ECHO® Best Practices Note

No. 1 Improving Degraded Land

Barren land in Mauritania.

The Problem of Land Degradation

Definition

What is land degradation? A lengthy definition by the UNCCD (United Nations Convention to Combat Desertification) appears in a 2005 World Meteorological Organization publication (WMO-No. 989). Elements of that definition that are most relevant to ECHO's network of development practitioners are:

1. Land degradation is a "reduction or loss, in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest..." [humid areas also experience degradation, especially on sloping land]
2. Land degradation results from processes such as "(i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical, and biological or economic properties of soil; and (iii) long-term loss of natural vegetation."

Extent and effects (WMO 2005)

The UNCCD estimates that over 250 million people are affected by land degradation, and about 1 billion people in over 100 countries are at risk. According to the WMO, 33% of the world's land surface is vulnerable to land degradation. Breaking that down further, they estimate that 46% of the land in Africa is vulnerable, with Sub-Saharan Africa being the most vulnerable; 25% of Asian lands are vulnerable.

Degraded lands lead to overall reduced productivity and reduced crop yields which directly impact population health. People affected by land degradation are often forced to move to new areas which creates instability in communities and can contribute to social problems such as petty crime as well as more violent crimes.

FAO Director-General, José Graziano da Silva, stated, "To feed a growing population that is expected to top the nine billion mark in 2050, FAO projects the need to increase agricultural output by at least 60 percent in the next decades. To do so, we must save and grow–increasing agricultural production while preserving the environment" (FAO 2012).

Causes and problems

Degraded lands are typically a more significant problem in areas with fragile ecosystems (deserts, semi-arid, volcanic islands, rainforests, etc) and in places with heavy population loads where people are forced to over-use the same land with no alternatives. Degraded lands are also associated with areas where the land is the main resource for everything: human food, animal food, building materials, fuel, income generation, etc. These pressures create constant "withdrawals" that, if not reversed, lead to exhaustion of the land resource.

What's Inside:

by ECHO staff

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Poor farming practices add to the degradation caused by continually "taking" from the land without returning anything to the soil. Deforestation, uncontrolled burning, overgrazing and excessive tillage leave soils exposed. In the tropics, where the heat from the sun is especially intense, bare soil turns into an "oven" in which plants and soil biology are subjected to temperature extremes. Lifeless soils lack the thriving microbial populations needed to cycle nutrients and enhance their availability to crop roots. Though it is possible to produce a crop on inert soil, it requires capital-intensive inputs and management.

Unprotected soils are also subject to compaction and erosion. In many areas, soils are subjected to heavy, even if short in duration, rainfall events. Raindrops hitting unprotected soil break up soil particles, resulting in hard, encrusted soils with low water infiltration capacity. This means that only a small amount of the rain will soak into the soil, replenish the water table and be available to support crop production. What does not soak in will run off the land carrying with it valuable organic matter and topsoil. Eventually this will result in gullies or crevices in fields which reduces the land available to farm. It also results in siltation of streams and rivers that leads to poor water quality that in turn leads to health and sanitation problems.

Inorganic fertilizers are often used to provide the needed nutrients on depleted, degraded soils. These, however, have a financial cost as well as an environmental cost. With rising petroleum costs (FAO 2011), mineral fertilizers are becoming less affordable to smallholder farmers. Even if they could afford them, a heavy reliance on inorganic fertilizers on land that is already damaged can lead to even further soil degradation. The buildup of salts, especially in arid climates, breaks down soil structure and eventually creates an environment in which very few plants are able to survive.

To summarize, specific problems and challenges pertaining to degraded lands include:

- Environmental damage
    - Deforestation
    - Erosion, loss of topsoil
    - Siltation of streams and rivers
    - Reduced water infiltration
    - Gradual drop in water table
- Human-induced damage
    - Competing uses for farm resources resulting in constant withdrawal of nutrients
    - Animal pressure from overgrazing or uncontrolled grazing
- Reduced soil health
    - Reduced soil fertility
    - Loss of soil organic matter
    - Damaged soil structure
    - Cost of inorganic fertilizers
    - Salting of soil with overuse of inorganic fertilizers

How can the smallholder farmer restore degraded soils? If extended fallow periods are not an option, how can they farm their soils each year while maintaining soil health? While there is no single recommendation that applies to every situation, below is a list and discussion of principles and best practices that ECHO's staff and network of development workers have found to be effective. While it is important to recognize that land degradation is influenced by factors such as policy, governments and markets, the content below focuses on land stewardship and farming practices.

