CPDC
Caribbean Policy Development Centre

CREATING FARMS THAT ARE RESILIENT TO NATURAL HAZARDS: SMALL FARMERS TRAINING MANUAL

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About CPDC

The Caribbean Policy Development Centre was established in 1991, by Caribbean NGOs to work towards policy change in the interest of Caribbean peoples. CPDC's mandate is to help Caribbean NGOs to:

- Understand how policies affecting Caribbean people are made,
- Share information about policies and decision-making processes,
- Work to influence and bring positive change to the development process, and
- Lobby for policies which are in the interest of Caribbean people.

The CPDC is a regional network, whose membership comprises other regional development organizations, national networks, umbrella organisations, national agencies, and individuals. Since its inception, the CPDC undertaken research, analysis, advocacy and lobbying and has formulated policy positions on a variety of issues relevant to Caribbean society. With a history of lobbying and an impressive portfolio of projects and programmes implemented on behalf of Caribbean peoples, CPDC has been recognised as an important social partner in the development of the region.

About CCRIF SPC

CCRIF SPC (formerly the Caribbean Catastrophe Risk Insurance Facility) is the world's first multi-country, multi-peril risk pool based on parametric insurance. CCRIF provides parametric catastrophe insurance for Caribbean and Central American governments, and for electric utility companies. CCRIF offers parametric insurance for tropical cyclones, excess rainfall, and earthquakes and for the fisheries and electric utilities sectors – insurance products not readily available in traditional insurance markets. The Facility operates as a development insurance company – as the goods and services it provides are designed to enhance the overall developmental prospects of its members. CCRIF has 23 members – 19 Caribbean governments, 3 Central American governments and 1 Caribbean electric utility company. Since its inception in 2007, CCRIF has made 54 payouts totalling US$245 million to 16 of its members. All payouts are paid within 14 days of the event.

CCRIF was developed under the technical leadership of the World Bank and with a grant from the Government of Japan. It was capitalized through contributions to a Multi-Donor Trust Fund (MDTF) by the Government of Canada, the European Union, the World Bank, the governments of the UK and France, the Caribbean Development Bank and the governments of Ireland and Bermuda, as well as through membership fees paid by participating governments. In 2014, a second MDTF was established by the World Bank to support the development of CCRIF SPC's new products for current and potential members and facilitate the entry of Central American countries and additional Caribbean countries. The MDTF currently channels funds from various donors, including: Canada, through Global Affairs Canada; the United States, through the Department of the Treasury; the European Union, through the European Commission, and Germany, through the Federal Ministry for Economic Cooperation and Development and KfW. Additional financing has been provided by the Caribbean Development Bank, with resources provided by Mexico; the Government of Ireland; and the European Union through its Regional Resilience Building Facility managed by the Global Facility for Disaster Reduction and Recovery (GFDRR) and The World Bank. .

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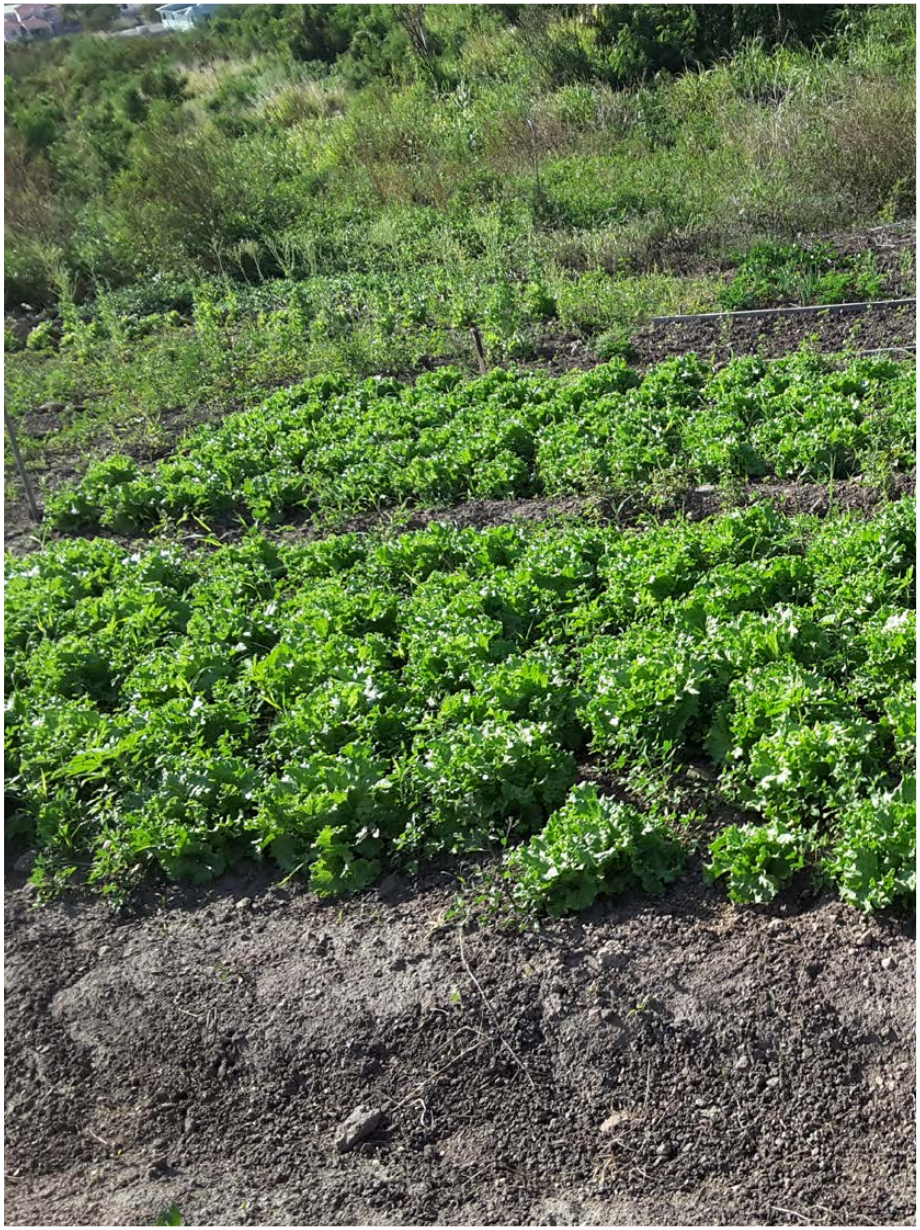


INTRODUCTION

CARIBBEAN CLIMATE DISASTERS AND CLIMATE CHANGE

Globally, the social and economic impacts of natural hazards have totalled billions of dollars in costs. These hazards affect individuals, families, local communities, businesses and governments. Economic losses from natural disasters continue to increase with devastating consequences for countries. These losses totaled US$92 billion in 2015.[1] In 2019, global losses were estimated at US$166 billion and US$210 billion in 2020.[2]

