MICROFINANCE FOR ECOSYSTEM-BASED ADAPTATION

Options, costs and benefits

Microfinance for Ecosystem-based Adaptation measures

The Microfinance for Ecosystem-based Adaptation (MEbA) project aims:

To provide vulnerable rural and peri-urban populations in the Andean region of Colombia and Peru with microfinance services and products that will allow them to invest in activities related to ecosystem sustainability, improving their income and resilience towards climate change effects.

The first products focus on small-scale agriculture because this is the most important economic activity in rural areas of Colombia and Peru. This sector is made up of a low-income population that relies on activities subject to climate risks and that can have either a positive or a negative impact on ecosystems and ecosystem services, depending on how they are carried out.

In this first stage, the project has focused on identifying options that can be financed through microfinance products and that meet, either on their own or in synergy with other options, the following MEbA criteria:

1. **Reducing pressure on ecosystems and the services they provide,**
2. **Enhancing the social or economic resilience of human populations vulnerable to climate change,**
3. **Reducing risks associated with climate events in production activities,**
4. **In their implementation, protecting, restoring or using biodiversity and ecosystems in a sustainable manner,**
5. **Having a positive impact on individuals' economy in the short term.**

The 40 systematized measures are presented below in fact sheets according to their contribution to reducing climate risks and other essential characteristics. To this end, a distinction was drawn between two traits of climate risks: the climate stimulus (or "threat"), and its potential effect on production activities, material assets or ecosystem services (the "impact").

Threats:
climate factors over which humans have little control.

Impacts:
the consequence of the manifestation of climate threats in the human context.

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0 FACT SHEET CONTENT DESCRIPTION

1 When climate threats materialize in one or more systems of interest, they will have impacts (ecological, productive or human). The proposed measures aim to reduce these impacts.

Up to three of the impacts addressed are indicated, although a given measure may often address more impacts. The impact icons are shown on the inside front cover of the binder.

2 Qualitative evaluation of the measure's potential effectiveness in reducing the stated impacts, as compared with the remaining measures and on a scale of 0 to 3.

3 Estimated time for results to be seen, in terms of increased productivity, income generation or system stability. Five years is the longest period foreseen and one year is the shortest, although certain actions may bear fruit almost immediately. Forestry measures generally take longer to produce results.

4 Indicates the focus (or scope) of the measure and its scale (or target audience). Some measures may have more than one focus or be applied on different scales.

Investment: Actions that result in higher yields or additional income in the short term.

Support: Actions intended to increase the resilience of the system, contributing to greater stability in the face of climate or market fluctuations over the medium and long term.

Individual: Actions intended for family units or persons striving to meet their own needs.

Collective: Actions intended for groups with common interests.

5 The measure's identification number. The names of the measures, in Spanish, were listed in alphabetical order. In order for the numbering of the two versions to match, the original identification number was kept in the English version.

6 The main characteristics of the measure and the objectives sought in implementing it.

7 The locations where the measure could be most suitable or useful.

8 The measure's main benefits for adaptation to climate change. In reference to climate risks, a distinction has been drawn between threats and impacts. The measures are intended, for the most part, to address impacts.

9 Summary of the steps to be followed in implementing the measure.

10 The diagrams provide greater detail on the implementation method or on the specific characteristics of the measure.

FACT SHEET CONTENT DESCRIPTION

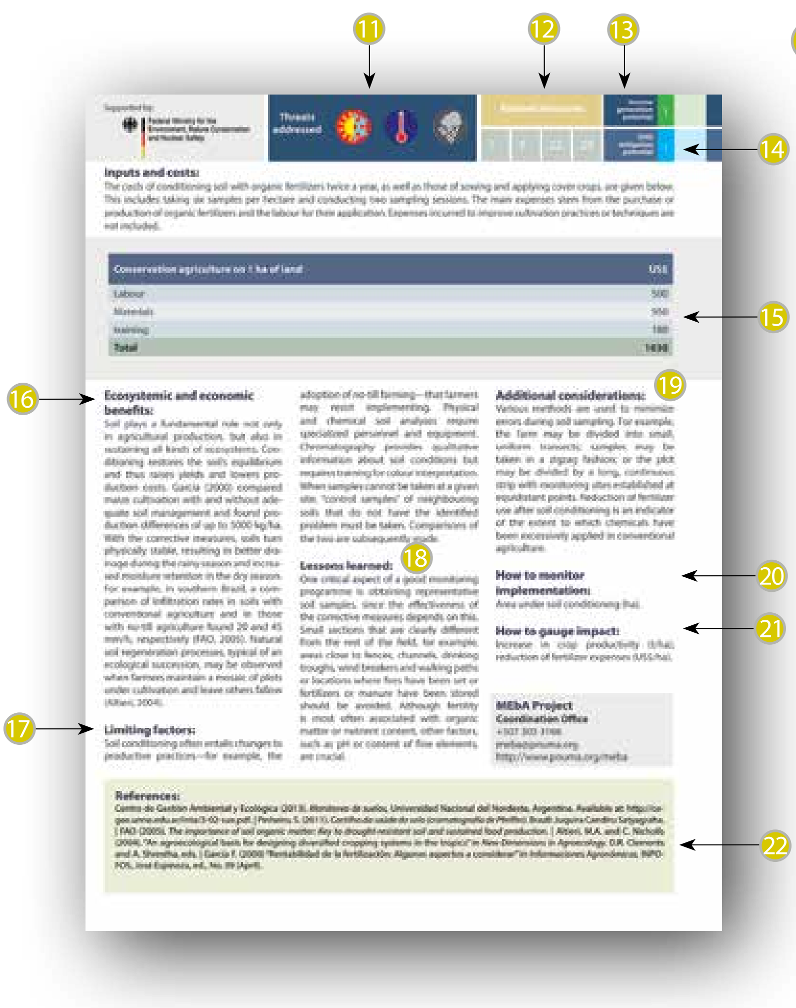
11 Threats are climate-related stimuli that are in a state of flux as a result of climate change and that may have impacts on productive, ecological or human systems. Individuals or communities have little control over them.

12 Complementary measures with which synergies may be established to increase resilience to climate change.

13 Qualitative evaluation of the measure's likely effectiveness in increasing earnings, as compared with the remaining measures and on a scale of 0 to 3.

14 Qualitative evaluation of the potential for the measure to reduce greenhouse gas emissions or store carbon, as compared with the remaining measures and on a scale of 0 to 3.

15 Summary table of costs. All tables contain the same items: labour, materials and training. The amounts are estimates and should be taken as a starting point for a more detailed analysis. In most cases, the costs given refer to start-up expenses but not to subsequent operations. Actual amounts may be lower if the user has some of the materials or if the labour costs covered by the user are considered a co-investment. Maintenance costs are not included in individual measures, although in collective measures they generally are. Two measures have slightly different tables: the agroecology fact sheet (no. 4) and the permaculture fact sheet (no. 25). These two measures refer to holistic systems that may be better illustrated by giving possible examples of their components.



16 This is a first estimate of quantitative data on a measure's benefits. Most data provided relate to productivity or income improvement as well as how each measure may increase ecosystem resilience.

17 The factors that should be taken into account before a measure is implemented, or the possible constraints on its implementation.

18 Recommendations based on past experience, or relevant observations from the literature.

19 Additional points for readers interested in learning more about the topic.

20 A yardstick for MEbA project partners to gauge receptiveness to the measure.

21 A yardstick for MEbA project partners to evaluate the measure's results.

This yardstick focuses chiefly on productive and economic issues, because measuring ecosystem impact would require methods beyond the project's possibilities. Nevertheless, the proposed measures are known to contribute considerably to agroecosystem resilience.

22 The main documents from which the information in the fact sheet is drawn, and which the reader may consult in order to learn more about the measure.

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Impacts addressed

Extent of impact reduction: 2

Results in: up to 1 year

1 ORGANIC FERTILIZERS

Scale: **Individual** / Collective

Focus: Investment / **Support**

Description:

Organic fertilizers are used to improve the physical, biological and chemical characteristics of the soil. Although cover crops like leguminous plants used as green manures and post-harvest residues are considered organic fertilizers, the term is generally associated with composts obtained from animal, plant or mixed waste. Composting uses, among other materials, organic waste from livestock (dung, slurry), remains from the processing of agricultural products (coffee, rice) and household waste (food leftovers and garden matter). Organic fertilizers offer an alternative to hydrocarbon-based synthetic fertilizers.

Where to implement:

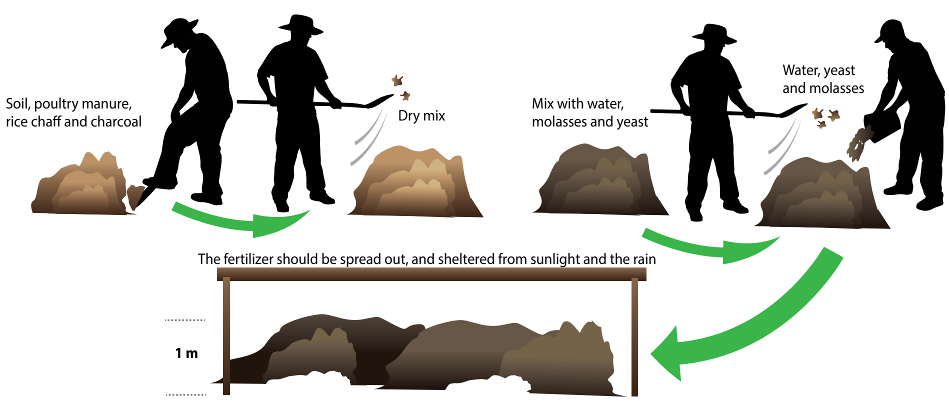
Organic fertilizers are applied on soil that has been overfarmed and degraded or that has low organic content or salinization problems. Such soil has lost physical and chemical properties or seen a reduction in biological activity. They are of particular interest for Andean areas with shallow soils, scarce organic matter and high exposure to rain or wind erosion. Their use is a prerequisite for organic agriculture certification.

Threats and impacts addressed:

By increasing the capacity of the soil to absorb and retain moisture, organic fertilizers help reduce the effects on crops of intense rainfall, drought and changes in rainfall patterns. In addition, improving the physical, chemical and biological characteristics of the soil increases productivity, diminishes the need for large amounts of agricultural inputs and controls erosion.

How to implement:

Preparation of 5 tons of Bokashi (fermented organic matter): (1) Start with a 1-ton layer of leaf soil. (2) Add 1 ton of poultry manure and moisten with a molasses solution. (3) Add a 500-kg layer of dung or coffee pulp. (4) Place 200 kg of rice chaff and moisten with the molasses solution. (5) Add a 100-kg layer of bran or semolina (coarsely ground flour). (6) Add 500 kg of charcoal. (7) Add a 200-kg layer of lime. (8) Repeat the procedure (steps 1 through 7) placing the same amounts on top of the existing layers. (9) Mix the ingredients and moisten until the mixture passes the "squeeze test". The process takes between 12 and 21 days and the fertilizer can be used immediately after preparation.



Source: Adapted from http://ganaderiasorganicas.blogcindario.com.

Inputs and costs:

Cost of producing 5 tons of Bokashi: The main costs are the purchase of materials, particularly poultry manure, and the manual labour for the preparation process. Two days of training are included to build capacity in controlling fermentation conditions. The final weight and volume of the product will be approximately 30% less than that of the inputs due to moisture loss.

Preparation of 5 tons of Bokashi	US$
Labour	120
Materials	283
Training	120
Total	**523**

Ecosystemic and economic benefits:

Organic fertilizers improve the soil's biological activity, especially in the case of organisms which turn organic matter into nutrients available for crops. Altieri (1999) describes two experiences of production with organic fertilizers: one in San Marcos, Peru, where production presented viable and stable yields without the use of toxic chemical products; and the other in Guinope, Honduras, where grain crop yields jumped from 400 kg/ha to between 1200 and 1600 kg/ha with the use of organic fertilization methods such as poultry manure and intercropping with leguminous plants. In terms of improving the soil's capacity to absorb and retain moisture, yields in drought conditions from crops produced with organic fertilizers were equal to or higher than those from conventional farming.

Limiting factors:

Proper preparation of organic fertilizers requires training in techniques to maximize the farm's resources. In the production process, moisture, nutrients and temperature levels must be controlled to ensure a proper decomposition of the organic matter, reduce pathogens and produce fertilizer of the desired quality. This is accomplished by ensuring proper aeration, achieving granules of a uniform size and controlling the carbon-to-nitrogen ratio.

Lessons learned:

The use of animal or human organic waste without prior treatment may pose health risks. Composting achieves high temperatures (60°C-65°C), which eliminate most pathogens. Maintaining these temperatures for a long period (at least one week) ensures that the fertilizer will be innocuous.

Additional considerations:

The nutrient content and composition of animal waste vary according to the type of animal, the handling of the waste and its state of decomposition. For example, poultry manure is the richest in nitrogen and, on average, contains twice as many nutrients as cattle manure. Green manures, by contrast, are species cultivated in rotation with other crops which are applied to cover the soil and improve its nutrient content. Green manures are the simplest and most economical source of nutrient-rich organic matter available to small farmers.

How to monitor implementation:

Area on which organic fertilizers are applied (ha); organic-fertilizer production (t, m^3).

How to gauge impact:

Productivity (t/ha); expenditure on agriculture inputs (US$).

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References:

Altieri, M.A. and C.I. Nicholls (2000). *Agroecología: Teoría y práctica para una agricultura sustentable.* Mexico City: UNEP | Altieri, M.A. (1999). *Agroecología: Bases científicas para una agricultura sustentable.* Montevideo: Editorial Nordan-Comunidad. | Borrero, C.A. (2009). *Abonos Orgánicos*, in Infoagro Systems website. Available at: http://www.infoagro.com/abonos/abonos_organicos_guaviare.htm. | PYMERURAL and PRONAGRO (Honduras) (2011). *Abonos Orgánicos.* Series: Producción orgánica de hortalizas de clima templado.

Impacts addressed

Extent of impact reduction: 2

Results in: up to 1 year

2 SOIL CONDITIONING

Scale	Individual
	Collective
Focus	Investment
	Support

Description:

Soil conditioning involves applying a series of techniques to restore organic matter, nutrients, biological activity and other essential elements for agricultural production to their optimal state. Simple analyses, such as chromatography, can be used to obtain qualitative information on soil health. A comparison of the resulting data with the established productive practices allows for improved fertilization or tilling. This, in turn, makes it possible to increase organic matter content, manage nutrients more efficiently and control erosion, among other improvements. Soil conditioning is achieved through organic fertilization, physical and biological means as well as better practices such as crop rotation or diversification.

Where to implement:

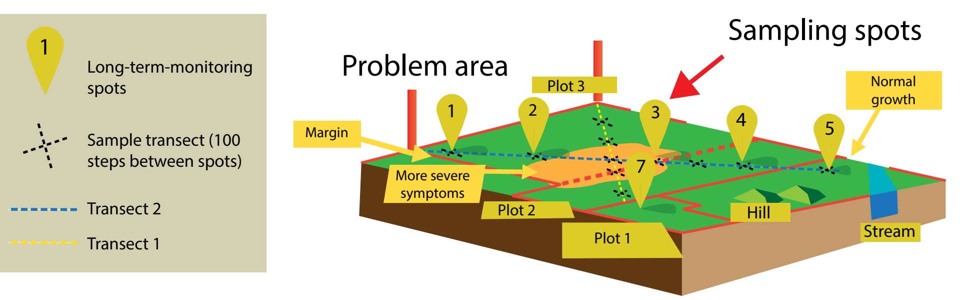
Conditioning is recommended for farms where the natural characteristics of the soil, like proper drainage, fertility and nutrient balance, have been lost due to inadequate farming practices, excessive fertilizer and herbicide use or erosion resulting from climate factors. Soil chromatography is also used for organic-fertilizer production to determine nutrient content and to evaluate the results of restoration projects.

Threats and impacts addressed:

Corrective measures aimed at improving soil structure, fertility, moisture retention and infiltration capacity mitigate the impact on crops of drought, extreme heat events and sudden temperature changes. The resulting increase in soil fertility improves productivity, reduces pest incidence and increases food security.

How to implement:

(1) Select specific monitoring sites, taking into account any differences among parcels and among areas with specific problems. (2) Analyse current conditions at the selected sites, for example, the degree of soil compaction and erosion, as well as organic matter content and nutrient deficiencies. (3) Identify corrective measures based on the results of the diagnosis, for example, applying mulch, using crops with strong main roots to address compaction or replacing chemical fertilizers with organic manure. Soil improvement is achieved through several combined measures, including minimum tillage, diversified systems and even pest management. (4) Establish a monitoring plan to evaluate the results of management practices, for example, studies of soil profiles, texture, structure, fertility, biological activity and crop health. (5) Use monitoring techniques like chromatography and physical and chemical analyses to identify additional corrective actions.



Source: Adapted from CEGAE (2013).

Supported by:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
based on a decision of the German Bundestag

Threats addressed

Related measures: 1 | 3 | 22 | 29

Income generation potential: 1

GHG mitigation potential: 1

Inputs and costs:

The costs of conditioning soil with organic fertilizers twice a year, as well as those of sowing and applying cover crops, are given below. This includes taking six samples per hectare and conducting two sampling sessions. The main expenses stem from the purchase or production of organic fertilizers and the labour for their application. Expenses incurred to improve cultivation practices or techniques are not included.

Soil conditioning, 1 ha	US$
Labour	165
Materials	1040
training	360
Total	**1565**

Ecosystemic and economic benefits:

Soil plays a fundamental role not only in agricultural production, but also in sustaining all kinds of ecosystems. Conditioning restores the soil's equilibrium and thus raises yields and lowers production costs. García (2000) compared maize cultivation with and without adequate soil management and found production differences of up to 5000 kg/ha. With the corrective measures, soils turn physically stable, resulting in better drainage during the rainy season and increased moisture retention in the dry season. For example, in southern Brazil, a comparison of infiltration rates in soils with conventional agriculture and in those with no-till agriculture found 20 and 45 mm/h, respectively (FAO, 2005). Natural soil regeneration processes, typical of an ecological succession, may be observed when farmers maintain a mosaic of plots under cultivation and leave others fallow (Altieri and Nicholls, 2004).

Limiting factors:

Soil conditioning often entails changes to productive practices—for example, the adoption of no-till farming—that farmers may resist implementing. Physical and chemical soil analyses require specialized personnel and equipment. Chromatography provides qualitative information about soil conditions but requires training for colour interpretation. When samples cannot be taken at a given site, "control samples" of neighbouring soils that do not have the identified problem must be taken. Comparisons of the two are subsequently made.

Lessons learned:

One critical aspect of a good monitoring programme is obtaining representative soil samples, since the effectiveness of the corrective measures depends on this. Small sections that are clearly different from the rest of the field should be avoided; for example, areas close to fences, channels, drinking troughs, wind breakers and walking paths or locations where fires have been set or fertilizers or manure have been stored. Although fertility is most often associated with organic matter or nutrient content, other factors, such as pH or content of fine elements, are crucial.

Additional considerations:

Various methods are used to minimize errors during soil sampling. For example, the farm may be divided into small, uniform transects; samples may be taken in a zigzag fashion; or the plot may be divided by a long, continuous strip with monitoring sites established at equidistant points. Reduction of fertilizer use after soil conditioning is an indicator of the extent to which chemicals have been excessively applied in conventional agriculture.

How to monitor implementation:

Area under soil conditioning (ha).

How to gauge impact:

Increase in crop productivity (t/ha); reduction of fertilizer expenses (US$/ha).

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References:

Centro de Gestión Ambiental y Ecológica (2013). *Monitoreo de suelos,* Universidad Nacional del Nordeste, Argentina. Available at: http://cegae.unne.edu.ar/inta/3-02-sue.pdf. | Pinheiro, S. (2011). *Cartilha da saúde do solo (cromatografía de Pfeiffer)*. Brazil: Juquira Candiru Satyagraha. | FAO (2005). *The importance of soil organic matter: Key to drought-resistant soil and sustained food production.* | Altieri, M.A. and C. Nicholls (2004). "An agroecological basis for designing diversified cropping systems in the tropics" in *New Dimensions in Agroecology.* D.R. Clements and A. Shrestha, eds. | García, F. (2000) "Rentabilidad de la fertilización: Algunos aspectos a considerar". *Informaciones Agronómicas*, No. 39 (April). INPOFOS.

Impacts addressed

Extent of impact reduction: 3

Results in: up to 2 years

3 CONSERVATION AGRICULTURE

Scale	Individual / Collective
Focus	Investment / Support

Description:

Conservation agriculture attempts to conserve natural resources and ensure that they are used efficiently, through the integrated management of soil, water and biological resources available on the farm, while using residual biomass to keep soil covered during crop production. It contributes to environmental conservation in three fundamental ways: through minimal-till farming to reduce soil disturbances, through permanent covering of the soil with mulch or cover crops to conserve moisture and nutrients and through crop rotation to avoid the dissemination of pests, diseases and weeds.

Where to implement:

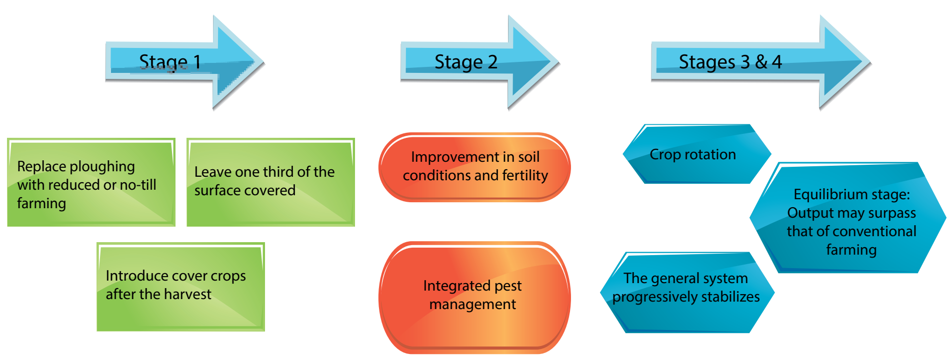
This measure is recommended in degraded areas where topsoil has been eroded, leaving the poorer soil layers exposed. It is also useful in areas or farms where the soil has low water-retention capacity, reduced plant cover and poor biomass production.

Threats and impacts addressed:

Conservation agriculture diminishes the impact on crops of frost, drought, strong winds, intense rainfall, changes in rainfall patterns and sudden temperature changes. This is mainly due to the protection of the soil by the establishment of a permanent layer of organic matter that helps regulate moisture and temperature in the root zone. Impacts such as the greater need for agricultural inputs and erosion can be mitigated by improving soil structure and fertility, whereas pest incidence is decreased by interrupting the pest cycle through crop rotation.

How to implement:

(1) Apply direct seeding, ensuring that at least 30% of the cropland is protected by mulch or other plant residue. (2) Reduce tillage to diminish soil disturbance. (3) Adopt the use of green manures and organic fertilizers. (4) Use mulch or cover crops to ensure that the ground surface is always protected by a live or inert cover. (5) Apply integrated pest management. (6) Introduce crop rotations that favour soil fertility (nutrient and water retention).



Source: Prepared by the authors.

Supported by:
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based on a decision of the German Bundestag

Threats addressed

Related measures: 2 | 22 | 23 | 31

Income generation potential: 2

GHG mitigation potential: 1

Inputs and costs:

Implementing conservation agriculture requires using cover crops and organic fertilizers, which represents the highest initial investment. The rental of machinery for no-till farming on one hectare of cropland is included. Three training days on changes in cultivation practices and proper management of nutrients and pests are considered.

Conservation agriculture on 1 ha of land	US$
Labour	500
Materials	950
training	180
Total	**1630**

Ecosystemic and economic benefits:

Studies carried out in Colombia by the International Center for Tropical Agriculture indicate that conservation agriculture could reduce the amount of sediments released to a nearby water source by up to 70%. In addition, once the initial investment costs are covered (US$ 250/ha, in this case) production under conservation agriculture could be 18% to 25% more profitable than production with conventional methods (Pareja, 2013). Quintero and Otero (2006) state that producing potatoes with no-till farming and peas with direct seeding after applying green manure could lower costs by up to 20% and 30%, respectively, compared with conventional methods. This has multiple ecosystem benefits: the rate of soil loss is lower than generation rates and soil structure is maintained or improved; infiltration is enhanced; runoff does not affect nearby surface water bodies; and biodiversity is maintained or improved. Conservation agriculture techniques could capture between 50 and 100 million tons of carbon per year in certain soils (European Commission, 2009) while food production levels would remain unchanged or increase (FAO, 2001).

Limiting factors:

The main limiting factor relates to replacing conventional management practices in agriculture, such as burning organic matter after harvest or excessive soil tillage. In addition, promoting this change in practices requires specialized technicians to train farmers, who may be sceptical of the results unless they see clear evidence of improved yields or soil health.

Lessons learned:

Crop rotation allows for an increase in fertility through a differentiated use of available soil nutrients. It also minimizes the dissemination of pests by breaking their cycles. Hence, an adequate planning of crop sequences that promote synergies is essential. For example, alternating species with surface and deep roots improves soil structure and other physical characteristics. Efficient management of crop residues is essential for obtaining good yields on a stubble cover; with more residue in the soil, erosion decreases and water storage increases.

Additional considerations:

Conservation agriculture lowers the demand for synthetic fertilizers because soil structure and biology improve substantially. Nutrients are used more efficiently and their loss through leaching is diminished. Hence, this production method not only improves yields but also has other important environmental benefits.

How to monitor implementation:

Area under conservation agriculture (ha).

How to gauge impact:

Yields (t/ha); reduction in expenditures on agricultural inputs (US$/ha).

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References:

Pareja, P. (2013). *Midiendo servicios ecosistémicos en agricultura.* CIATBlogs. | FAO (2001). "Concepts and impacts of conservation agriculture", *Conservation Agriculture: Case studies in Latin America and Africa.* pp. 7-20 (FAO Soils Bulletin No. 78). | FENALCE (2001). Tecni-Fenalce: Boletín Informativo de la Subgerencia Técnica. "Aspectos relacionados con la fertilización en Colombia", Fabio Polania Fierro (ed.) vol. 3, No. 1 (Jan.). | European Commission (2009). "Agricultura de conservación", in *Agricultura sostenible y conservación de los suelos: Sistemas y prácticas agronómicas no perjudiciales para el suelo*, Information sheet No. 5, Sustainable Agriculture and Soil Conservation. | Quintero, M. and W. Otero (2006). *Mecanismo de financiación para promover Agricultura de Conservación con pequeños productores de la cuenca de la laguna de Fúquene: Su diseño, aplicación y beneficios*. Peru: Proyecto Regional Cuencas Andinas. International Potato Centre (CIP).

Impacts addressed

Extent of impact reduction: 3

Results in: up to 3 years

4 AGROECOLOGY

Scale	Individual / Collective
Focus	Investment / Support

Description:

Agroecology is a holistic production method that works at the agroecosystem level. It is based on adopting an integrated management approach for resource conservation as well as diversifying and enhancing synergies among the components of the agroecosystem, balancing energy and nutrient flows and adapting productive activities to local conditions. It promotes a high degree of interaction among its components to preserve biodiversity and attain sustainable production. For example, this method combines polyculture, the presence of animals and the usage of cover crops, organic fertilizers and varying soil depths with soil conservation and ancestral practices (terracing and production in raised cultivation beds).

Where to implement:

This method is useful in soils or ecosystems whose ecological equilibrium has been altered by excessive agricultural usage, regions with ancestral agricultural knowledge which may be reintroduced or productive zones requiring diversification for enhanced resilience to changing market or climate conditions. It is particularly important on small farms seeking to reduce reliance on chemical inputs, whether for environmental or economic considerations.

Threats and impacts addressed:

By restoring agroecosystem balance, agroecology enhances crop resilience to frost, drought, strong winds, intense rainfall, changes in rainfall patterns and extreme heat. The switch to better practices and holistic resource management contributes to erosion and pest control, promotes income diversification and increases long-term productivity.

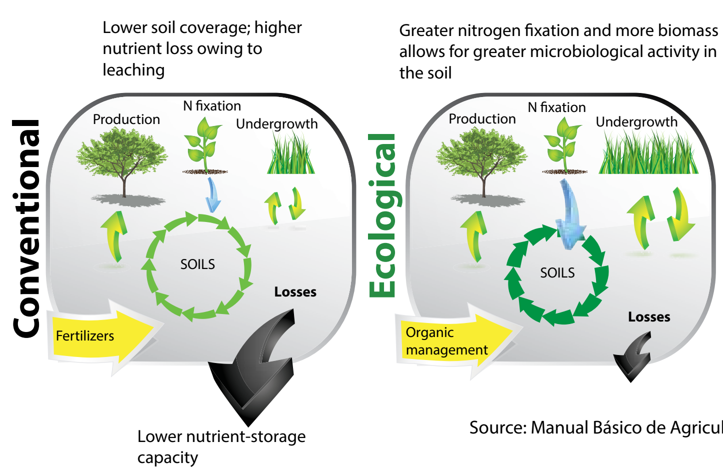
How to implement:

(1) Determine, with expert support, which practices will be developed based on the physical conditions, productive trends, local resources and traditional knowledge found at the site. (2) Implement these better practices bearing in mind how they interact, so as to establish synergies among components in the agroecosystem. (3) Permit self-organization and monitor the presence of beneficial and antagonistic ecological indicators to promote the desired interactions. Since agroecology encompasses much more than abiding by a list of measures, a set of components is presented below, as an example of a diversified production system that could be established with an emphasis on conservation practices. It is assumed that water is abundant and the soil is fertile.

Year 1: Agroforestry system on 0.5 ha of land and conservation agriculture on 2000 m^2

Year 2: 500 m^2 terrace with crop rotation and crop diversification

Year 3: 2,500 m^2 mixed-plant nursery.



Source: Manual Básico de Agricultura Ecológica (n.d.)

Supported by:
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Threats addressed

Related measures

6 7 25 33

Income generation potential 3

GHG mitigation potential 2

Inputs and costs:

The calculation given below refers to the cost of implementing a few sample agroecology practices on one hectare of land for a period of three years. The cost of each individual component in the table below is the sum of the labour and material costs estimated in the respective fact sheet (e.g. agroforestry) and adjusted proportionally to its actual area or number of units in this system. Training is estimated separately and for the combined practices, which involve polyculture, minimum tillage, mulch application and nutrient and pest management without synthetic inputs.

