figure 40 Compressed silage mix.

- Collection and processing of the forage and sealing the silage in containers should be done in the shortest possible time;
- Make a molasses mix (molasses or brown sugar dissolved in equal parts of water). Approximately 11 Viss (18Kg or 40lbs) of molasses or brown sugar is needed per ton of crop forage;
- Sprinkle the molasses mix every 6” layer of chopped ‘green organic mass/ silage mix’;
- Aim for a 50% moisture content that is easily compress tightly (see Figure 40);
- It is necessary to expel the maximum amount of air within the forage before closing the silo/ drum, or silage bag (see Figure 41 for more details);

Figure 41 Locally designed silage press.

Silage is often ready in as early as 6 weeks. If kept under airtight conditions the silage can last up to 6 months. Note: at times 3-6 inches of the top silage should be discarded. Good silage is a pale yellow – brownish color, bad silage dark brown or black and should not be used.

7.5 Pasture management

The management of pastures is crucial for good herd management. It is also important to practice appropriate management throughout the year. There are many different types of grasses, and every climatic region has grasses that are specifically adapted to the conditions. In some cases it may be worth considering tilling the grazing site and sowing grass varieties that are more appropriate to animal needs.

Overgrazing is probably the most significant threat to grass land. Once the protective grass cover is destroyed, the topsoil is prone to erosion. Degraded pastures or land with little plant cover is difficult to re-cultivate. Therefore, it is important that the use and intensity of grazing on a particular piece of land is appropriate to its production capacity.

Sufficient time must be given to a pasture to recover after intensive grazing. Fencing off of areas and rotation of the grazing animals on several pieces of land is the best option for managing the farm and the overall landscape. Creating ‘grazing cells’ restores overgrazed pastures; reduce the incidence of intestinal parasites encountered while the animals graze, and increase land productivity. The intensity and timing of grazing, as well as the cutting of the grass, will influence the varieties of plants growing in the pasture.

How grazing affects plant root growth

Plants get the energy needed for growth from the sun through photosynthesis in their green leaves. The root system is in the dark and totally reliant on the leaves to supply the carbohydrates required for maintenance and growth. When grass plants are continuously grazed short, the root mass decreases to what the leaf area can support (Figure 42).

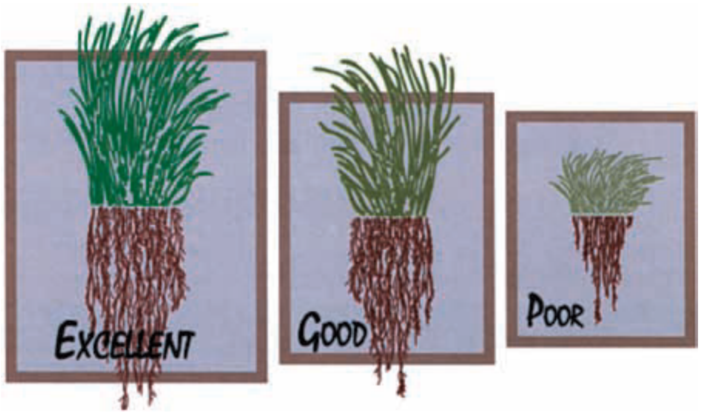


Figure 42 Illustration demonstrating the level of root growth to that of leaf growth

The general rule of thumb is to begin grazing when the pasture is 7 to 8 inches tall and stop grazing when the average height of the pasture is 3 inches tall. Over grazing not only reduces the health and vigor of the plants (causing a decrease in the regrowth rate), but it pre-disposes the pasture to weed invasion. Non-irrigated pastures are less resilient to grazing than irrigated pastures. They are slower to recover and often must wait for precipitation to be revitalized. Thus, for non-irrigated pastures, begin grazing when the forage is 8 to 12 inches tall, and stop grazing when the average height is 4 to 6 inches.

5 steps to small pasture management[15]

Step 1 Pasture Inventory

Take a walk through each pasture and conduct an inventory of the grass and weed species, fences, gates, and water troughs. When conducting this inventory, determine what kinds and amounts of grass species currently growing and where they are located. Are there bare areas with no grass?

Are some areas made up of only one grass species taller than the rest? Animals may overgraze some areas and under-use others due to the species present. Identify weeds in the pasture, particularly species that may be poisonous to animals.

Next, examine the condition of the pasture fence. Improvements may be needs, some fencing may need to be added to improve animal distribution and grazing. Providing additional water may be a necessary part of a pasture management plan. Locate streams, ditches, ponds, or wetlands in the pastures. Consider fencing animals away from these areas to minimize nutrient contamination and protect habitat for fish and wildlife.