The International Federation of the Red Cross estimates that from 2008 to 2017 a total of 3,751 global natural hazards were recorded, of which 3,157 (84.2%) had weather-related triggers, with floods and storms alone accounting for almost two-thirds of all incidents.[3]

Small island developing states (SIDS) are particularly vulnerable to natural hazards. Their exposure to meteorological hazards and rising sea levels, small size, high density and concentration of population especially along the coast, and high per capita costs of roads, ports and airport infrastructure contribute to this vulnerability.[4] Similar to other SIDS, Caribbean islands face high levels of vulnerability and also experience costly, frequent and intense natural disasters. These islands are considered to be among the 25 most vulnerable nations in terms of disasters per capita or land area.[5] The Organisation for Economic

Co-operation and Development (OECD) notes that the Caribbean is the second most environmentally hazard-prone region in the world.[6] Natural hazards are the main environmental challenge, along with climate change, loss of biodiversity, lack of access to clean water, and air and water pollution. The region faces particular vulnerabilities to sea-level rise, floods, earthquakes, volcanic eruptions, landslides, droughts, and hurricanes, most seismic hazards such as volcanic eruptions and earthquakes are not particularly exacerbated by climate change.

The impact of natural disasters has been well documented. In the Eastern Caribbean, Dominica, Grenada and St. Vincent and the Grenadines have experienced severe weather occurrences which pose threats to agriculture and coastal areas, and increase the risk of water and food insecurity. Traditionally, agriculture has played a central role in the Caribbean and the economic costs of natural disasters to the region's farming communities have been substantial. The most notable impacts of natural disasters on small farming operations have been caused by the passage of tropical storm and hurricane systems.

In Grenada, the devastation caused by Hurricane Ivan in 2004 resulted in significant losses to the agricultural sector. The World Bank estimated

1 Hallegatte, Stephane, Adrien Vogt-Schilb, Mook Bagalore, & Julie Rozenberg, "Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters", 2017, The World Bank. https://www.gfdrr.org/sites/default/files/publication/Unbreakable_FullBook_Web-3.pdf

2 "Record Hurricane Season and Major Wildfires: The Natural Disaster Figures for 2020", Munich Re, January 7, 2021. https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/media-information/2021/2020-natural-disasters-balance.html#1105489295

3 International Federation of Red Cross and Red Crescent Societies, "Leaving No One Behind," 2018 World Disasters Report, Geneva, Switzerland, 2018. https://media.ifrc.org/ifrc/wp-content/uploads/2018/10/B-WDR-2018-EN-LR.pdf

4 Slany, Anja, "Multiple Disasters and Debt Sustainability in Small Island Developing States," UNCTAD Research Paper No. 55, United Nations Conference on Trade and Development, December 2020. https://unctad.org/system/files/official-document/ser-rp-2020d14_en.pdf

5 Otker, Inci and Krishna Srinivasan, "Bracing for the Storm," Finance and Development (March 2018). https://www.imf.org/external/pubs/ft/fandd/2018/03/pdf/otker.pdf

6 OECD et al., Latin American Economic Outlook 2020: Digital Transformation for Building Back Better, OECD Publishing, Paris, September 2020. https://doi.org/10.1787/e6e864fb-en.

that Hurricane Ivan destroyed up to 90 per cent of forest vegetation and resulted in the loss of topsoil and nutrients crucial to agricultural production. St. Vincent and the Grenadines experienced significant damage in 2010 with the passage of Hurricane Tomas. The losses attributed to the agricultural sector by Hurricane Tomas were estimated at US$26 million. In 2017, Hurricane Maria impacted Dominica with devastating consequences, as all sectors of the country were affected. Damage to the agricultural sector was estimated at US$55 million.[7]

The importance of agriculture to the region cannot be overestimated or overvalued. The sector has been identified as an important area that drives social and economic development in the region, affecting food production, employment and land use. Bishop (2013) noted that the agri-sector assists in maintaining community cohesion, social stability and contributes to ensuring a minimum level of food security in the Caribbean. Key to the sector's survival are smallholder producers who engage mainly in inter-cropping and mixed farming, and whose contribution has been hailed by organisations such as the International Fund for Agricultural Development (IFAD 2011) as the backbone of primary agricultural food production within the region.

Small farmers are often low-income earners who generate relatively small returns from their holdings (FAO 2013). These farmers have also been negatively affected by the increasing intensity of tropical weather systems and the unseasonal weather patterns related to climate change. The Inter-American Institute for Cooperation on Agriculture (IICA 2014) notes that there is significant evidence to suggest that the Caribbean is experiencing the effects of a changing climate, indicated by more prolonged and frequent droughts, greater variability in rainfall, and drier and hotter summers. Storms, hurricanes and flood events have resulted in losses of agricultural assets, livestock, and crop infrastructure.

Globally, small farmers are considered to be disproportionately vulnerable to natural hazards and climate change. Where heavy rainfall occurs with high winds, risk to forestry crops is high. Changes in temperature, rainfall and the frequency or intensity of extreme weather events directly affect their crop and animal productivity and their household's food security, income and well-being.

Wind disasters are responsible for tremendous physical destruction, injury, loss of life and economic damage. Wind disasters such as hurricanes and tornadoes occur relatively frequently and affect populations in multiple ways. The estimated average annual damage caused by these hazards exceeds US$6 billion, constituting more than 50 per cent of all total weather-related damage and more than 40 per cent of total natural disaster-related damage.[8] Tornadoes, storms, and cyclones/hurricanes are weather systems characterized by strong winds. Hurricanes are classified by a five-category system based on maximum sustained wind speed occur frequently in the Caribbean. Between 1979 and 2019, the five most deadly hurricanes which impacted the Caribbean region took a total of 11,152 lives.[9]

All categories of hurricanes can cause catastrophic wind damage and significant loss of life simply due to the strength of their winds. Additionally, they can produce deadly storm surges and rain-induced floods. The accompanying strong winds and torrential rains often result in swollen rivers, flash floods and landslides.

7 ACP-EU, Post-Disaster Needs Assessment: Hurricane Maria, A Report by the Government of Commonwealth of Dominica, November 15, 2017. https://reliefweb.int/sites/reliefweb.int/files/resources/dominica-pdna-maria.pdf

8 Marchigiani, Raffaele, Stephanie Gordy, James Cipolla, Raeanna C. Adams, David C. Evans, Christy Stehly, Sagar Galwankar, Sarah Russell, Alan P. Marco, Nicholas Kman, Sanjeev Bhoi, Stanislaw P. A. Stawicki, and Thomas J. Papadimos, "Wind Disasters: A Comprehensive Review of Current Management Strategies," International Journal of Critical Illness and Injury Science 3 no. 2, (2013): 130–142.