Components of a three-year agroecology project on 1 ha	Year	US$
0.5 ha agroforestry system	1	1575
0.2 ha conservation agriculture	1	290
500 m^2 terrace	2	1308
500 m^2 crop rotation and diversification	2	142
0.25 ha mixed-plant nursery	3	2583
Training	1-3	3600
Total	1-3	**9498**

Ecosystemic and economic benefits:

Agroecology minimizes the impacts of food production on the environment. For example, the use of organic matter for green manures and mulch preserves the soil and water while fertilizing the soil. Fields with slopes from 1% to 15% not covered with mulch may present a soil loss of 76.6 t/ha, while losses diminish to 2.4 and 0.04 t/ha if 2 and 6 t/ha of mulch is applied, respectively. Regarding the contribution of nutrients, green manures like velvet beans (*Stizilobium* spp and *Mucuna pruriens*) can produce up to 150 kg/ha of nitrogen. Using a combination of mulch systems, a group of farmers was able to produce 3 t/ha of maize per year without chemical fertilizers. Even though certain yields of conventional agriculture are higher, when soil loss and consumption of energy, water and other resources are factored in, the benefits of the ecological system become evident (Altieri and Nicholls, 2000).

Limiting factors:

Holistic agroecosystem management poses challenges in terms of interpreting the causes and effects of procedures and managing the interaction of all the components as if they were a single organism. This requires experience, training and expert assistance. Agroecology focuses less on output than on the general health of the system. By contrast, when only yields are measured it might seem that conventional agriculture is more profitable.

Lessons learned:

It has been observed that pests have a lesser incidence on the productivity of diversified systems in which agroecology principles have been implemented. This may be because of the synergic effects that fertile soils with good organic matter content have on the biological control of pathogens as well as the greater diversity of insects present in the undergrowth.

Additional considerations:

Andean traditional practices show how agroecology may be adapted to adverse climatic conditions and difficult topography. For example, terraces reduce the slope, retain water and soil and increase the farming area. In the area that is added, crops and animals are established in diversified systems, such as with multiple potato varieties on the same piece of land or the breeding of cows, sheep, llamas and smaller animals.

How to monitor implementation:

Area under agroecological production (ha).

How to gauge impact:

Food production (t/ha); expenses for agricultural inputs (US$).

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References:

Altieri, M.A. (1999). *Agroecología: Bases científicas para una agricultura sustentable.* New York: Sustainable Agriculture Networking and Extension, SANE. UNDP. | Altieri, M.A. and C. Nicholls (2000). *Agroecología: Teoría y práctica para una agricultura sustentable.* Mexico: UNEP. | *Manual Básico de Agricultura Ecológica* (n.d.). Available at http://www.juntadeandalucia.es.

Impacts addressed

Extent of impact reduction: 3

Results in: up to 3 years

5 ORGANIC AGRICULTURE

Scale	Individual / Collective
Focus	Investment / Support

Description:

Organic agriculture is a production system based on practices that make it possible to completely eliminate petroleum-based agrochemicals. It increases soil fertility and biological activity over the long term with the use of organic and green fertilizers and crop diversification. Pest control is achieved by applying ecological herbicides and pesticides as well as by rotating crops. Another noteworthy feature is the use of efficient irrigation systems which, in addition to rationalizing water use, promote fertilization. Organic agriculture excludes the use of genetically modified seeds; it is guided by fair-trade criteria; and it promotes food security among producers. It also aims to have products certified as organic in order to increase their market value.

Where to implement:

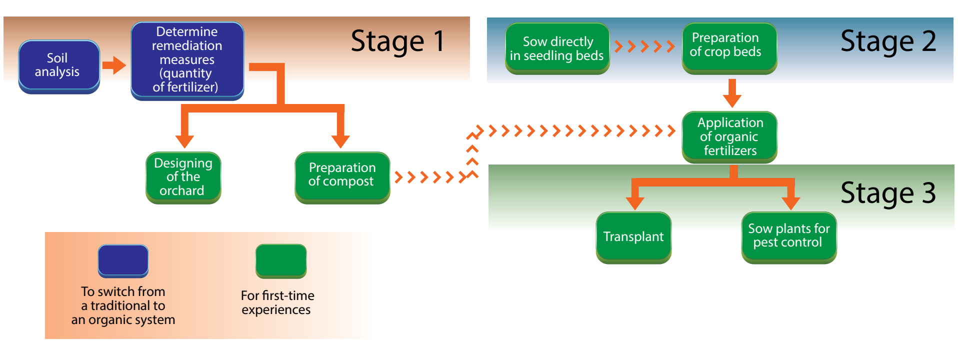
This production system may be implemented in agricultural regions where producers wish to eliminate agrochemicals for environmental reasons (preventing the contamination of downstream water bodies), economic reasons (obtaining certification so as to increase the market value of their products) or specific site-related reasons (improving soil fertility). Producers wishing to implement organic agriculture should have direct access to nearby markets where consumers have sufficient purchasing power to buy their products.

Threats and impacts addressed:

Improving the soil structure diminishes the potential for erosion and increases the soil's capacity to retain moisture, lessening the impact on crops of extreme heat, sudden temperature changes and drought. Increasing the presence of microorganisms and ensuring an appropriate balance of nutrients promotes the recovery of soil fertility, which in turn enhances productivity and reduces the need for synthetic agricultural inputs. The climate-induced spread of pests may be controlled with organic or ecological techniques.

How to implement:

(1) Apply for organic certification. (2) Design and plan organic production taking into account specific site conditions (soil, pests, climate, viable crops, markets). (3) Prepare the cultivation beds with fertilizers and other organic inputs. (4) Plant herbs and shrubs specifically for pest control. (5) Seed under a diversified system. (6) Transplant and nurture the seedlings and control pests according to the established plan.



Source: Prepared by the authors.

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Threats addressed

Related measures: 1 | 17 | 23 | 30

Income generation potential: 3

GHG mitigation potential: 1

Inputs and costs:

The costs given here are for a diversified organic agriculture production system on one hectare of land. The main expenses relate to purchasing seeds, restoring the soil and preparing and using inputs. Four days of training on the production method are assumed. Labour requirements for cultivation are not included.

Organic agriculture, 1 ha	US$
Labour	690
Materials	1080
Training	240
Total	**2010**

Ecosystemic and economic benefits:

An evaluation of organic agriculture practices in Latin America and the Caribbean found that the difference in small farmers' net income, per hectare, when using organic agriculture compared with conventional agriculture, was US$587 for bananas, US$108 for coffee and US$199 for sugar (IFAD, 2003). In another evaluation, on certified organic coffee production in Peru, Tudela (2005) found a cost-benefit ratio of 1.23 for organic producers compared to 0.75 for conventional producers. The organic product market is one of the fastest-growing markets. For example, exports of Peru's five leading organic products increased by 50% from 2010 to 2011 (Gómez, 2012). Organic agriculture helps to restore soil fertility. Altieri (1999) reports that the use of leguminous plants (green manures) may produce between 2.3 and 10 t of dry matter and fix between 76 and 367 kg of nitrogen per hectare. Eliminating the use of agrochemicals curbs crop, soil and water pollution with toxic elements.

Limiting factors:

The International Federation of Organic Agriculture Movements (IFOAM) considers a product organic only once three years have passed since the standard recommended practices were first implemented (IFOAM, 2012). Such practices require a proper handling of nutrients and pests; hence, prior training is needed and technical support for at least two years is recommended. Organic practices are also more labour-intensive and require greater efforts in agricultural techniques, which increases the short-term production cost.

Lessons learned:

Before switching from conventional to organic agriculture, producers must be aware that outputs tend to diminish during the initial stages and subsequently stabilize. This is due to the focus on fertilizing the soil and not only the crop, which takes time. The efficiency of organic agriculture increases if it is combined with other measures such as diversified systems, pest control and nutrient management.

Additional considerations:

Implementing organic agriculture is more feasible if producers are motivated and have a thorough understanding of the practices involved, if soil fertility is optimal from the outset and if producers are able to access markets where their products are in demand. Profitability increases over time, especially if the organic fertilizers and ecological pesticides are prepared on site.

How to monitor implementation:

Area under organic production (ha); farmers applying for certification (number).

How to gauge impact:

Productivity (t/ha); annual income (US$).

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References:

Altieri, M.A. (1999). *Agroecología: Bases científicas para una agricultura sustentable.* Montevideo: Editorial Nordan-Comunidad. | IFAD (2003). *La adopción de la agricultura orgánica por parte de los pequeños agricultores de América Latina y el Caribe,* International Fund for Agricultural Development, IFAD, Informe No. 1337 (April). | Tudela, J.W. (2007) "Determinantes de la producción orgánica: caso del café orgánico en los valles de San Juan del Oro – Puno". *Economía y Sociedad*, No. 64 CIES, Lima, 2007. | IFOAM (2012). *The IFOAM Norms for Organic Production and Processing.* Germany. | Gómez, R. (2012). "La agricultura orgánica: los beneficios de un sistema de producción sostenible" (2012). Lima: Centro de Investigación de la Universidad del Pacífico. Discussion paper.

Impacts addressed	Extent of impact reduction	Results in:
	3	up to 2 years

6 BEEKEEPING

Scale	**Individual** / Collective
Focus	**Investment** / Support

Description:

Beekeeping, or apiculture, is the management and raising of honey bees so as to rationally utilize their products and take advantage of the benefits they provide, such as honey, wax, royal jelly, propolis, pollen, venom, as well as pollination. A colony is a group of organized bees. Bees organize as a society with different categories of individuals in different stages of development. The colony is introduced into a box, called a hive, where the bees are raised. The introduction of beehives in crop fields diversifies growers' income and helps them to increase yields and improve crop quality.

Where to implement:

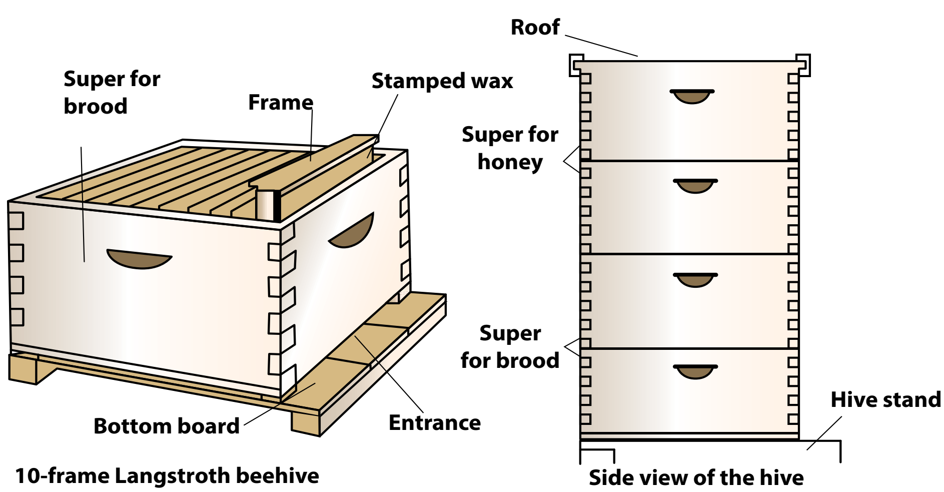
Preferably, beehives are located in warm regions with annual precipitation between 500 and 2800 mm that are highly biodiverse and propitious for plant growth and have long blooming seasons that facilitate honey production (Reyes and Cano, 2000). Beehives should not be located near population centres, industrial areas, livestock ranches or wastewater channels.

Threats and impacts addressed:

Beekeeping raises the productivity of nearby cropland and increases food security. It also lessens the impact of phenological changes through pollination and enhances the general resilience of farmers by providing them with an alternative source of income in the event of crop loss or damage.

How to implement:

(1) Determine the target colony density according to the surrounding vegetation. The recommended density is four colonies per hectare for an apiary with 20 to 30 hives. (2) Position the hives taking into account the prevailing winds, given that excessive wind makes it difficult for bees to exit and enter the hive. (3) Arrange the hives horizontally, and tilted slightly forward, so as to allow water to drain and facilitate the work of the cleaning bees. The availability of water in the surrounding area is an important factor. If water is not available, water containers should be installed.



Source: SAGARPA. (n.d.)

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Threats addressed	N/A

Related measures				Income generation potential	3
4	12	25	33	GHG mitigation potential	0

Inputs and costs:

Installation of a 10-hive production system. The main expenses are for the acquisition of materials for a complete hive, including protective equipment for the beekeeper, and labour to install the system. Two days for training in beekeeping and on the basic principles of production are included.

Beekeeping, 10-hive system	US$
Labour	495
Materials	734
Training	120
Total	**1349**

Ecosystemic and economic benefits:

Beekeeping has many benefits: (1) pollination of flowering plants, whether wild or cultivated; (2) production of honey, wax and other derivatives which provide an important source of income for some households; and (3) production of pollen, propolis and royal jelly, which also may be sold, although more specialized techniques and materials are required. In a study on the economic benefits of bee pollination for small-scale agriculture, Kasina and others (2009) estimated that about 40% of the annual value of the crops considered came directly from the ecosystemic services provided by bees. According to Magaña and Leyva (2011), in apicultural production, the rate of return may be as high as 38%.

Limiting factors:

Beekeeping depends on a series of environmental variables (wind, rainfall, climate) that should be considered when a production unit is installed. Operating an apiary requires taking preventive cleaning and disinfection measures to reduce the likelihood of disease. The proper operation and maintenance of a beekeeping system requires training and capacity-building.

Lessons learned:

To supplement their income during periods in which honey production is low, producers must consider ways to diversify, including selling propolis, royal jelly, apitoxin and pollen. The correct establishment of apicultural production requires conducting a prior test to determine how well the colonies adapt to the area and to monitor flowering. The more knowledgeable a beekeeper is of the floristic and climatic issues related to the location where the system is to be implemented, the more likely the project is to succeed.

Additional considerations:

Beekeepers' livelihoods and success depend on the presence of natural resources: bees, flowering plants and water. Although several environmental factors influence the quality and quantity of honey, a beekeeper can increase output by controlling certain variables such as the quality of the honeycomb, the internal volume of the hive and the age and the genetic quality of the queen (Pesante, 2009).

How to monitor implementation:

Apiary units installed (number).

How to gauge impact:

Additional income generated (US$ per apiary).

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Impacts addressed

Extent of impact reduction: 2

Results in: up to 3 years

7 SEED BANKS

Scale	Individual / **Collective**
Focus	**Investment** / **Support**

Description:

Seed banks are a mechanism set up by groups of local producers to store and classify, in safe, dry and dark locations, the most resilient and adaptable seeds offering the best product quality. The seeds are stored in hermetic containers to keep out dampness, and their fertility and moisture content are evaluated frequently. The aim of a seed bank is to maintain a reserve of the local genetic diversity to strengthen small farmers' autonomy, sustainability and food security. Seed banks operate like money banks: farmers borrow seeds before planting and return them with interest after the harvest. They may also function as businesses that sell organic seeds.

Where to implement:

Seed banks may be set up in places where farmers are interested in working together to preserve a stock of native species for human consumption or ecosystem restoration. They are particularly useful in locations with a high degree of genetic diversity or with varieties of native crops such as maize and beans. It is often possible to set up seed banks in existing facilities rather than building a new structure for them.

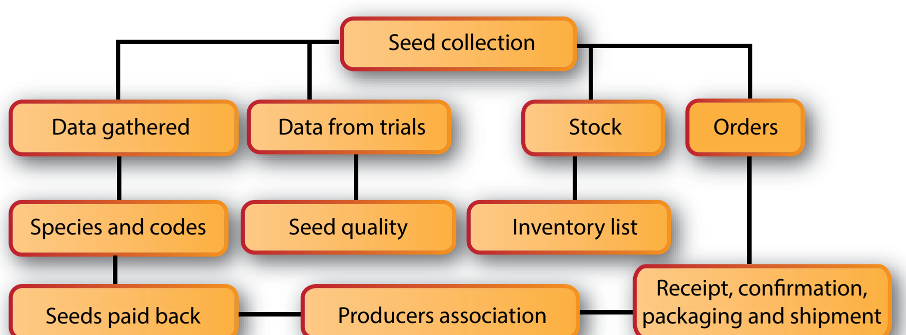
Threats and impacts addressed:

Seed banks enhance food security by preserving seeds with high agricultural and ecosystemic value that adapt to changing climate conditions. They make it possible to develop and preserve varieties that are more resistant to drought, flooding, extreme heat, frost and other climate events. Seed banks also offer the potential to diminish the impact of phenological changes on agricultural production. If they are set up as a business, they diversify income, which enhances overall producer resilience.

How to implement:

(1) Select the plants with the best growth patterns, pest resistance, product quality and resilience to extreme climatic events. (2) Extract, clean and dehydrate the seeds. (3) Weigh the best seeds and calculate their moisture levels. (4) Label the seeds. (5) Store the seeds in dark, fresh, dry and secure places. It is important to document the packing and storage procedures to be able to rapidly access samples of germplasm and carry out germination tests to ensure seed viability. (6) The seeds may be traded by farmers or sold on the market, depending on the original purpose of the bank.

SEED BANKS



Source: Prepared by the authors.

Supported by:
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Threats addressed

Related measures: 4 | 18 | 25 | 38

Income generation potential: 2

GHG mitigation potential: 0

Inputs and costs:

The estimated cost covers the adaptation of a facility and the acquisition of materials to set up a bank with 100 kg of seeds. The cost of building a storeroom is not included. The main expense is for a scale to weigh the seeds and calculate their moisture content. Four days of training in operating and managing the bank are assumed.

100 kg seed bank	US$
Labour	30
Materials	907
Training	240
Total	**1177**

Ecosystemic and economic benefits:

The value of the genetic information in seeds has long been understood. For example, it is estimated that by 1997, the global economy had generated around US$ 115 billion in annual benefits from the use of wild varieties as a source of pest resistance and environmental resilience (Couch and others, 2013). At the community level, the possibility of having easily accessible, resilient seeds at planting time or in emergency situations is crucial for small farmers' subsistence. In 2008, when a tropical storm damaged 90% of the maize and bean crops in a community in Honduras, the seeds in the local bank were distributed for the farmers to replant, which reduced losses (The Development Fund, 2011). Seed banks enhance agrobiodiversity. Almekinders (2001) reports that Andean farmers in Peru cultivate, individually, between 10 and 20 varieties of potatoes, but as a community they keep a large inventory, available to all though a trading system.

Limiting factors:

A functioning seed bank needs community work and organization as well as training in appropriate management techniques. Selecting resilient seeds is a time-consuming process, and knowledge and experience is required to improve varieties. Seeds should not come from plants contaminated by genetically modified species or fields where such species are used, to ensure their genetic purity. The appropriation of local genetic diversity by small farmers runs counter to the economic interests of large agribusinesses.

Lessons learned:

Maintaining and operating the seed bank must be financially feasible; consequently, it is recommended that the initial objectives include business considerations and provide for the selling of seeds from the outset. Selling local varieties in broader markets is a strategy to improve the socio-economic conditions of the community. A seed bank becomes more relevant if it is part of a comprehensive project for accessing markets and commercializing products.

Additional considerations:

Seed banks allow traditional knowledge to be recorded and shared, and they acquire special significance in places where local varieties are disappearing because of the use of hybrid or genetically modified seeds. A regional network of banks can be created with a common control protocol and seed care and management techniques in order to facilitate communication and the sharing of experiences.

How to monitor implementation:

Seed banks installed (number).

How to gauge impact:

Varieties or species preserved in seed banks (number, kg); contingencies addressed with seeds from banks (number).

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References:

Almekinders, C. (2001). *Management of Crop Genetic Diversity at Community Level*, Eschborn: Deutsche Gesellschaft für Technische Zusammenarbeit (DGTZ). | The Development Fund/UTVIKLINGSFONDET (2011). *Banking for the Future: Savings, Security and Seeds.* | SAGARPA (Mexico) (n.d.). *Almacenamiento y conservación de granos y semillas.* | Couch, S. and others (2013). "Feeding the future". *Nature* No. 499, 4 July, pp. 23-24.

Impacts addressed

Extent of impact reduction
2

Results in:
up to
5
years

8 WINDBREAKS

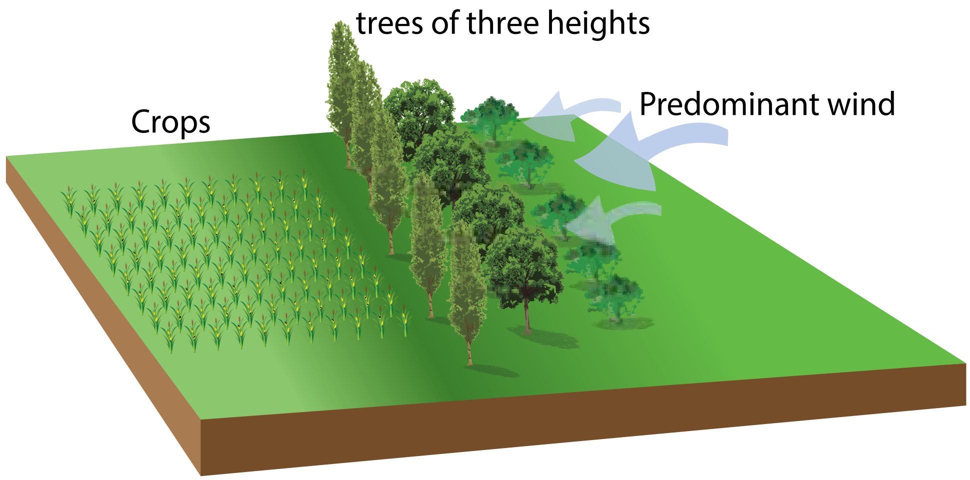
Scale	Individual
	Collective
Focus	Investment
	Support

Description:
Windbreaks comprise one or more rows of trees and shrubs of different heights placed perpendicular to the prevailing wind direction. Their purpose is to reduce the force of the wind close to the ground, and thus its mechanical action on crops, pasture and livestock. They are used to curb wind erosion and to help regulate climate conditions on farms. Windbreaks may also be used as living fences that demarcate the boundaries of a property or zones within it. In addition to their main purpose, they provide benefits such as climate regulation and landscape improvement.

Where to implement:
Windbreaks are recommendable in the Andean Altiplano as well as regions whose topography is characterized by steep slopes and frequent, intense winds. They are of particular interest in locations with low precipitation and more intense winds during the winter or dry environments, where it is necessary to conserve moisture and regulate climate conditions.

Threats and impacts addressed:
Windbreaks are used mainly to diminish the impact of strong winds that may damage crops and cause soil erosion. They also reduce the effect on crops of drought, extreme heat and even frost, due to the microclimate that trees foster.

How to implement:
(1) Position the barrier such that it will be perpendicular to the predominant winds. (2) Plant the rows of trees and shrubs taking into account the three heights of trees and shrubs that normally compose a windbreak barrier: tall, medium, short. The row with the tallest trees should have trees with flexible wood. (3) Space the trees out such that, once they are fully grown, the tree density in the barrier will be compact (occupying between 50% and 60% of available space) and turbulent currents due to wind infiltration will be prevented. (4) Fertilize, water and perform the required maintenance until the rows have taken hold. Trees about two years old should be planted to maximize the survival rate and accelerate the formation of the barrier.



Source: Adapted from SAGARPA (2012).

Inputs and costs:

The cost of implementing a 400 m windbreak barrier with trees of three different heights, with a 3 m planting density for the row with the tallest trees, is given below. The main costs relate to the purchase of plants and labour for planting. One day of training is included, as well as five days of annual upkeep.

Windbreak barrier 400 m long with three different heights	US$
Labour	330
Materials	1380
Training	60
Total	**1770**

Ecosystemic and economic benefits:

Strong winds may cause 70% to 100% of a crop to be lost or damaged, especially in the case of bananas, sugar cane, vegetables and fruit trees. Windbreaks may reduce wind speed by 60% to 80% (SAGARPA, 2012). Other benefits include the generation of a favourable microclimate for plant development and the reduction of wind erosion. For example, Altieri and Nicholls (2000) report 0.38 cm soil loss in a crop protected by a *Gliricidia sepium* and *Paspalum conjugatum* barrier, compared with 4.20 cm for an unprotected crop. These barriers also help regulate soil and air temperatures, reduce evapotranspiration and improve the distribution of soil moisture and the provision of such marketable products as fruits, seeds, timber and firewood. The trees increase the economic value of a property and improve the aesthetics of the landscape. They also favour biodiversity and reduce the pressure on the forests (Ojeda and others, 2003).

Limiting factors:

Some trees and shrubs may not be apt for the particular conditions of the location in question. Hence, it is important to select windbreak species according to site characteristics (soil, slope, climate, endemism) and the desired service (height, density, width of the crown, branches, rate of growth, longevity, resistance to drought, aesthetic value and value for wildlife).

Lessons learned:

In areas with long dry seasons, irrigation may be necessary to ensure that the barrier takes hold. Windbreak barriers are an important element of sustainable production methods like agroecology and permaculture, because, in addition to their main function, they allow for more efficient water management, enhance biodiversity, increase the organic-matter content of the soil and even help control pests.

Additional considerations:

A single species should be planted in a given row to avoid growth variations. In windbreaks with multiple rows, a different species can be used in each row to minimize the risk of tree loss due to disease, increase the life of the curtain and improve growth. "Woodland shelter" barriers protect livestock from the wind and provide shade.

How to monitor implementation:

Length of windbreaks planted (m); area under windbreak protection (ha).

How to gauge impact:

Decrease in losses or damages (t/ha, US$); additional windbreak products (number, t).

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References:

Altieri, M.A. and C. Nicholls (2000). *Agroecología: Teoría y práctica para una agricultura sustentable.* Mexico City: UNEP. | Ojeda P.A., M. Restrepo, Z. Villada and C. Gallego (2003). *Sistemas silvopastoriles, una opción para el manejo sustentable de la Ganadería.* Santiago de Cali, Valle del Cauca, Colombia: Fundación para la Investigación y Desarrollo Agrícola (FIDAR). | Ospina, A. (2003). *Cercas vivas.* Cali. Valle del Cauca. Colombia: Fundación Ecovivero. | SAGARPA (2012). "Cortinas Rompevientos" in *Fichas Técnicas sobre Actividades del Componente de Conservación y Uso Sustentable de Suelo y Agua* (COUSSA). Mexico. | Venegas, P. (n.d.). *Establecimiento de Barreras Rompevientos.* Costa Rica: Ministerio de Agricultura y Ganadería, Dirección Regional Pacífico Central.

Impacts addressed

Extent of impact reduction

1

Results in: up to 1 year

9 BIODIGESTERS

Scale	Individual
	Collective
Focus	Investment
	Support

Description:

A biodigester system utilizes organic waste, particularly animal and human excreta, to produce fertilizer and biogas. A biodigester consists of an airtight, high-density polyethylene container within which excreta diluted in water flow continuously and are fermented by microorganisms present in the waste. The fermentation process is anaerobic, i.e., it takes place without oxygen, and the bacteria responsible for decomposition are methanogenic (i.e., they produce methane, also known as biogas). The processed manure is an organic, pathogen-free fertilizer that is rich in nitrogen, phosphorus and potassium. The products are primarily for self-consumption on farms.

Where to implement:

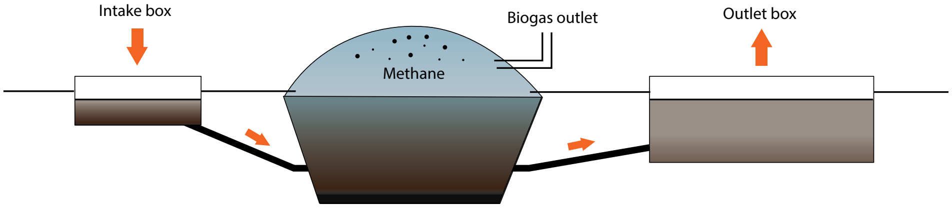
Biodigester systems may be implemented in any rural or urban area with sufficient space and a sufficiently large number of animals to generate at least 100 kg of manure a day. They are particularly useful on family farms that have livestock as a source of organic matter, cultivation areas on farms where fertilizer can be used and living quarters that can use biogas. They can be implemented on farms that need to improve soil fertility or the quality of life of the producers if the conditions referred to above are in place. Permanent access to water is required.

Threats and impacts addressed:

By producing a nutrient-rich fertilizer, this system reduces the need for agricultural inputs. Adding manure to soils reduces their deterioration and increases their productivity. Soil to which organic fertilizers have been added is less vulnerable to pests, erosion and drought. The methane that is produced, rather than entering the atmosphere, is used for domestic activities (cooking, heating water), which, by converting it to carbon dioxide, decreases its global warming potential.

How to implement:

(1) Prepare the site. (2) Calculate the volume of manure produced. (3) Select and purchase a biodigester that meets the volume requirement. (4) Set up the biodigester. (5) Design and construct a system to channel the excreta to the biodigester. (6) Construct a system to channel the methane to the location where it will be used. (7) Collect the organic fertilizer and leachates. (8) Apply the fertilizer. (9) Use the biogas.



Source: http://www.novus.com.br.

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Threats addressed N/A

Related measures: 1 | 4 | 22 | 32

Income generation potential: 1

GHG mitigation potential: 2

Inputs and costs:

Purchase and set up of a 10 m³ anaerobic-biodigestion system capable of processing 100 kg/day of excreta from farm animals. The main expense is for the biodigester, the pipes and the cooking stove. The cost of labour for maintenance, which is considerable, is not included because it is assumed that this labour will be provided by the producers. Two days of training on system operation and maintenance are assumed.

10 m³ biodigester for 5 heads of cattle	US$
Labour	90
Materials	960
Training	120
Total	**1170**

Ecosystemic and economic benefits:

Under optimal conditions, some 3 to 4 l of fertilizer are produced per kg of excreta, and its systematic use restores poor and infertile soils and increases yields. For example, a controlled experiment in Brazil, which ran trials with various doses, found that a 60 m³/ha dose of effluent applied to lettuce crops surpassed the results of mineral fertilization in terms of height, number of leaves, diameter and fresh mass of the lettuce (Chiconato, 2013). For a 10 m³ system, assuming that chemical fertilizers are completely replaced with the effluent and that biogas is used for cooking, the potential savings is US$ 350 per month. The utilization of biogas diversifies or replaces energy sources for household consumption (1 m³ of biogas replaces 0.5 kg of LP gas). Ferrer and others (2009) report that the biogas produced by a 5 m³ system is sufficient to cook for three to four hours a day. This has positive effects for the health of the users and the ecosystem by replacing the burning of dung or firewood.

Limiting factors:

Proper operation requires an average temperature above 15°C. In areas with lower temperatures, a greenhouse or a thermal insulation system must be constructed, since biogas production decreases in cold temperatures (Poggio and others, 2009). The site where the biogas is to be used must not be more than 150 m apart from the biodigester, because, beyond this distance, gas pressure decreases.