Principles

Improving soil health

Build soil organic matter: Soil organic matter (SOM) is derived primarily from animal manures and plant material in varying stages of decomposition. Plant material includes above-ground residues, as well as roots, of plants in farmers' fields. The most stable form of SOM is humus, which darkens the top layer of soils, providing an indicator of the presence of SOM in a soil.

Organic matter improves soil aggregation (formation and stability of soil particles), increases the water- and nutrient-holding capacity of the soil, and releases nutrients that crops need to grow. Of particular importance in the tropics is the fact that SOM also increases the accessibility of nutrients to plant roots through both chemical (e.g., moderation of soil pH) and biological (proliferation of microorganisms that increase the ability of crop roots to scavenge and take up plant nutrients) means (Bunch 2002 in EDN 74).

Because organic matter continually decomposes, it must be replenished regularly to preserve this important reservoir of fertility on agricultural lands.

Replace lost nutrients: As crops grow, they take up nutrients. Any biomass removed from the field, therefore, contains minerals that are lost to the soil. Unless those nutrients are replaced, soil fertility begins to decline. Swift and Shepherd (2007) wrote:

> *Agricultural systems with insufficient nutrient input on land with poor to moderate potential are the root cause of human-induced soil degradation in Africa...Mid-1990s estimates show that every country in Africa had a negative nutrient balance in its soils, in that the amount of nitrogen, phosphorus and potassium added as inputs was significantly less than the amount removed as harvest, or lost by erosion and leaching.*

Nutrients can be replaced through inorganic or organic fertilizers, and practices that contribute to SOM.

Minimize soil disturbance: Disturbing the soil through frequent tillage removes any protective surface mulch and breaks up soil aggregates (particles), adversely affecting soil structure and biology. It also leads to a loss of organic matter, reducing soil fertility. Farming practices that minimize tillage or other soil disturbances help to preserve the soil's physical structure and organic matter while protecting it from weathering forces of the sun, rain and wind. The need for tillage can be greatly reduced by utilizing ground covers, green manure, cover crops, crop residues and mulches.

Controlling erosion

Keep the soil covered: Bare soil is easily eroded by rainfall, especially on steeply sloped land. Mulching and the rotational/sequential planting of cover crops reduces soil erosion. Keeping the soil covered also shields it from harsh sunlight, moderating temperatures and thereby allowing soil organisms to thrive.

Maximize rain water efficiency/infiltration: "Rainwater harvesting" strategies increase the percentage of rain water that percolates down into the soil, minimizing the amount of water lost to surface runoff. There are many techniques used separately or in combination. Some of them include terracing, planting perennials along contours, and microcatchments.

Build soil and water conservation structures: Why? These are physical barriers that prevent soil erosion on sloping land, protecting the soil resources of a farm or cropland. They can also be designed to capture water or increase infiltration, thereby lessening the negative impact of water on soil as well as increasing the availability of water for agricultural or other uses. How are they beneficial? While structures may have significant up-front cost associated with them, they can have immediate positive impact. They can be useful in stabilizing a severely damaged area, allowing subsequent erosion control strategies involving vegetation to succeed.

Diversifying for resilience

Quote: "Cultivate a wider range of plant species–both annuals and perennials–in associations, sequences and rotations that can include trees, shrubs, pastures and crops, in order to enhance crop nutrition and improve system resilience." (Save and Grow, FAO).

Select suitable crops/varieties: Look for crops and varieties with traits such as drought tolerance and ability to scavenge nutrients. Sorghum and millet, for example, are generally more drought tolerant than maize. Keep in mind that traits can vary between varieties of each crop.

Develop crop diversity: Provided the system does not become overly complex, growing more than just one crop increases the resilience of smallholder farms. Fallow crops, intercropping and sequential rotations are all ways to incorporate more than just one crop.