A pasture inventory should also determine soil type and fertility. Soil testing helps in selecting the correct type and amount of fertilizer and lime necessary to optimize growing conditions for a specific pasture.

Step 2 Creating a Sacrifice Area

During the wet, winter months when soils are saturated and grass growth is minimal, it is important to rest grass crop areas. Allowing animals to graze throughout the year on the same plot of land significantly reduces grass growth later.

Note that soil compaction results when animals graze on saturated soils, making it difficult for grass to grow in the spring. A sacrifice area provides a place to put animals while pastures rest. It is called a sacrifice area because a small portion of ground is “sacrificed” for the benefit of the remaining pasture. In the late summer when rain is limited and grasses go dormant, using this area will keep your pastures from being overgrazed.

Grazing grass below three inches stresses the plant by reducing the leaf surface which grasses use to make their own food, thus forcing them to use up food reserves in their roots. Eventually, the grass depletes its stored reserves and dies, leaving bare spots in your pastures. Remember the **‘Grazing Golden Rule: Keep grass at least three inches tall.’**

[15] Source: https://www.premier1supplies.com/img/newsletter/05-22-14-goat/PastureGrazingMgmt.pdf (July 18 2016)

Step 3 Rotational Grazing

Grazing pastures below three inches stresses the plant by reducing the leaf surface which grasses use to make their own food, thus forcing them to utilize food reserves in their roots.

Eventually, the grass depletes its stored reserves and, thus leaving bare spots in your pastures. As part of an inventory, areas in the pasture where animals grazed the grass closer to the ground than in other areas should be identified. In large, single pastures, animals selectively graze, eating short, tender grass down to the ground, returning as it regrows, while snubbing taller grass considered less palatable. Eventually, grass in the overgrazed areas die, increasing erosion and runoff potential and leaving space for weeds to colonize.

To prevent overgrazing and force animals to graze more evenly, create a rotational grazing scheme. Divide larger pastures into several, smaller pastures and then rotate animals through these fields. Temporary fencing works best to set up smaller fields and leaves flexibility to rearrange as necessary. Turn animals out to graze a field when grass reaches six to eight inches and move them when grasses reach three to four inches in height. Grasses in the first pasture rest while the animals start on a new pasture. Resting grasses allows them to regrow and collect energy to survive.

Growing conditions determine the length of time necessary for grass regrowth. For example, when grass grows quickly in the spring, animals may be able to return to a field within two to three weeks. As growth slows down in late summer and early fall, fields may need six to eight weeks to regrow. In this instance, sacrifice areas used in late summer and fall provide a place to put animals if all pastures require a rest to recover. Rotational grazing entails more effort, but pays off in healthy animals, thriving pastures, decreased feed and vet costs, fewer weeds, less bare soil, and reduced runoff.

Step 4 Mowing and Harrowing

Once animals graze down most of the grass in a pasture to three inches, in addition to moving them to another pasture, it is often necessary to mow the just grazed pasture.

Mowing after animals graze a pasture evens out the grass height, which promotes more even grass growth of all species during the recovery period. Mowing also encourages plants to produce more leaves and fewer stems, thus producing a more palatable, thicker, and hardy grass stand. Mowing also helps control some weed species. Mowing weeds, such as thistle, prevents them from going to seed, thus reducing the number of weeds later. Animals, such as sheep and goats, graze some weed species, particularly if the weeds are kept short, making them more palatable.

Harrowing (dragging) your pasture after grazing breaks up manure and evenly distributes the nutrients in the manure. Breaking apart manure piles prevents grass from being smothered by manure. Dispersing manure piles also helps control parasites and pest insects. Flies prefer fresh manure for laying their eggs and survive for days within the moist middle of manure. Breaking apart piles exposes fly and parasite larvae to sunlight, which drys them out and kills them. A harrow with teeth or tines may be adjusted to tear up the ground more aggressively, which may be useful if you are planning on over seeding any pastures. A section of chain link fencing, weighted down with concrete blocks makes a simple and inexpensive harrow item.

Step 5 Fertilizing

Like any plant, grass requires nutrients to grow. By following recommendations provided through soil testing, thus, only applying the correct amount of fertilizer with the correct balance of nutrients required by the pasture plants. This saves money and avoids over-application, which allows fertilizer to runoff into nearby streams, water bodies, and possibly, your well.