Lessons learned:

The biodigester must be used constantly; otherwise, a process of putrefaction sets in within the container. When this occurs, the container must be emptied and the system cleaned. The system's efficiency increases when the biodigester is integrated into the farm and is connected to the latrines. It is important not to exceed the maximum recommended organic matter capacity, according to the design of the biodigester, to ensure that the manure remains in the container for a sufficient amount of time for the pathogens to be removed.

Additional considerations:

The excreta must be diluted in a 1:3 ratio, for which urine or water may be used. Any solids, along with any inorganic material, should be removed before the excreta are introduced into the digester. If the animals have been given antibiotics, at least four days should be allowed to go by before using the manure, because antibiotics can harm the bacteria inside the reactor. The biogas is used for stoves with conventional valves connected to a hose or pipe, without any type of pressure regulator.

How to monitor implementation:

Biodigesters installed (number).

How to gauge impact:

Fertilized area (ha); methane used (m³/year); fertilizer and biogas produced (l/month).

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References:

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Impacts addressed

Extent of impact reduction: 2

Results in: up to 1 year

10 FOG CATCHERS

Scale	Individual / **Collective**
Focus	Investment / **Support**

Description:

Fog catchers are a system that uses plastic meshing held in place by frames to intercept fog banks formed by clouds in Andean valleys and plateaus. The water droplets contained in the fog bump up against the threads in the meshing, accumulate and fall, by the force of gravity, into a gutter that conveys the water to a deposit. Fog is a low-cost, alternative source of water for a large sector of the Andean population, which generally pays more for this resource than urban dwellers with access to basic utility services. Community-based systems consist of several catchers installed in a series.

Where to implement:

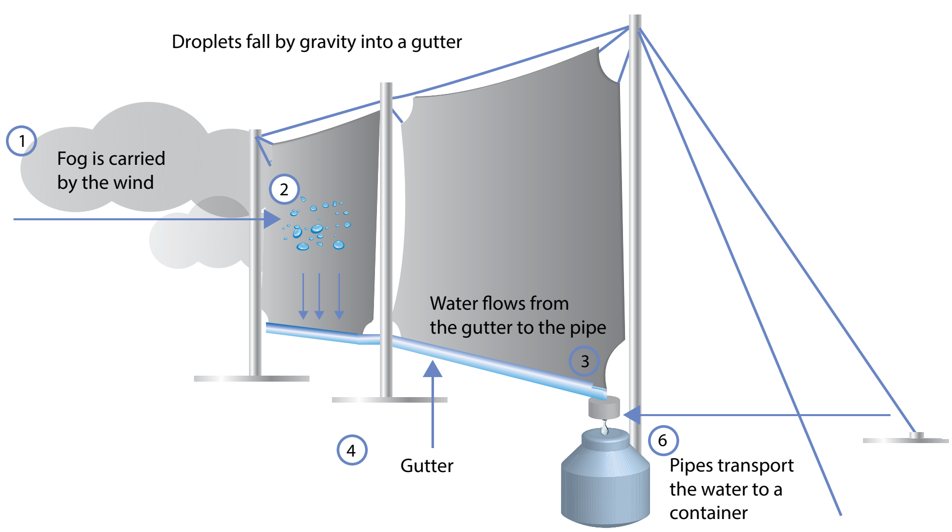
These systems are used on farms or settlements lacking alternative sources of water and where the climate favours fog formation. In the Andes these conditions are found mainly in the western cordillera. Summits and high mountainsides are ideal for establishing a gravity-based water supply network. An individual catcher requires about 15 m^2 of land and a collective system requires about 0.5 ha.

Threats and impacts addressed:

This technique enhances the water security of populations that are highly vulnerable to climate change, mitigating the impacts of drought and extreme heat on people, crops or animals. A secure source of water may increase soil productivity and mitigate the effect of changes in rainfall patterns. Nevertheless, in some regions climate change may alter the conditions that are conducive to fog formation.

How to implement:

(1) Select the sites offering the greatest fog-catching capacity and where the collected water can most easily be distributed. (2) Use tensors to secure two 6 m poles, 12 m apart and perpendicular to the predominant wind, to ensure that they can withstand strong wind gusts. (3) Fasten the 4 m high double screen (ideally, a 35% Raschel shade mesh). (4) Place a water catchment gutter under the screen. (5) Install the storage and distribution system. (6) Install a simple water treatment system, if needed.



Source: Aránguiz and others (2009).

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Threats addressed

Related measures				Income generation potential	1
18	28	30	33	GHG mitigation potential	0

Inputs and costs:

Construction and installation costs for one 48 m² fog catchers with a 500 l storage capacity are presented. The main expenses are for the purchase of materials (poles, mesh, pipes, tank) and the labour to install the system. Two days for training on proper use and maintenance are included.

48 m² fog catchers	US$
Labour	135
Materials	320
Training	120
Total	**575**

Ecosystemic and economic benefits:

A comparative study on the efficiency of fog catchers in nine regions of Chile reports monthly volumes between 51 and 184 liters per square metre of Raschel mesh. The study estimated that water supplied with fog catchers costs 34% less than water from tank trucks (FAO, 2000). Fog is an alternative water source that does not affect or use traditional supplies such as wells, rivers or lakes, thus promoting the ecological equilibrium of surface and groundwater bodies. Stored water can be used for reforestation programmes and fire control or for small orchards, with subsequent benefits to the ecosystem or the household economy.

Limiting factors:

The correct sizing of the system requires reliable statistics on the volume of stable fog. Fog catchers are a water recollection technique requiring considerable space in order to obtain significant amounts of water. Unless the community is involved in designing and constructing the system, problems may arise due to improper maintenance or use. Conveyance costs may be high if the fog catchers are far from the population centre.

Lessons learned:

Although the collected water is initially potable, it may become contaminated in the different supply stages. For this reason it must be treated before being consumed. If the aim is to have irrigation water, drip systems should be installed to ensure a sustainable use of the water and suspended solids should be removed with prior treatment to avoid the obstruction of the drippers.

Additional considerations:

Current efforts focus on improving water collection efficiency and the durability of the meshes and support poles. Given that in some cases, windborne toxic minerals accumulate in the water, a study should be carried out prior to construction. The success of the community-based implementation depends on the degree of empowerment and ownership conveyed to end users during the design, construction and maintenance of the system.

How to monitor implementation:

Fog catcher units installed (number).

How to gauge impact:

Volume of collected water (l/month).

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References:

FAO (2000). "Captación de agua de las nieblas costeras (Camanchaca), Chile". *Manual de Captación y Aprovechamiento del Agua de Lluvia*. (Series: Zonas áridas y semiáridas No. 13). Santiago, Chile. Available at: ftp://ftp.fao.org/docrep/fao/010/ai128s/ai128s07.pdf. | Aránguiz, G. and others (2009). *Diseño generativo: Aplicación en sistemas de atrapanieblas en el norte de Chile.* Universidad de Chile.

Impacts addressed

Extent of impact reduction

2

Results in: up to 1 year

11 SOLAR DEHYDRATORS

Scale: **Individual** / Collective

Focus: **Investment** / Support

Description:

Solar dehydrators are passive-flow systems that reduce the water content of fruits, vegetables, seeds or meat by concentrating solar heat and continuously drawing in air. Their main purpose is to conserve and add value to agricultural products by maintaining their nutritional or genetic value and inhibiting the proliferation of microorganisms that cause decomposition. This allows the producers to process the products and increase their profit margin. Given that the heat source is the sun and the dehydrating agent is the wind, drying efficiency depends on design factors (orientation and capacity) and climate conditions (temperature, moisture, exposure to sunlight and wind speed).

Where to implement:

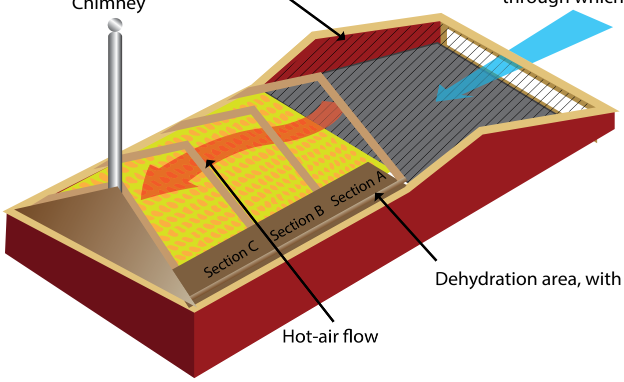
These systems are especially useful on farms with a production surplus or with products requiring additional processing, such as coffee. Constant exposure to sunlight for at least six hours a day, along with low relative humidity, is required. Locations with continuous, moderate wind and good solar irradiation are ideal for implementing solar dehydrators.

Threats and impacts addressed:

The primary aim of solar dehydrators is to provide producers with greater food security and diversify their income, thus increasing their general resilience. Food and seed preservation helps offset productivity losses and phenological changes caused by climate change.

How to implement:

(1) Design the system taking into account: the type of products to be dehydrated, the volume of production and the climatic and physical conditions (temperature and humidity) of the location. (2) Plan to position the dehydrator so as to maximize daily solar incidence, and so that the air entrance is perpendicular to the direction of the prevailing wind. (3) Build the dehydrator. (4) Select products that are in good condition. (5) Slice the products taking into account how they are to be packaged (with a maximum thickness of 1 cm). (6) Pretreat according to the specific product (whitening, salting or sugar-coating). (7) Place the product on trays. (8) Monitor the dehydration procedure (checking to determine if the expected weight has been attained). (9) Package. (10) Store.



Source: Adapted from INTI (2007).

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Inputs and costs:

The costs given below are to build and install a 19 m² solar dehydrator with a 6 m² drying area capable, under optimal conditions, of dehydrating 48 kg of tomatoes per day. The main costs are for the construction materials (wood, plastic cover) and labour. Two days of technical training on using the dehydrator are considered.

Solar dehydrator with a 6 m² drying area	US$
Labour	195
Materials	424
Training	120
Total	**739**

Ecosystemic and economic benefits:

Dehydrators allow producers to fully utilize a harvest as well as to diversify their income and have food and income during lean periods by meeting off-season demand. Dehydrators add value to and improve the appearance of farmers' products and help avoid losses due to market volatility. For example, a comparison of prices for dehydrated and fresh peaches reported by Peru's ministries of agriculture and production points to a ratio of 9 to 1 between the two. Dehydration reduces the weight of foodstuffs, facilitating their handling and lowering fuel consumption for distribution. Dehydrators do not require external energy (either gas or electricity); hence, operating costs are minimal and no greenhouse gas emissions are produced.

Limiting factors:

Although dehydrators increase producers' economic resilience, their operation will depend on the climate conditions of the location. On cloudy days, with humidity above 95% or temperatures below 5°C, the drying period is longer, which favours decomposition. To accelerate the drying process under adverse conditions, ventilators can be used to force air to circulate. This requires an outside energy source.

Lessons learned:

When the products dry very quickly, an unwanted crust may form. To avoid this, decrease the air flow or increase the amount of product on the trays. Fruits should not be mixed with herbs or meat, as the aroma from one product may transfer to another. In places with extreme wind or frequent hail, the plastic covering may be blown away or damaged, and more resistant materials such as glass should be considered.

Additional considerations:

In very humid environments, the drying area can be divided, with products placed only at the rear in order for the front area to provide additional heat. Optimal dehydration conditions vary from one product to the next, but, in general, a range from 55°C to 65°C is sought. At higher temperatures, nutrient quality tends to decrease. Pre-treatment with citric acid is recommended to prevent fruits, vegetables and meat from darkening, and with sugar or salt to prevent fruit or meat, respectively, from decomposing.

How to monitor implementation:

Units constructed (number).

How to gauge impact:

Additional income (US$); dehydrated product (kg).

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References:

Instituto Nacional de Tecnología Industrial (INTI) (2007). *Manual de construcción del deshidratador solar Aureliano Buendía*. Argentina. Available at: http://www.inti.gov.ar/pdf/deshidratador.pdf. | "Frutas deshidratadas", in *Crea tu empresa: documento ampliado para la ficha 18*. Peru: Universidad del Pacífico-Ministerio de la Producción. | *Información del mercado mayorista No. 2 de Frutas*. Peru: Ministerio de Agricultura y Riego, 2013.

Impacts addressed

Extent of impact reduction

3

Results in: up to 1 year

12 CROP DIVERSIFICATION

Scale	Individual / Collective
Focus	Investment / Support

Description:

Crop diversification refers to growing various agricultural products on a single plot, especially two or more crops in alternating rows. Various diversification models exist but they can all be broadly referred to as polyculture, including: intercropping, mixing annual crops with fruit and forest trees and planting different vegetable varieties. Several objectives may be sought, including controlling herbivorous insects, achieving biological control by cultivating antagonist species, efficiently using horizontal and vertical spaces in a plot or increasing farmers' income. Diversified systems are generally more resilient than single-crop systems.

Where to implement:

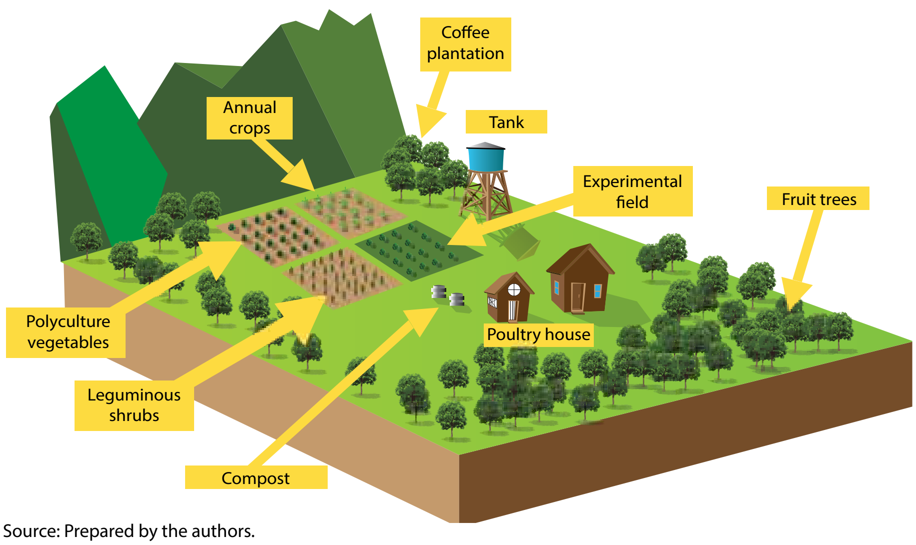
Crop diversification may be implemented on any section of a farm, as long as the selection of crops is appropriate for the physical and chemical conditions of the soil. It is particularly useful for making the most of limited land as well as for enhancing agrobiodiversity.

Threats and impacts addressed:

Through the growing of a variety of crops, diversification increases food security and reduces the need for agricultural inputs. Mixed systems are more resilient to pests, extreme temperature changes, drought and changing rainfall patterns. Diversification is an alternative for distributing losses in the event of crop damage or if harvest yields decrease.

How to implement:

(1) Select the most suitable crops for the climate and environment of the farm, taking into account market preferences. (2) Devise a plan to manage and monitor cultivation practices (e.g., pest and weed control, nutrient management, irrigation) and calculate production costs. (3) Select the most suitable companion plants. It is important to seek positive synergies from relations among crops, avoiding intercropping with varieties that require the same soil nutrients. (4) Plant the varieties according to the established plan and the timing of the harvest. (5) Incorporate farming practices such as organic fertilizer production and use, soil conservation, crop rotation and integrated pest management.



Source: Prepared by the authors.

Inputs and costs:

The cost of diversifying one hectare of cropland is given below. The main expenses are for the purchase of seeds and the preparation of organic fertilizers and ecological pesticides, as well as the labour to sow and fertilize the crops. Two days of training in managing the diversified system are included.

Crop diversification (carrots/lettuce/beans) on 1 ha of land	US$
Labour	675
Materials	360
Training	180
Total	**1215**

Ecosystemic and economic benefits:

Crop diversification has a series of benefits for a plot, including the recycling of nutrients, the establishment of microclimates, the regulation of local hydrological processes and the management and control of pests and plant diseases (Altieri, 2002). Altieri also mentions that polyculture has led to 20% to 60% increases in output, and that in Mexico planting one hectare of maize, squash and beans yields as much food as planting 1.73 ha only with maize. Another advantage of mixed systems is the greater stability of the yield when climate conditions change, with a variability coefficient 30% lower, on average, than with monoculture.

Limiting factors:

It is important to consider the adaptability of the different partnerships used in diversification. This requires familiarity with the agroecological conditions of the area and the requirements of the different species to be planted in the mixed system. The main limiting factor relates not to the physical characteristics of the crops but to the design of highly integrated strategies in the planning stage so as to achieve beneficial interactions as a result of diversification.

Lessons learned:

Although the per-crop yield of the harvest under mixed systems is generally lower than that of monoculture, total output tends to be higher. Diversified systems may recover beneficial ancestral practices such as those of the traditional *milpa* (intercropping of maize, squash and beans). In the Andean region, a variety of crops can be cultivated in mixed systems—for instance, tubers such as potatoes, oca, ulluco and mashwa; roots such as arracacha, yacon and achira; grains such as maize, quinoa and cañihua, as well as fruits such as tree tomatoes, sauco (*Sambucus*) and passion flowers (*Passiflora*).

Additional considerations:

Diversification may involve species other than vegetables, legumes and fruits—for example, medicinal, aromatic or wild plants. Diversification should be complemented with other farming practices like mulching or soil covering, the integration of small animals or the establishment of greenhouses for areas with frequent frosts.

How to monitor implementation:

Area cultivated with mixed planting arrangements (ha); associated varieties planted per cultivation unit (number).

How to gauge impact:

Income increase (US$); varieties produced (number, t).

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References:

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Impacts addressed

Extent of impact reduction: 2

Results in: up to 1 year

13 DRAINAGE SYSTEMS

Scale	Individual / Collective
Focus	Investment / Support

Description:

Agricultural drainage is carried out by systems that intercept and convey excess water across a plot and dispose of it in a safe location. The water is transported by gravity, in a non-erosive manner, in surface or sub-surface channels. The aim is to control the specific moisture content for each type of crop and avoid losses resulting from excess water in extreme situations. The size of the system depends on the depth of the water table and the maximum volume to be disposed of, but in general channels are between 0.4 and 1.5 m deep and 0.5 and 1.2 m wide.

Where to implement:

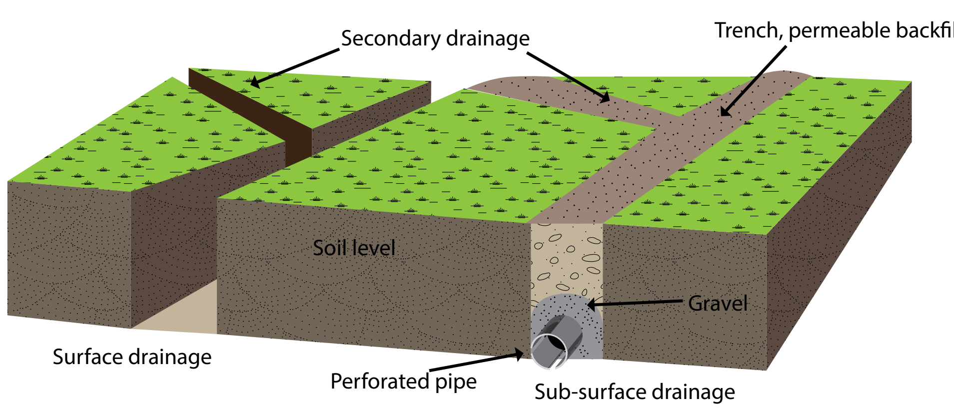
Agricultural drainage is implemented on plots with slopes from 1% to 25% on which there is a need to control the groundwater level or that are periodically flooded. They are particularly useful in areas subject to flooding like alluvial valleys or land with low permeability and clay or silt soils.

Threats and impacts addressed:

Drainage avoids crop damage from intense rain and flooding by removing excess water. It also controls soil moisture content, allowing crops to grow properly, which increases productivity and, consequently, food security. The moisture retained during the rainy season may be beneficial during the dry season.

How to implement:

(1) Identify the areas on the parcel where water naturally runs off. (2) Identify the type of drainage to be used (surface or sub-surface). (3) Calculate the depth, width and length of the drainage system according to the source and amount of water to be removed, the problem that it creates, the permeability of the soil and the type of crop that the measure is intended to benefit. (4) Excavate the ditches with an inclination that will avoid the accumulation of sediment and allow the runoff to flow at a speed of at least 0.25 m/s. (5) Complement surface drainage with compacted ridges and sub-surface drainage with filler consisting of rocks or gravel in addition to installing runoff pipes.



Source: Prepared by the authors.

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Threats addressed

Related measures
28 36 37 40

Income generation potential 0

GHG mitigation potential 0

Inputs and costs:

The cost of constructing a surface drainage system 0.5 m wide, 0.8 m deep and 1000 m long on approximately 5 ha of land is given below. The main inputs are the labour to excavate and move material as well as to analyse soil, precipitation and runoff conditions. Two days for training in constructing and operating the system are considered.

Surface drainage system 0.5 m x 0.8 m x 1000 m	US$
Labour	2325
Materials	1000
Training	120
Total	**3445**

Ecosystemic and economic benefits:

Drainage systems save energy used in irrigation by controlling soil moisture. They prevent crop loss from flooding and maintain agricultural soil conditions so as to maximize yields. They eliminate excess water on farmland and control the groundwater level to ensure the best balance of water and salts in the crop root zone (Pizarro, 1985). Polón and others (2011) report that in heavy soils that have been improved by drainage, production increases ranged from 50% to 100% for cereals and from 90% to 200% for tubers. This benefits of the measure are seen at the end of one annual cycle.

Limiting factors:

Agricultural drainage cannot be implemented on flat land where runoff cannot be safely disposed of. Underground drainage is more costly by orders of magnitude than surface drainage. Drainage channels transect plots, which makes it more difficult to use machinery and limits its access in general.

Lessons learned:

It is important to start with the smallest number of drainage channels possible and to complement the hydraulic infrastructure with simpler measures, such as contour trenches and keyline ploughing, to promote infiltration of excess runoff. The dimensions of the system are important because improperly designed drainage can parch the land.

Additional considerations:

Drainage systems require maintenance and constant monitoring. They may be complemented with absorption wells, water storage tanks and pumping systems. Many of the problems of agricultural soil could be mitigated with appropriate drainage systems, but the proper operation of the system and its limitations must be understood.

How to monitor implementation:

Length of drainage systems constructed (m).

How to gauge impact:

Increase in productivity (t/ha); area protected with agricultural drainage (ha).

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References:

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Impacts addressed

Extent of impact reduction: 1

Results in: up to 3 years

14 ECOTOURISM

Scale	Individual
	Collective
Focus	Investment
	Support

Description:

Ecotourism is an economic-development tool based on conserving and sustainably using existing ecosystem goods and services and making them available to visitors. It mainly consists of low-scale local tourism in protected areas or in agricultural areas (agrotourism) that allows visitors to appreciate nature, and the values and cultural traditions associated with it, and purchase sustainable products. It promotes exchanges between visitors and the community and encourages environmental education and fair trade. This type of tourism is based on local resources, is low impact and offers socio-economic benefits to the populations responsible for conserving the goods or services promoted.

Where to implement:

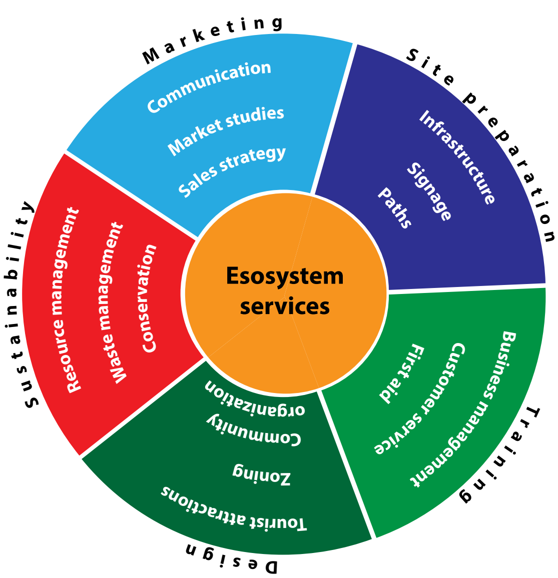
Ecotourism projects may be implemented in natural settings that offer particular landscape, cultural or ecological attractions and, preferably, that have access to a target population segment or market. The location should have community organizations to provide a variety of site-related services (lodging, meals, guided tours). Agrotourism projects can be carried out on farms or in agricultural areas with innovative production procedures (organic agriculture, shade-grown crops, restoration, conservation), lodging and services.

Threats and impacts addressed:

The main purpose of ecotourism is to allow producers to diversify their income by complementing their activities to mitigate the stress from certain impacts of climate change such as lower agricultural productivity, damaged crops, the need for more inputs and even declining water availability. Although ecotourism does not address impacts directly, it does help reduce the reliance on climate to generate income.

How to implement:

(1) Identify the site's landscape, ecological and cultural appeal based on its ecosystem goods and services. (2) Evaluate the system's carrying capacity. (3) Evaluate the feasibility of the project and draw up a business plan. (4) Promote networking among local community organizations, government authorities and other key stakeholders in order for an agreement to be reached on responsibilities and benefits. (5) Obtain permits and comply with other regulatory requirements. (6) Receive training in business management and customer service. (7) Provide workers with training on resource conservation, restoration and sustainable use. (8) Prepare the site. (9) Carry out marketing activities. (10) Implement conservation, waste management and water management practices and other measures necessary to reduce the environmental impact of the activity.



Source: Prepared by the authors.

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Threats addressed

Related measures: 4 | 11 | 16 | 21

Income generation potential: 3

GHG mitigation potential: 1

Inputs and costs:

The cost given below is for the development of an ecotourism project on 5 ha of land. The main expenses relate to the materials for preparing the site, a short consultancy on project design, and training in business and customer service. The construction of facilities for basic services is included, but not that of rooms or other structures. Fifteen days of comprehensive training is assumed.

Ecotourism on 5 ha of land	US$
Labour	735
Materials	2650
Training	900
Total	**4285**

Ecosystemic and economic benefits:

Ecotourism projects promote the conservation of natural areas while safeguarding their biological and cultural diversity. Economic incentives for tourism in Costa Rica have made it possible to conserve 21% of the country's territory in national parks (Dasenbrock, 2002). An analysis of several ecotourism projects in Belize discussed by Lindberg and others (1994) indicates that approximately 30% of the local population benefited from the new jobs created. A small-scale community project in Río Blanco, Ecuador, which offers visitors lodging in cabins within natural areas and the opportunity to appreciate traditional Quechua dances, represents at least 20% of the annual income of participants, who work there only four hours per day during the tourism season (Schaller, 1995).

Limiting factors:

The proper implementation of ecotourism projects requires planning, training and appropriate ecosystem management. In addition, fostering of consultation and consensus-building processes is needed, in order to gain community approval, which takes time. Generally, ecotourism projects should be financed for a minimum of three to five years to ensure that they reach their required internal rate of return. To cover lodging-construction costs, which are significant, additional funding sources are generally required along with reinvestment in the project. The maximum number of visitors should be established based on the ecosystem's carrying capacity in order to prevent damage to the area that is to be protected and promoted.

Lessons learned:

The likelihood of success can be increased by establishing networking links among key stakeholders (local government, NGOs, protected area commissions) in order to receive support with planning or with financial incentives; by understanding environmental regulations (conservation categories, zoning guidelines) in order to know what is permitted in the area; and by integrating local businesses in order to diversify the services offered. Training on the importance of properly managing the resources of the area will ensure their conservation and the permanence of the project.

Additional considerations:

The community must clearly understand the benefits and responsibilities related to a tourism development of this kind, and a transparent process must be established to ensure their equitable distribution. Damage and degradation may be prevented by establishing regulations on the ecological behaviour of visitors and employees as well as by appointing persons to enforce these regulations. Visitors exert less stress on the ecosystem when ecotechnologies are used for the provision of services (e.g. water and sanitation, waste management). Research and teaching institutions can act as key partners by providing scientific information on the site and helping estimate its carrying capacity.

How to monitor implementation:

Ecotourism or agrotourism projects carried out (number).

How to gauge impact:

Income generated (US$); areas preserved (number, ha).

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Impacts addressed

Extent of impact reduction

1

Results in: up to 1 year

15 EFFICIENT BIOMASS STOVES

Scale	Individual
	Collective
Focus	Investment
	Support

Description:

A gasifier is an efficient stove that uses different kinds of biomass and offers an alternative to traditional and inefficient firewood stoves. Biomass is placed in a combustion chamber, which controls the oxygen, triggering a process known as pyrolysis in order to produce charcoal. The released gas is combusted on the burner, producing a blue flame. When combustion is optimal, no smoke is produced and 60% of the fuel that would normally be used on a traditional firewood stove is saved. About 25% of the biomass is reduced to black charcoal, also known as biocarbon, which is used for soil conditioning.

Where to implement:

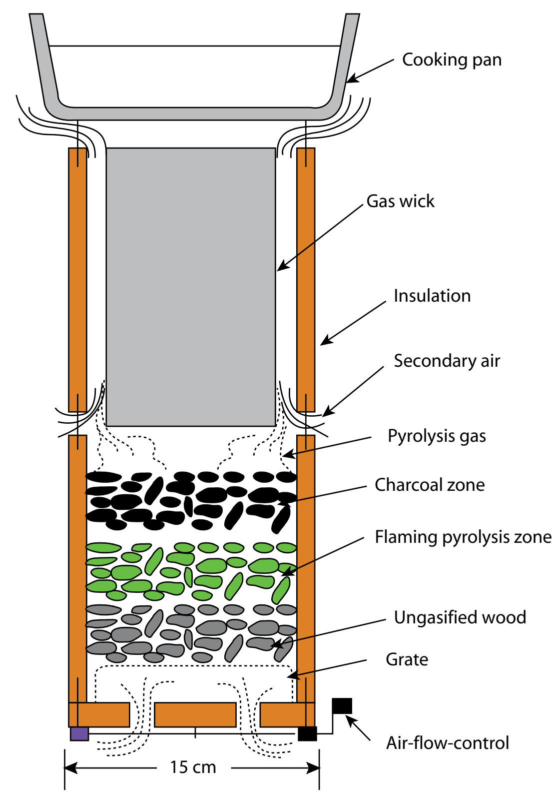
Efficient stoves may be installed in rural, urban and peri-urban areas where households cook with firewood and suffer the health effects associated with poor combustion (smoke, soot, particles). In areas with scarce forest resources, gasifiers may be combined with reforestation actions, forest management or sustainable firewood production to devise a robust measure for not only mitigating but also adapting to climate change.

Threats and impacts addressed:

Efficient stoves produce biocarbon that is used to improve soil structure and hence to reduce not only the impact of intense rainfall and drought but also the need for greater agricultural inputs. Improved soils are more resilient to erosion. This combustion method conserves forest resources and significantly decreases greenhouse gas (GHG) emissions resulting from biomass combustion. It thus mitigates climate change in two ways: by reducing deforestation and by reducing GHG emissions.