Integrate trees and animals: Smallholder farms typically contain trees and animals anyway. The degree to which these are integrated such that nutrients are kept within the overall system greatly influences the long-term productivity of farm lands. Incorporating trees provides timber and fuelwood, reducing the need to gather wood from forest lands. Animal wastes can be utilized for crop production.

Improving rangelands

Control grazing: Overgrazing by free-roaming livestock can remove significant amounts of biomass from rangelands. This eventually reduces SOM and the capacity of the land to sustain further grazing. Rotational grazing of blocks of land and cut/carry systems are ways to control animal grazing.

Improve quality of grazing land: Many rangelands are also dominated by grasses with low protein content. Incorporating leguminous species safe for livestock consumption improves forage quality while also contributing to the fertility of the soil.

Best Practices

- Build soil organic matter through the use of leguminous cover crops and/or trees.
- Cover the soil with crop residues, living mulches, and/or dispersed trees.
- Disturb the soil as little as possible, leaving organic mulches on the soil surface.
- Concentrate fertility close to crop plants.
- Utilize microcatchments and, where possible, water-holding structures such as sand dams to capture and hold rainwater for agricultural use.
- On sloping land, establish barriers along contours to minimize erosion.
- Build resilience through diversification, integrating crops, trees and animals into small farms in ways that cycle nutrients as efficiently as possible.
- Select and implement farming systems that incorporate multiple conservation agriculture principles. Below are several figures representing successful farming systems and associated best practices:

Foundations for Farming

Also known as Farming God's Way, this system emphasizes keeping the soil covered, minimizing soil disturbance, and maximizing nutrient efficiency through target applications of inorganic or organic fertilizers in permanent planting stations.

Photo source: EDN 98 article in which this image appeared with permission from Brian Oldrieve and Grant Dryden

Zai Pit Microcatchment System

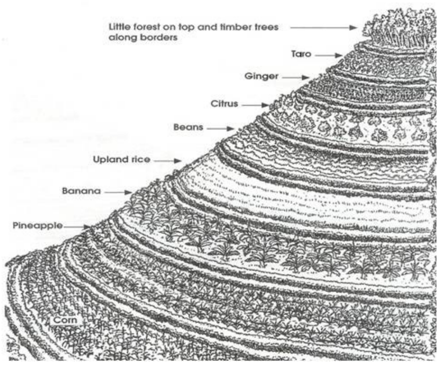
A sytem originating in Burkina Faso, West Africa, in which sorghum or millet seeds are sown in planting basins containing a mixture of soil and fertilizer (manure or microdose of inorganic fertilizer). The planting pits harvest rainwater and concentrate fertility close to plant roots.

Photo Source: Sent to ECHO by Chris Reij

Farmer Managed Natural Regeneration

Farmers allow and manage regrowth of stumps of native trees in their fields. Resulting trees provide leaf litter, increasing soil organic matter, as well as firewood and timber. A related approach, Farmer Managed Agroforestry System, also integrates trees and crops but with greater emphasis on planting native and exotic trees.

Photo Source: Sent to ECHO by Tony Rinaudo



Sloping Agricultural Land Technology

An approach with proven success in the Philippines where high rainfall has adverse effects on hillside agriculture. Erosion of topsoil on sloping land is reduced by planting crops between hedgerows established along contours.

Photo Source: Mindanao Baptist Rural Life Center

Healthy soil is the foundation of healthy ecosystems. A healthy ecosystem is an integrated relationship between abundant life in the soil as well as healthy plants and animals in a continuous cycle of life, death, decay and regeneration.

Indicators of soil health include both soil fertility and soil biology. On degraded lands, soils are typically depleted of organic matter. Without organic matter, applied nutrients are easily lost to leaching (especially nitrogen and potassium) or are bound (especially phosphorus) with other compounds in the soil. Under these conditions, practices that add organic matter to the soil can greatly increase the effectiveness of manure or inorganic fertilizers. Mike McGahuey, in a World Agroforestry blog, put it well: "The question is not, 'Should farmers use inorganic or organic fertilizer?' but rather, 'How can farmers increase soil organic matter in a cost-effective way in order to recycle nutrients, increase fertilizer-use efficiency and establish the foundation for building and sustaining soil productivity in Africa?'" (http://blog.worldagroforestry.org/index.php/2012/04/26/679/).