Excess nutrients harm fish and wildlife, and even pose a potential health risk to your family and animals if they make their way into drinking water. If a soil test recommends an application of fertilizer, consider utilizing manure as an inexpensive source of organic fertilizer. Avoid applying any fertilizer or manure during rainy months since the fertilizer nutrients are more likely to leach into nearby water; wasting your time and money, and potentially harming fish and wildlife.

While soil tests may not recommend fertilizers, they may recommend lime. Acidic soils release fewer nutrients to grasses, Over-applying fertilizers also increases soil acidity, exacerbating the problem. Applying lime increases the pH (measure of acidity), releasing more nutrients from the soil that make them more available for grasses. Liming also enhances the effectiveness of fertilizers or manures applied. Furthermore, raising the pH makes soil bacteria more active, which releases more valuable nutrients. Lime contains calcium and magnesium, both important for healthy plant growth. After applying lime to pastures, a flush of growth may make it look like that land was just fertilized, since the lime releases much-needed nutrients.

7.6 Cow dung and other animal dung as fertilizer

Cow dung and other animal dung cannot be used as manure directly, as it is not very rich in nitrogen and its high ammonia content can burn plants as well. Therefore, *cow dung and other animal dung manure is first composted and then used as a fertilizer on the farm*.

Composting animal dung not only eliminates ammonia gas, pathogens like E. coli, and weed seeds, but also adds a generous amount of organic matter to the soil. Mixing this compost into the soil enhances its water retention capacity, meaning less frequent watering of fields. Moreover, it helps to break compacted soil and enhancing aeration.

Composted dung manure also contains beneficial bacteria that can convert nutrients into easily accessible forms, which can be slowly released into young plant roots. Composted cow dung and other animal dung also reduces the release of greenhouse gases **(carbon dioxide, methane, and nitrous oxide - referred to as greenhouse gases and abbreviated as GHG)** by a third, making it eco-friendly.

How to compost cow dung

To create composted manure, cow dung is mixed in a bin with straw or hay in addition to organic substances obtained from vegetable matter, garden debris, etc., along with small amounts of lime or ash. The size of the bin is a matter of great importance. Composting requires a certain amount of heat that cannot be sufficiently produced in small bins. However, larger bins may not get enough air. And, frequent turning of the bin is necessary for good compost to be made.

Dung & Weeds

One of the most common disadvantages in utilizing farmyard manure for forage production is the presence of weed seeds in the animal dung that may germinate later when applied to the field. To overcome this problem, dry the animal dung under the sun to about 40% moisture content, then sieved through a ½ inch wire-mesh and store for at least 40 days before application. After two weeks of storage the temperature of the stored dung should reach more than 60^{o} C - killing unwanted weed seeds in the dung.

Importance of cow urine as a bio-fertilizer

In India, the use of cow urine as a medicine as well as a fertilizer can be traced to the Vedic and pre-Vedic periods. Due to its immense therapeutic value, cow urine has been widely referred to as a medicine. Cow urine also has multiple uses in agriculture. Laboratory research on cow urine has shown that it contains sodium, nitrogen, sulfur, and vitamins A, B, C, D, and E. Cow urine is also rich in several minerals such as manganese, iron, silicon, chlorine, magnesium, calcium salts, phosphate, lactose and carbolic acid. Cow urine is not a toxic effluent. It mainly consists of 95% water, 2.5% urea, and the remaining 2.5% a mixture of various minerals, hormones, salts and enzymes. Urea is also a major component of many chemical fertilizers.

Cow urine in agriculture

In the world of sustainable agriculture, cow urine is beneficial for farmers, since it contains a variety of nutrients that can be used as a liquid fertilizer. The multiple uses of cow urine have been elaborately explained in several ancient Indian texts. Cow urine can be used as a bio-pesticide in organic farming along with cow dung, cow milk and other herbal ingredients. The use of cow urine in various forms could help improve the efficiency of microorganisms in soil and enhance the growth of crops. Farmers who have used cow urine have found that the residual effect is pronounced even in the next cropping. Cow urine can help improve soil texture and create a good environment for the growth of earthworms in soil.