How to implement:

Gasifiers are bought, not constructed. The installation and operation steps are as follows: (1) Analyse existing sources of viable biomass to avoid deforestation and degradation. (2) Install the gasifier and the extractor chimney. (3) Receive training on the proper use and combustion method. (4) After combustion, crush the residual black charcoal, inoculate with soil-regenerating bacteria and mix with earth. (5) Apply the biocarbon as a substrate on crops or use it to restore degraded soil. (6) Keep a record of biocarbon produced, processed and applied and of the consumption and source of biomass used in the gasifiers.



Source: http: //energy-without-carbon.org.

Inputs and costs:

Purchase and installation expenses are calculated for a gasifier that consumes 1.4 kg of firewood per load, which on average is sufficient for 1.5 to 3 hours of cooking. One day of training is assumed. However, the per-unit training cost may decrease if more gasifiers are installed.

Gasifier with capacity of 1.4 kg of firewood per load	US$
Labour	30
Materials	500
Training*	60
Total	**590**

* For training costs it is assumed that at least 10 gasifiers will be installed.

Ecosystemic and economic benefits:

Using data from an efficient-stove project in Mexico, Díaz (2011) states that the greatest economic benefits are the savings on firewood and the reduction in health impacts (53% and 28% of total benefits, respectively). Daily firewood consumption for a family of 4.5 is approximately 21 kg. A 60% reduction in firewood consumption for cooking translates into annual savings of 45 t of firewood per household, which helps conserve forest resources. The gasifier's more efficient combustion reduces CO_2 emissions into the atmosphere by 3 t per household per year. The biocarbon that is obtained can be used to restore and condition soils, improving their fertility and physical properties.

Limiting factors:

A gasifier requires an initial investment and, unlike other systems, cannot be manufactured in artisanal-type operations. The main challenge is to close the carbon loop and ensure that biocarbon is incorporated into the soil as an integral part of the implementation process. As this technology requires changing some practices, users must receive training and have a sense of ownership. Without this step, there is a risk that users will return to traditional firewood stoves.

Lessons learned:

The performance of the gasifier depends, *inter alia*, on its proper use and maintenance as well as on following the correct installation procedure. Not all efficient stoves are suitable for users' customary practices, which limits their degree of acceptance. A user-perception study should be carried out before the gasifier is promoted on a large scale.

Additional considerations:

As a result of the need for efficient stoves that use less wood and above all that extract smoke from the home, many types of purportedly efficient stoves have been designed and installed without any prior study to substantiate manufacturers' claims. A study comparing firewood consumption and cooking time for a traditional stove versus some efficient models promoted in Latin America found that traditional stoves are more efficient for boiling water, but less so for cooking maize or beans. All the models tested have the advantage of significantly reducing the quantity of unhealthy particles (Blanco and others, 2009).

How to monitor implementation:

Installed units (number).

How to gauge impact:

Annual firewood savings (kg/year); biocarbon incorporated into the soil (kg).

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References:

Blanco S., B. Cárdenas, V. Berruta, O. Masera and J. Cruz (2009). *Estudio comparativo de estufas mejoradas para sustentar un programa de intervención masiva en México.* Mexico City: Informe final. Instituto Nacional de Ecología. Revised Sept. 2012. | Clesla, W.M. (1995). *Climate Change, Forests and Forest Management: An Overview.* Rome: FAO Forestry Paper No. 126. | Delinat-Institut. (2011). *El biocarbón como material orgánico para la mejora del suelo.* Arbaz: Delinat-Institut für Ökologie und Klimafarming. | Díaz, J. and others (2011). *Estufas de leña*. Red Mexicana de Bioenergía, A.C. Available at: http://www.rembio.org.mx/2011/Documentos/Cuadernos/CT3.pdf.

16 FIREBREAKS

Scale: Individual | **Collective**
Focus: Investment | **Support**

Description:

The purpose of firebreaks is to prevent forest fires from spreading before they damage the ecosystem, cropland or personal property. To construct a firebreak, a band of vegetation between 4 and 6 m wide is dug out and vegetation and dirt are removed until the mineral soil is reached. Firebreaks generally begin and end in places where fire cannot reach due to a lack of combustible matter. The extracted vegetation is disposed of on the side of the lane opposite that from which a fire could be expected to come.

Where to implement:

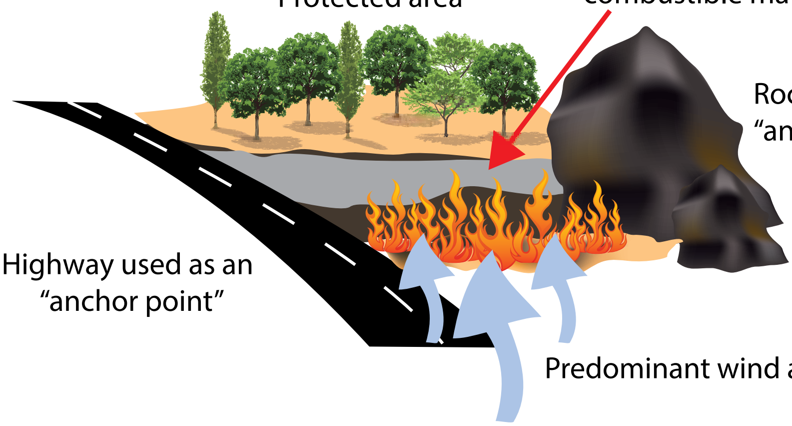
Firebreaks are useful in places with a high incidence or risk of forest fires due to prolonged seasonal drought and the consequent accumulation of inflammable vegetation. The risk of fires increases with high temperatures, low relative humidity, wind and the presence of dry combustible matter in the immediate surroundings.

Threats and impacts addressed:

Firebreaks reduce the impact of the higher incidence of forest fires due to rising global temperatures and the seasonal precipitation deficit. Protecting forests helps maintain their water- and climate-regulation services, which decreases the effect of extreme heat and intense rainfall.

How to implement:

(1) Clear areas between 4 and 6 m wide. The higher the vegetation and the stronger the predominant winds, the wider the strip must be. (2) Firebreaks begin and end in spots that a fire cannot reach (boulders, sandpits, rivers or roads). These secure spaces are known as "anchor points". (3) The firebreak must follow as straight of a line as possible, and winding paths should be avoided. (4) It is important to construct alternate roads or walkways to be used as escape routes. (5) Maintenance must be carried out at least once a year.



Source: Prepared by the authors.

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Threats addressed

Related measures: 21 28 29 33

Income generation potential: 0

GHG mitigation potential: 1

Inputs and costs:

The cost of constructing a 1000 m by 6 m firebreak, equivalent to the perimeter of an area no larger than 6.25 ha, is given below. The main inputs are hand tools, digging costs and personal safety equipment. Two days of training are considered.

Firebreak 1000 m long (6 ha)	US$
Labour	555
Materials*	150
Training	120
Total	**825**
* Total plus fire protection and firefighting equipment	3585

Ecosystemic and economic benefits:

According to partial records, in Colombia 14,492 forest fire events were reported between for 1986 and 2002, affecting 400,788 ha, more than 135,000 of which are in the central Andean Altiplano (MINAM, 2002). Highland fires have a greater impact because they affect areas near watershed headwaters. Firebreaks protect material, agricultural and ecosystemic resources; hence their benefit is related to their effectiveness at providing protection. For example, a 400 m firebreak would be sufficient to protect 1 ha of forest. The ecosystemic and biodiversity services of tropical forests have been valued at roughly US$ 6120/ha per year (TEEB, 2009).

Limiting factors:

It is difficult to construct firebreaks in urban areas, because of the limited available space, as well as in areas subject to constant flooding, such as swamps. Technical assistance is needed to determine the width of the firebreak based on the vegetation height and wind speed. Improperly constructed firebreaks may cause erosion.

Lessons learned:

Firebreaks and auxiliary equipment require maintenance in order to be effective. It is important not to wait for an eminent danger before beginning to repair the equipment or to remove vegetation accumulated along the firebreak. Maintenance must be performed at least once a year, at the beginning of the dry season.

Additional considerations:

A second firebreak and high-pressure water systems should be considered for places at high risk of fire. Second firebreaks may also be used as observation routes and interpretative trails.

How to monitor implementation:

Length of firebreaks constructed (m).

How to gauge impact:

Area protected with firebreaks (ha).

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References:

Ministerio de Ambiente, Vivienda y Desarrollo Territorial de Colombia (2002). *Plan nacional de prevención, control de incendios forestales y restauración de áreas afectadas*. Comisión Nacional Asesora para la Prevención y Mitigación de Incendios Forestales. | The Economics of Ecosystems and Biodiversity (2009). *TEEB Climate Issues Update* (Sept.) Available at: http://www.teebweb.org.

Impacts addressed

Extent of impact reduction: 3

Results in: up to 1 year

17 SOLAR HYDROPONICS

Scale	Individual
	Collective
Focus	Investment
	Support

Description:

A solar hydroponic system produces vegetables by using continuously flowing water as a medium for transporting nutrients. It is made up of a greenhouse and a water reservoir that occupies the entire base of the greenhouse for the recirculation of nutrients in a closed system. It has a solar pump that uses photovoltaic cells and batteries to feed the low-pressure drip-irrigation system. Solar hydroponic systems are highly efficient and require two hours of maintenance per week. Products may be envisioned for on-site consumption or to be sent to market. Plants grow on an organic-fertilizer substrate and the water reservoir may be used as an aquaculture tank.

Where to implement:

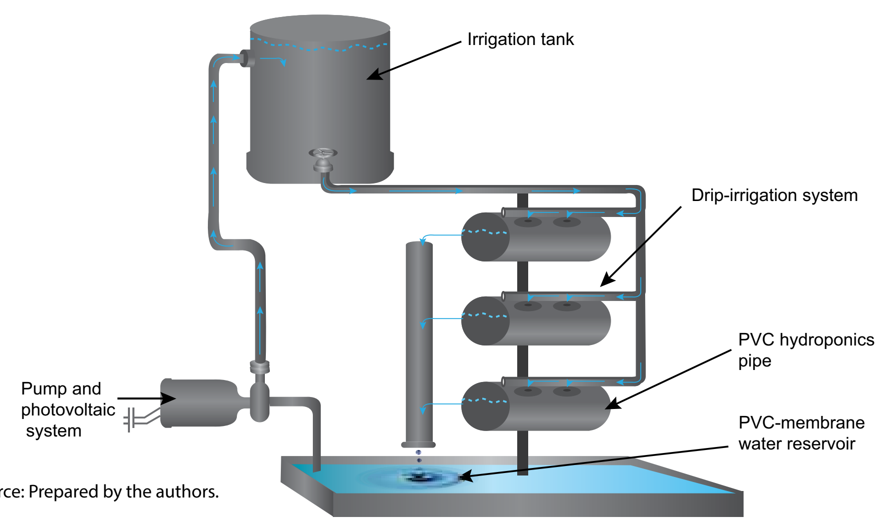
Solar hydroponic systems may be installed at any altitude. The west end of the Andean Altiplano, where soil conditions are poor, is particularly suitable. They may also be implemented in areas with a high population density and within family orchards, because they require little space. Fertile soil is not required, but a nearby water source is.

Threats and impacts addressed:

Given that solar hydroponics is a controlled system that does not require soil and that is protected by a greenhouse, production is not hindered by intense rainfall, hail, sudden temperature changes, drought or changes in rainfall patterns. This allows for a considerable increase in local productivity, food security and household income.

How to implement:

(1) Design the system (capacity, varieties to be cultivated) based on site characteristics and production objectives. (2) Prepare the site. (3) Assemble the greenhouse. (4) Place the membrane or water tank at the base of the greenhouse. (5) Prepare and assemble the hydroponic pipes. (6) Install the pumping system. (7) Set up the drip-irrigation system. (8) Put the shade mesh in place. (9) Seed the selected varieties of vegetables in an organic-fertilizer substrate on the hydroponic pipes. (10) Attend to the plants and perform system maintenance. The water in the lower deposit must be changed three or four times a year to avoid acidity and to prevent the lack of nutrients from hindering crop growth. The water resulting from the process may be used as a source of nutrients to irrigate crop fields



Source: Prepared by the authors.

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Threats addressed

Related measures: 22 23 26 30

Income generation potential: 3

GHG mitigation potential: 1

Inputs and costs:

The estimated cost is for the construction of a hydroponic system 5 m long by 1.2 m high that includes: a greenhouse, shade mesh, the drip-irrigation mechanism and couplings, a pump with a 40 W photovoltaic panel with battery, a 100 l tank, geomembranes and greenhouse plastics. Three days of training are included.

1.2 x 5 m solar hydroponic system with a 6 to 9 l/s photovoltaic pumping system	US$
Labour	225
Materials	1891
Training	180
Total	**2296**

or gardens.

Ecosystemic and economic benefits:

A solar hydroponic system reduces the impact of agriculture on natural areas by attaining high yields in small spaces. It helps preserve soils and stimulates not only production but also the local food market. More than 300 vegetable plants per month or 30 ripe plants per square meter can be grown (UNDP, 2003). For example, the dual-level system suggested above can produce, as a conservative estimate, an average of 60 plants per square meter per month. A family's economy can improve as a result of food production for home consumption as well as from approximately US$ 105 per month in additional income.

Limiting factors:

The system should necessarily be installed on land with a low slope and access to a water source. The location must have direct solar incidence more than four hours a day. The system produces about 5000 l of wastewater a year that cannot be disposed of in natural streams because of the amount of nutrients it contains. Preferably it should be used to irrigate gardens or family orchards, but this requires considerable space.

Lessons learned:

The system should be easy to access, for the provision of frequent maintenance. The pump and photovoltaic equipment require little maintenance, but they must be installed by a specialized technician. It is important to ensure that the irrigation network does not become clogged with solid particles present in the water.

Additional considerations:

Solar incidence should be studied at the proposed location to determine the amount of available shade and the shade rate of the meshing. To select the species to be grown, local climate conditions and the preferences of the target market must be understood. Two variables that should be taken into account during the operation of the system are the pH and the nutrient concentration. Controlling these variables requires training and practice.

How to monitor implementation:

Systems operating (number); vegetables produced per month (kg).

How to gauge impact:

Families with hydroponic systems (number); additional income earned (US$/month).

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References:

UNDP (2003). *Hidroponía familiar: cultivo de esperanzas con rendimientos de paz.* Armenia, Colombia: FUDESCO Armenia. | FAO (2003). *La Huerta Hidropónica Popular: Curso audiovisual.* Santiago, Chile: Manual Técnico, 3rd ed.

Impacts addressed

Extent of impact reduction: 3

Results in: up to 1 year

18 FAMILY ORCHARDS

Scale	Individual
	Collective
Focus	Investment
	Support

Description:

A family orchard is a small-scale, intensive cultivation system that makes optimal use of space, production strata and family labour. These systems primarily produce vegetables, condiments and medicinal herbs, although fruit trees and tubers can also be grown. Crop diversification in family orchards allows food to be produced year-round. In general, 70% of the products are for home consumption and the remaining 30% are sold to earn supplemental income.

Where to implement:

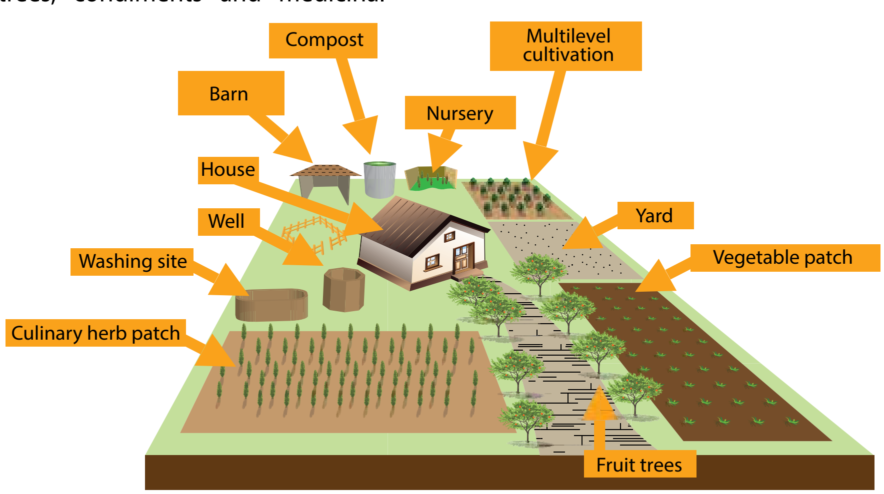
A family orchard is located in flat areas measuring at least 42 m^2 adjacent to the house with adequate sunlight and water. It may be implemented in urban, peri-urban and rural locations using community spaces, yards and rooftops. It is a suitable alternative in multiple environmental conditions.

Threats and impacts addressed:

The diversity found in family orchards makes for resilient systems that distribute losses in the event of extreme rain or heat or due to the presence of pests. When fruit trees are planted, slow-onset events like drought have less of an impact on the soil and crops because of the microclimate that the trees promote. This measure increases families' food security and reduces the need for agricultural inputs for production. It also ensures the preservation of endemic seeds and seeds resilient to phenological changes.

How to implement:

(1) Select an implementation area taking into account the size of the family unit and the available space. The minimum size is 42 m^2. On an area of this size over 25 varieties of plants can be cultivated, providing sufficient food for a household of six. (2) Draw up a list of the vegetables, fruit trees, condiments and medicinal plants to be cultivated. (3) Use this list to devise a comprehensive design, bearing in mind the required spacing between plants, polyculture synergies, requirements in terms of access, irrigation as well as the seedling and composting areas. (4) Prepare the substrate with a mixture of compost (30%), fertile soil (50%) and sand (20%) to obtain the required moisture, drainage and fertility. (5) Seed the vegetables and remaining crops, attending to them and providing maintenance as necessary. The first harvest will be obtained in three months.



Source: Adapted from FAO (2000).

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Threats addressed

Related measures: 1 | 11 | 12 | 23

Income generation potential: 2

GHG mitigation potential: 1

Inputs and costs:

The cost of preparing and sowing a 42 m^2 diversified orchard is given below. The main inputs are fertile soil, seedlings, a simple irrigation system, organic fertilizer and ecological herbicides. Four days of training are also considered to ensure proper implementation.

Construction of a 42 m^2 family orchard	US$
Labour	90
Materials	1235
Training	240
Total	**1565**

Ecosystemic and economic benefits:

FAO (2009) reports that a project for vegetable production in urban locations in Colombia attained a monthly average harvest of 20 kg on 10 m^2 of land. This represented savings of US$ 42 a month on food expenses. In another study, Altieri and Nicholls (2000) report that family orchards observed in Mexico and the Amazon region use land very efficiently and include a large variety of crops with different growth habits. In these orchards the structure and strata configuration resemble those of a tropical forest. Satisfying part of a family's food requirements with intensive systems such as orchards reduces the expansion of the agricultural frontier.

Limiting factors:

Family orchards require space near the household, sunlight and easy access. The family must be motivated to set up the orchard and carry out maintenance, as there is a continuous need for work. When the purpose is to supplement household income, market access is necessary because the products are perishable. Species must be selected with the aid of an experienced local farmer or technician to implement the rotations and introduce mixed crops.

Lessons learned:

A log should be kept to record problems and specific solutions for each crop, the required inputs, the planting and harvest cycles, along with the relationship between production costs and market prices. Diversified systems become more resilient to pests through soil fertility management, multi-cropping, the integration of weeds that repel insects and other preventive measures.

Additional considerations:

Family orchards have been observed to have a higher success rate when they are managed by women and young people, who normally spend more time at home. Results have also been favourable in schools and urban environments, as in the case of backyard orchards or green rooftops. This measure is closely related to pest control and soil management practices as well as organic fertilizer production.

How to monitor implementation:

Orchards installed (number); cultivated area in family orchards (m^2).

How to gauge impact:

Savings or additional income (US$/family); increased productivity (t/ha).

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References:

Food and Agricultural Organization (FAO) (2009). *Agricultura urbana y peri-urbana da frutos: Huertas para autoconsumo generan ahorros para familias de bajos recursos*. Press release 1 July 2009. Santiago, Chile. Available at: www.fao.org.co/comunciado_huertas_lac.pdf. | ADRA Perú (2009). *Producción de hortalizas en biohuertos familiares*. Available at: www.ecohabitar.org/wp-content/uploads/2013/06/produccion-hortalizas-en-biohuertos-familiares.pdf. | FAO (2000). *Mejorando la nutrición a través de huertos familiares.* Manual de capacitación para trabajadores de campo en América Latina y el Caribe. | Altieri, M.A. and C.I. Nicholls (2000). *Agroecología: Teoría y práctica para una agricultura sustentable*. Mexico: UNEP.

19 GREENHOUSES

Scale	Individual
	Collective
Focus	Investment
	Support

Description:

A greenhouse is a closed structure, covered with translucent materials, that creates optimal climate, water, pest control, soil fertility and ventilation conditions in order to attain high productivity more quickly, at lower cost and with less of an environmental impact. Climate variables inside the greenhouse are controlled with several devices and materials including, *inter alia*, shade mesh, windows and openings, forced ventilation and humidifiers. The shape of the structure and the material with which it is covered will vary according to the specific purpose (for example, germination).

Where to implement:

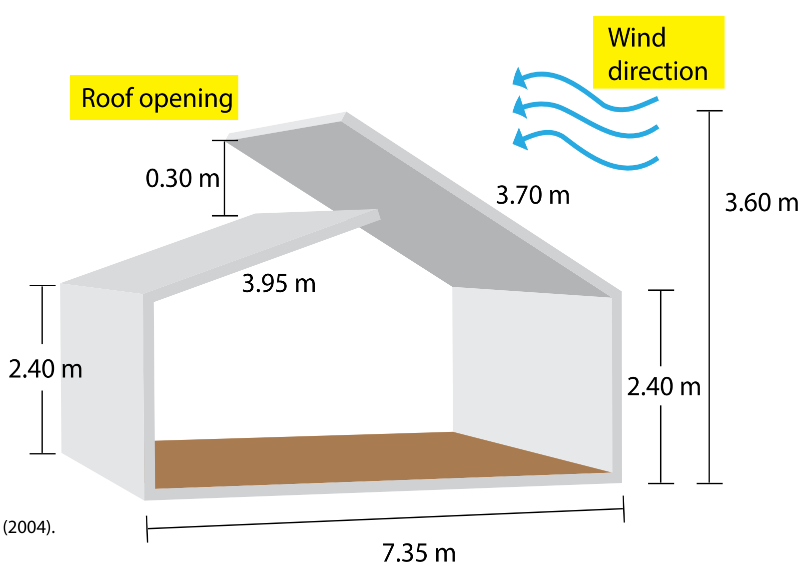
The following land-related issues should be considered before installing a greenhouse: fertility (the soil's physical, chemical and microbiological condition); drainage capacity; availability and proximity of a source of water for irrigation; access roads; ventilation requirements, including wind direction; light (avoid locations near high trees); slope (flat topography is ideal); and orientation (amount of solar irradiation).

Threats and impacts addressed:

By providing a space with the most suitable microclimate for cultivation, greenhouses diminish the impact of changing rainfall patterns, strong winds, hail, frost and extreme heat. This raises productivity, avoids crop damage and failure and improves food security.

How to implement:

(1) Site the greenhouse taking into account the factors described above and the characteristics of the crop. (2) Design the greenhouse with dimensions no greater than 10 to 12 m wide by 60 m long, to facilitate crop management. The smallest fixed opening in the roof should be between 30 and 40 cm high so as to permit adequate ventilation. (3) Assemble the structure and cover it with the selected material. The structure may be made of wood, guadua, iron, galvanized steel, aluminium, PVC or a combination of these materials. (4) Install removable curtains at the front and on the sides to regulate relative humidity while continually monitoring climate conditions. (5) Prepare the crop beds and sow.



Source: Barrios (2004).

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Threats addressed	Related measures				Income generation potential	3
	22	23	30	38	GHG mitigation potential	0

Inputs and costs:

Construction of a 500 m² greenhouse for tomatoes. The main expense is the purchase of materials, particularly polyethylene rolls for the cover and the planks and posts for the structure. The installation labour will also entail expenses. Three days' training in greenhouse operation and maintenance are considered.

500 m² greenhouse	US$
Labour	240
Materials	3023
Training	180
Total	**3443**

Ecosystemic and economic benefits:

A greenhouse can increase crop yields by shortening growing cycles and raise crop quality through a controlled indoor atmosphere. A tripling of yields in tomato crops has been observed, from 40 t/ha in outdoor cultivation with modern methods compared with 120 t/ha in a greenhouse (Jaramillo, 2006). At this level of output, the system for which the estimated costs are given above could produce six tons of tomatoes per crop cycle. Other benefits include the preservation of the soil's structure and nutrients. In the greenhouse's protected environment, the soil remains firm and is not eroded by rain or wind.

Limiting factors:

Greenhouses require a high initial investment and skilled workers, and they are also expensive to operate. Internal ambient conditions must be constantly monitored to ensure proper pest and disease control. The spread of a pest or disease within a greenhouse may damage the entire production in 24 hours, which usually does not occur with outdoor cultivation. Strong rain and wind, as well as hail, may damage the cover material.

Lessons learned:

Greenhouse crops, because they grow under optimal conditions, generally command a higher market price as a result of their appearance, weight and size. The notion that greenhouses are not exposed to insects or disease is erroneous. The internal environment is highly conducive to pest propagation. The type and model of the greenhouse must be in keeping with the producer's financial possibilities. The cover material should be durable and easy to maintain.

Additional considerations:

Global warming has raised temperatures in greenhouses. This requires new models to be devised with more internal space and larger ventilation areas, as well as implementing stricter phytosanitary controls on crops. Regular maintenance of the structure and cover is important, and the greenhouse must be inspected before the rainy or windy season. For greenhouses to be considered as an ecosystem-based adaptation option, additional measures, such as organic fertilization, drip irrigation, or integrated nutrient management should be considered.

How to monitor implementation:

Area of greenhouses built (m²).

How to gauge impact:

Production (t/ha); operating costs (US$/ha).

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References:

Escobar, H. and R. Lee (2002). *Producción de tomate bajo invernadero*. Bogota: Universidad Jorge Tadeo Lozano, Centro de Investigaciones y Asesorías Agroindustriales (CIAA), Colciencias. | Jaramillo N., J.E. and others. (2006). *El cultivo de tomate bajo invernadero*. Boletín Técnico No. 21. Corpoica. Centro de Investigación La Selva. Rionegro, Antioquia, Colombia. | Barrios, O. (2004). *Construcción de un Invernadero*. Fundación de Comunicaciones, Capacitación y Cultura del Agro FUCOA. Ministerio de Agricultura. Santiago, Chile.

Impacts addressed

Extent of impact reduction

2

Results in: up to 1 year

20 VERMICOMPOST

Scale	Individual
	Collective
Focus	Investment
	Support

Description:

Vermicompost is an organic, nutrient-rich fertilizer that results from the degradation of organic matter, under controlled conditions, by the joint action of earthworms of the genus *Eisenia* (typically *Eisenia fetida*, also known as red californian earthworms) and microorganisms. The worms act on a substrate composed of organic waste, manure, poor soil and straw. This allows for the required carbon to nitrogen ratio (C:N) to be attained for proper decomposition. Vermicompost contributes nutrients and adds organic matter to the soil while improving its structure, with a positive effect on fertility, infiltration capacity and moisture retention.

Where to implement:

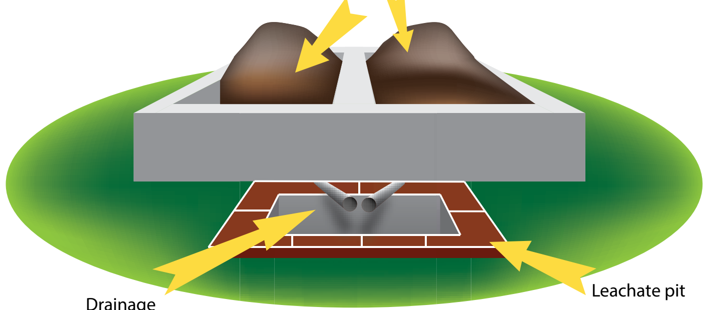
Vermicompost can be produced in any rural, urban or peri-urban setting that generates a large quantity of household or agricultural organic waste. As manure is an optimal input, the process can be associated with agricultural and livestock-breeding practices. Any altitude is suitable for vermicomposting, but adjustments must be made in locations where the mean temperature is less than 15°C. Water requirements are minimal.

Threats and impacts addressed:

Applying vermicompost to poor soils slows their deterioration and considerably increases their productivity. This minimizes the need to resort to chemical fertilizers and pesticides and increases food security. Vermicompost lessens the impact of sudden temperature changes on crops and conditions the soil, making it more resilient to drought and changing rainfall patterns. Improving the soil structure through vermicompost application also reduces the likelihood of erosion.

How to implement:

(1) Calculate the size and number of vermicompost beds needed according to the amount of manure and waste produced. (2) Build the beds (brick walls and reinforced concrete floor) with a 3% slope and a channel system below. Build a greenhouse on top of the beds, if necessary. (3) Add a mixture consisting of 2/3 substrate and 1/3 mature vermicompost to the bed, at the end opposite to the leachate pit. (4) Add 1 kg of worms for every 50 kg of mix to begin the decomposition process. (5) Moisten until the mix passes the “squeeze test”. (6) Aerate by turning. (7) Slowly add the substrate mixture at the same end of the bed, pushing the vermicompost to the opposite end. (8) Repeat the process. (9) After 45 days, remove the mature vermicompost. (10) Sift the vermicompost and use or package for sale.



Source: Prepared by the authors.

Inputs and costs:

The cost of building a vermicompost production system with two cultivation beds, each 6 m long by 1.2 m wide and 0.5 m high, is given below. The beds are made of masonry and include a cover. The main inputs are the construction materials, fertile soil for inoculation, mature vermicompost, earthworms and a recipient for leachates. The cost of a greenhouse is included, should one be needed. Labour for construction, but not for maintenance and operation, is included. Two days of training are assumed. The system requires, at a minimum, an average input of 6 m^3 of organic waste per month, and in this period it will produce approximately 4 m^3 of compost, equivalent to 3 t of dry fertilizer available for use.