9 "Five deadliest hurricanes to hit the Caribbean in past 40 years", Loop News Jamaica, October 28, 2019, https://www.loopjamaica.com/content/5-deadliest-hurricanes-hit-caribbean-past-40-years-1

CLIMATE RISK FINANCING FOR SMALL FARMERS

There is no doubt that small farmers are greatly affected due to their inherent vulnerabilities and comparatively lower capability for risk reduction and adaptation. The availability of risk reduction finance for these farmers is limited, and where available, farmers are often unaware of such mechanisms. Higher incidence of agricultural risks (climatic and non-climatic) warrants the provision of crop insurance products to farmers for transferring their risks. Financial agricultural risk mitigation instruments, including insurance, can provide smallholder farmers – a group that is typically excluded from the most basic financial services – with affordable tools to transfer risk deriving from climate variability, allowing them to make investments and reduce their vulnerability to shocks[10].

A CPDC (2021) study noted that over the last twenty years, the use of parametric Insurance (PI), having emerged from different arenas which would have included climate smart agriculture (CSA) practice, has increased in the area of insuring against extreme weather risks in Latin America and the Caribbean. As the terminology suggests, 'parametric' insurance is a category of insurance based on the use of specific measured 'parameters', such as rainfall amount, wind speed or seismic activity linked to an insured's loss. The claims payment amount is fixed in advance in the insurance contract and comes into effect when threshold conditions (i.e., parameters) are exceeded. In the agricultural sector, PI plays a key role as a risk management tool that affords small-scale farmers a financial safety net, especially those facing risks associated with climate change, and can give farmers greater investment security, therefore allowing them to invest in agricultural inputs in order to expand production [11].

CCRIF SPC offers parametric insurance policies to 19 Caribbean governments for tropical cyclones, excess rainfall and earthquakes and some governments have used their payouts to support the agriculture sector, for example in St. Lucia following Hurricane Matthew in 2016. Through the Climate Risk Adaptation and Insurance in the Caribbean project (CRAIC) , CCRIF and partners, the Munich Climate Insurance Initiative and the ILO Impact Insurance, have developed the microinsurance product, the Livelihood Protection Policy (LPP), which offers individuals such as farmers and day labourers access to financial protection against losses that result from heavy rainfall and strong winds. The LPP provides quick payouts (within 14 days) after a policy is triggered. Also, CCRIF offers to governments the COAST parametric insurance policy, which requires that payouts provided to the government are automatically disseminated to persons in the fisheries sector, including fishers, boat captains and crew, and fish vendors etc. Also available is the Flexible Hurricane Protection (FHP) product, launched by the Caribbean Resilience Execution Agency for Dominica (CREAD), which aims to assist the people of Dominica to manage the effects of storms and hurricanes.

A 2020 CPDC study on natural disaster impacts on small farming operations in the Eastern Caribbean countries of Dominica, Grenada and St. Vincent and the Grenadines revealed that farmers currently face greater uncertainty than usual due to the acute vulnerability of their livelihoods resulting from the Caribbean's high exposure to extreme weather events and the impacts of climate change.[12]

10 Risk management practices of small farmers: https://think-asia.org/bitstream/handle/11540/8149/Risk-Management-Practices-of-Small-Farmers.pdf?sequence=1

11 Caribbean Policy Development Centre[CPDC] , "Gender and Climate and Disaster Risk Finance and Insurance" https://climate-insurance.org/wp-content/uploads/2021/05/Gender-and-Climate-Disaster-Risk-Finance-and-Insurance-A-Focus-on-Small-Scale-Farmers-in-Antigua-and-Barbuda_-Barbados-2.pdf

12 Caribbean Policy Development Centre [CPDC], "Situation Analysis of Natural Disaster Impacts on Small Farming Operations in Three Easter Caribbean Countries", 2020, https://cpdcngo.org/download/a-situational-analysis-of-natural-disaster-impacts-on-small-farming-operations-in-three-eastern-caribbean-countries-11/

The study highlighted the significant challenges small farmers confront due to the negative effects of natural hazards and climate change on their productive capacity. The immediate effects of natural hazards on their livelihoods include the loss of crops, farming inputs, farming equipment and income. Post-disaster livelihood recovery for most small farmers is marked by prolonged periods of difficulty accessing technical and financial support, particularly from government entities. These combined impacts of repeated exposure to natural hazards also cause psycho-social effects such as feelings of despair due to the inability to provide for their families.

The impacts of climate change and natural hazards are felt throughout the year. Small farmers highlighted critical effects such as extended drought conditions, flash flooding, increases in pests and diseases, and changes in the occurrence, duration, and intensity of the annual wet and dry seasons. These changes severely affect crop cultivation and livestock production, as well as the management of holdings by small farmers.

The findings of the study resulted in several viable recommendations being made by the small farmers to minimise the impacts of these issues. Their recommendations included the following:

1. Sensitisation of small farmers in disaster risk management and resilience-building
2. Training in climate-smart agriculture techniques to sustain farm productivity and increase profitability
3. Knowledge and skills acquisition in cultural practices such as the development of seed banks, use of windbreaks, and crop selection to minimise harvest loss and reduce soil erosion
4. Capacity building for farmers' organisations to enable provision of higher levels of diversified services to members
5. Increased collaboration among key agricultural agencies to ensure more targeted and effective support of small-scale farmers

Based on the recommendations provided by small farmers and technical experts, it is evident that the formulation and/or enhanced implementation of national agricultural plans with a central focus on small-scale farmers and inclusive of a comprehensive disaster management plan is necessary. The economic and social costs of natural hazards are heavy. In the aftermath of destruction, already scarce resources have to be directed towards recovery efforts. Better preparation should diminish the need for countries to finance the cost of rebuilding after natural disasters and allow farmers to make necessary repairs or take other actions to return to work.

PURPOSE OF THIS MANUAL

This training manual is an output of a project entitled *Strengthening the Capacity of Small Farmers in the Eastern Caribbean to Respond to the Effects of Natural Disasters through Disaster Risk Management and Adaptation Measures*, funded by The Inter American Foundation (IAF) and CCRIF SPC. The project seeks to improve small farmers' resilience and their ability to mitigate, as much as possible, and recover from natural hazards. The manual presents a participatory approach to training on regional climate change issues and natural hazards identified by small farmers in the CPDC (2019) study. The manual has been divided into the following thematic areas:

MANAGING DROUGHT

EXTREME RAINFALL EVENTS

EXTREME WIND EVENTS

POST-DISASTER RECOVERY AND CONFRONTING CLIMATE CHANGE

The target audience for this manual is small rural farmers, disaster risk management officers and agriculture extension officers.