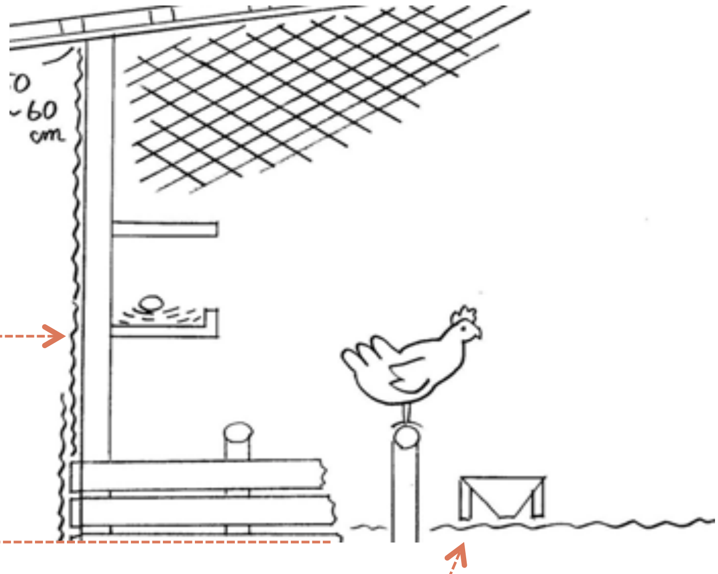
Cow urine could also be used as a growth promoter for various crops. Farmers cultivating paddy using only cow dung and cow urine as manure report increased yields year after year.

Cow urine and vermicompost: By fully utilizing organic farm wastes and cattle shed waste, a farmer could easily improve the quality of the soil in their field and produce good crops. By adding cow urine to the compost pit, a farmer can get superior quality vermicompost with higher concentration of micronutrients. The application of vermicompost made with the help of cow urine can significantly improve the yields.

Cow urine as bio-pesticide and bio-enhancer: 'Panchkavya' made up of five cow products (milk, curd, ghee, urine and dung) is also used as a fertilizer and pesticide in agricultural operations. Studies have shown that apart from producing good organic manure, cow urine is also a very effective pest controller and larvicide when used alone or in combination with several plant preparations. Studies have claimed that a farmer reaps twin benefits with the use of cow urine in combination with neem extracts as a pesticide. While neem wards off pests, cow urine is a rich source of urea - an important nutrient for enhancing soil fertility. Thus, the farmer reaps the second benefit in the form of lower input costs.

Alternative animal composting practices[16]

Chicken - bokashi



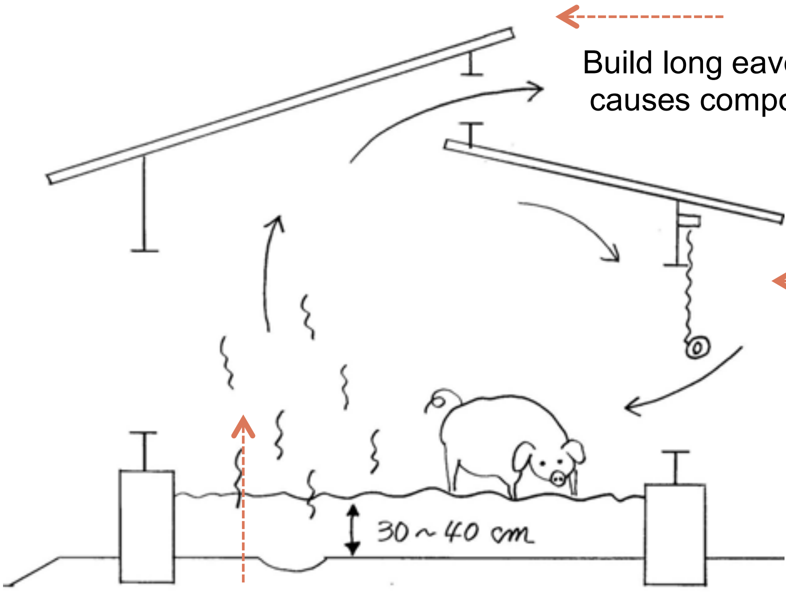
Eaves are made long to avoid rain blowing in.

Walls have to be covered by metal nets or boards fixed with narrow spaces to keep harmful animal out.

Chicken dung on the fermentation bed turns to be 'chicken-bokashi' by actions of microorganisms.

Spread think layers of fallen leaves, dry grasses, etc. on the ground to make the fermentation bed

Pig - bokashi



Build long eaves to keep rainwater out. Rainwater causes compost to spoil, and makes the area unhygienic

Keep ventilation good. Let moisture evaporate from the fermentation bed.

Make a thick bed. Spread dry organic materials such as grasses, fallen leaves, twigs, rice hull, etc. in large quantities. When taking the bed out for composting, do not remove it altogether. Leave half so that fermentation bacteria stay in the pen.

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[16] Wakui, Y. 2009. Organica Farming Technology in Japan: Pilot project for better farm income by organic based vegetable production. Koibuchi College of Agriculture and Nutrition. Japan.