Two 7 m^2 vermicompost beds	US$
Labour	255
Materials*	1567
Training	120
Total	**1942**
*Total including materials for greenhouse construction	3442

Ecosystemic and economic benefits:

The systematic application of vermicompost restores poor and unfertile soils. The solid and liquid vermicompost produced is a high-quality organic fertilizer and a substitute for chemical fertilizers. On the basis of data from Maccio (2011) it is possible to estimate that substituting 180 kg of urea per hectare of cultivated land requires between 3 and 5 t/ha of vermicompost. Producing the compost on the farm will yield savings of approximately US$ 30/ha. If the product is to be sold, average monthly production of 1 ton of solid vermicompost and 20 kg of worms per bed could generate approximately US$ 450 in revenue in that period. This makes it clear that for the substitution of synthetic fertilizers with organic fertilizers to be cost-effective, they must be produced onsite rather than purchased.

Limiting factors:

Vermicomposting requires 80% constant moisture and a temperature from 15°C to 25°C. Training sessions must be conducted before the measure is carried out, in order for the farmer to understand how process conditions should be controlled to ensure a product of constant quality. Three months are required for the presence of earthworms to stabilize compost production. In tropical climates, red ants may reduce production or even bring it to a halt by attacking the earthworms.

Lessons learned:

For community vermicompost systems, a group of persons must be put in charge of the operation and maintenance. Waste must be inspected before being added, and animal remains or waste with an excessive citric content must be avoided. Manure from sick animals or animals receiving antibiotics treatment is not to be used.

Additional considerations:

The size and number of beds is determined by the monthly volume of waste available. While dimensioning the beds, it should be considered that one cubic meter of substrate requires 20,000 worms, that each worm consumes 1 g of substrate mix per day and that the final compost volume will be 60% of the initial input mix (López Torres, 2012). For vermicompost with household organic waste, ensure that the C:N ratio is 17:33.

How to monitor implementation:

Liquid and solid vermicompost produced (kg/month and l/month, respectively).

How to gauge impact:

Area of soil restored or of cropland fertilized (ha).

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References:

López Torres, A.J. (2012). *Evaluación de cinco densidades poblacionales y dos fuentes de alimentación en la producción de lombriabono y carne de lombriz roja californiana* (Eisenia fetida). Thesis in agronomy, Universidad de El Salvador. | Maccio, M., and others (2011). *Aprovechamiento de un fertilizante Alternativo para la Caña de Azúcar en Predios de Superficie Reducida.* Tucumán, Argentina: Instituto Nacional de Tecnología Agropecuaria (INTA).

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Impacts addressed	Extent of impact reduction	Results in:
	3	up to 5 years

21 SUSTAINABLE FOREST MANAGEMENT

Scale	Individual / **Collective**
Focus	Investment / **Support**

Description:

Sustainable forest management promotes local community development while conserving biodiversity and sequestering carbon; it can even eliminate deforestation and restore forest cover. This is achieved through practices like reduced-impact logging, respecting conservation areas, protecting seed trees, censusing and mapping commercial trees, protecting against fires and promoting natural forest regeneration (selective pruning and clearing). It is based on the recognition of land tenure, proper resource use and management as well as community participation and commitment (CCMSS, 2010).

Where to implement:

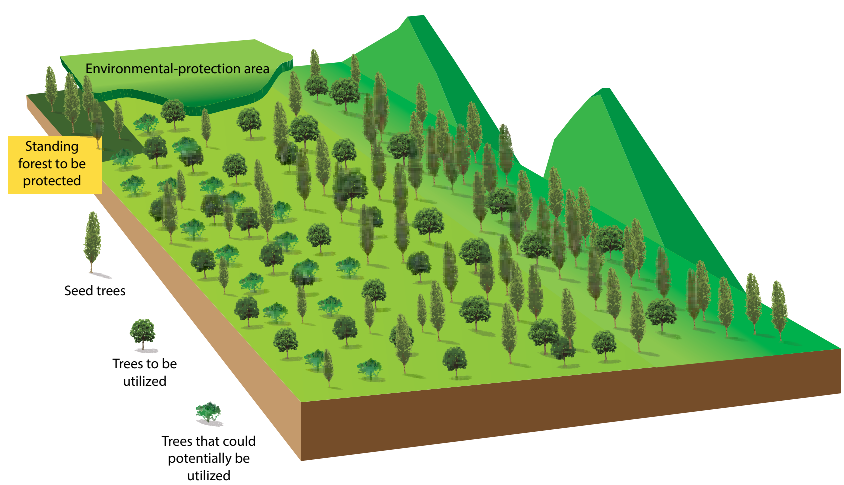
Sustainable forest management is of particular interest to forest regions and communities where its implementation can promote sustainable forest use and community-based forest conservation. In particular, it applies to areas with small, degraded forests and regions with high deforestation rates where the intention is to revalue the forest as a resource.

Threats and impacts addressed:

Sustainable forest management lessens the impact on people, crops and the surrounding environment of frost, drought, strong winds, flooding, landslides, intense rainfall, changing rainfall patterns, extreme heat and fire through the various ecosystem services provided by conserved forests. These services include climate and water regulation, soil generation, erosion prevention and nutrient recycling. In addition, capturing and storing CO_2 in forests helps mitigate climate change.

How to implement:

(1) Identify the area to be managed and establish usage rights among the community. (2) Map the site and conduct a forest inventory to identify productive areas (high and medium forest), protection areas (rivers, trails) and regeneration areas (degraded zones). (3) Determine the current and potential inventory of trees for logging (natural regeneration inventory). (4) Design a forest management plan based on the classification of species by commercial group, species to be utilized, logging cycle and the administrative division of the area. (5) Establish a monitoring system. (6) Incorporate timber and non-timber products into value chains.



Source: Adapted from Guzmán (2012).

Inputs and costs:

Approximate annual cost of maintenance and management of 10 ha of forestland. The main expenses relate to labour for maintenance, clearing, cleaning and logging. Fifteen days of training on mapping and inventorying, community management, production chains, conservation practices and formulating a management plan are included.

Sustainable forest management on 10 ha/year	US$
Labour	3225
Materials	1610
Training	900
Total	**5735**

Ecosystemic and economic benefits:

The economic benefits of ecosystem and biodiversity services—such as provision services (food, water, energy, raw materials and genetic resources), regulation services (climate, water, erosion prevention) and cultural services (recreation, tourism)—generated by 1 ha of tropical forest have been valued at more than US$ 16,000, with an average of US$ 6,120 in 2007 (TEEB, 2009). The main economic benefits are the direct creation of formal jobs and the distribution of the earnings from community forest management to households. The extraction, processing and sale of forest products generate annual income of between US$ 1000 and US$ 2000 per member of the community forest enterprises (Sabogal, 2008). This income is generally additional to that obtained from individual productive activities.

Limiting factors:

Sustainable forest management requires certainty regarding land tenure and organizational capacity within the community. There is also a need for the support of forestry engineers to formulate management plans and provide training to establish community production enterprises. A lack of awareness of this alternative leads the owners of community lands to make choices that are socially and environmentally disadvantageous, which conveys the false idea that it is not possible to make a living off of the forest.

Lessons learned:

Sustainable forest management creates the conditions to promote economic equity, social peace and justice, democratize power and improve forest ecosystem management. The experience in Mexico demonstrates that, with the required support, rural communities can manage complex industrial, administrative and commercial processes. In addition, communities may utilize and sell several non-timber products, such as honey, resin, mushrooms and earth.

Additional considerations:

Some organizational aspects that have allowed for more efficient forest management are the establishment of community forest monitoring councils and the institutionalization of professional administrators, along with encouragement of young people so they may acquire the necessary training (Brady and Merino, 2004). Forest certification from the Forest Stewardship Council (FSC) is a useful tool for positioning, differentiating and valuating products in the market. Wood that bears the FSC's seal has been produced according to environmental sustainability and social equity principles, with differentiated criteria for plantations and the conservation of natural forests. The target public is responsible consumers.

How to monitor implementation:

Area under sustainable forest management (ha).

How to gauge impact:

Wood production (m^3), income per worker (US$); preserved area (ha).

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References:

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Impacts addressed

Extent of impact reduction: 2

Results in: up to 1 year

22 INTEGRATED NUTRIENT MANAGEMENT

Scale	Individual / Collective
Focus	Investment / Support

Description:

The purpose of integrated nutrient management is to increase agricultural yields and protect agroecosystems. This technique consists of adding nutrients and organic matter to plants through a balanced use of organic fertilizers and green manures as well as mineral fertilizers. The aim is to avoid the overuse of synthetic fertilizers and the consequent contamination of water bodies and the degradation of the soil.

Where to implement:

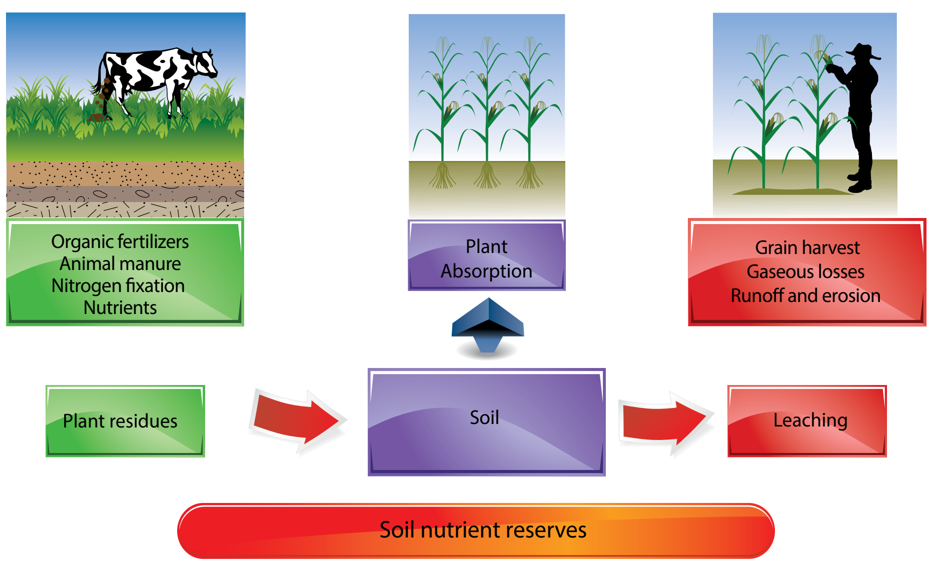
This measure is useful in places where the fertile layer of soil shows signs of exhaustion or degradation, especially as a consequence of fertilizer overuse. It is highly recommended in farms near surface bodies of water to reduce or eliminate agrochemical leachates. It should also be considered an alternative in soils with a high exposure to water or wind erosion.

Threats and impacts addressed:

More efficient nutrient consumption mitigates the impacts of phenological changes and increases crop productivity, which enhances food security. Improving the structure of the soil makes it more resilient to drought, erosion and intense rainfall. The heightened use of organic rather than hydrocarbon-based synthetic fertilizers diminishes greenhouse gas emissions, which cause climate change.

How to implement:

(1) Conduct an agronomic valuation of the farm (crops appropriate for the soil characteristics). (2) Identify the limiting factors on the nutrient balance. (3) Determine the nutrient sources and select the corrective treatments for their loss. For example, for losses due to leaching, cover crops are used. (4) Apply organic amendments (compost, humus, manure) and soil micronutrients. (5) Establish a plan to monitor the use and application of fertilizers to evaluate results and assess soil fertility.



Source: Prepared by the authors.

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Threats addressed: N/A

Related measures: 5 | 19 | 30 | 31

Income generation potential: 1

GHG mitigation potential: 2

Inputs and costs:

Implementation of integrated nutrient management on 1 ha of land. The costs include organic fertilizer and green manures, as well as mineral fertilizers and agricultural labour for their application. Two days of training are assumed.

Integrated nutrient management, 1 ha	US$
Labour	315
Materials	1390
Training	120
Total	**1825**

Ecosystemic and economic benefits:

Studies on the benefits of balanced fertilization and organic amendments in maize, wheat and soy found an increase in gross income of about US$ 1293/ha. This practice not only increased the output per unit of area, but also had residual effects on subsequent harvests. In controlled experiments, higher yields of about 2204, 559, and 1031 kg/ha were found for maize, wheat and soy, respectively (Fixen and García, 2006). Integrated nutrient management contributes to soil and water preservation, reducing nutrient loss caused by leaching and runoff and avoiding eutrophication. For example, in the system made up by the Fúquene, Cucunubá and Palacio lagoons (Colombia), economic incentives of about US$ 1300 per ha are given to farmers to improve nutrient management and other practices in potato cultivation. Hence the aim is to reverse the eutrophication of the lagoons with an investment of some US$ 21 million for a total of 16,933 ha of potato crops (Moreno, 2007).

Limiting factors:

An effective evaluation of nutrient requirements is essential to plan the appropriate use of available organic fertilization sources and soil amendments. Integrated nutrient management requires expert knowledge and training in order to be effective. The switch to agricultural practices less dependent on chemicals often runs up against resistance.

Lessons learned:

For integrated nutrient management, there must be synchronization between a crop's demand for nutrients and the fertilization of the soil. For example, dividing nitrogen applications during the growing cycle rather than applying the entire dose at once before seeding is an effective way to improve its uptake by plants.

Additional considerations:

Not all the fertilizer applied is absorbed by the crops. The residual nitrogen and phosphorus that reaches water bodies, through runoff, causes their eutrophication: clear water becomes turbid, oxygen decreases, fish die and the ecosystem deteriorates. Thus, soil preservation and efficient nutrient use reduces some impacts of agriculture on the environment.

How to monitor implementation:

Area cultivated under integrated nutrient management schemes (ha).

How to gauge impact:

Yield increase (t/ha); reduction in cost of fertilization (US$/ha).

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References:

Moreno Díaz, C.A. (2007). *Instrumentos de política diseñados de manera participativa y enfocados hacia la conservación de los servicios ambientales en la laguna de Fúquene con base en su valor económico.* Bogota: Corporación Autónoma Regional de Cundinamarca (CAR). | Fixen, P. and F. García (2006). "Decisiones efectivas en el manejo de nutrientes . . . mirando más allá de la próxima cosecha", *Informaciones Agronómicas del Cono Sur*, Potash & Phosphate Institute of Canada, Argentina, pp. 1-7. (Dec.). | Gruhn, P., F. Goletti and M. Yudelman (2000). "Manejo integrado de nutrientes, fertilidad del suelo y agricultura sostenible: problemas actuales y futuros retos", *Visión 2020* (Resumen 2020) No. 67, Washington (Sept.).

Impacts addressed

Extent of impact reduction: 3

Results in: up to 1 year

23 INTEGRATED PEST MANAGEMENT

Scale	Individual / Collective
Focus	Investment / Support

Description:

Integrated pest management is achieved by combining several agricultural practices—crop rotation, mechanical control and biological control—in lieu of pesticides, herbicides and other chemical inputs (Garming and Waibel, 2005). This technique can be carried out with any agricultural production model, and it has a broad sphere of application, as it can be implemented on any kind of crop (including vegetables, fruits, cereals and forestry products). Comprehensive information on the life cycles of pests, as well as on their interaction with the surrounding environment, is used to combat them with resources available on the farm.

Where to implement:

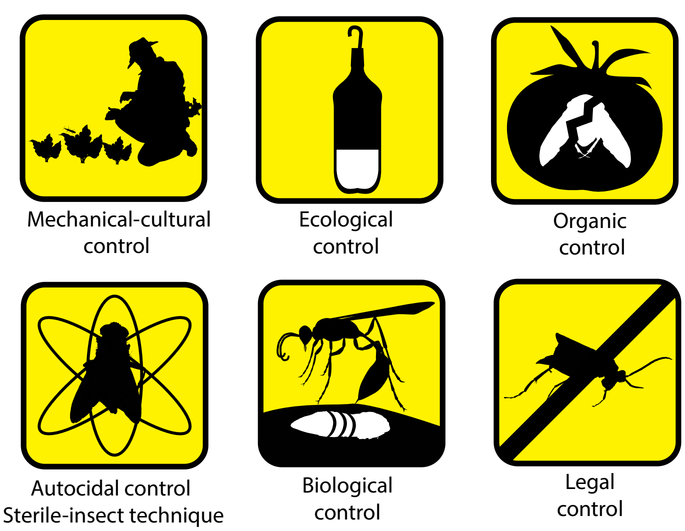
Integrated pest management can be implemented in any productive region, but it is especially useful in locations where expected changes in temperature and precipitation increase the likelihood of the emergence of different types of pests and diseases. For example, integrated pest management is an alternative in coffee-growing zones of Peru and Colombia where coffee rust has caused considerable losses.

Threats and impacts addressed:

Integrated pest management is a viable and efficient alternative to decrease potential damage to crops by opportunistic species that take advantage of changes in rainfall patterns or temperature to propagate. Through alternative control methods, it reduces the need for greater agricultural inputs. Combined with other measures, it helps increase yields considerably.

How to implement:

(1) Identify and diagnose the problem to be addressed (one or two pests). (2) Obtain information on biology, population dynamics, hosts, damage to crops and natural enemies. (3) Establish preventive practices such as introducing attractant and repellent plants. (4) Prepare and apply ecological herbicides and pesticides. (5) Implement biological and mechanical controls. (6) Continually monitor the pests and diseases that arise, and keep a log of the results of the methods used.



Source: Adapted from http://granjaecologicaenlinea.com.

Inputs and costs:

The cost of implementing integrated pest management on 1 ha of tomato in a greenhouse, based on biological, mechanical and ecological controls, is given below. The main inputs are the preparation of ecological herbicides and pesticides, the sowing of repellent plants, the purchase of traps and labour for cultivation activities. Three days of training are assumed.

Integrated pest management, 1 ha	US$
Labour	345
Materials	1000
Training	180
Total	**1525**

Ecosystemic and economic benefits:

Integrated pest management reduces the need for toxic pesticides, benefiting human health and the environment. In a Cornell University study, an environmental impact index was used to compare the application of traditional pesticides to treat whiteflies in tomato and potato crops with integrated pest management practices. For the tomatoes, it was found that the index fell from 73.4 to 7.21 and for the potatoes it dropped from 57.75 to 2.44. In both cases, this represents a considerable decrease in environmental impact. Another study on the control of whitefly in vegetables describes a 36% reduction in the number of pesticide applications. Additional earnings of US$ 2402/ha for tomatoes and US$ 3168/ha for pepper were reported, with a 47% and 45% internal rate of return, respectively (Ortiz and Pradel, 2009).

Limiting factors:

The farmer must know the biology and the behaviour of the pest in order to take appropriate decisions to manage it. This requires training and technical assistance. The measure should also be adapted to local conditions, because biological control is based on promoting a pest's natural enemies. The inappropriate introduction of species for biological control may have severe consequences on the ecosystem. For example, Zimmerman and others (2007) refer to the case of the cactus moth (*Cactoblastis cactorum*), which was used in Australia as a biological control to eradicate the exotic cactus *Opuntia lasiacanta*. However, the moth made its way to Mexico, where it now represents a risk to the area with the greatest diversity of opuntias in the world.

Lessons learned:

In integrated pest management, periodic (weekly) evaluations must be carried out because insect populations are dynamic and different factors determine their increase or decrease. For example, a pest can propagate on the basis of its own biology and reproduction or in response to environmental changes (climate, crop growth or decrease of natural enemies).

Additional considerations:

It is important to complement integrated pest management practices with other elements like the management of the farm and technical knowledge of the crop. For example, at certain stages of their development plants are more vulnerable to certain pests, and knowledge of these cycles allows specific treatments to be identified.

How to monitor implementation:

Area under integrated pest management (ha).

How to gauge impact:

Increase in yields (t/ha); reduction in pesticide use (US$/year).

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References:

Garming, H. and H. Waibel (2005). *Análisis económico del Programa CATIE-NORAD MIP/AF*. Germany: Pesticide Policy Project Publication Series, University of Hannover, Development and Agricultural Economics, Faculty of Economics and Management, Special Issue No. 10 | Ortiz, O. and W. Pradel (2009). *Guía introductoria para la evaluación de impactos en programas de manejo integrado de plagas (MIP)*. Peru: International Potato Center (CIP), p. 60. | *¿Qué es manejo integrado de plagas?*, Granja Ecológica en Línea. Available at: http://granjaecologicaenlinea.com/que-es-manejo-integrado-de-plagas/ | Zimmermann, H., S. Bloem and H. Klein (2007). *Biología, historia, amenaza, monitoreo y control de la palomilla del nopal* Cactus cactorum. Mexico: FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

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Impacts addressed	Extent of impact reduction	Results in:
	3	up to 1 year

24 NATURAL RETAINING WALLS

Scale	Individual / **Collective**
Focus	Investment / **Support**

Description:

Natural retaining walls are constructed with local materials and other elements. They give stability to the land and increase its capacity to contain landslides by modifying its natural slope. They may be constructed with gabions (5 x 7 cm mesh cells filled with rocks and tied together) or with a combination of rocky and clay-based materials and arranged and compacted to exert pressure against the ground so as to hold it in place as well as reduce erosion. Hence, they serve to stabilize hillsides. Natural retaining walls are an alternative to concrete retaining walls, which have significant economic and environmental costs.

Location:

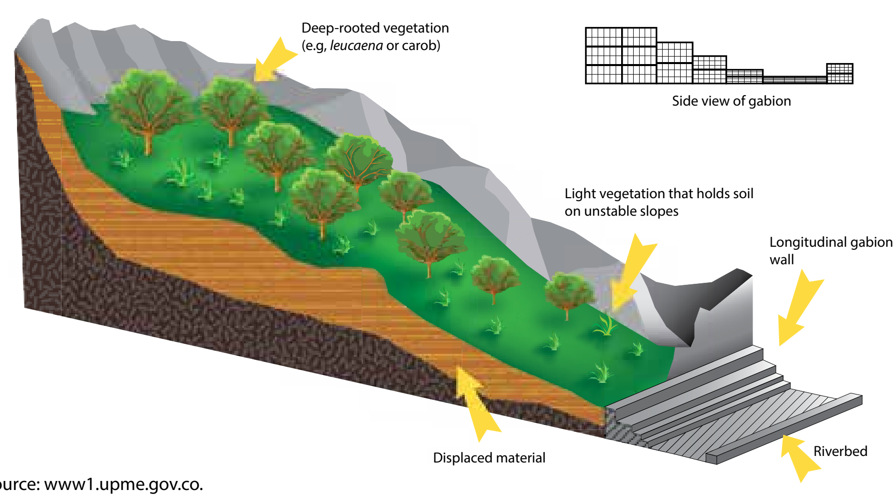
This measure is suitable for locations where dwellings, workplaces, cropland or grazing land are at risk of disturbance owing to landslides—for instance, hillsides with slopes steeper than 50%. They are normally constructed in places with eroded soils and areas along the banks of natural channels at risk because of flow surges or flash floods.

Threats and impacts addressed:

The main function of these structures is to avoid massive landslides and damage to infrastructure. Soil retention on hillsides allows vegetation cover to be established, thereby reducing erosion from rain and wind. Given that they are permeable structures, natural retaining walls promote water seepage and help retain moisture in the soil, which reduces the impact of drought.

How to implement:

(1) Design the wall with the help of a qualified professional, taking into account the slope, the amount of earth to be retained, the average rainfall intensity, the kind of soil and the runoff coefficient. (2) Demarcate the retaining wall's dimensions on the hillside. (3) Make the necessary cuts in the land to build the structure and allow the material to be trucked or carried in. (4) Build the gabions with stone and cyclone mesh. (5) Erect the wall. (6) Give the wall annual maintenance to ensure that it continues to serve its purpose.



Source: www1.upme.gov.co.

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Threats addressed

Related measures				Income generation potential	0
13	28	29	36	GHG mitigation potential	0

Inputs and costs:

The cost to construct a 200 m³ gabion wall is given below. The main inputs are labour and construction materials, such as cyclone mesh. The stone is assumed to be purchased, but this expense may decrease significantly if local materials are used. Five days for annual maintenance and two days of training in the construction method are included.

25 m long (200 m³) gabion retaining wall	US $
Labour	2370
Materials	4675
Training	120
Total	**7165**

Ecosystemic and economic benefits:

Natural retaining walls protect soil and its plant cover from landslides. Both soil and vegetation are pillars of ecosystem services. If a wall 25 m long is—conservatively—assumed to retain at least 3000 m² of land at risk, and if the portion corresponding to the value reported in the TEEB (2009) for forest ecosystem services is used, the wall would be protecting a value of approximately US$ 2000 per year. If the land were used for vegetable production this amount could rise to US$ 45,000 a year, based on typical yields and current market values. Retaining walls also promote the establishment of plant species, which increases the survival of seedlings and prevents erosion.

Limiting factors:

Natural retaining walls may not be built on hillsides with sandy soil. To make retaining walls with stone, the stones must be larger than 30 cm in diameter. If the wall is to be built on a rocky bed, it should be anchored with rebar. Construction costs of natural retaining walls are high, and specialized technical knowledge is needed to design them.

Lessons learned:

Retaining walls are generally built in conjunction with soil conservation, restoration and reforestation practices as part of a broad strategy to mitigate risks and recover ecological functionality. Vegetation that takes hold on the wall should be removed at least once a year to ensure the wall's structural soundness. When a wall is constructed, the installation of pipes and drainage channels should be considered, in order to allow runoff that otherwise might place the wall's stability at risk to drain.

Additional considerations:

To minimize construction costs, local natural material (rocks, dirt) should be used. In humid zones, with annual precipitation above 700 mm and highly permeable soil, gabion-based walls should be constructed. If possible, stakes should be placed on the hillside to distribute the weight on the structure.

How to monitor implementation:

Length of walls constructed (m).

How to gauge impact:

Planting area and dwellings protected (m² and number, respectively).

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References:

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Impacts addressed

Extent of impact reduction	Results in:
3	up to 3 years

25 PERMACULTURE

Scale	Individual / Collective
Focus	Investment / Support

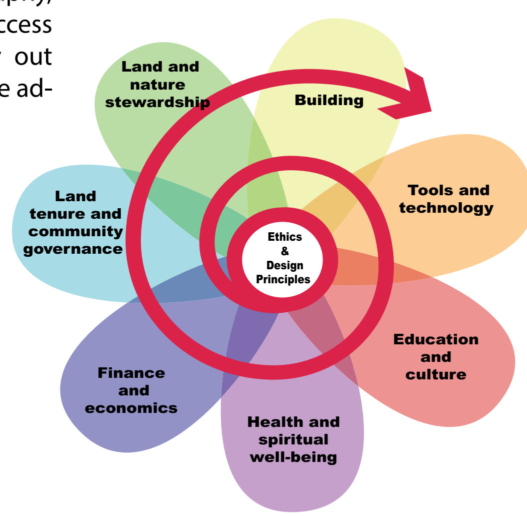
Description:
Permaculture ("permanent agriculture") refers to promoting sustainable production and housing systems according to three core tenets: care of the Earth, care of the people and sharing of surplus. Alternative techniques for production (organic agriculture, polyculture with animal husbandry, resource conservation), landscape design (water reservoirs, terraces, restoration) and ecological housing (rainwater catchment, wastewater filters, renewable energy) are implemented. Space and systems are managed taking into account the inputs and surpluses of every component in relation to the other design elements, in order to establish synergies.

Where to implement:
Permaculture techniques are useful on farms that wish to integrate production and housing components in a sustainable business project—for example, for organic farms or agrotourism. They may be implemented on all kinds of soils, particularly those that have lost their fertility or are eroded. The farm should have access to nearby markets or to a given target public to sell its products.

Threats and impacts addressed:
Permaculture makes it possible to address diverse threats and impacts of climate change, because it enhances overall resilience in an integrated manner. Ecological implementation measures raise productivity and enhance food security, diversify production and income, save water, reduce the need for agricultural inputs, prevent erosion and increase soil and plant cover. All of this reduces the impact, *inter alia*, of extreme heat, changing rainfall patterns, drought and intense rainfall.

How to implement:
(1) With expert assistance, devise the design and the implementation plan based on the site's characteristics (topography, soil, climate, viable crops, market access and available resources). (2) Carry out the selected practices and landscape adaptations according to the plan. (3) Monitor and follow up on the implemented measures. Given that permaculture design incorporates various long-term practices and techniques, a set of sample associated measures, in this case aimed at maximizing productive and economic aspects, is given here. In practice, these measures would be established along with landscape management and sustainable housing.

Year 1: Soil restoration, organic agriculture and vermicompost
Year 2: Beekeeping and resilient-seed bank
Year 3: Greenhouse with a drip irrigation system.



Source: www.permacultureprinciples.com.

Inputs and costs:

The cost of integrating a few sample techniques under a permaculture design is calculated for one hectare over a period of three years. The cost of each individual component in the table below is the sum of the labour and material costs estimated in the respective fact sheet (e.g. soil conditioning) and adjusted proportionally to its actual area or number of units in this system. Training is valued separately and comprehensively for the three-year period.

Components of a three-year permaculture project on 1 ha of land	Year	US$
Soil conditioning, 0.5 ha	1	603
Organic agriculture, 0.5 ha	1	885
Construction of one 7 m^2 vermicompost bed	1	911
100 kg seed bank	2	937
Beekeeping with 10 hives	2	1229
500 m^2 greenhouse with drip irrigation system	3	4795
Training	1-3	3600
Total	1-3	**12960**

Ecosystemic and economic benefits:

Permaculture reduces the risk of crop and productivity loss as a result of phenological changes, given that it allows for more than 25 marketable products to be obtained per hectare. The incidence of pests in polyculture systems is lower than in monoculture. For example, a compilation of 209 studies on the effects that agrobiodiversity has on the incidence of herbivore insects found that 52% of the 287 species analysed were less abundant in diversified systems than in monocultures (Andow, 1991). In an article on the possibility of reaching global peak phosphorus and its consequences for conventional agriculture, Rhodes (2013) stresses the role of permaculture in helping to balance the cycle of this essential element. King (2008) states that these systems contribute to enhancing ecological and community resilience because they increase biodiversity and self-sufficiency and promote knowledge-exchange networks and market-niche opportunities. In implementation experiences, a 30% reduction has been found in fertilizer and pesticide expenses.

Limiting factors:

Changing the approach to make systems resilient with sustainable production is no easy task. For example, such techniques as soil restoration are generally seen as an investment that is not recovered in the short term, even though it has a considerable effect on the general stability of the system. The ineffective implementation of techniques due to the lack of knowledge on the appropriate method for doing so, or the failure to consider the system as a whole, may result in losses instead of benefits.

Lessons learned:

Permaculture systems are more efficient when they are focused on implementing solutions on a human scale, with the use of local resources, and on changing the landscape only to recover its supporting function. The concepts of self-regulation and feedback that are an integral component of permaculture design may be valuable in ecosystem-based adaptation strategies. Expert support is recommended during the design and construction of the interventions, along with specific advice to ensure their correct implementation over time.

Additional considerations:

In Latin America and the Caribbean a broad network of farms is developing agricultural and housing systems by applying permaculture principles. These farms act as adaptive models to replicate the experiences in different climatic and social conditions. In order to create productive systems that are sustainable, their components must be closely interlinked. One way to accomplish this is by appropriately locating plants, animals, infrastructure and roads and performing landscape adaptations where needed.