SECTION 1

SUSTAINABLE FARMING PRACTICES

INTRODUCTION

Farming is about the protection and conservation of the land and its environs, the management and application of traditional and modern scientific knowledge, and the application of economic and accounting principles for the production of livestock and produce. This manual focuses on agricultural farming and associated small farmers. Farming is both a science and a business. The land is the productive base of the farming enterprise and must be kept in a healthy condition. The principle of sustainability must be understood and actions should be taken to implement various elements of the concept in a timely fashion. Sustainability incorporates processes and actions through which farmers avoid the depletion of natural resources in order to keep an ecological balance that maintains nature's services that maintain our quality of life. If farmers and other stakeholders build and/or strengthen the natural resilience within the agricultural sector, the benefits of better quality and increased quantities of produce can be reaped.

Designing and implementing a production plan is critical for farmers and farming enterprises, if they are to be successful. An example of a production plan for agricultural crops is provided below.

STEPS	ACTIVITY	IMPORTANT FACTORS	COMMENT
1	Site selection	Past history of crops, soil profile, rain fed or irrigation, disease history, slope of land, weed control.	Selecting the right site is pivotal to creating the best environment to be successful.
2	Land preparation	Soil type, levels of soil compaction, wind direction: cross wind rows or not, incorporation of mulch or fertilizer. Preparation should be done following contour lines.	Preparing the foundation for production is critical.
3	Seedling establishment	Adequate moisture level of soil, available nutrients, etc.	Healthy seedlings are more resilient and generally yield more produce at harvest time.
4	Disease and pest inspection/ control	Checking both sides of the leaves, root crown and branches.	Regular checks will tell you when to start remedial actions, which can save money and increase yields if done adequately. Use proactive measures that prevent build-up of pests.
5	Establishing irrigation systems and schedules	Monitoring soil moisture levels before and after wetting.	Plants having access to water is extremely important. Water is necessary for several critical processes like cell growth and multiplication, fruit initiation, food production and general well being of plants.
6	Inspecting for signs of nutritional deficits	Looking for signs of paleness, blotches or yellow spotting or wilting.	Early detection will allow you to treat plants early and maintain their growth and productive processes.
7	Disease control	Implementing the relevant disease control remedy on a timely and thorough basis (adequate plant coverage).	This may mean the difference between total crop loss or reduced yield. It may also improve the quality of produce.
8	Harvesting	Avoiding damage to plants, handling produce carefully, packing properly without damaging produce.	Significant yields can be lost at the harvesting and post-harvest stages if there is poor handling. While harvesting, take care not to damage branches that will bear in future.

Table 1. Production Process Plan

In the production phase, the farmer should also be thinking about optimizing production in the context of drought. For example, planting at a higher density (more plants per unit area) can give higher yield for the space used, but requires more water and nutrients to satisfy the plant growth and yield. In a drought situation, it may be more effective to grow at single density, so that the roots of each plant can still get adequate water and nutrients. A higher density in the context may result in poorer yield per unit area.

SECTION 2

DROUGHT

INTRODUCTION

In any country, and even more so in small island developing states, having access to and the management of water is key to food production and hence towards achieving food security. Any farming enterprise that does not effectively manage its water will face severe difficulties in producing good quality commodities. Drought is a complex natural hazard: a prolonged dry period in a natural climate cycle. It is a slow-onset phenomenon caused by a rainfall deficit combined with other predisposing factors[13] such as heat, wind and soil conditions. Drought often results in displacement of people and leads to water and food shortages and is likely to have a long-term environmental, economic and health impact on the population.

Droughts are the most detrimental of all natural disasters. Globally, approximately one-fifth of the damage caused by natural hazards can be attributed to droughts, and the cost of droughts is estimated to be around US$80 billion[14] per year. The FAO estimates that more than 80 per cent of the damage and losses caused by drought are to agriculture, especially livestock and crop production.[15] A major drought can reduce crop yields and crop area because less water and soil moisture are available for crop growth. Drought can reduce the total amount of

13 https://www.who.int/hac/techguidance/ems/drought/en/

14 Gerber, Nicolas and Alisher Mirzabaev, 2017, "Benefits of Action and Costs of Inaction: Drought Mitigation and Preparedness – A Literature Review". Integrated Drought Management Programme (IDMP) Working Paper 1, World Meteorological Organization (WMO), Geneva, Switzerland and Global Water Partnership (GWP), Stockholm, Sweden, https://library.wmo.int/doc_num.php?explnum_id=3401

15 Food and Agriculture Organization of the United Nations [FAO], "The Impact of Natural Hazards and Disasters on Agriculture, Food Security and Nutrition", 2015, http://www.fao.org/3/i5128e/i5128e.pdf

cropping area for any one crop, after some of the plants are stunted or die (smaller area to harvest from). Sometimes farmers are forced to forego complete crops, either pre or post planting, when water has to be rationed. The overall cropping area is therefore reduced, either way.

Droughts also result in increased cost, workload, and stress on farmers.

Drought impacts crop growth and development at different levels, including soil moisture uptake, root growth, shoot growth, various plant processes such as photosynthesis, respiration, plant water uptake, and final yield.

In recent years, there has been global concern that droughts may be increasing in frequency, severity, and duration given changing climatic conditions and documented increases in extreme climate events.[16]

In 2020 a state of emergency was called in St. Lucia due to prolonged drought. Irrigation of crops using any water not collected on-farm was banned island-wide. Fines were issued to farmers not complying. Other islands in the region were similarly impacted. Adopting an approach that emphasizes drought risk reduction is imperative given the spiraling impacts of droughts and projected trends for increased frequency, severity and duration.

HOW TO REDUCE THE IMPACTS OF DROUGHTS

As the dry seasons in the Caribbean become less predictable, longer and more intense, water management has become the key factor to farms' success or failure. During dry periods farmers spend most of their on-farm time irrigating. The following sections first focus on simple and affordable water management changes, progressing to more aggressive actions.

16 Wilhite, Donald A., Mannava V. K. Sivakumar and Roger Pulwarty, "Managing Drought Risk in a Changing Climate: The Role of National Drought Policy", Weather and Climate Extremes 3 (June 2014): 4-13, https://doi.org/10.1016/j.wace.2014.01.002

Simple and easy practices to use less water

- Plant a crop after a significant rainfall to slow the loss of this water to evaporation.
- Prepare your soil flatter for the dry season, and plant in trenches or furrows or deeper holes. This depends on crop, production system and location: planting in furrows is theoretically good (e.g., the early cane hole system for sugar cane), but not likely practical on a farm where other mechanical operations such as spraying and fertilizer spreading have to be done.
- When approaching the dry season, do not dig deep drains, or dig no drains at all.
- Mulch walkways: exposed spaces between beds suck water out of the bed.
- Focus on growing crops in low-lying areas and areas less exposed to direct, strong wind.
- Plant drought-tolerant crops and varieties. In most countries this information can usually be accessed from the Ministry of Agriculture and extension officers.
- Establish shelter/shade crops to create micro-climates. This is dependent on the type of crops. Most tropical vegetable crops need full sunshine to perform best, however, shelter from gusty wind can benefit all.