Annex A - Smallholder agro-ecological farm assessment tools

A

Basic smallholder agro-ecological farm – farmer self assessment tool

The following basic farmer self-assessment tool is to be completed by BRiLSS farmer beneficiaries after completing their training on the relevant session materials presented in this training manual. A simple check mark can be placed in the appropriate column and row. Farmers can re-assess their progress to becoming fully 'agro-ecological' as often as they wish by simply filling in a new form and comparing the difference. To extend the assessment, farmers should track their 'farm profitability' NOT by cropping season but by their overall farm profitability over a one year. Expected is the more (and consistency within) agro-ecological farming practices adopted, farm profitability should increase over the span of 2-3 years.

No.	Agro-ecological farming practice	Always	Usually	Seldom	Never
Soil management					
1	Maintaining soil structure via reducing tillage/ ploughing application				
2	Allowing for the building up of soil organics:				
	▪ No burning of crop waste or field weeds				
	▪ Composting of crop waste on the farm field				
3	Application of soil and water management conservation practices				
	▪ Growing of cover crops				
	▪ Application of mulch				
Nutrient management					
4	Recycling animal waste				
	▪ Urine				
	▪ Dung				
5	Application of appropriate crop rotations				
6	Use of green manure crops				
7	Application of natural/ organic soil amendments				
	▪ Compost				
	▪ Indigenous micro-organisms				
	▪ Fermented rice bran				
	▪ Fermented plant juice				
	▪ Bokashi				
	▪ Other				
Plant and crop management					
8	Agro-ecological weed management				
	▪ Spring tillage prior to planting				
	▪ False seedbed tilling				
	▪ Shallow summer tillage				
9	Pest and disease management				
	▪ Companion planting				
	▪ Agniastra use				
	▪ Neemastra use				
	▪ Crop rotation				
	▪ Other natural pesticides				
	▪ Crop diversity through intercropping				
10	Seed selection & management				
	▪ Seed harvesting & selection				
	▪ Seed processing (wet and or dry)				
	▪ Seed treatment and storage				
Animal husbandry					
11	Balancing livestock numbers with farm crop capacity to feed				
12	Implementing pasture management practices				
	▪ Rotational grazing				

	▪ Mowing and harrowing practices				
13	Maintaining appropriate shelter for livestock				
14	Growing fodder legumes for animal feed - direct				
15	Growing fodder legumes and other edible leaf/ vegetable materials for animal feed + silage processing				
16	Control of animal waste run-off into water resources				
17	Regular animal health check-ups				
18	Vaccination				

Advanced smallholder agro-ecological farm – farmer self assessment tool[1]

The following advanced farmer self-assessment tool is to be used by farmer extension officers and other facilitators involved in facilitating the transition or smallholder farmers from conventional farming practices to that aligned with the full agro-ecological farming framework, e.g. in consideration of achieving economic viability, ecological integrity, and social equity. The assessment tool should be done through a facilitator – farmer interview process. Following an 'assessment', the facilitator should work with the farmer to identify key areas of improvement to work on over a one to two year period. At this time, a re-assessment can be done. Note that there is a scoring system built into the assessment.

Scoring: Level of achievement score: 0 = no achievement, 3 = full achievement, and leave blanks if the question is 100% not applicable. For every blank, subtract 3 points from the total possible score in each section.

SMALLHOLDER FARM ECONOMIC VIABILITY ASSESSMENT						
Q-Type	**Farmer Question**	**Level of Achievement**				**Recommended Practices and Guidance**
		0	1	2	3	
Financial Stability	Do you plan your activities to support the long-term economic viability of your farm?					Small-scale farmers in lower income countries should at least be able to explain verbally how their activities contribute to the long-term economic viability of the farm (including social and environmental aspects).
	If you only have one source of income, have you considered the risks and it this an informed choice?					Having more than one source of income may increase the economic viability of your farm. This may include multiple crops, different customers and non-farming activities.
	Do you have a business plan to maximize the long-term economic viability of the farm?					At the least the farmer should be able to explain this verbally. The plan should include: ✓ An approach to optimize sustainable yields and inputs efficiency ✓ Risk mitigation strategy to survive shocks, e.g. drought, and price fluctuations ✓ Market requirements
	Do you keep records of yields, costs, income and profitability of your farm?					These records are important to monitor the economic viability of your farm and provide input to define management plans.
	Is your base production gross margin negative or well into the positive area?					The gross margin percentage (G) is the profit (P) divided by the selling price or revenue (C). G = P / R = (R - C) / R
Market Access	Do you discuss with your customers/ buyers the best timing for crop deliveries to					This can be applicable to a single farm of a group of farms, e.g. cooperative.