How to monitor implementation:

Projects with permaculture design (number, ha).

How to gauge impact:

Increase in yields (percentage, t/ha); preserved or regenerated ecosystems (number, ha).

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References:

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Impacts addressed

Extent of impact reduction: 2

Results in: up to 1 year

26 AQUACULTURE

Scale: **Individual** / Collective

Focus: **Investment** / Support

Description:

Aquaculture, or fish farming, is a system in which aquatic species, generally tilapia fish of the genus *Oreochromis,* are raised in surface water tanks, which can be constructed with different techniques and materials depending on the region. The systems are easy to build and operate and they constitute a source of income and nutritious food. The tanks may or may not include mechanical aeration and pumping. Another species prized for its high commercial and nutritional value is the rainbow trout (*Oncorhynchus mykiss*), but handling this species requires more space and a constant source of quality running water to maintain the ideal quantity of dissolved oxygen for their growth. For their breeding, long rectangular tanks are constructed to receive a constant flow of water from nearby rivers.

Where to implement:

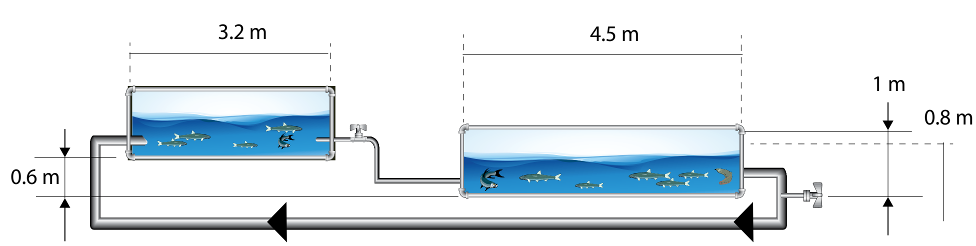
Aquaculture systems are best implemented in regions below 2800 m, with annual average temperatures above 12°C and a good water supply. A space of at least 35 m^2 is required. They are ideal for regions where the daily diet has a low concentration of protein and phosphorus and for agrotourism or ecotourism projects as well as for communities seeking to diversify income and production.

Threats and impacts addressed:

Fish farming helps improve the family daily diet, which increases food security. The tanks function as reservoirs for irrigation during the dry season, and the nutrients contained in the water help fertilize crops, decreasing the need for agricultural inputs. Diversification into fish farming is an alternative in the event of a decline in agricultural productivity.

How to implement:

(1) Seek expert advice to determine the species to be raised and to calculate consumption requirements and potential output. (2) Excavate or place tanks, as the case may be. (3) Decide on the water-recirculation or oxygenation pumping system, if applicable. (4) Build the system. Two tanks are to be built or put in place for the growth of the selected species. For tilapia, one of the tanks (3.2 m in diameter by 1 m high) is for fingerlings and the other (4.5 m by 1 m) is for fattening. (5) Use the wastewater for continuous-flow cultivation, that is, introduce fresh water into the system and drain water from the bottom of the tank continuously, striving to reutilize the effluent to irrigate crops and thus prevent the contamination of nearby water sources.



Source: Prepared by the authors.

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Threats addressed N/A

Related measures: 17 22 25 28

Income generation potential: 3

GHG mitigation potential: 0

Inputs and costs:

Construction of two open-air water tanks made of geomembrane and steel with a respective volume of 4 and 8 m³ and having a maximum throughput of 300 kg/m³ per year. The main costs are for materials for the installation such as the solar pumping system, the geomembrane, a steel sheet and pipes. The costs of organic food for the fish and labour for the construction of the system are also considerable. Three days of training on the operation and maintenance of the system are assumed.

Aquaculture, two tanks, 4 and 8 m³	US$
Labour	255
Materials	2024
Training	180
Total	**2459**

Ecosystemic and economic benefits:

With this measure the introduction of exotic species for extensive aquaculture in surface water bodies is avoided, as are the subsequent impacts not only on the trophic structure of the lake ecosystem but also on the nutrient content of the water. For example, Figueredo and Giani (2005) report increases of up to 260% in the concentration of nitrogen and of up to 540% in the concentration of phosphorus in a reservoir after the introduction of tilapia. This increase is, by contrast, beneficial in closed systems if the wastewater from the process is used as manure for fields to help diminish agrochemical consumption (1 m³ of effluent substitutes 1 kg of synthetic fertilizers). Aquaculture is an alternative for diversifying income: according to estimates based on data from Saavedra-Martínez (2006), the system described above is capable of producing 3600 fish or 3.5 tons per year. If the fish are sold at an average price of US$ 1.47 each, the profit would be US$ 0.37/fish, for an additional net monthly income of at least US$ 140.

Limiting factors:

Access to quality fingerlings and organic food is required, along with a flat surface to install the tanks. Solar incidence must be more than four hours a day. Sudden temperature changes may hinder the development of the fish and hence total output. In regions where temperatures fall to freezing, greenhouses should be constructed for protection.

Lessons learned:

Care must be taken to avoid contaminating surface water bodies with wastewater from the tanks. In particular, in raising trout it is important to monitor the quality of the water exiting the system before it is released into rivers or streams. It is therefore recommended that the fish be given the proper dose of food, so that it is completely consumed, and that the effluent water be treated if necessary.

Additional considerations:

It is essential to have the assistance of a specialist in aquaculture to evaluate the project's sustainability and to select the most suitable design and species. Electricity consumption for pumping decreases if there is a height difference of at least 35 cm between the tanks. Tilapia can conservatively reach a weight of between 0.4 and 0.6 kg within six to nine months, whereas trout reach 0.3 kg in seven to twelve months.

How to monitor implementation:

Systems functioning (number); installed production capacity (kg/month).

How to gauge impact:

Income increase (US$/month); families with aquaculture tanks (number).

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References:

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Impacts addressed

Extent of impact reduction: 3

Results in: up to 1 year

27 FILTER DAMS

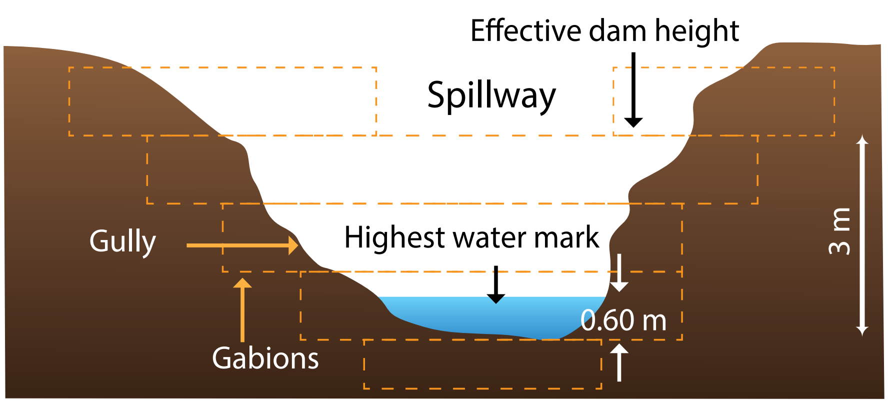
Scale	Individual / **Collective**
Focus	Investment / **Support**

Description:
Filter dams are permeable containment structures built in gullies, perpendicular to the flow of water, intended to slow the runoff, reduce water erosion, retain sediment and promote seepage. They may be made of logs, stacked stones or gabions (5 x 7 cm mesh cells filled with rocks and tied together). The material to be used depends on local availability and the size of the gully. The sediment should be extracted regularly and it may be used in efforts to stabilize hillsides or, if it has a high organic-matter content, to improve croplands.

Where to implement:
Filter dams can be built in areas with any kind of climate and vegetation that are affected by water-erosion problems. They are particularly useful in gullies in arid and semi-arid regions with an advanced state of erosion for the purpose of restoring productive potential. They are also recommended when material transport due to water runoff at the top of a watershed is high, placing housing, crops or infrastructure at risk. The dams should be located as close as possible to the source of the sediment.

Threats and impacts addressed:
By slowing runoff and retaining sediment, filter dams curb erosion and reduce the potential for floods or landslides downstream and consequently for crop damage. Because of the increased infiltration, soil moisture also increases and aquifers are recharged, reducing the effect of drought and extreme heat. Applying the retained organic matter onto agricultural lands helps increase their fertility and productivity.

How to implement:
(1) With the help of a specialist, select the gully where the filter dam is to be constructed, taking into account potential production on the land downstream, the location of hydraulic structures and the physical conditions of the basin. (2) Select the construction material for the dam according to the gully's characteristics (rocks or logs for small gullies and gabions for large ones). (3) Calculate the dimensions of the dam and spillway taking into account the size of the gully, the hillside slope and the annual runoff volume. (4) Clear, plot and level. (5) Excavate to prepare the terrain for construction and embedding. (6) Compact the terrain on the base and walls. (7) Assemble the dam with the selected material (the gabions, logs or rocks) and set it in place. (8) Extract the sediment twice a year and apply it on poor soil or unstable hillsides.



Source: SAGARPA (2010).

Supported by:
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based on a decision of the German Bundestag

Threats addressed

Related measures: 21 | 24 | 28 | 29

Income generation potential: 0

GHG mitigation potential: 0

Inputs and costs:

Construction of three small gabion filter dams (with a total volume of 90 m³), 500 m apart, on a gully 5 m wide by 2 m deep. The main costs are for the purchase of stone and gabion mesh in addition to the construction work. Two days are assumed for training on the construction method, operation and maintenance of the structure.

Filter dams (90 m³) made of gabions	US$
Labour	1215
Materials	2040
Training	120
Total	**3375**

Ecosystemic and economic benefits:

A World Bank study (2006) estimates the average annual cost of erosion and salinization of agricultural land in Peru at between 1200 and 1300 soles per hectare (approximately US$ 450/ha). Although more data are needed, it seems clear that filter dams can bring these costs down significantly. A filter dam 1 m high can retain up to 21.3 m³ of material (SAGARPA, 2010). The deposits of organic matter can be used to improve soils, contributing to higher yields, food security and income. For example, with the application of the volume of organic matter retained by a 1 m dam, three family orchards could be maintained, translating into savings on food purchases of some US$ 1440 annually. This measure favours water infiltration into the ground, which in restored soils can be as high as 5 mm/hour (FAO, 1988).

Limiting factors:

At high altitudes, where materials cannot be brought in either by vehicle or on foot, dams should be made with the most appropriate assambled material available. Gabion filter dams are expensive and they are not recommended for small gullies. The construction of gabion dams requires technical advice to ensure proper dimensions and structural stability. Dams made with other matrials are less expensive, but they are not suitable for large gullies and they have a shorter useful life.

Lessons learned:

To ensure erosion is controlled, complementary work should be carried out to conserve the hillside, such as the introduction of contour trenches, drainage systems and absorption terraces, as well as restoration of soil, native grasslands and forests. Filter dams require maintenance and desilting at least twice a year, immediately before and after the rainy season.

Additional considerations:

Log dams or dams made with stacked rocks are recommended for V-shaped gullies and flows of less than 1 m/s. Logs are recommended to control small and narrow gullies (less than 1 m deep) and their effective height should not exceed 1.5 m. Stone dams are recommended for medium to small gullies (between 1 and 5 m deep), with a moderate slope, and they must not exceed 3 m in effective height. Gabion dams are used for gullies more than 2 m deep.

How to monitor implementation:

Filter dams constructed (number); eroded area attended to (m²).

How to gauge impact:

Regenerated cropland area (m²); volume of sediment recovered (m³).

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References:

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Impacts addressed

Extent of impact reduction 3

Results in: up to 1 year

28 RAINWATER RESERVOIRS

Scale	Individual	Collective
Focus	Investment	Support

Description:

This measure consists of constructing small dams and artificial reservoirs to store water. These water bodies receive surface runoff from basins with an area of several dozen hectares. They are normally located on embankments and used for irrigation and as a source of water for livestock and wildlife, but they may also be used to fight forest fires. Preferably they are constructed with materials available at the site, and the impermeable soil horizon may consist of compacted clay or a high-density polyethylene geomembrane. The size of the reservoir will depend on the cropland area, crop requirements, annual rainfall, size of the basin and length of the dry season.

Where to implement:

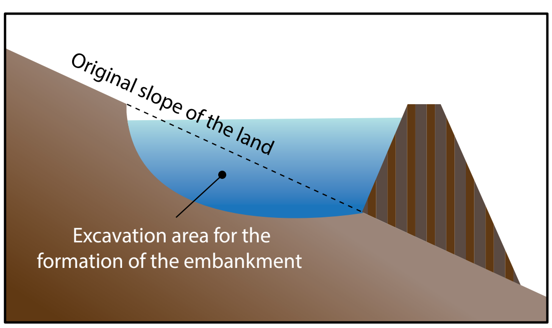
Rainwater reservoirs are useful in zones with a long dry season and they are ideal in silty and clayey soil with low productivity or soil with an impermeable top layer. They may be built on land degraded or eroded by rainwater runoff, on hills with slopes of less than 30° or on non-farm land.

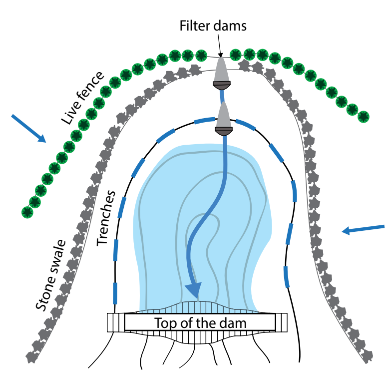
Threats and impacts addressed:

Rainwater reservoirs mitigate the impact that drought and heat waves have on crops and livestock. They increase water availability and extend cultivation periods, raising local yields and enhancing food security.

How to implement:

To contain water in basins or fields on a low slope, walls must be built. The walls or dikes are constructed with the material extracted from the site to form the shallow basin. If the soil does not have an impermeable horizon, using a plastic membrane should be considered. (1) Calculate the demand for water during the dry season, taking into account requirements for livestock and irrigation and to have a surplus for fires or water contingencies. (2) Select land with low agricultural yields and on a low slope. (3) Obtain information on precipitation and runoff to determine the catchment and storage capacity, as well as on safety issues to be considered. (4) Carry out excavation and compacting work and construct other needed elements (filter dams, intake, bottom discharge and spillways). (5) Perform maintenance once a year by removing accumulated silt.





Source: SAGARPA (2009).

Inputs and costs:

The calculation given below is for a 500 m³ surface reservoir, assuming the use of local materials and an existing impermeable horizon. The main expenses are for the purchase of cyclone mesh and stone; for the soil, precipitation and runoff analyses; as well as for the rental of machinery. The cost of the labour to construct additional structures is also significant. The cost of plants to retain the surrounding soil is included, as is that of five days of annual maintenance and three days of training on construction and operation.

500 m³ rainwater reservoir	US$
Labour	1850
Materials	2560
Training	180
Total	**4590**

Ecosystemic and economic benefits:

Reservoirs serve as a water source for local species and help restore biological cycles by increasing relative humidity and access to water. They also favour the establishment of a microclimate, especially if the work is followed by revegetation actions. They help raise productivity on nearby land by allowing for crop irrigation. A 500 m³ reservoir can meet the water needs of 80 heads of cattle or up to 2500 m² of vegetable crops during the dry season. During this period and on such an area it is possible to harvest 60,000 plants, which, if sold on the market for US$ 0.60 each, would bring in an annual revenue of US$ 3000 to US$ 5000. The investment is recovered in one or two years (SAGARPA, 2009).

Limiting factors:

On highly permeable soil, construction may be more expensive. In areas where a high amount of material is transported by water runoff, reservoirs should be complemented with other hydraulic measures like filter dams. However, this also increases the cost. In specific cases, pumping is required, for example, when crop lands are far away or at higher elevations than the reservoir. Implementation requires a considerable area for water catchment as well as to form the reservoir. Design and construction require supervision by specialists to ensure proper hydraulic operations.

Lessons learned:

The stored water will be of better quality if additional works are carried out to filter runoff and reduce sediment inflow (e.g., filter dams and soil restoration). The catchment basin used to fill the reservoir is selected so as to maximize the intake of water and minimize the conveyance of material to the reservoir. Silted material must be removed once a year.

Additional considerations:

Generally, a minimum ratio of 10:1 between the volume that could potentially be received from the basin and the volume in the reservoir is required for the construction to be cost-effective and to not have an adverse effect on ecosystems downstream. In areas with high solar irradiation and strong winds, reservoirs must be deeper to reduce evaporation. Actions must be taken to control mosquitoes and vectors, especially when the water level is low.

How to monitor implementation:

Reservoirs constructed (number); storage capacity installed (m³).

How to gauge impact:

Irrigated land (ha); animals with access to water from reservoirs (number).

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References:

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Impacts addressed

Extent of impact reduction: 3

Results in: up to 5 years

29 SOIL RESTORATION

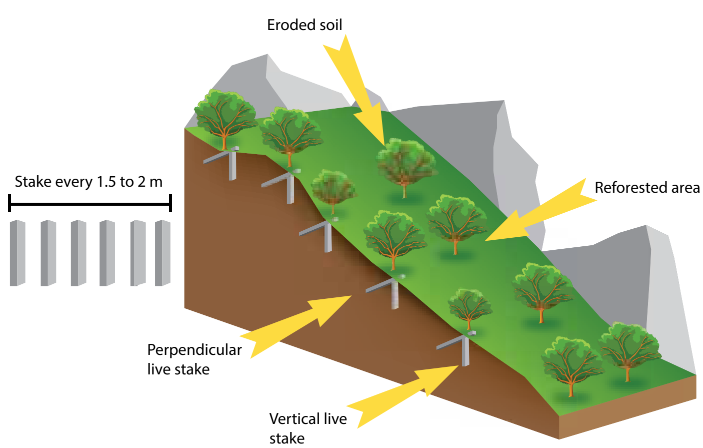
Scale	Individual
	Collective
Focus	Investment
	Support

Description:
Soil restoration refers to actions to regenerate natural soil cycles through revegetation with shrub and creeper species, reforestation with native arboreal species and containment work with stakes. The aim is to stabilize the soil and increase the supply of organic matter, which promotes restoration. Geomesh is also used when the soil is highly eroded and degraded and the slope exceeds 25%. Soil is restored in accordance with the particular biological and edaphological conditions, and this also determines which species will be selected. The plants are obtained from local nurseries to ensure their adaptability and safeguard the site's endemic genetic diversity.

Location:
This measure is used to recover poor, degraded or low-permeability soils. It is applied in deforested or eroded areas where there is a risk of landslides, but it is also useful on the boundaries of conserved areas to buffer the impact of the expansion of the agricultural frontier. It may be applied to improve the structure and fertility of compacted soils on livestock farms.

Threats and impacts addressed:
Restoring soils raises their infiltration capacity, which recharges aquifers and increases water availability. Increased moisture content helps tree and shrub species take hold, and their roots retain soil and prevent erosion and landslides. The trees generate a microclimate that reduces the effect on crops or ecosystems of frost, abrupt temperature changes, strong winds, extreme heat, hail and intense rainfall. The set of processes that arise from the presence of trees regulate temperature and moisture in the surrounding soil and air, which decreases the potential for drought.

Implementation Steps:
(1) Evaluate the soil's condition and devise the restoration programme with technical support. (2) Plant pioneer species to increase the stability and organic matter content of the soil. (3) Plant live stakes of native arboreal species measuring about 1.2 m on slopes with severe erosion and reinforce with stakes placed perpendicular to the slope of the terrain. (4) Reforest with native species from local nurseries or transplant seedlings from surrounding forest areas, where feasible. Assume an average density of 1200 trees/ha. (5) Carry out complementary actions for soil and water retention. (6) Perform maintenance work. (7) Assess the programme and take follow-up actions.



Source: Prepared by the authors.

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Threats addressed

Related measures				Income generation potential	0
21	25	27	33	GHG mitigation potential	3

Inputs and costs:

The cost of restoring 1 ha of land is given below. The main items are the labour required for the forestry work, the purchase of trees from nurseries, seeds and tools, as well as geomesh, in the event of extreme erosion. Three days of training and five days of annual maintenance are included.

Soil restoration, 1ha	US$
Labour	1440
Materials	1266
Training	180
Total	**2886**

Ecosystemic and economic benefits:

Each year, about 75 billion tons of soil are eroded from the world's terrestrial ecosystems and most of this erosion occurs on agricultural land (Pimentel and Kounang, 1998). Multiple benefits are obtained from protecting the soil with plants: an increase in flora and fauna; improved soil quality, moisture and fertility; erosion control; carbon sequestration; temperature and water regulation; and improved biodiversity and agricultural productivity (Durán and Rodríguez, 2009). A project in Brazil that established nurseries to restore degraded tropical forests, with an approximate cost of US$ 3500/ha, had several of the benefits listed above. The economic valuation TEEB (2009) projects the net present value of these restored forests, 40 years after restoration, at about US$ 105,000/ha with a discount rate of 1%. In the short term, restored areas provide neighbouring communities with natural resources that support their livelihoods.

Limiting factors:

There is little information on the basis of which to quantitatively value the short-term benefits of restoration, which may create the false impression that it is not important, necessary or cost-effective. Species must be selected on the basis of a prior analysis of the site and they should be adapted to local climate conditions and be of the required genetic quality; otherwise, the investment may be lost or the equilibrium of the ecosystem disturbed.

Lessons learned:

Reforestation must include maintenance and monitoring for at least two years to ensure high survival rates. This is a long-term process with integral benefits for the entire community; hence, it requires the participation and ownership of the beneficiaries. During the restoration process, care must be taken to avoid colonization of the area by opportunistic species from degraded locations so as to ensure the development of local species and those characteristic of healthy forest areas.

Additional Considerations:

This technique should be combined with complementary works like infiltration pits, contour trenches, drainage systems and terraces to promote proper water and soil management as well as the survival of the vegetation. Ideally, this measure is applied collectively, because it involves large areas of land and must be applied irrespective of property boundaries. Maintenance of the reforested trees decreases two years after planting, but the steps taken to care for the area should remain in effect until the ecological cycles of a healthy forest have been established.

How to monitor implementation:

Restored soil area (ha).

How to gauge impact:

Inhabitants who benefited from restoration actions (number).

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References:

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Impacts addressed

Extent of impact reduction: 3

Results in: up to 1 year

30 DRIP IRRIGATION

Scale	Individual
	Collective
Focus	Investment
	Support

Description:

Drip irrigation allows for the optimal usage of water and fertilizers through their application close to crop roots. This is achieved by delivering small water flows at low pressure through a variable number of emission points, called drippers, and at a high application rate, which saves water. Water is saved in two ways: it is made to seep into the soil without evaporating or running off, and it is delivered at the root zone, just where the plants need it. The system is easy to design and set up and it generally consists of a water source, a pumping unit, a fertilization unit, filters, the distribution network and the drippers.

Where to implement:

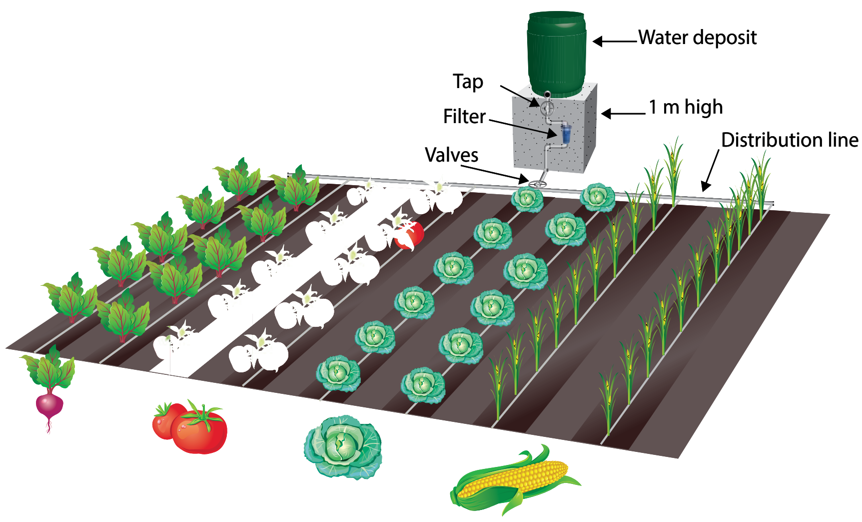
Drip irrigation systems are suited for both flat and inclined fields because they do not cause erosion. They are particularly useful in areas with a prolonged dry season that have a reliable water source, such as a reservoir, and there is an interest in increasing yields or lengthening cultivation periods by rationally using water. If there is sufficient difference in height between the water source and the field, distribution may be gravity-based rather than pump-based.

Threats and impacts addressed:

The effects on crops of drought, extreme heat and changing rainfall patterns may be mitigated with drip irrigation systems through the efficient water use. The water savings allows production to continue where and when less water is available, which increases food security.

How to implement:

(1) Identify the crop and the area of the farm in which drip irrigation will be set up. (2) Analyse the soil characteristics and the amount of water needed for the crops. (3) Design the system with the aid of a technician. (4) Assemble the system, including excavating the trench, laying the pipes, constructing structures for the different elements (pumps, filters, water tanks) and installing drippers at the irrigation points in the network. (5) Carry out system maintenance, ensuring that the drippers do not get clogged by suspended or dissolved solids in the water.



Source: Adapted from www.agronegocios.com.py.

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Threats addressed

Related measures				Income generation potential	3
17	19	28	38	GHG mitigation potential	1

Inputs and costs:

The costs given below are for the adaptation of one hectare of land with drip irrigation. The main inputs are the materials for the distribution network, including the pump, the filtering and fertilizing systems and the drip line. The cost of labour for installation is also considerable. Three days of training in system operation and maintenance are assumed.

Drip irrigation, 1 ha	US$
Labour	525
Materials	4320
Training	180
Total	**5025**

Ecosystemic and economic benefits:

The primary ecosystemic benefit is efficient water use. Drip systems have been able to reduce water consumption by up to 70% compared with conventional irrigation systems. This is because plants receive the exact amount of water they require for optimal growth (FINTRAC, 2001). In addition, producer's income rises by as much as 35% as a result of the higher yields stemming from efficient fertilizer usage, or "fertirrigation", i.e., the controlled application of nutrients with irrigation water. Another example is a comparative study of cotton cultivation which found that the gross margin per hectare was US$ 60 higher with drip irrigation than with sprinkler irrigation, using the same dosage of fertilizer. The same study reports that drip irrigation effectively applied 27% more water to the plants than did the conventional sprinkler system (Dippenaar and others, 1997)

Limiting factors:

The initial investment is high due to the quantity of materials to be purchased, and for an automated system the outlay is even larger. If improperly installed, the system may result in water deficiencies and the poor development of roots and plants. For this reason, assistance should be received from a qualified technician. There is a high risk of obstruction of the emitters and consequently of uneven irrigation. Hence it is necessary to include a filtering system suitable for the characteristics of the water used.

Lessons learned:

Some producers have designed low-cost sand filters made with locally available materials. Covering the soil with organic matter (crop residue or green manures) helps preserve moisture and provides additional nutrients to the soil, thus increasing irrigation efficiency. The most successful cases are obtained when farmers have a clear understanding of the technical characteristics of the system and of the crop's water requirements.

Additional considerations:

Drip irrigation may be complemented by other cultivation measures like integrated pest management, integrated nutrient management, hydroponics and organic agriculture to increase output and the market value of the crops. In particular, when this technique is combined with the installation of a greenhouse, a highly efficient productive system able to compete on the market is obtained.

How to monitor implementation:

Systems installed (number), area with drip irrigation (ha).

How to gauge impact:

Productivity increase (%, t/ha); reduction in water consumption (%, m^3).

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Impacts addressed

Extent of impact reduction: 1

Results in: up to 1 year

31 CROP ROTATION

Scale: **Individual** | Collective

Focus: Investment | **Support**

Description:

Crop rotation consists in sequentially producing plant species in a given location by alternating crops every year, every two years or every three years. This diversified production system prevents the build-up of pests and diseases as well as the exhaustion of the soil that usually occur with production of a single crop (or crops of a single family) in successive agricultural cycles. The rotation sequence is planned such that the requirements of one crop complement those of the next in order to maintain the soil nutrient balance. This technique is used, in particular, to sow and harvest green manures to complement the cultivation of commercial or in-house consumption products.

Location:

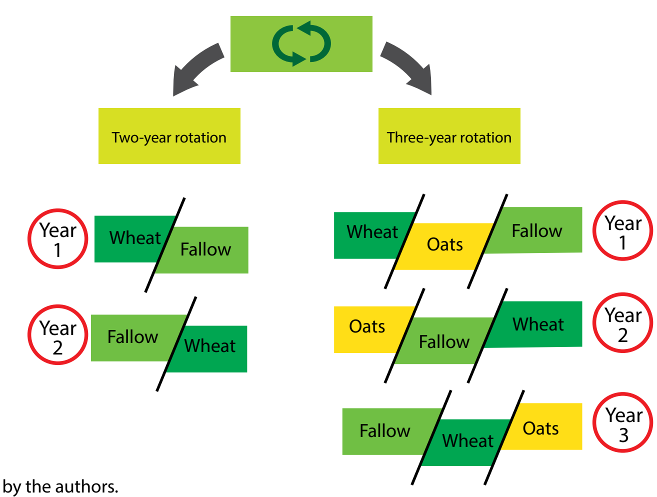
A range of soil types, altitudes and climate conditions is suitable for crop rotation. Nevertheless, the specific characteristics of the site in terms of the nutritional requirements of the crops and the interaction among them when they are alternated must be taken into account. This technique is particularly relevant for poor, eroded or exhausted soil that has lost its fertility because of the use of synthetic fertilizers, the repeated cultivation of the same crop or the increased intensity of climate events.

Threats and impacts addressed:

The threats of changing rainfall patterns, drought, frost and intense rainfall may be managed on a single piece of cropland, but at different times in the year, by rotating crops resistant to adverse climate conditions. Crop rotation increases food security and decreases the need for agricultural inputs, in addition to being an efficient way to control pests and diseases.

Implementation Steps:

(1) Select a plot for recurrent and systematic cultivation. (2) Carry out a study to determine market demand for potential crops. (3) Consider if adapting the selected crops to the climate and soil conditions of the farm will be feasible. (4) Evaluate the availability of economic and technological resources (labour, seeds, machinery). (5) Establish rotations making it possible to take maximum advantage of the farm's resources, and avoid sowing plants of the same family in order to break pest cycles and complement nutritional requirements. (6) Sow plants with different root systems in order to ensure that they efficiently use all the soil layers during the different rotations.



Source: Prepared by the authors.