BEST PRACTICES FOR IRRIGATION AND WATER MANAGEMENT

One should aim to use water as efficiently as possible. This can be done by applying the right amount of water, at the right time, in the right place. Drip irrigation allows us to do this more effectively than sprinkler types. Systems which recycle water, e.g., aquaponics, are most efficient and save as much as 90 per cent of the water applied. Keeping soil rich in organic matter, mulching, using windbreaks and protective structures all help to improve the effectiveness of drip irrigation.

Photo 1: *Irrigation head showing meter (on ground) and open space for fertilizer injector*

A drip irrigation control head is helpful for managing drip irrigation. The control head should ideally have the following components:

- Meter to measure the amount of water applied
- Manual on/off valve or a timer to allow automatic watering
- Filter to keep lines from getting blocked up easily
- Fertilizer injector to apply fertilizer along with the water

It is important to monitor crops as well, when irrigating, to get feedback on how well the watering system is working. It is also helpful to remember that plants need water to take in nutrients. Applying fertilizer through the water, e.g., fertigation, through drip lines or by hydroponics allows for the best application of plant nutrients.

Photo 2

(Photo Credit: Stevenson Skeete) Photo 2 Example of a drip line with a valve (red) that c an vary the flow for that individual row of crop.

Some benefits of using drip irrigation are:

- Delivers water directly in the crop root zone and can save up to 66 per cent of water used by sprinkler system

Operates with low water pressure and can be left on for long periods while the farmer is not present

Drip irrigation also has some challenges:

- Can be costly to set up
- Labour-intensive to move and repair lines
- Repair of lines is a continuous process. Proactive care of lines reduces the need for repairs.

GUIDELINES FOR IRRIGATION MANAGEMENT:

Test the soil's moisture level before irrigating (to detect moisture level, insert a finger into the soil 3/4 inches deep in several locations near your crop's root zones; however, if you want to be more accurate purchase a tensiometer or moisture sensors, which are relatively cheap). These are good for measuring soil moisture, and some can also be linked to the irrigation system to allow feedback and control.

Apply water at a timing that suits the growth phase of crops. If water is limited, make sure that there is enough to supply the times when plants are flowering, setting fruit or pods and fruit or tuber growth. For example, people often irrigate watermelon plants carefully just after planting, but relax the watering later when the fruit are growing and the demand for water is peaking. If one cannot satisfy this demand, it may be better to delay planting a particular crop than to risk poor yield and produce quality.

Check drip emitters often to make sure they are working properly and that plants are getting the correct amount of water. This is especially important for water from wells, rivers and ponds. Use a good filter and check it often. Drip is the most efficient, but there are several uses of overhead application, including germinating seedbeds and pressure spraying plants to disrupt pest infestations of aphids, whitefly, and mites.

Photo 3: Tensiometer

PHYSICAL CHANGES TO THE LANDSCAPE TO CAPTURE AND STORE MORE WATER IN-FIELD

Contour ploughing, drains and bunds

A contour line is a perfectly horizontal line (parallel to the horizon). The best practice for water and soil conservation is to make the beds and drains as level as possible, forcing water to infiltrate down into the soil and not run off.

CONTOUR CULTIVATION

Flat horizontal beds and drains slow the movement of water down the slope, allowing more in-soil water storage during dry season. Contour drains should be as level as possible for their whole length. Excess water will always find a way to flow downwards even if there is only a slight gradient. In the dry season, it is important to remember that drains speed up the removal of the already limited amount of water in the beds.

CONTOUR BUNDS

These are mounded beds (or berms) along the contour with drains on the upslope side. Berms are often created (small raised areas) in landscapes. On a hillside they follow the contour lines. When contour drains are cut, the soil that is removed is placed on the downhill side of the drain (see Illustration 1). These mounded strips (called bunds or berms) run along the contour, helping to form the drains. The drains safely channel excess water that would otherwise rush down the hillside, eroding soil and eventually causing gullying.

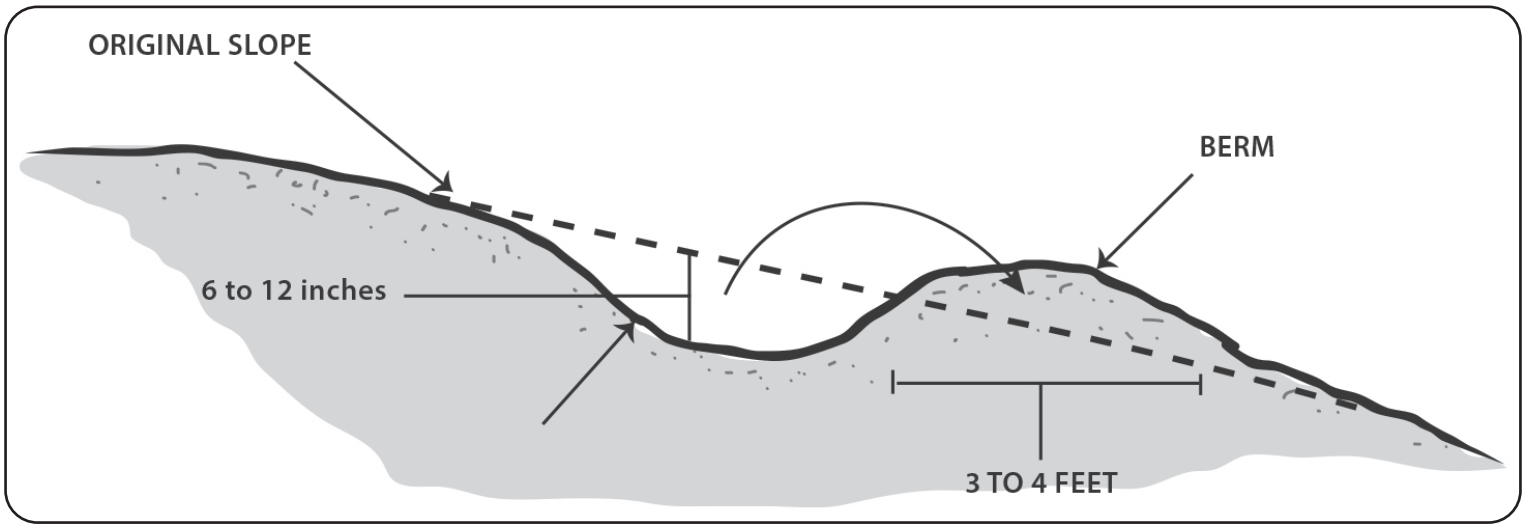


Illustration 1: A contour bund

CONTOUR SWALES

Large contour swales are created to stop and collect water moving down-slope and store it in long extended underground ponds called a 'lens' along contour lines (see Figure 3 below). During heavy rainfall events, significant amounts of water can be stored above ground in the swale trench in extremely large swales and released slowly into the subsoil down-slope as it begins to dry. These types of interventions can permanently change dry landscapes into wetter, fertile ones. However, it involves very dramatic changes to the water table that will permanently change the natural paths and rate of water and nutrients moving through the system. This will leave some areas with less water and nutrients but most areas with increased amounts. Before undertaking permanent earthworks, a survey and assessment should be conducted and engineers consulted.