Keeping the soil covered with plant residues is key to increasing soil organic matter and ultimately restoring degraded soils to the point that they can sustain crop production. Promoters of a farming system called Foundations for Farming, also known as Farming God's Way, refer to this covering as "God's blanket." Over time, organic mulches control rainwater runoff, minimize soil erosion, result in improved soil structure, buffer the soil against extreme pH, and steadily release nutrients that crops need. Replenishing organic matter is especially important in developing farming systems that do not rely completely on inorganic fertilizers, which are increasingly difficult for farmers to afford.

The concept of an organic mulch sounds simple, but how can a farmer realistically apply multiple tonnes per hectare of organic material to a field? The answer to this leads to a discussion of incorporating leguminous plants as green manure/cover crops (gm/ccs) in farming systems. ECHO research in South Africa showed that, with less than 500 mm of rainfall and no mineral or organic fertilizer, lablab (*Lablab purpureus* 'Highworth') spaced 50 x 50 cm apart in the field produced 13 metric tonnes of above-ground plant biomass on a dry weight basis. The resulting biomass contained over 200 kilograms of nitrogen per hectare. In comparison to non-leguminous, natural fallows, leguminous gm/ccs often accumulate more nitrogen without requiring initial fertilizer inputs. Legumes can do this because their roots are easily colonized by soil bacteria that help the plants to convert atmospheric nitrogen to plant-usable forms. Deep-rooted legumes (e.g., lablab and many tree species) are able to bring nutrients up to the soil surface that were previously leached below the root zones of maize or other crop plants. Because the organic material is grown in place, there is no need to transport it. All of that biomass, as long as it is not removed from the field, increases soil fertility and creates an environment conducive for soil microbial life (important for cycling plant-essential nutrients and suppressing weeds. Gm/ccs such as cowpea and lablab also produce edible beans that can be harvested and eaten in addition to grain crops.

In very dry regions, consider the use of long-lived (perennial) trees and shrubs, as their deep roots enable them to withstand significant periods of drought. Leaf litter from the tree canopy contributes to soil organic matter, and prunings provide useful byproducts such as fuelwood and timber. Farmer Managed Natural Regeneration (FMNR) is a system in which the stumps of trees cleared for farming purposes are allowed to regrow and are managed to provide dispersed shade for underlying crops. In the tropics, the partial shade does not hinder cereal crop growth but in fact can increase grain yields. This system has been promoted extensively by Tony Rinaudo and has been successfully implemented in Niger and other Sahelian regions. A related approach, Farmer Managed Agroforestry System, expands on FMNR to include intentional planting of trees into farming systems. Under less extreme conditions, such as those in many parts of Sub-Saharan Africa, there is enough rainfall to keep the ground covered through the use of annual or semi-perennial gm/ccs.

Whether trees or annual cover crops, or a combination of the two are used, it is important to recognize that many factors influence their effectiveness. The various species vary in their climatic requirements. Velvet bean (*Mucuna pruriens*), for example, grows well under sub-humid or humid conditions while lablab prefers a drier climate. Attention should be given to spacing and growth habits of the crops involved to minimize competition of gm/ccs and grain crops for soil moisture and nutrients. It is also important to account for competing uses of crop residues; the need for animal fodder is perhaps most significant in areas where farmers have livestock as well as crops. A good source for selecting a gm/cc system consistent with your crop production goals and climate is a booklet compiled by Roland Bunch entitled *Restoring the Soil: A Guide for Using Green Manure/Cover Crops to improve the Food Security of Smallholder Farmers*.

Keeping soils covered also entails minimum tillage. Frequent plowing breaks up soil aggregates, exposes the soil–along with soil microbes–to high temperatures from the sun, and can lead to losses of topsoil due to erosion by wind and rain. Therefore, we advocate disturbing the soil as little as possible and leaving crop residues on the soil surface. These residues, as explained earlier, have a moderating influence on soil parameters. We have found that soils are ten degrees cooler under the dense canopy of a gm/cc than bare ground. It may be necessary to disturb the soil through weeding operations, but this can be minimized–and restricted to a shallow top layer–by timing any hand-weeding activities to occur when weeds are small. Tilling/plowing plant biomass into the soil does have some advantages. It reduces loss of nitrogen to the atmosphere by placing organic biomass and resulting nutrients deeper in the soil profile. For these reasons, some have suggested that it may be beneficial in year one, before crop residues have had time to decompose and contribute much to soil fertility.