Supported by:
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Threats addressed

Related measures: 3 | 22 | 23 | 32

Income generation potential: 1

GHG mitigation potential: 1

Inputs and costs:

The cost of a rotation system with maize and beans on 1 ha of land, including inputs for fertilization and pest control, is given below. The main expenses are for farm labour and the production of organic fertilizers and ecological pesticides. Three days of training on how to establish beneficial rotations are assumed.

Crop rotation (maize and beans) on 1 ha	US$
Labour	1200
Materials	600
Training	180
Total	**1980**

Ecosystemic and economic benefits:

Crop rotation keeps the soil covered, promotes biological equilibrium, diminishes pest cycles and diseases, incorporates nutrients and conserves energy. For example, Altieri (1999) cites a 1978 study in which maize-based crop rotation that incorporated forage legumes and grains reduced fossil fuel consumption by up to 45% compared with continuous cultivation. He also cites a 1983 study in which the native legume *Lupinus mutabilis* contributed up to 200 kg of nitrogen per hectare for the following potato crop. The economic benefits are the higher yields and the distribution of losses in the event of disease or climate events (Sauca and Urabayen, 2005; Altieri and Nicholls, 2004). These benefits also stem from reduced pesticide and fertilizer use due to the greater availability of nutrients, the breaking of pests' life cycles and the intensification of biologic activity in the soil.

Limiting factors:

At the time of rotation, technical and economic variables must be considered, including the amount of time available to seed and harvest the next crop and the demand for products in different periods of the year. Crop calendars are, therefore, very important for implementing rotation. Rotation strategies take into account periods during which the land is left fallow, whereas in conventional agriculture such periods might be considered a failure to fully utilize the land.

Lessons learned:

Proper sequencing is fundamental for the success of crop rotation, because the production of a given crop depends on the nutrients required by its predecessor. For example, experiences in Central America show that continual rotation of maize and velvet beans (*Mucuna pruriens*) may be maintained for up to 15 years with a reasonable level of productivity (2-4 t/ha) and without any apparent decline in soil quality (Altieri and Nicholls, 2004).

Additional considerations:

Rotation also helps ward off insects, weeds and disease by effectively breaking the lifecycle of pests. Certain crops—for example, garlic and some aromatic plants—act as repellents. Hence, they are rotated with vegetables, to bring about efficacious pest and disease control (Nuñez and Vatovac, 2006; FEDEARROZ, 2011).

How to monitor implementation:

Area under rotation schemes (ha).

How to gauge impact:

Expenses on agricultural inputs (US$/ha).

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References:

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Impacts addressed

Extent of impact reduction: 2

Results in: up to 3 years

32 AGROSILVOPASTORAL SYSTEMS

Scale	Individual / Collective
Focus	Investment / Support

Description:

Agrosilvopastoral systems combine techniques that associate tree species (forest or fruit) with livestock and crops on the same land, with the aim of bringing about significant ecologic and economic interaction. These combinations may coexist in the same space and time or be arranged sequentially, and the aim is to optimize output and ensure sustained yields with less environmental impact. Each element in the system contributes to the others: the trees provide shade to the animals and crops; the animals fertilize the soil and propagate the seeds; and the crops constitute food for the animals.

Where to implement:

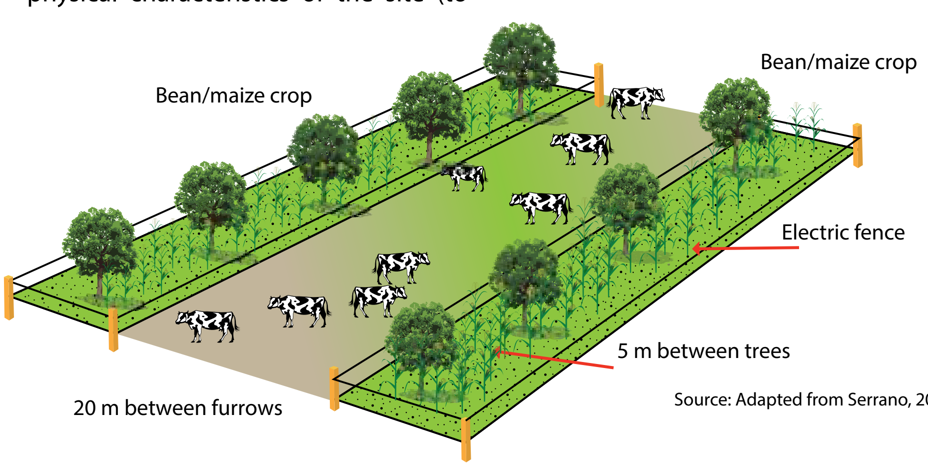
These systems are ideal for small farms on which diversified production is sought based on a natural-resource-conservation approach. In particular, such production systems are recommended for initiating a soil restoration and reforestation process in areas degraded by extensive grazing. If implemented on hillsides or mountainsides, the agrosilvopastoral system should be complemented by additional measures to retain soil and avoid compaction.

Threats and impacts addressed:

Regenerating the forest cover establishes a microclimate that helps mitigate the impacts on crops of sudden temperature changes, changes in rainfall patterns, extreme heat, intense rainfall and strong winds. Trees generate organic matter that rebuilds the soil. This augments its infiltration and moisture-retention capacity, which reduces the effect of droughts. Animal manure raises the soil nutrient content, reduces the need for agricultural inputs and has positive effects on productivity. Carbon sequestration and the potential for climate change mitigation also increase.

How to implement:

(1) With expert assistance, identify the physical characteristics of the site (topography, soils, drainage) that will help determine which system elements will be selected, how they will be managed and what their potential productivity will be. (2) Establish a management plan that identifies the areas to be used for livestock, agriculture and trees based on the site's carrying capacity and the required forage consumption. (3) Select the woody, creeper, herbaceous and shrub species to be planted, including pasture for livestock and annual crops. (4) Clean and delimit the different production areas, and seed and transplant the layers according to the plan while ensuring that the crop-growing areas remain protected from the animals. (5) Perform maintenance according to the management plan.



Source: Adapted from Serrano, 2013.

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Threats addressed

Related measures: 2 | 4 | 23 | 35

Income generation potential: 3

GHG mitigation potential: 1

Inputs and costs:

The cost of establishing an agrosilvopastoral system is given below. The main inputs are plants, seeds and trees; producing and applying organic fertilizers and ecological pesticides; labour for planting crops and transplanting trees; and the purchase and installation of an electric fence to protect the agricultural area. Four days of training on how to encourage positive synergies among the elements of the system are included.

Agrosilvopastoral system, 1 ha	US$
Labour	585
Materials	1350
Training	240
Total	**2175**

Ecosystemic and economic benefits:

Diversified production associated with restoring arboreal vegetation in livestock areas is the main benefit of this system. This allows small producers not only to improve the conditions in their environment but also to reduce the risk of financial loss to which they are frequently exposed. Iglesias and others (2011) state that between 60% and 70% of plant biomass may be used in livestock feed without creating a conflict regarding production for human consumption. They mention, in particular, that if nitrogen-fixing trees are used, soil fertility increases and an animal food supplement is obtained. In terms of economic issues, Chaparro (2005) carried out a cost-benefit evaluation of a 1 ha agrosilvopastoral system made up of guava, maize and a tropical forage named *naranjillo* (*Trichanthera gigantea*) and reported an internal rate of return of 21% and a net present value of US$ 1087 per hectare. Chaparro also underscores that this system was 7% more profitable than an agroforestry system composed of guava, banana and maize.

Limiting factors:

There is a general lack of knowledge on agrosilvopastoral models, and their implementation requires training and specialized technical advisory services. For example, inadequate planning of the forestry component might prevent mechanization from being used for the harvest and hinder the preparation of forage. These systems are centred on modifying current management practices and exploring alternatives, which requires that the producers have conviction and a sense of ownership. It also demands a long-term commitment, in terms of both investment and of monitoring the results.

Lessons learned:

The presence of animals helps to control weeds, but if they selectively feed on certain species they can also alter the forest composition. Livestock accelerate the recycling of nutrients in the soil by fertilizing it with dung and urine, but they also compact it through constant trampling, which limits crop and tree growth. Compacted soil and soil lacking herbaceous cover due to browsing is highly prone to erosion. For this reason, it is indispensable to regulate the number of animals, according to the site's carrying capacity.

Additional considerations:

Very dense shade may lower crop productivity. Tree roots may compete with crops for moisture during the dry season and for oxygen during the rainy season. Beekeeping might be an additional measure of product diversification in these systems, provided that bee hives are not placed close to the livestock.

How to monitor implementation:

Area with agrosilvopastoral systems (ha); associated products within each system (number).

How to gauge impact:

Value of production (US$/ha).

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References:

Chaparro G., L.A. (2005). *Viabilidad financiera de sistemas agrosilvopastoriles multiestrata y agroforestales, en fincas ganaderas convencionales del departamento de Santander, Colombia* (thesis). Colombia: Centro Agronomico Tropical de Investigacion y Enseñanza | Iglesias, J.M., F. Funes-Monzote, O.C. Toral, L. Simón and M. Milera (2011). "Diseños agrosilvopastoriles en el contexto de desarrollo de una ganadería sustentable. Apuntes para el conocimiento". *Pastos y Forrajes* vol. 34, No. 3, (July-Sept.) pp. 241-258. | Ruiz, M. (1983). *Avances en la investigación de sistemas silvopastoriles*. Cited in Iglesias and others (2011). | Serrano, J. (2013). *Silvopastoreo en Colombia.* Available at: http://jairoserrano.com/2011/02/silvopastoreo-en-colombia.

Impacts addressed

Extent of impact reduction: 2

Results in: up to 3 years

33 AGROFORESTRY SYSTEMS

Scale	Individual / Collective
Focus	Investment / Support

Description:

An agroforestry system consists of a series of techniques designed and implemented to utilize multiple strata of an agroecosystem: from timber-yielding trees, fruit trees and annual crops to shrubs, herbs, creeper species and tubers. The aim is to raise productivity in a diversified system that will have less of an environmental impact than conventional agriculture. The process makes the system more resilient and promotes the sustainable use of agricultural and forest products. Timber species are replenished with native varieties which are mostly grown in nurseries and later transplanted.

Where to implement:

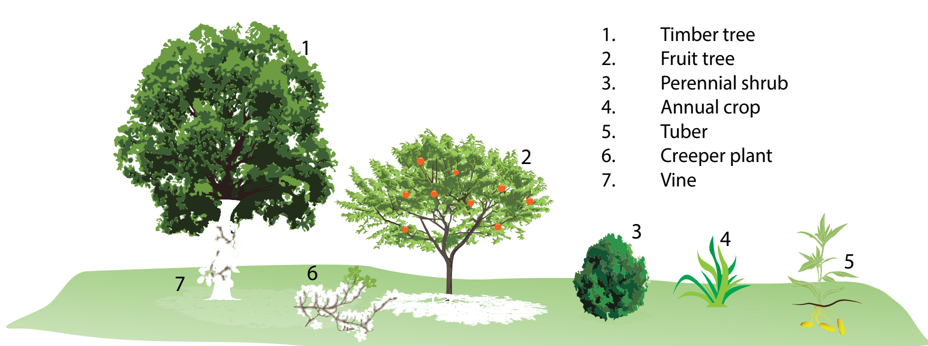
Agroforestry systems may be implemented at degraded sites that are suitable for farming or forestry in order to reclaim forest areas without sacrificing production. In particular, the combination of applied techniques helps restore poor soils with limited fertility and low organic content. They are especially useful for the purpose of enhancing agrobiodiversity, and they are recommended at altitudes between 1000 and 2800 m above sea level and in areas on which the slope is less than 40% (SAGARPA, 2012).

Threats and impacts addressed:

The presence of trees reduces exposure to the sun, wind and rain and regulates air and soil moisture. These factors promote the establishment of a microclimate and mitigate the effects on crops of extreme heat, wind and intense rainfall as well as drought and frost. This diversified system enhances food security, decreases the potential for soil erosion by wind or water and reduces the need for greater agricultural inputs, due to beneficial interactions among species in different strata.

How to implement:

(1) Design the system with support from a specialist and taking into account the specific characteristics of the site (soil, climate, topography, potential crops and plant species, market access). (2) Select the species to be included in the system (timber-yielding and food trees, medicinal and edible shrub and creeper plants; herbaceous plants that are edible or used as green manures or for pest control). (3) Clean and delimit the area taking into account the contour lines and distinctive topographical elements. (4) Obtain tree species at greenhouses and transplant. (5) Plant on the strata indicated on the design. (6) Carry out maintenance according to the general management plan.



Source: Prepared by the authors.

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Threats addressed

Related measures: 21 28 29 40

Income generation potential: 2

GHG mitigation potential: 2

Inputs and costs:

The cost of implementing an agroforestry system with timber-yielding trees, food trees and shrub and creeper plants on 1 ha is given below. The main expenses are the labour to condition the terrain and agricultural labour as well as the purchase of the species to be planted. Four days of training in the production system are included.

Agroforestry system, 1 ha	US$
Labour	450
Materials	2700
Training	240
Total	**3390**

Ecosystemic and economic benefits:

These systems have reversed the loss of productivity stemming from environmental degradation associated with conventional cultivation practices. For example, yields of agroforestry systems have been found to be more than 100% higher than those of slash and burn practices. An evaluation of shade-grown coffee in Peru found that yields were five times higher (2.3 t/ha) on plots using agroforestry systems than on plots without those systems (Brack, 2004). Data from SAGARPA (2012) were used to conclude that a mixed field with maize, squash and beans as well as fruit trees can generate gross annual revenue of US$ 3000/ha. Concerning the mitigation of climate change, Etchevers and others (2005) report that this type of system may achieve annual carbon accumulation rates of between 0.87 and 1.85 t/ha.

Limiting factors:

A high initial investment is required and special care must be taken with the species planted until they have taken hold. Farmers must understand that this is a long-term production system and they must receive proper training in managing it. For example, the return on investment for timber-yielding and fruit trees is seen in the medium to long term (about 5 years for fruit trees and 15 years for timber-yielding trees).

Lessons learned:

If annual herbs are to be planted, self-germinating species (coriander, marigold) should be used to reduce labour requirements. When timber or fruit trees are planted, varieties supplied by a local nursery should be used, and individuals with a diameter of more than 1.5 cm should be selected for transplanting in order to increase the survival rate. To protect the crop area against disturbances, such as trampling and browsing by livestock, a fence should be placed around it. Exotic species with an invasive potential or allelopathic properties, such as andean oak and eucalypthus, should be avoided.

Additional considerations:

The species should be selected with the help of specialized technicians familiar with the area, and selection should conform to the customary practices of the community and be based on agroecology or permaculture principles. Tree species should be planted in the first weeks of the rainy season. In crop areas, pests and disease that are adapted to moisture and shade conditions may proliferate. Consequently, integrated pest management is required.

How to monitor implementation:

Area under an agroforestry system (ha).

How to gauge impact:

Varieties and volume of yields (number/ha, t/ha); annual revenue generated (US$).

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References:

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Impacts addressed

Extent of impact reduction: 2

Results in: up to 3 years

34 SILVOPASTORAL SYSTEMS

Scale	Individual / Collective
Focus	Investment / Support

Description:

A silvopastoral system is a technique for livestock production in which animals interact with timber species either through browsing or by eating the tree forage after it has been cut. The aim of this system is to obtain diversified products such as wood/firewood, fruits, milk, meat or forage. Trees and shrubs may either take root naturally or be planted by the producer within the grazing area and later be used for timber, industrial and fruit production or multiple other purposes while supporting animal production (Ojeda and others, 2003).

Where to implement:

This measure is recommended in locations with extensive livestock breeding on soils that are unprotected, have little or no forest cover and are used for grazing. This is often land that has little biodiversity and is at risk of erosion. Silvopastoral systems are particularly useful in places where alternatives are sought to diversify income or increase the agrobiodiversity of ranches.

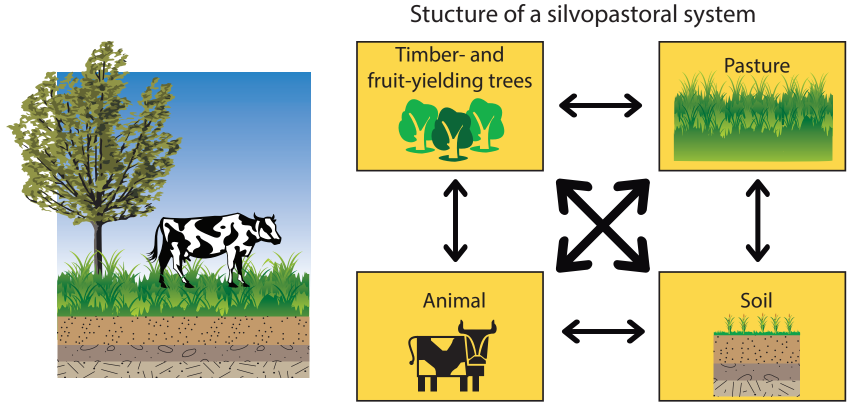
Threats and impacts addressed:

This measure reduces the impact of drought, extreme heat and strong wind on animals and grasses because timber-and fodder-yielding as well as multipurpose tree species help establish a microclimate and serve as buffer zones against climate events. Food security is also boosted by product diversification; the need for more agricultural inputs is reduced; and possible productivity losses are reversed.

How to implement:

(1) Devise a plan to select, arrange and sow the plant material on the plots chosen for the different strata—for example, small (*Gramineae*), medium (*Leucaena*) and tall (carob [*Prosopis* spp]). (2) Estimate forage production on the plots according to sample yields of the pasture and the area of the plots. (3) Determine forage consumption, taking into account that each animal will consume 10% to 12% of its weight per day. (4) Determine the carrying capacity in light of the yield of the pasture in the selected paddock and the weight of the animal. (5) Plan a rotational grazing scheme throughout the plots, establishing periods of use and rest. Periods of use are short, and are followed by long periods of rest for plant recovery. (6) Utilize the different productive strata according to the initial plan.

Stucture of a silvopastoral system



Source: Ojeda and others (2003).

Inputs and costs:

The cost of implementing a silvopastoral system on one ha of land with a combination of pasture and timber species is given below. The main inputs are trees and pasture to be planted, an electric fence and the preparation of organic fertilizers and ecological pesticides. Labour to implement the system is a significant portion of the cost. The purchase of livestock is not included. Three days of training in implementing the system are assumed.

Silvopastoral system, 1 ha	US$
Labour	315
Materials	822
Training	180
Total	**1317**

Ecosystemic and economic benefits:

With this measure soil recovers and improves, local water and nutrient cycles are strengthened, biologic diversity is preserved and CO_2 is captured. For example, five years after the implementation of the Colombian sustainable livestock (Ganadería Colombiana Sostenible) project, the monitoring of birds in the silvopastoral systems indicated a 32.2% increase in sightings of all species and a 90% increase in sightings of migratory species. In addition, 61 species of interest for conservation were recorded, with the consequent ecosystem service of pollination that these changes brought about (Zuluaga and others, 2011). In economic terms, Murgueitio (2000) notes that some models may generate a benefit-cost ratio of 1.31 and a net present value of US$ 213 per year per hectare if during the first two years an incentive equivalent to the opportunity cost of the land is offered while the trees grow.

Limiting factors:

Compared with conventional extensive livestock management, the silvopastoral system requires more care and knowledge of the interaction among its components, in addition to a change in the producer's culture and practices. Producers may resist adopting such a change. Considerable time is required for timber species to develop; hence a long-term investment is required. Unless preventive measures like fencing are used, the animals may destroy the investment in plants by browsing and trampling on them.

Lessons learned:

The most suitable areas for the plots must be identified in a land-management plan for the farm, taking into account such factors as soil quality, topography, former use and ease of access. To promote the change in livestock farming practices to mixed systems, it is often necessary to resort to economic incentives ranging from the donation of trees, shrubs and forage to payment for environmental services (Murgueitio, 2009).

Additional considerations:

It is important to select suitable plant species. These species must be characterized by good biomass yield and quality (forage production) so as to increase the carrying capacity of the silvopastoral system. The costs of introducing timber species (trees and shrubs) and the time required for development may be significant.

How to monitor implementation:

Area under silvopastoral management (ha).

How to gauge impact

Livestock production under the silvopastoral system (kg/animal); livestock density (number of animals/ha); wood or fruit production (m^3, t).

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References:

Murgueitio, E. (2000). "Sistemas agroforestales para la producción ganadera en Colombia" *Pastos y Forrajes* vol. 3, No. 1. | Ojeda, P., J.M. Restrepo, D.E. Villada and J.C. Gallego (2003). *Sistemas Silvopastoriles, una opción para el manejo sustentable de la Ganadería*. Santiago de Cali, Valle del Cauca, Colombia: Fundación para la Investigación y el Desarrollo Agrícola (FIDAR). | Murgueitio, E. (2009). *Incentivos para los sistemas silvopastoriles en América Latina*. Avances en Investigación Agropecuaria vol. 13 No. 1 pp. 3-19. | Zuluaga A.F., C. GIraldo, J. Chará (2011). *Servicios ambientales que proveen los sistemas silvopastoriles y los beneficios para la biodiversidad*. Manual 4, Proyecto Ganadería Colombiana Sostenible. GEF, World Bank, FEDEGAN, CIPAV, FONDO ACCION, TNC. Bogota, Colombia.

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Impacts addressed

Extent of impact reduction: 3

Results in: up to 3 years

35 NATURAL SHADE

Scale	Individual / Collective
Focus	Investment / Support

Description:

This measure consists of providing shade by planting perennial trees in order to shelter animals, crops and other plant species from excessive sun exposure and increase the yields of some harvests. The procedure is carried out in two steps: first, pioneer vegetation characteristic of the ecosystem is introduced in order to protect the soil and regulate moisture; subsequently, trees that naturally give shade are planted. Planting trees for shade also promotes the diversification of production and income because additional products may be obtained, such as fruits, wood or forage.

Where to implement:

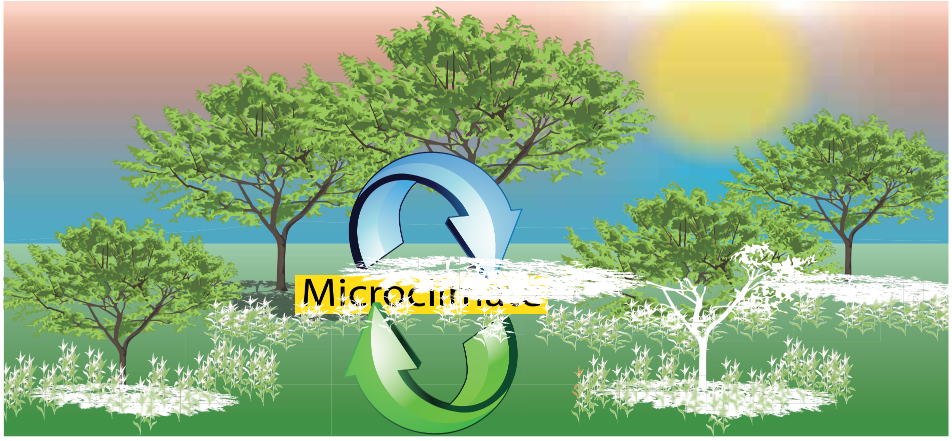
This technique is useful in croplands that require shade or have a rugged topography with a steep slope (50% or more). In particular, it is recommended for shallow and unstructured soils that are at risk of erosion, and that have low organic content, low natural fertility, poor drainage, low permeability and low moisture retention. It is also used in disturbed sites in order to restore soils and raise yields or the recovery rate of the ecosystem.

Threats and impacts addressed:

The presence of shade prevents excessive sunlight and maintains moisture in the soil and air, generating a microclimate that reduces the impact of droughts, extreme heat events and sudden temperature changes. Trees protect the soil from erosion and shelter crops from rain, hail or intense wind. They also help increase the productivity of certain crops, such as coffee and cacao.

How to implement:

For crops: (1) Analyse the site. (2) Design and plan the reforestation (selection of species, locations, planting times and spacing between trees) taking into account the services expected from the system. (3) Plan the management practices for the selected trees. (4) Obtain seeds or shoots. (5) Clear away any weeds. (6) Plant. (7) Integrate crops and tree management. *For areas where restoration is sought*: (1) Evaluate current ecosystem conditions. (2) Design and plan restoration. (3) Select species. (4) Clean the land. (5) Sequentially plant species for the desired ecological succession. (6) Monitor.



Source: Prepared by the authors.

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Threats addressed

Related measures

12 25 33 38

Income generation potential 2

GHG mitigation potential 2

Inputs and costs:

Establishment of natural shade in 1 ha of land. The main expense is the purchase of trees and payment of labour to plant them and ensure their survival. Twenty-five days of annual maintenance and a two-day training period are assumed. The cost of seeding the crops is not included.

Natural shade, 1 ha	US$
Labour	735
Materials	1550
Training	120
Total	**2405**

Ecosystemic and economic benefits:

Trees regulate temperature and promote the recycling of nutrients and organic matter, in addition to reducing the water deficit in crops (Altieri, 1999). Shade maintains the soil's structure and moisture improving its porosity and fertility, and thus decreasing the need for fertilizers (Farfán and Mestre, 2004). With data from Farfán (2007) and from the Federation of Coffee Producers of Colombia it has been estimated that a shade coffee plantation can produce more than 3500 kg/ha a year, with an approximate market value of US$ 7300. The sale of fruits from shade trees can be even more profitable than that of the crop produced under them. In an agroforestry system in Honduras, in which cacao was associated with rambutan, revenue of US$ 9165/ha and US$ 16,389/ha was obtained, respectively (FHIA, 2004).

Limiting factors:

Native trees from the region that are compatible with the intended crops must be used; consequently, expert assistance is recommended in selecting the species and designing a plan for long-term production. Because shade may promote disease and pests adapted to high humidity or a lack of light, the establishment of integrated pest management practices is required.

Lessons learned:

For coffee plantations, shade has greater benefits in regions under water stress and for soils with physical limitations. A cover of 30%-35%, and no greater than 45%, is recommended to obtain optimal coffee yields (Farfán and Urrego, 2004; Soto-Pinto, 2000). These values may vary for other crops, especially during their growth stage. In the case of shade for restoration purposes, it is recommended that the communities become involved in selecting the species and implementing the work, since this increases the ownership of the measure.

Additional considerations:

Measures to regulate shade (for example, pruning) are fundamental for obtaining good yields. Therefore, it is essential to have annual records of production and cover percentages in order to correlate the two variables and determine shade needs at the beginning of each cycle. In addition, restoration is a long-term process for establishing and regenerating forest cover.

How to monitor implementation:

Area cultivated under shade (ha); perennial trees planted (number/ha).

How to gauge impact:

Income per crop under shade (US$/ha); area restored with shade (ha).

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References:

Altieri, M.A. (1999). *Agroecología: Bases científicas para una agricultura sustentable*. New York: Sustainable Agriculture Networking and Extension (SANE), UNDP. | Farfán, F. and A. Mestre (2004) "Manejo del sombrío y fertilización del café en la zona central colombiana". *Cenicafé, Avances Técnicos*. No. 330. | Soto-Pinto, L. and others (2000). "Shade effect on coffee production at the northern Tzeltal zone of the state of Chiapas, Mexico". *Agriculture, Ecosystems and Environment*. No. 80, pp. 61-69. | Farfán, F. and J. Urrego, (2004). "Comportamiento de las especies forestales *Cordia alliodora, Pinus oocarpa* y *Eucalyptus grandis* como sombrío e influencia en la productividad del café" *Cenicafé* vol. 55 No. 4, pp. 317-329. | Farfán, F. (2007) "Producción de café en sistemas agroforestales" in *Sistemas de producción de café en Colombia*. Cenicafé-FNC. | Fournier, L. (1980). "Fundamentos ecológicos del cultivo del café". IICA. Costa Rica. | Fundación Hondureña de Investigación Agrícola (2004). *Guía técnica Cultivo de Cacao bajo sombra de maderables o frutales*. La Lima, Honduras.

36 AGRICULTURAL TERRACES

Scale	Individual Collective
Focus	Investment Support

Description:

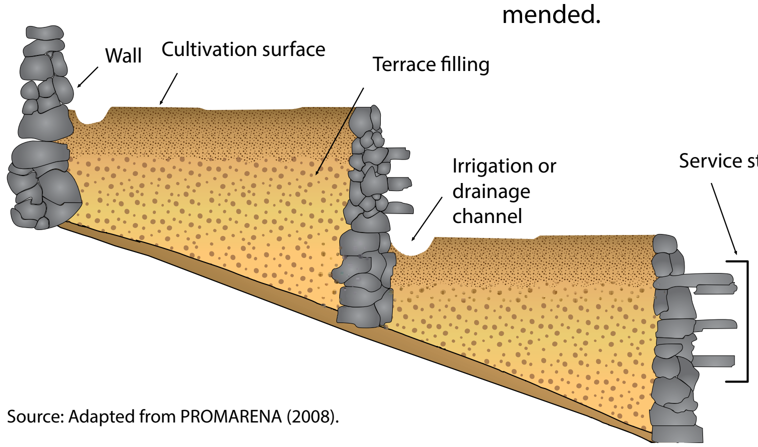
The ancient Andean technique of terracing consists of making cuts in steep slopes to form contour ridges and establish cultivation surfaces that are supported by stone walls. Because the terraces are positioned perpendicular to the flow of water they reduce erosion, retain soil and moisture and thus generate a microclimate conducive to crop growth. While their main purpose is to increase the amount of cropland, they also reduce the slope of the hillsides and thus prevent landslides that might affect structures, dwellings and crop areas that are downstream. Traditional terracing construction and restoration techniques require a large investment of labour, which must be provided by the community.

Where to implement:

Historically, terraces were built in the Andean Altiplano to adapt agricultural production to extreme conditions, but they may be built at any altitude range with slopes between 10% and 35%. They are particularly useful on hill or mountain sides with eroded soils for the purpose of increasing the agricultural area and preventing landslides. In the southern hemisphere, if terraces are constructed from east to west, and facing north, the walls absorb more heat, which promotes crop growth.

Threats and impacts addressed:

Transforming the landscape of hillsides prone to erosion into cultivation terraces increases agricultural productivity and food security. Terraces prevent landslides and erosion by reducing the intensity of runoff. They also reduce the risk of drought by raising the soil moisture content and allowing water to slowly infiltrate. Heat is absorbed through the walls, which provides greater thermal regulation and decreases the effects of sudden temperature changes and the likelihood of frost.



Source: Adapted from PROMARENA (2008).

How to implement:

(1) Study the characteristics of the site, such as soil type, relief, precipitation, runoff, sun exposure and the availability of materials with which to construct the terraces. (2) Plot the contour lines and calculate the slope of the drains. (3) Dig trenches 50 cm deep following the contour lines. (4) Construct the retaining wall above the trenches, using the largest stones first. The wall will not normally exceed 2 m in height and, if needed, may be reinforced with cementing agents. (5) Fill the terrace with the excavated material and add a surface layer of fertile soil. (6) Perform annual maintenance on the walls to ensure stability. For the reconstruction of ancestral structures, the assistance of technical specialists is recommended.