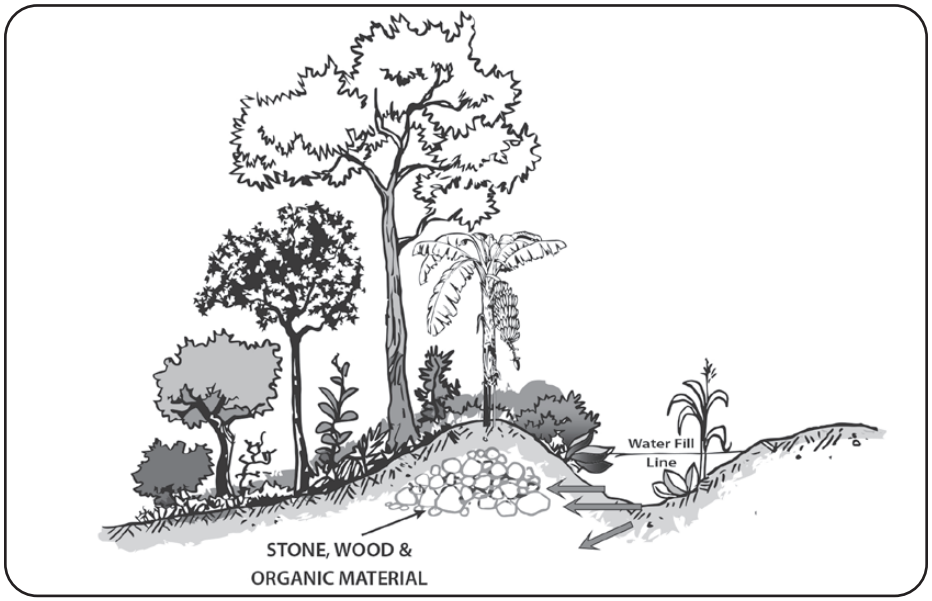


Illustration 2: Demonstrates the position of the berm on the contour bund. This is the most common form of hillslope cultivation in the region.

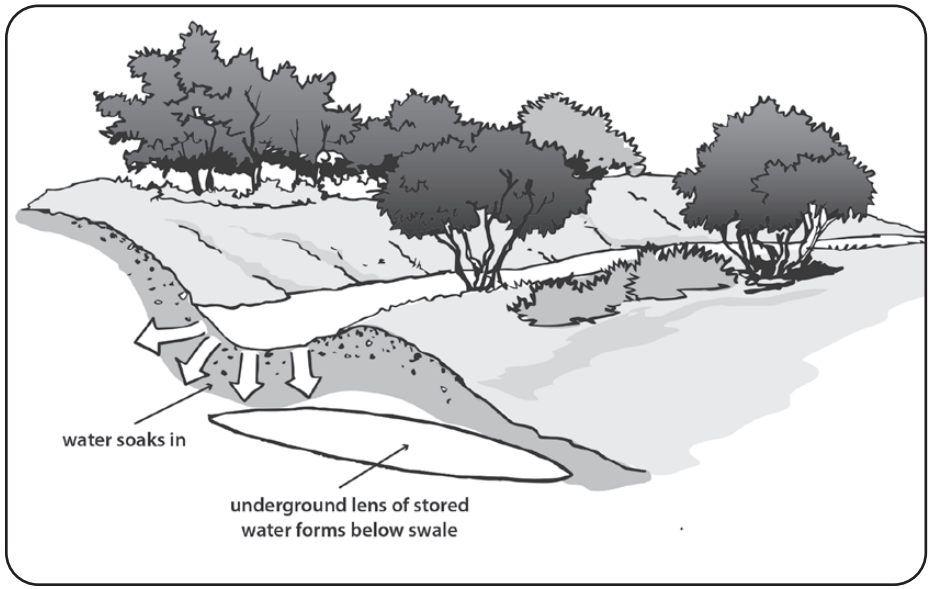


Illustration 3: Showing increased storage of water under the swale

Buried stone, wood and organic material increase the water storage capacity of the swale. Trees planted near the material will root into it very quickly, benefitting from the stored water, free drainage, and the nutrients released as organic matter breaks down. Swales combine perfectly with Agroforest buffer strips. Agroforest buffer strips can be used to reduce the impact of gusty winds (see example on pages 45, 46).

MULCHING: NATURAL AND ARTIFICIAL MULCHING COMPARED

Mulching is an old art of covering crop beds with natural (e.g., dry grass) or artificial materials, usually to improve moisture retention and suppress weeds. Natural mulch materials, such as shredded leaves or dry grass, also tend to cool the surface and add nutrients as they decompose.

Living mulch is a remedy for both drought and heavy rainfall (See page 33 Section on Extreme Rainfall Events). Soil is rarely left completely uncovered in nature. Mulching can lead directly to increased yields and profits in both the short and long term while greatly reducing the amount of water lost to evaporation from the soil surface. Figure 5 provides examples of mulching from Trinidad and Tobago and Guyana.

Mulching practices	Opportunities and best practices	Challenges and considerations
ORGANIC MATTER MULCH: VETIVER 	• Mowed grass – rainy season • Fallen leaves – dry season • Vetiver grass cut and used as mulch • Seaweed – washed to remove salt • Mulch drains or inter-bed spaces	• Keep 2-3' away from the base of plants • Avoid thick mulching in areas that are very wet and prone to slug and snail infestation • Do not mulch with weeds that re-grow
BLACK PLASTIC MULCH IN GUYANA 	• Affordable, easy to apply/install • Is becoming widely available in the region • Works excellently for water conservation when used with drip tape • Can almost eliminate weed growth	• Damages easily and replacement needed every 1-2 years, creates a lot of waste • Generates excessive heat, in tropics white plastic with reflective liner is much better, but less available • Rainfall becomes unavailable to crops, therefore continual irrigation required (could incorporate water storage in design and use harvested water)
LIVING MULCH IN TRINIDAD 	• Plant fast growing plants that cover large areas like lettuce or pac choi, mustards, etc. • After establishment, secondary main crops can be planted to minimise exposure • Harvest or remove mulch crop before target crop is affected by competition	• Living mulches within the same plant family as the main crop can harbour pests and disease that affect the crop • Competition for water and resources • During periods of living mulch establishment soil is left exposed

Table 2

WATER COLLECTION, STORAGE AND CATCHMENT PONDS

Photo 4: Tanks used for rainwater harvesting in Grenada

Photo 5: Buried pipe at natural spring site

Bury outlet drain pipe carefully during construction by compacting clay around pipe to limit leakage. Rainwater harvesting (see Photo 5)

- Collect water off roof structures, concrete pads, plastic liners or tarps installed on the landscape
- One heavy rainfall can be enough for weeks if enough collection and storage capacity is available
- Water catchment ponds

Simple hand-dug catchment ponds can collect and store thousands of gallons while providing habitat, creating micro-climates and other positive impacts, including:

- Increased biodiversity and helping bees
- Creation of an alternative income (fish and prawns)
- Family food sovereignty

CAUTION!