[1] Reference: The matrices have been adapted from the Farm Sustainability Assessment (FSA) developed by the Sustainable Agricultural Initiative (SAI) platform, and added upon to fit the SWISSAID Myanmar EF II beneficiary context.

	ensure good prices and to maintain quality?					
	Do you have a documented system for ensuring food safety and quality of your products?					Typical safety and quality hazards are: ✓ Biological, including infection and cross-contamination ✓ Chemical ✓ Physical, including foreign matter ✓ Cross-contamination with allergens
Autonomy	Does the 'farm' have a degree of autonomy from the debt?					A farm should be operated and managed from the view of the owner. Thus, crop choices should not be made on the basis of unwanted influences or dependencies related to contract farming and or buyer production agreements.
Effiency	Is the labor input acceptable and manageable vis-à-vis the crops you grow?					One of the aims of agro-ecological farming is to balance and or reduce labor costs vs. the base production cost of the crop product. Some crops do require more labor, some less, but on average, labor inputs should not exceed 50% of the base production cost (all costs - total labor costs/ all costs = %). Labor includes household and hired labor, including contracted work to perform a tasked, e.g. tilling, planting, market preparation etc.
	Sub Total A					**Total possible marks – 27 – Section Score =**

SMALLHOLDER FARM SOCIAL EQUITY ASSESSMENT						
Q-Type	**Farmer Question**	**Level of Achievement**				**Recommended Practices and Guidance**
		0	1	2	3	
Working Conditions	Do you ensure that permanent or temporary workers can safely do their tasks?					This means asking workers to take un-necessary risks to perform their tasks, and or to perform these tasks without the appropriate safety equipment.
	Do you inform permanent or temporary workers of their legal rights and obligations and establish working contracts or relationships in accordance with national laws?					This includes providing workers with clear information about payment received for their work and their employment conditions.
	Do you ensure that daily working hours for permanent or temporary workers do not exceed the maximum number of hours set by national regulations and or International Labor Organization's conventions?					This includes: 1. Working hours are limited to 48 hours or less per week. 2. Overtime does not exceed 12 hours per week, unless agreed and overtime is not forced. 3. Employees are given reasonable breaks while working and sufficient rest periods between shifts.
	Do you pay your permanent or temporary					A living wage (on full time basis) is sufficient to meet basic needs of an

	workers a living wage?					average household, such as food, clean water, shelter, clothes, education, healthcare etc.
	Do you compensate permanent or temporary workers that become ill due to work related activities?					Compensation may include: ✓ Continuing to pay their wage ✓ Compensate the family of the worker in kind
	Do you prohibit employing children under the age of 15?					If you are a family farm, you can record a higher level of achievement if the children participate in farming practices under the following conditions (and local laws do not prohibit it): 1. Only for light work and are not forced or bonded labor; 2. 14 hours maximum per week; 3. Can ensure that the attend school and that the work does not interfere with schooling; 4. Do not work in unhealthy situations; and 5. Are always accompanied by an adult.
	Do you pay permanent or temporary male and female workers the same rate?					This means that the same skill level, experience, type of work and level of responsibility is awarded in the same way.
	Do you prevent discrimination of permanent or temporary workers?					Discrimination is not permitted, on the basis of gender, ethnic background, national origin, religion, disability, sexual orientation and or political affiliation.
Local Community	Does your farm contribute actively to the neighboring communities?					Thus may include: 1. You are an active and engaged member in your community trying to contribute to its further development; 2. You hire labor mainly locally and purchase products locally where possible; and 3. You promote farming as an attractive profession to the younger generation.
	Do you take measures to reduce disturbance from noise and odor to the neighboring community?					Adequate measures include: 1. Informing the community about spraying practices, including fertilizer, pesticide and manure use; and 2. Planning operations at times that minimizes disturbance.
	Sub Total B					**Total possible marks – 30 – Section Score =**