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Threats addressed

Related measures

4	12	13	14

Income generation potential 2

GHG mitigation potential 1

Inputs and costs:

The construction cost of a 700 m² terrace on a hillside with a 10% slope, with a retaining wall 100 m long by 1.5 m high, is given below. The main inputs are the labour for excavation, wall construction and filling; stone and seeds; and production and application of organic fertilizers. Five days of annual maintenance and two days of training are assumed.

700 m² terrace (100 m stone wall)	US$
Labour	945
Materials	887
Training	120
Total	**1952**

Ecosystemic and economic benefits:

Agricultural terraces raise productivity considerably. For example, Altieri (1999) reports that after terraces were restored in a project in Peru the first yields increased by between 43% and 65% for potatoes, maize and barley compared with conventional hillside cultivation. Erosion and soil loss were also prevented to a significant degree. Chow and others (1999) note that annual soil loss for potato crops declined from 20 t/ha on hillside crops to 1 t/ha on terraces with contour channels. Terraces have a highly beneficial economic effect. With the increased yields, the investment is recouped in the first year after construction, and net revenue generated over the following ten years is twice as high as that from conventional hillside cultivation (Rist and San Martín, 1993).

Limiting factors:

The main difficulty in building these structures is the amount of labour required. The reconstruction of one hectare of terraces is estimated to require up to 2000 worker-days (Altieri, 1999). In addition, on slopes greater than 35% construction and maintenance are more difficult. Since the measure has to be implemented by the community, good organization is essential, as is motivation so that participants will assume ownership of the production method and be responsible for its maintenance.

Lessons learned:

Community support schemes in terrace-recovery and restoration projects have been successful when low-interest loans are granted for agricultural inputs in exchange for labour to reconstruct specific areas of the terraces. It is advisable that civil society organizations provide support by coordinating efforts and giving technical advice. Implementation is more effective if farmers are organized and have specific production aims based on sustainable practices.

Additional considerations:

Terraces can be used as an element of risk management, benefiting entire communities. The Andean highlands are estimated to have more than 500,000 ha of terraces, of which 75% need restoration. Given the reported benefits, this measure has a high value for ecosystem-based adaptation because it increases communities' overall resilience.

How to monitor implementation:

Area of terraces constructed or restored (m²).

How to gauge impact:

Additional income (US$/year); inhabitants with terrace protection (number).

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References:

Altieri, M. (1999). "Applying agroecology to enhance the productivity of peasant farming in farming systems in Latin America", *Environment, Development and Sustainability* vol. 1 No. 3-4, pp. 197–217. | Rist, S. and J. San Martín (1993). *Agroecología y saber campesino en la conservación de suelos*. 2nd ed. AGRUCO. Universidad de Cochabamba, Bolivia. | Chow T., W. Rees and J. Daigle (1999). "Effectiveness of terraces/grassed waterway systems for soil and water conservation: A field evaluation", *Journal of Soil and Water Conservation* vol. 54, No. 3, pp. 577-583. | Proyecto de Manejo de Recursos Naturales (2008). *Guía metodológica para la rehabilitación y construcción de terrazas prehispánicas*. La Paz, Bolivia.

Impacts addressed

Extent of impact reduction: 2

Results in: up to 2 years

37 INFILTRATION PITS

Scale: Individual / Collective

Focus: Investment / Support

Description:

Infiltration pits are generally 0.5 m wide, 0.5 m deep and 2 m long. They are dug 4 to 6 m apart along the contour lines on inclined landscapes. Their main purpose is to retain water in the soil for a prolonged period and increase infiltration and groundwater recharge. They also help maintain soil moisture, contribute to the accumulation of rainwater for irrigation and enhance the growth of native or reforested vegetation. In fields with steep slopes, they slow the runoff, preventing erosion and potential landslides.

Where to implement:

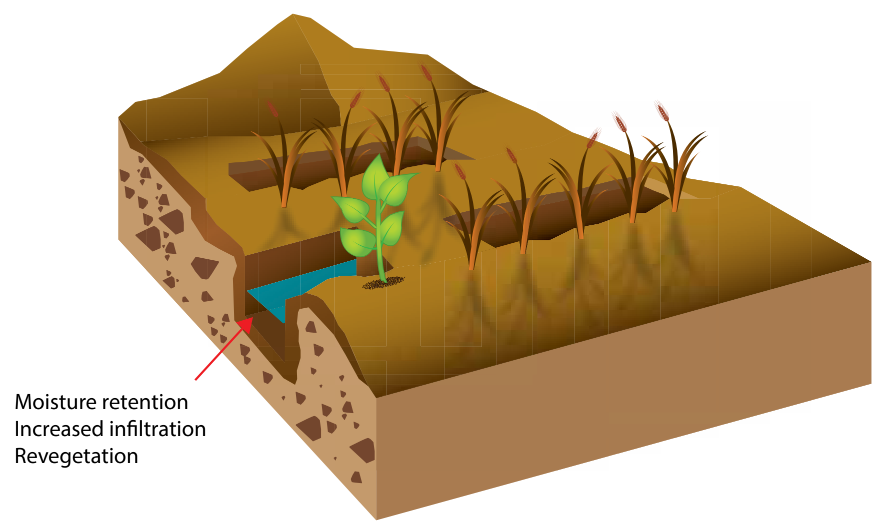
Infiltration pits are used in arid or semi-arid regions where precipitation is irregular, particularly on hill or mountain sides with no vegetation in order to reforest or establish orchards. They are also useful in regions where it is necessary to promote water infiltration and groundwater recharge or to control flow surges and thus reduce the likelihood of flooding and of sediment accumulation downstream.

Threats and impacts addressed:

Infiltration pits reduce water erosion on hill and mountain sides and diminish the effect of drought on adjacent areas by retaining moisture in the soil and helping plant species take hold. They promote groundwater recharge and thus increase water security. Increased soil moisture allows surrounding plant species to withstand sudden temperature changes and extreme heat.

How to implement:

(1) Calculate the volume of the pits based on the catchment area and runoff volume. (2) Calculate the distance between pit lines along the contours of the terrain. (3) Plot the contour lines. (4) Mark the field every two meters, making adjustments for the topographic conditions. (5) Dig the pits. (6) Form a rounded ridge on the downstream side of the pit, of the same length as the pit, and compact. (7) Repeat the process along the next contour line. Note: If the purpose is to improve the yield of perennial crops, one pit is constructed per tree, and the size of the pits is adjusted according to the density of trees.



Source: SAGARPA (2009).

Inputs and costs:

The cost of digging 650 infiltration pits, each with a volume of 0.5 m^3, on one hectare is given below. The main expenses for materials are the topographic study and the runoff analysis as well as the purchase of the A device and tools. Digging is the main expense for labour. Five days for annual maintenance and two for training are assumed.

Infiltration pits, 650 pits/ha	US$
Labour	2010
Materials	1080
Training	120
Total	**3210**

Ecosystemic and economic benefits:

Infiltration pits promote ecosystem restoration by controlling erosion on hill and mountain sides and retaining water. Increased water infiltration recharges aquifers and makes more water available in low areas. A project with 650 pits/ha in a 250 ha field obtained an average water harvest of approximately 8 m^3 per pit (5200 m^3/ha) per year, with annual precipitation of 800 mm (Cota and others). This measure reduces downstream silting in the watershed and controls runoff. Constructing pits for a perennial tree field improves the production of fruit and timber products owing to increased soil moisture. The same function may help promote the succession of native species.

Limiting factors:

Maintenance to remove sediment is generally not cost-effective; hence, the pits eventually fill up (that is, after approximately 10 years) and their useful life ends. This practice is not recommended for sandy soils because the pits may collapse during the rainy season. Nor is it recommended on parcels with poor drainage and intense rainfall, because of the risk of aggravating erosion. Given that an excessive number of pits may damage the soil structure, the calculations should be made with the assistance of qualified technicians.

Lessons learned:

This kind of project is recommended for semi-arid and temperate zones and on slopes of not more than 40%. Water infiltration may decrease the catchment of runoff that feeds reservoirs. It is important, therefore, to involve any downstream producers who have water-containment structures. When the practice is carried out in conjunction with reforestation activities, the pits should be dug a few weeks before planting to accumulate more moisture and promote tree survival.

Additional considerations:

When the intention is to retain moisture, the base of the pit should be compacted to reduce rainwater infiltration. In clayey soils, with a low degree of infiltration, deeper pits are built to ensure storage and promote seepage. When the practice is carried out in conjunction with the planting of trees, the improvement in the soil far outlives the usefulness of the pits because the tree roots preserve the soil's porosity. In degraded sites, infiltration pits are generally combined with other practices to improve soil structure and fertility.

How to monitor implementation:

Units constructed (number/ha).

How to gauge impact:

Volume of water retained (m^3/ha-year); trees benefited (number).

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References:

SAGARPA (2009). *Tinas Ciegas.* Subsecretaría de Desarrollo Rural. Dirección General de Apoyos para el Desarrollo Rural. | SEMARNAT-CONAFOR. (2008). *Protección, Restauración y Conservación de Obras Forestales: Manual de Obras y Prácticas.* Chapter 4: Obras y prácticas. | Cota, E. and others (n.d.). *Recarga de acuíferos mediante la construcción de tinas ciegas.* Available at: http://www.inecc.gob.mx/descargas/cuencas/2011_cnch2_mon_ecota1.pdf. | Practical Action (2012). "Infiltration pits for rainwater harvesting". Available at: http://practicalaction.org/infiltration-pits-for-rainwater-harvesting.

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Impacts addressed

Extent of impact reduction: 3

Results in: up to 1 year

38 MIXED-PLANT NURSERIES

Scale	Individual / Collective
Focus	Investment / Support

Description:

Mixed-plant nurseries are agronomic facilities at which plants are germinated and cultivated and where they grow under controlled conditions of light and moisture. Their main purpose may be to diversify income through the sale of high-quality timber, fruit and ornamental species or to reproduce resilient native species for reforestation or restoration. The plant species are reproduced by vegetative propagation and reproduction. Their upkeep and maintenance require such techniques as efficient irrigation systems or integrated pest and nutrient management. Plant nurseries generally produce their own organic fertilizers and ecological pesticides.

Where to implement:

Nurseries may be set up in easily accessible rural, urban or peri-urban areas with at least 2500 m^2 of land as well as water and fertile soil (or compost production). They should be located near both forest areas and population centres, so as to facilitate gathering seeds and cuttings as well as hiring labourers and selling the products. The nursery must be positioned so as to take full advantage of solar irradiation. Bare-root nurseries require flat land with fertile and permeable soil and must be located at altitudes no higher than 2500 m.

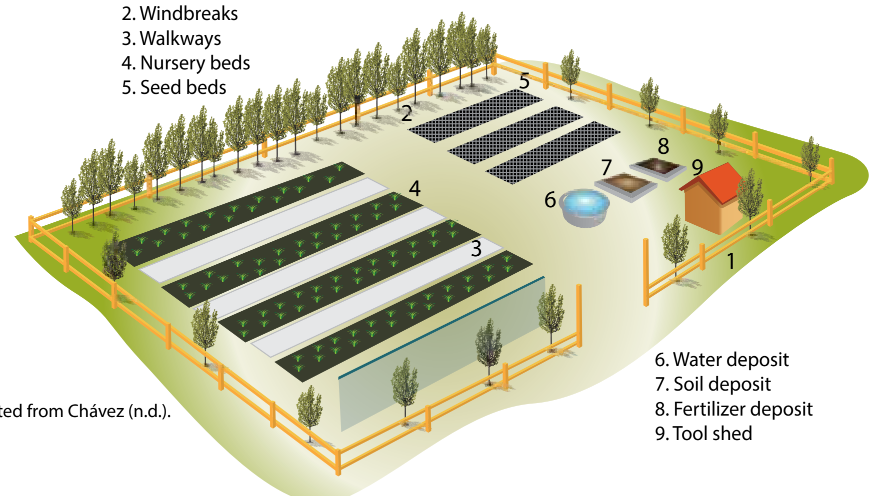
Threats and impacts addressed:

Nurseries may produce plant varieties adapted to local climate conditions as well as native species for conservation and restoration. They increase the resilience both of crops and of the surrounding ecosystem and mitigate the risk of crop losses or damage and the impact of lower yields or reduced food security. They allow plants to acclimate to changing temperatures, extreme heat, drought or intense rainfall.

How to implement:

(1) Select the location taking into account the characteristics of the land, soil, climate, crops and species with commercial value. (2) Clean and prepare the site. (3) Set up the facilities and infrastructure (paths, drainage channels, windbreaks, fences, greenhouses, flowerbeds, storerooms and seedbeds) and purchase the equipment. (4) Obtain seeds, cuttings and stakes. (5) Pre-treat, seed and carry out first transplant. (6) Remove weeds and weak plants. (7) Carry out second transplant (if applicable). (8) Acclimate. (9) Put up products for sale.

1. Perimeter fence
2. Windbreaks
3. Walkways
4. Nursery beds
5. Seed beds



6. Water deposit
7. Soil deposit
8. Fertilizer deposit
9. Tool shed

Source: Adapted from Chávez (n.d.).

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Threats addressed

Related measures: 8 | 21 | 23 | 30

Income generation potential: 3

GHG mitigation potential: 1

Inputs and costs:

The cost given below is for a 5000 m^2 container-type nursery with a production area of 2500 m^2. The main expense is for the materials needed to prepare the site and build the infrastructure as well as for the inputs required to sell the products. Four days of training in operating the nursery and caring for the plants are assumed. The cost of the labour required for the operation, which is considerable, is not included.

Plant nursery, 0.5 ha	US$
Labour	1050
Materials	4115
Training	240
Total	**5405**

Ecosystemic and economic benefits:

A 0.5 ha container-type nursery can produce up to 23,000 plants a year—whether of timber, forest, fruit or ornamental species. At current prices this translates into some US$ 10,000 in sales per year and approximately US$ 3,000 in net profit, once expenses for containers, production of organic inputs and labour are deducted. Plant nurseries supply trees to agroforestry systems which, although not as diverse as natural forests, are much more diverse than single-crop fields. A study in Costa Rica comparing diversity in natural forests, cacao fields, shade-grown banana and single-crop banana fields found 85, 35, 14 and 0 tree and palm species, respectively (Guiracocha, 2000). The services provided by trees to natural and agricultural systems include protection from rain, wind and solar radiation; regulation of air and soil temperatures; moisture retention; and organic-matter production (Altieri, 1999).

Limiting factors:

Nursery plant maintenance is labour-intensive, which means that operating costs are high and they must be located in areas close to population centres. They cannot be located in deep valleys where sunlight and ventilation are uneven. Abundant water is needed.

Lessons learned:

Training in cultivation methods increases the likelihood of success of a plant nursery. Grafting makes it possible to select trees with the required traits, to accelerate production and to improve plant quality. The best period for collecting seedlings and cuttings is the rainy season. For gathering stakes the best period is when trees are dormant, either in winter or during the dry season. Seeds must be collected between the ripening of the fruit and dissemination.

Additional considerations:

The land should have a slope of 1%-2% to encourage drainage, and a windbreaker should be planted around the perimeter of the nursery to limit the loss of plant moisture. Given that demand for plants is variable, market studies should be carried out to select the species that are the most profitable and in the greatest demand and thus to ensure the viability of the project.

How to monitor implementation:

Area of operating plant nurseries (ha); plants produced (number).

How to gauge impact:

Income generated (US$); preservation of native species (number).

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References:

Chávez, M. (n.d.). *Proyecto de Fortalecimiento al Desarrollo Productivo comunitario: Vivero.* SMADS Government of Argentina. | AGRINFOR (2003). *Viveros Forestales: Manual técnico para las actividades agropecuarias y forestales en las montañas.* National Commission, Turquino-Manatí Plan. Cuba. | Giracocha, G. (2000). *Conservación de la Biodiversidad en los Sistemas Agroforestales Cacaoteros y Bananeros de Talamanca*, Costa Rica: Master's thesis. Turrialba, CATIE. | Altieri, M.A. (1999). *Agroecología: Bases científicas para una agricultura sustentable.* New York: Sustainable Agriculture Networking and Extension (SANE), UNDP.

Impacts addressed

Extent of impact reduction

3

Results in:

up to

1

year

39 WARU-WARUS

Scale: Individual / **Collective**

Focus: **Investment** / Support

Description:

In Quechua, *waru-waru* means 'cultivation ridge'. Waru-warus are a cultivation and water storage technique that utilizes the frequent flooding of the Andean Altiplano to establish alternating soil ridges and furrows. On the ridges diverse crops are grown which otherwise would not thrive in such an extreme climate. Archaeological evidence indicates that waru-warus were used to produce plentiful harvests despite floods, drought and frost at altitudes of almost 4000 m (Erickson and Chandler, 1989). The investment required for this labour-intensive, traditional construction is considerable. Hence, the community must be united in supporting it.

Where to implement:

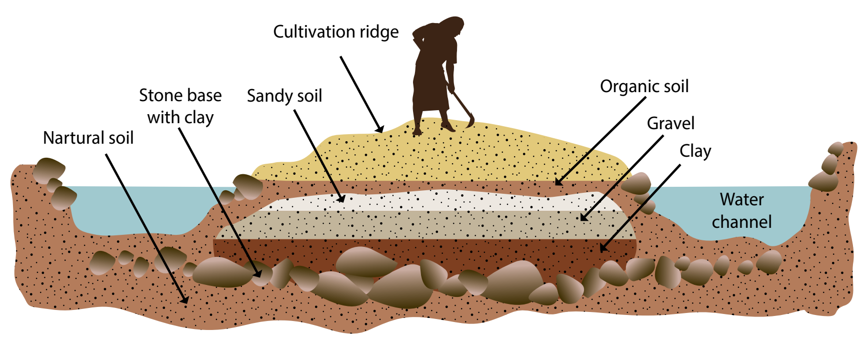
The Andean Altiplano is where this cultivation technique has traditionally been implemented, particularly in semi-flat areas, wetlands and areas subject to seasonal flooding. Waru-warus are built in valleys at an average altitude of 3500 m. The construction technique may be adapted to locations at a lower altitude but with similar characteristics—for example, riverbanks with moderate slopes—using modern methods to extract and move the soil.

Threats and impacts addressed:

Waru-warus are implemented as a strategy to diminish the risk of extreme climate events. They accumulate heat during the day (approximately 3°C) and transmit it to the contiguous crop beds, reducing the likelihood of frost. During intense rains the excess water is drained and stored in the irrigation channels thus reducing the potential for drought. Waru-warus contribute nutrients and promote crop diversity and longer growing seasons, all of which increases productivity.

How to implement:

(1) Once the soil has been found to have a low permeability, plot the contours, indicating where the channels, approximately 3 m wide by 1 m deep, are to be excavated. (2) Use the extracted material to form a platform with clearly differentiated layers in order to balance water infiltration with soil retention, as follows: stone base (40 cm), clay (30 cm), gravel (15 cm), sand (15 cm) and fertile soil (40 cm). (3) Establish a spatial ratio of 60% consisting of platforms to 40% consisting of channels. The orientation and shape will vary according to the topography of the location. For the reconstruction of ancestral structures, specialized technical support is recommended.



Source: http://culturaunemi.blogspot.mx.

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Inputs and costs:

The cost of constructing waru-warus on 2500 m^2 of land is given below. It is assumed that the work will be carried out mechanically rather than manually. The main inputs are the rental of machinery, minor manual chores, tools and training. It is also assumed that the excavated material will be used to form the crop beds. Four days are assumed for training in the construction method, operation and maintenance of the system.

Construction of waru-warus on 2500 m^2 of land, using machinery	US$
Labour	5550
Materials	450
Training	240
Total	**6240**

Ecosystemic and economic benefits:

Waru-warus produce a microclimate that increases crop diversity and lengthens production time, with yields rising by between 200% and 300% (UNDP, 2005). In a project to restore 850 ha of terraces and 173 ha of channels, 1247 families benefited from yields that increased from 5 to 8 t/ha for potatoes and from 3 to 8 t/ha for oca. Income increased by more than 400% (Sánchez, 1994). In another case, Altieri (1999) compares the yield of potatoes in the pampas with those produced in waru-waru systems and reports 1-4 t/ha and 13 t/ha, respectively. Waru-warus catch water in the high areas and create controlled irrigation systems that prevent the formation of gullies and the deterioration of soils, benefiting native flora and fauna. This traditional cultivation system is suitable for extreme climates and promotes community unity.

Limiting factors:

The cost of the manual labour for construction, cleaning, sowing, harvesting and maintenance is high: approximately 270 worker-days per hectare per year (Altieri, 1999). These systems cannot be constructed on highly permeable soils or on hillsides with a slope greater than 8%. The community must be motivated, highly organized and in agreement. Another challenge is selling products in a small, isolated market.

Lessons learned:

If the labour were paid at current market rates, it would be prohibitively expensive to construct or rehabilitate these systems with microfinance credits. Nevertheless, in some cases organizations have offered low-interest loans as well as seeds and other inputs in exchange for the restoration of abandoned structures. That said, certain conflicts have also been seen to arise between the traditional structures of indigenous organization and the expectations of the aid agencies when these systems are implemented (UNDP, 2005).

Additional considerations:

Experience shows the importance of re-evaluating traditional techniques on resource-conservation, crop diversification and rotation as well as the flexibility of planting times. This allows the peoples that inhabit the Andean Altiplano to adapt to current extreme conditions and future climate change. Ecosystem-based adaptation to climate change requires the recovery of traditional knowledge, including efficient production methods and botanical knowledge.

How to monitor implementation:

Waru-warus constructed (ha).

How to gauge impact:

Productivity (t/ha); income (US$/family).

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References:

UNDP (2005). "Experiencia 3. Suka Kollus: Una comunidad conviviendo con las inundaciones y sequías", in *Gestión Local del Riesgo y Preparativos de Desastres en la Región Andina: Sistematización de buenas prácticas y lecciones aprendidas.* | Altieri, M. (1999). "Applying agroecology to enhance the productivity of peasant farming in farming systems in Latin America", *Environment, Development and Sustainability* vol. 1 No. 3-4, pp. 197–217. | Sánchez, J. (1994). "A seed for rural development: the experience of EDAC-CIED in the Mashcon Watershed of Peru". Cited in Altieri (1999). | Altieri, M.A. (1992). "Sustainable agricultural development in Latin America: exploring the possibilities". *Agriculture, Ecosystems and Environment,* 39: 1-21. | Erickson, C. and K. Chandler (1989). "Raised fields and sustainable agriculture in the Lake Titicaca Basin of Peru", in J.O. Browder (ed.), *Fragile Lands of Latin America*, Westview Press, Boulder, pp. 230–243. Cited in Altieri (1999).

40 CONTOUR TRENCHES

Scale: **Individual** | Collective

Focus: Investment | **Support**

Description:

Contour trenches are simple systems that control surface runoff. They interrupt, diverge and distribute runoff at a rate that is non-erosive to promote infiltration and channel excess water to a location where it will not cause damage. They are constructed in a manner similar to furrows: an excavation is made at a right angle to the slope and following the contour. The excavated soil is placed at the lower end of the trench such that it forms a ridge which is compacted and stabilized with perennial vegetation. If extreme events occur, the plants help retain the soil with their roots and trap overflowing sediment. Agricultural soil protected with these trenches retains moisture, promoting crop growth.

Where to implement:

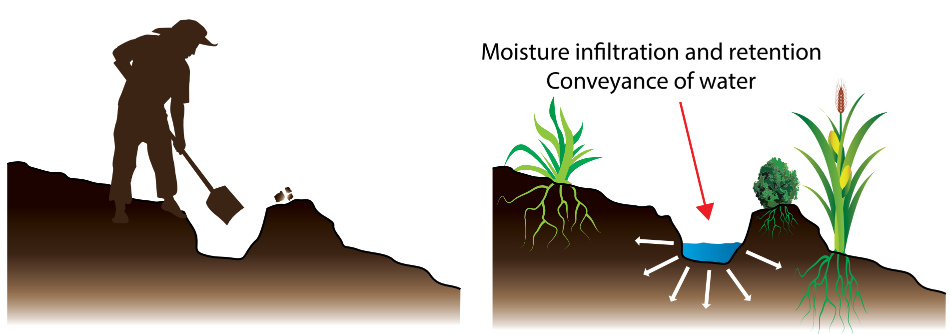
This measure is particularly useful on arid, relatively flat farmland that has lost its fertile soil and that is subject to flooding during intense rainfalls. The adjacent locations, to which the runoff is to be channelled, must have sufficient infiltration capacity to absorb excess water. Given the ease with which they are built, contour trenches are widely used, especially in fields with slopes of less than 10%.

Threats and impacts addressed:

By retaining soil moisture, contour trenches reduce the impact of drought and heat waves on crops. In addition, in the event of intense rainfall, they channel the runoff and reduce erosion and crop loss caused by flooding.

How to implement:

(1) Determine the maximum precipitation levels in the area, the soil types and the infiltration coefficient. The contour trench must be able to withstand moderate flooding. (2) Dig a trench up to 40 cm deep by 50 cm wide, perpendicular to the slope and following the contour line in the field. The optimal slope of the trench varies between 0% and 5% depending on the slope of the terrain. (3) Place the excess material to form a ridge on the lower end of the trench. (4) Determine the space between each trench, based on the slope and the amount of rainfall. With a 2% slope and less than 1200 mm of precipitation, the trenches should be 40 m apart. (5) Stabilize the ridge with perennial vegetation. (6) Carry out regular maintenance, especially after intense rain.



Source: Adapted from http://plantwater.freeservers.com.

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Threats addressed

Related measures
18 25 29 32

Income generation potential 0

GHG mitigation potential 0

Inputs and costs:

The construction cost of a 1000 m contour trench, equivalent to the perimeter of an area no larger than 6.25 ha, is given below. Basic field tools are needed, as are labour and plants. As the measure is very easy to implement, only one day of training is included. Five days of annual maintenance are assumed.

1000 m contour trench	US$
Labour	1275
Materials	400
Training	60
Total	**1735**

Ecosystemic and economic benefits:

Contour trenches significantly decrease the risk of crop loss due to flooding. A trench 300 m long can protect the production of one ha of land. If cultivated with maize, the production would have a value of at least US$ 1800 a year. They also promote infiltration and groundwater recharge. One linear metre of a 0.6 m x 0.6 m trench can catch 360 l of water per rain event. Consequently, a 100 m trench could infiltrate up to 36000 l of water (Altieri and others, 2006). The organic sediment that is deposited in the trenches may serve for soil conditioning and lower fertilizer expenses. The ridges are formed with perennial endemic vegetation that is used to produce firewood and that attracts insects and native fauna, contributing to pest control and natural pollination.

Limiting factors:

Contour trenches are not suitable on highly eroded soil or fields with steep slopes. Although they are easy to construct and inexpensive, the degree of protection is relatively low compared with other structures like drainage systems or terraces. In rocky soils excavation costs are significantly higher.

Lessons learned:

It is useful to build oversized trenches in order to extend their useful life even if maintenance is inadequate. The silt in the trench and the erosion of the ridge gradually reduce the flow capacity of the system. When a higher degree of infiltration is sought, spaces may be left unexcavated, which will lead to the formation of intermittent trenches that will store water.

Additional considerations:

Retention trenches are easy to implement, require little training and quickly produce results. Unless properly designed, however, they may cause erosion. They can be complemented with drainage or rainwater catchment systems or used to restore ecosystems. When the runoff contains large amounts of sediment complementary measures such as plant, wood or stone barriers should be used, to intercept the sediment and prevent the excessive silting of the trenches.

How to monitor implementation:

Length of trenches built (m); area of land with trenches (ha).

How to gauge impact:

Productivity (t/ha); reduction in losses from flooding (US$/ha).

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References:

Altieri, M.A. and others (2006). *Manejo del agua y restauración productiva en la región indígena mixteca de Puebla y Oaxaca*. Cited by Altieri, M.A. and P. Koohafkan (2008). *Enduring Farms: Climate change, smallholders and traditional farming communities*. Third World Network. Penang, Malaysia. | SAGARPA (n.d). *Manejo de escurrimientos.* Serie Sistema de Agronegocios Agrícolas. | *Acequias a nivel.* PASOLAC. Fundación para el desarrollo Agropecuario y Forestal, Nicaragua. Available at: http://www.funica.org.ni/docs/conser_sueyagua_08.pdf. | SAGARPA (n.d). *Zanja derivadora*. Available at: http://www.coussa.mx/Docs/MaterialTec/Fichas/18ZANJA_DERIVADORA.pdf.

Next Steps

The systematization of EbA measures presented in the precedent fact sheets will be used to carry out a more rigorous and detailed cost-benefit analysis, as well as to identify options focused on other areas of interest for the project.

The next step is to classify the 40 proposed measures into:

- Measures that, on their own, meet all the MEbA criteria and that may be included, individually, in microfinance services and products;
- Measures that, partially or completely, meet the MEbA criteria and that may be included in microfinance services and products in conjunction with other measures, as part of a simultaneous package;
- Measures that, partially or completely, meet the MEbA criteria and that may be included in microfinance services and products in conjunction with other measures, as part of a staggered package.

To illustrate this process—and even though the proposed actions do not fully cover the breadth of the concepts—two cases of packages of staggered measures were included, in the permaculture and agroecology fact sheets.

These systematized measures are expected to be useful for guiding decision-making in the credit methodology of microfinance institutions and for enhancing producers' resilience to climate change. In the end, the producers themselves will be in charge of putting them into practice. This exercise has undoubtedly been very useful for those of us who see ecosystem-based adaptation not as an option, but as a need and an opportunity to begin to make a transition towards sustainability.

CREDITS

Microfinance for Ecosystem-based Adaptation: Options, costs and benefits. Complete set: 40 fact sheets. **Compiled by:** United Nations Environment Programme, Regional Office for Latin America and the Caribbean and Frankfurt School-UNEP Collaborating Centre for Climate and Sustainable Energy Finance. **I** Senior editor: Jacinto Buenfil. **I** General coordinator of the MEbA Project: Jason Spensley. **I** Coordinator of the MEbA Project for the Frankfurt School-UNEP Collaborating Centre: Christoph Jungfleisch. **I Content development:** Jacinto Buenfil, Integradora de Servicios y Sistemas Ambientales (ISSA), Carlos Andrés Alape. **I Translation:** Pauly Bothe, Alan Hynds. **I Copy editing:** Alan Hynds. **Design and illustrations:** Óscar Alonso **I Layout:** Gema Alín Martínez.

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