The placement of a pond is critical to both structural stability and its collection ability/ capacity.

- Ensure the down-slope pond wall is at least as wide as the pond is deep
- Install a pond liner and cover pond, if possible, to improve retention during dry periods
- Plant trees around ponds to create shade and reduce evaporation
- Building ponds close to and creating a diversion channel from a natural waterway that flows during heavy rainfall events changes a storage pond into a catchment pond

DIVERTING FROM WATER COURSES AND RIVERS USING SMALL DAMS

Sustainable damming of waterways: Key considerations

1. Find a diversion point that is protected from heavy flow events.
2. Divert water as high above your farm as possible. At 17m or 50', near maximum water pressure is achieved.
3. Divert the water into a tank or reservoir that can be easily cleaned out.
4. Filter collected water before it enters pipes leading to the farm using the appropriate screens and filters.
5. Remove only the amount of water that is needed: limit excess water flowing to the farm.
6. An overflow system at a diversion tank must take excess water from the tank and return it to the water course as close as possible to the extraction point.

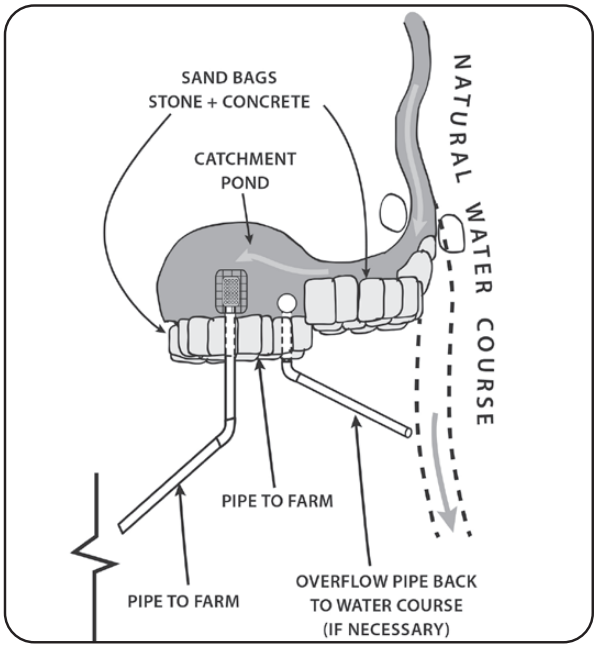


Illustration 4: Sustainable damming of water.

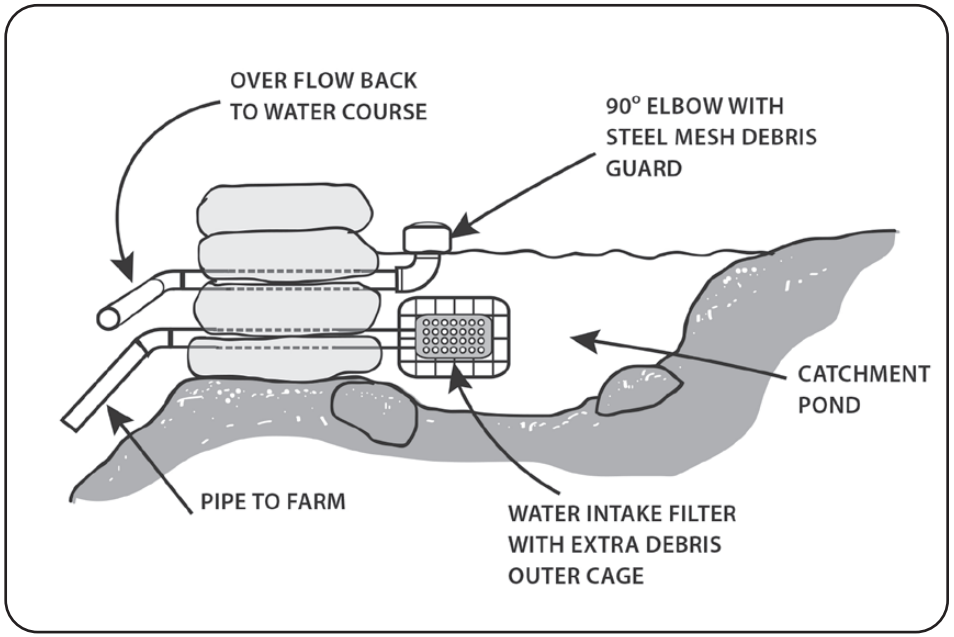


Illustration 5: Irrigation system without a fuel pump

SUSTAINABLE PUMPING: SOLAR, WIND AND HYDRO-RAM PUMPS

Most farmers that pump water for agriculture use gasoline or diesel mechanical pumps. Illustration 4 illustrates an irrigation system with a fuel pump. This has been effectively done for generations in the region. Alternative and sustainable methods that do not burn fossil fuels can be much less expensive and more reliable.

HYDRO RAM PUMPS

Farms with a steady watercourse nearby and at least 15 feet of reasonably steep change of elevation along this course can utilise a Hydro-ram pump. This simple but amazing design, which uses parts available at hardware stores and costs under XC$500, allows users to continuously pump water from a flowing watercourse up 50 or more feet of elevation above the pump with no power required.

The hydraulic hammer effect uses the force of moving water to create a perpetual kick-back airlock that squeezes 25% of the water entering the pump out of the compression chamber with considerable pressure in a small pipe; 75% is lost to the system.

The user should install a water storage tank/pond at the highest point the pump can deliver water to and gravity feed the farm's irrigation system, diverting overflow back to the watercourse or into swales or ponds. Patented ready-to-install versions are available online.