SMALLHOLDER FARM ECOLOGICAL INTEGRITY ASSESSMENT						
Q-Type	**Farmer Question**	**Level of Achievement**				**Recommended Practices and Guidance**
		0	1	2	3	
Farm Management	Did you make an assessment of the suitability of all your land for its current or planned use?					Small-scale farmer in lower income countries should be able to explain their assessment verbally. The assessment takes into account: 1. Previous sue; 2. Current characteristics of land and adjacent land 3. Potential impact on neighboring activities, land, and water bodies;

						and 4. Respect for the rights of communities regarding access to natural resources.
	Do you have an up-to-date farm management plan that addresses all relevant farming risks and opportunities/					Small-scale farmer in lower income countries should be able to explain their assessment verbally. An alternative is such cases can be a written farmer group or community plan. Risks and opportunities refer to (at the least): ✓ Legal requirements; ✓ Natural habitat degradation ✓ Rare and endangered species ✓ Farm animal welfare; ✓ Soil pollution and erosion ✓ Water pollution, pesticide drift, fire and smoke
	Do you regularly seek advice, training and collaboration on sustainable production, technologies and human resource management?					Potential sources: other farmers, input suppliers, buyers, research institutes, extension workers and or professional service providers.
	Do you use crop rotation where applicable?					For example: Crop rotation (annual or other intervals), this may include cover crops and grazing, rotation of cultivation and fallow ground, multiple plots with rotational cultivation. Not that rotation benefits productivity and biodiversity and provides potential diversified income sources.
Planting	Have you ensured that you are new planting material and or grafting material is of high quality and from a trustworthy source?					This includes certified material or material that can be traced back to its propagation source. This can be from reputable seed producers, neighbors, and cooperatives.
	Do you take into account the optimum plant spacing for your local situation/ farm context?					The choice of plant spacing can take into account any of the following: 1) Minimize the use of plant protection inputs and fertilizer leakage, 2) Optimize yield per hectare, 3) Optimize crop quality, and 4) Facilitate harvest. Also: Intercropping (planting two or more crops in proximity) and companion planting could be considered to improve and stabilize farm income and benefit bio-diversity.
	Do you avoid the cultivation and use of invasive species					Invasive species are those that can come to dominate an area and may result in a loss of native species.
	When selecting and using varieties, do you make an informed choice?					An informed choice can take into account:, 1) Yield performance, 2) Disease resistance, 3) Pest resistance, 4) Soil characteristics and crop

						rotation, 5) Customer requirements, 6) Fertilization needs, 7) Water needs, 8) Genetic diversity on farm, and 9) Environmental impact.
Soil Management	Do you perform periodic soil sampling to monitor the changes in soil condition (and make a record of this)?					Soil sampling includes: 1. Knowing soil NPK, pH and micro-nutrient levels; and 2. Keeping records of the aforementioned
	Do you take measures to avoid soil erosion?					(Wind and water caused) Special attention should be paid to sloping fields and areas where soil is exposed. Measure that minimize erosion are: 1) following contours, 2) Using terracing, 3) Using cover crops, 4) Minimizing tillage, and 5) placing wind breaks
	To improve the productivity of your soil, do you take measures to conserve and improve soil health?					This would include at least two of the examples below for a level 1 achievement: 1. Minimum tillage to preserve structure 2. Retain or return crop residues to the field to build organic matter levels in the soil 3. Use of organic manure and compost 4. Use of cover crops 5. Avoid excessive use of agro-chemicals 6. Manage soil water drainage in the wet season, and soil moisture in the dry season, e.g. mulching.
	Do you avoid soil compaction by farm machines or livestock?					This includes at least two of the example below for a level 1 achievement: 1. Using low pressure tires; 2. Avoiding passing of livestock and machines under wet conditions 3. Minimizing passes on the field (ploughing) 4. Avoid using the same trails
Nutrient Mgt.	Do you choose organic and inorganic fertilizer type, quantity and application method to increase nutrient efficiency and reduce negative environmental impacts?					Fertilizers include chemical fertilizers, green manures, compost and animal manure. Note: the less chemical fertilizers in use garners a higher level of achievement. Note: It is strongly recommended to not over apply chemical fertilizers or manure to avoid pollution of the environment (water and soil)
	Do you have a nutrient management plan?					The plan should include: 1. Overview of nutritional requirements of cultivated crops 2. Soil type/s of the farm fields (and sample analysis) 3. Application rates and intervals of either mineral or organic fertilizers 4. Planting of green manure or cover crop schedule to capture nitrates in the soil
	Do you keep records of fertilizer applications?					Records can include: Location, application method, date of application, product trade name, composition, product etc.