By preserving soil structure, minimum tillage results in numerous pore spaces through which water can pass. Increasing water-filtration capacity helps to maximize the amount of rain water that seeps into the soil as opposed to running off farmers' fields and washing away topsoil. There are numerous strategies that can be implemented along with minimum tillage to "harvest" rainwater.

In parts of West Africa, starting with Burkina Faso, a basin system of agriculture called "zai" has been promoted and successfully implemented on severely encrusted soils with very little water infiltration capacity. The zai system makes use of micropits (approx 30 cm wide by 20 cm deep), into which organic inputs (e.g., manure or compost) and crop seeds are placed. As each zai pit is dug, the soil is placed on the downhill side, resulting in a crescent-shaped, mini water catchment area. Stone bunds, established along the contours of the land, are often implemented in combination with the zai pits. Combining innovations enhances the amount of rainwater that can be "harvested" and kept on the field. Other rainwater harvesting strategies include half moons and terracing. On a larger scale, where feasible, dams can be constructed to raise the water table in areas surrounding streams and riverbeds. A unique type of dam that has been implemented successfully in East Africa is the sand dam. The premise of a sand dam is to store water in sand, which reduces loss of water to evaporation.

Addressing issues of soil health and water resources allows farmers to more effectively diversify their farms, growing multiple crops and integrating trees and animals for increased resilience. If one crop fails, another may survive, thus mitigating shortfalls due to drought or other disasters. Trees and animals provide byproducts for on-farm use or income generation. Many smallholder farms already incorporate animals. The grazing of farm animals needs to be controlled and managed to guard against the loss of plant cover and resulting land degradation due to overgrazing. Trees can be managed as hedges, with prunings used to mulch fields and/or to feed to livestock. Farms best able to sustain production on marginal lands are those that most efficiently cycle nutrients, building and keeping fertility on the land.

To summarize, improving the capacity of degraded lands to grow crops is crucial to ensuring long term food security. Although there is no single practice that applies to all climates and situations, there are specific, practical steps that farmers can take to improve their soils. These center around preserving and building soil organic matter, protecting against erosion, and diversifying for resilience. The practices discussed above have proven successful on ECHO's Global Demonstration Farm and in many developing countries. There is still much to learn. We encourage and invite feedback through our networking portal, www.ECHOcommunity.org, where there are a number of geographical and topic-based forums where you can contribute ideas and network solutions.

References and Resources

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Links to information on farming systems

Foundations for Farming (also known as Farming God's Way)

- Foundations for Farming: http://www.foundationsforfarming.org/
- Farming God's Way: http://www.farming-gods-way.org/

Farmer Managed Natural Regeneration and Zai:

- Reij, C., G. Tappan, and M. Smale. 2009. Agroenvironmental transformation in the Sahel: http://www.ifpri.org/sites/default/files/publications/oc64ch07.pdf
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Sloping Agricultural Land Technology: http://www2.mozcom.com/~mbrlc/

ECHO Technical Notes (https://echocommunity.site-ym.com/?page=tech_notes)

Acid Soils of the Tropics (*TN* 48)

A-Frame Level (*TN 55)*

Farmer Managed Agroforestry System (*TN* 60)

Farmer Managed Natural Regeneration (*TN* 65)

Foundations for Farming (*TN* 71)

Green Manure Crops (*TN* 10)

Soil Fertility (*TN* 57)

Zai Pit System (from *Agricultural Options for the Poor* book)

EDN articles (https://echocommunity.site-ym.com/?page=EDN_Docs)

A Fresh Look at Life below the Surface (*EDN* 96)

Nutrient Access vs Quantity (*EDN* 74)

ECHO Asia Resources (http://echocommunity.org/?page=AsiaImpactCenter)

Modified Green Manure Cover Crops (slide presentation)

Sustainable Upland Farming (slide presentation)

The Use of Green Manure Cover Crops for Relay Cropping in Northern Thailand (*EAN* 10)