Crop Protection	Do you apply integrated pest management (IPM)?					IPM includes evaluating pest levels and control options, and selecting a crop protection method that maximizes human safety and minimizes environmental impact and is economically justifiable. As part of IPM farmers are encouraged to create biodiversity habitats that may attract natural enemies of pest and disease.
	Do you use crop protection products that are officially registered in your country, and keep a record of their use?					If in use, you are recommended to phase these out.
	Do you follow the maximum authorized rates of crop protection products, the label recommendations and the appropriate pre-harvest intervals and re-entry times?					Pre-harvest intervals determine how long after application a product can be harvested. Re-entry times determine after how long it is safe again to enter the treated area without protection.
	Do you apply chemical crop protection products only when necessary and use non-chemical pesticides instead of chemical pesticides where possible?					Chemical crop protection products include chemical pesticide, insecticides, herbicides, fungicides and rodenticides. Natural crop protection includes: Choosing disease and pest resistant crop varieties, use of crop rotations, mechanical methods of suppressing, e.g. weeding, pruning, trimming, and biological pest control measures, e.g. companion planting.
Waste and Water Mgt.	Do you reduce, reuse, and recycle waste and by-products of harvesting and processing?					As an example: ✓ Composting organic debris on-farm and re-using it for soil conditioning (where there is no risk of disease transmission); ✓ Selling your crop-by-products to alternative markets; and ✓ Use your crop by-products for alternative purposes, e.g. animal fodder.
	If you irrigate, do you have a water management plan to optimize water usage, water quality, and water availability, and to reduce wastewater, and keep records of irrigation activities?					A water management plan includes: 1. The timing and amount of irrigation in relation to crop requirements; 2. The added value of irrigation in relation to the yield and quality of crops produced; 3. Predicted rainfall and evaporation, using either daily rainfall records or weather forecasts to plan irrigation schedules, and 4. An inventory of water resources And, to include two of the conditions below: a. Avoiding depletion of water resources, beyond the recharge capacity; b. Cooperation with other water users;

						c. Diversity of sources of water to reduce impact and to ensure water assess continuity across seasons. Smallholder farmers should be able to verbally explain their plan.
	Do you take measures to avoid water and soil pollution from waster water					Adequate measures are based on a risk assessment that covers chemical, mineral, and microbial composition. The farm measures protect surface and ground water from direct pollution considering the following: 1. Waster water is assessed regularly, and properly managed; and 2. Untreated sewage water cannot be used for irrigation.
	Do you prevent run-off of chemicals, mineral and organic substances including pesticides, fertilizer and manure?					
Biodiversity	Have you assessed bio-diversity and identified priority actions to preserve biodiversity on your farm?					An assessment includes: 1. Identification of on farm rare and endangered species (plant and animal); 2. Identification of priority actions that promote biodiversity on farm; and 3. Take part in a biodiversity plan at landscape level if available and practical. Smallholder farmers should be able to explain the potential impacts of their operations on biodiversity and how they avoid potential negative impacts and create potential benefits of the operations on biodiversity.
	Have you left all primary forest, wetland, and protected grasslands or other native ecosystems in their original condition over the last 5 years?					This includes ensuring that no practices were used that could weaken or destroy primary forest, wetland or grassland or other native ecosystems.
Livestock & Husbandry	Is your farm suitable to integrate livestock?					The farm should have sufficient space for shedding and grazing, sufficient fodder or by-products to feed, sufficient know-how on keeping, feeding and treating livestock of interest.
	Is fodder in adequate quality and quantity available for all livestock?					For example, does the farm produce the following: 0.5tons per month for 1 horse, 0.4tons per month per cow, 0.1tons per month per goat. Additionally, animals should not be feed synthetic food additives or medicines, e.g. antibiotics, growth hormones.
	Is there sufficient access to clean drinking water for all livestock					Sufficient access to clean drinking water means this is available 24hours/ day, and for container waters, water is change daily.
	Are sheds of sufficient size and with adequate light and fresh air?					Animals have sufficient room to move around and perform natural behaviors.

	Are animals healthy and have regular veterinary check-ups?					Resources must be available to ensure livestock is vaccinated (for local conditions) and have bi-annual check-ups from a qualified technician.
	If applicable, do you apply small pasture management practices					This includes: 1. Having an inventory of grass and weed species, fences, gates and water sources and troughs; 2. Knowing what weeds in your pasture that may be poisonous to livestock; 3. Creating a sacrifice area to recovery of pasture land; 4. Apply rotational grazing; and 5. Apply mowing and harrowing after the land has been grazed upon.
	Sub Total C					**Total possible marks – 90 – Section Score =**

Sub-section A - _____ Points/ 27
Sub-section B - _____ Points/ 30
Sub-section C - _____ Points/ 90

Overall score (A=B=C) = _____ Points/ 1

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