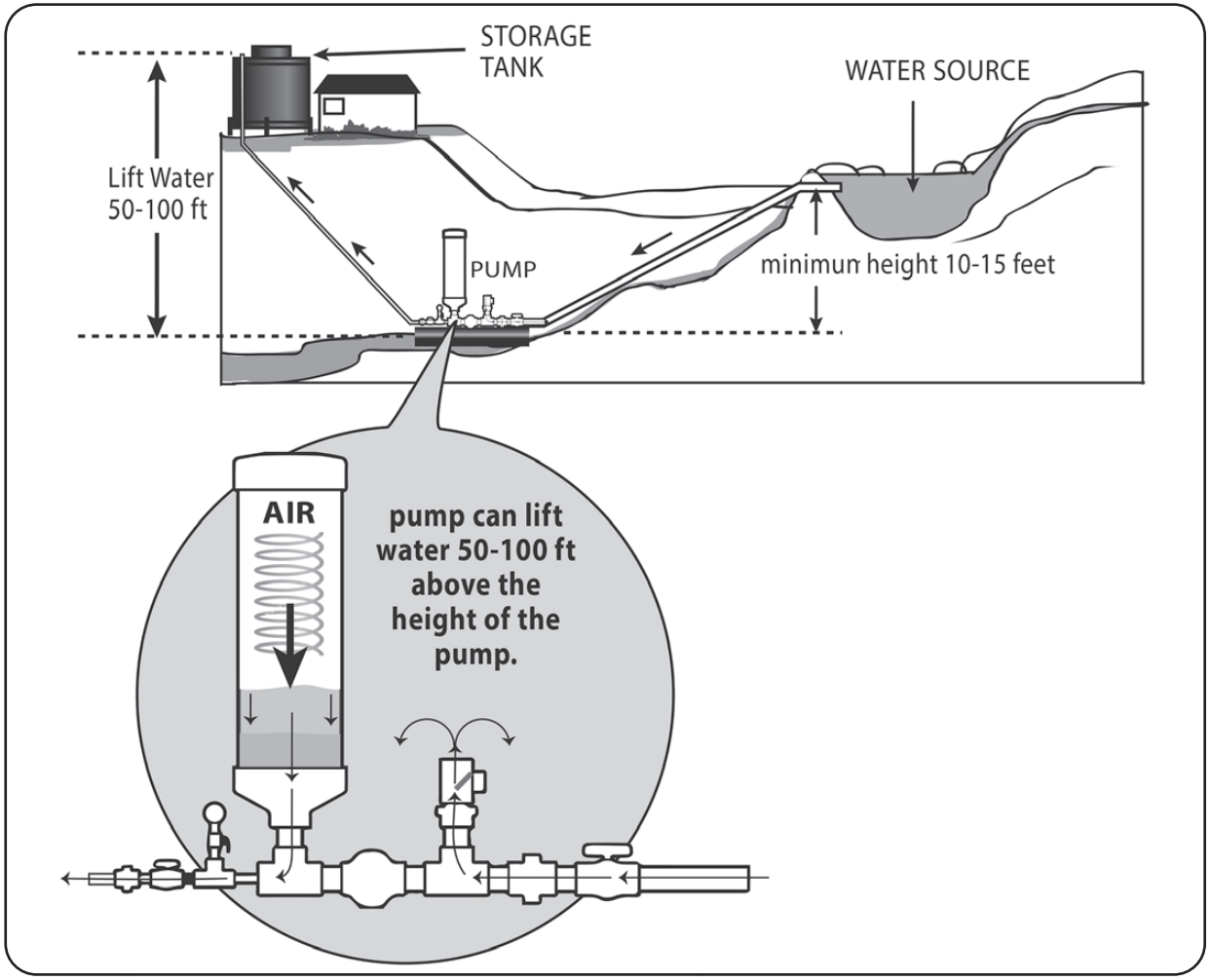


Illustration 6: Irrigation System Fuel Pump

SOLAR WATER PUMPS

A small array of solar panels connected to a direct current (DC) water pump can also pump water whenever the sun is shining. DC water pumps are inexpensive, can be ordered online and are a great backup to any system, especially after a storm event.

Photo 6: Solar pump

WIND-POWERED PUMPS

Wind-powered pumps have been used for hundreds of years with good results and require no electronic parts (see Illustration 5).

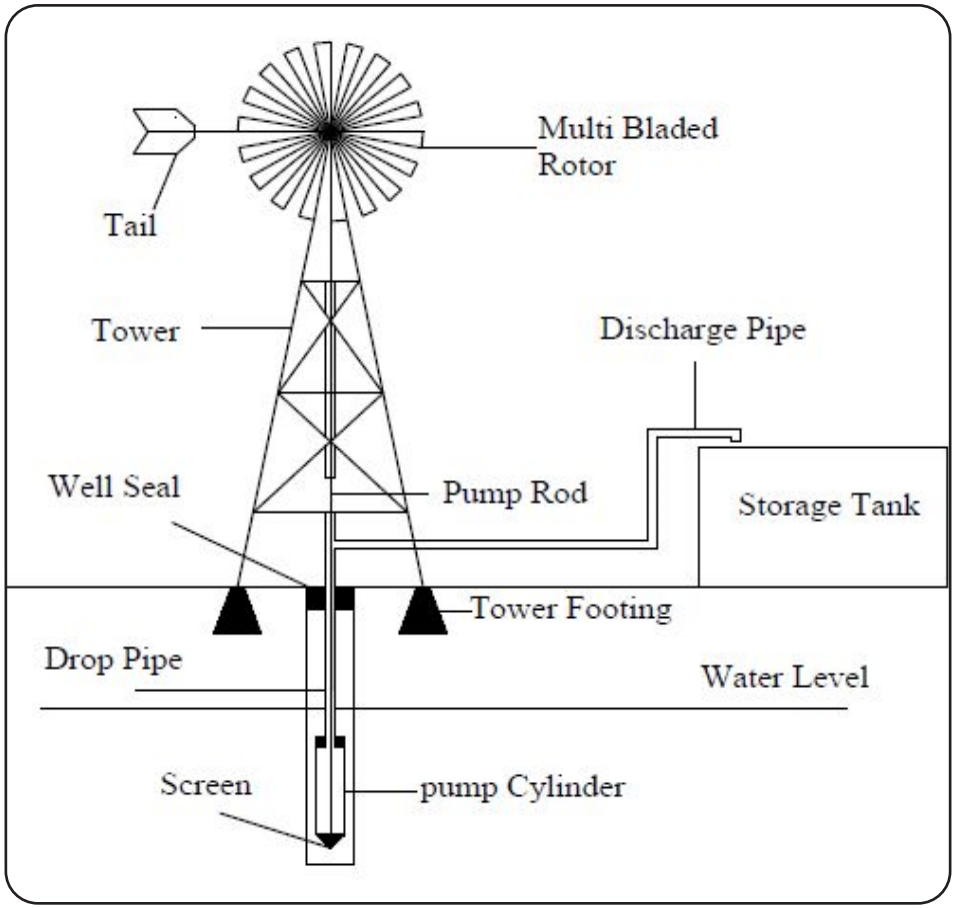


Illustration 7: Demonstration of solar and wind pumps.

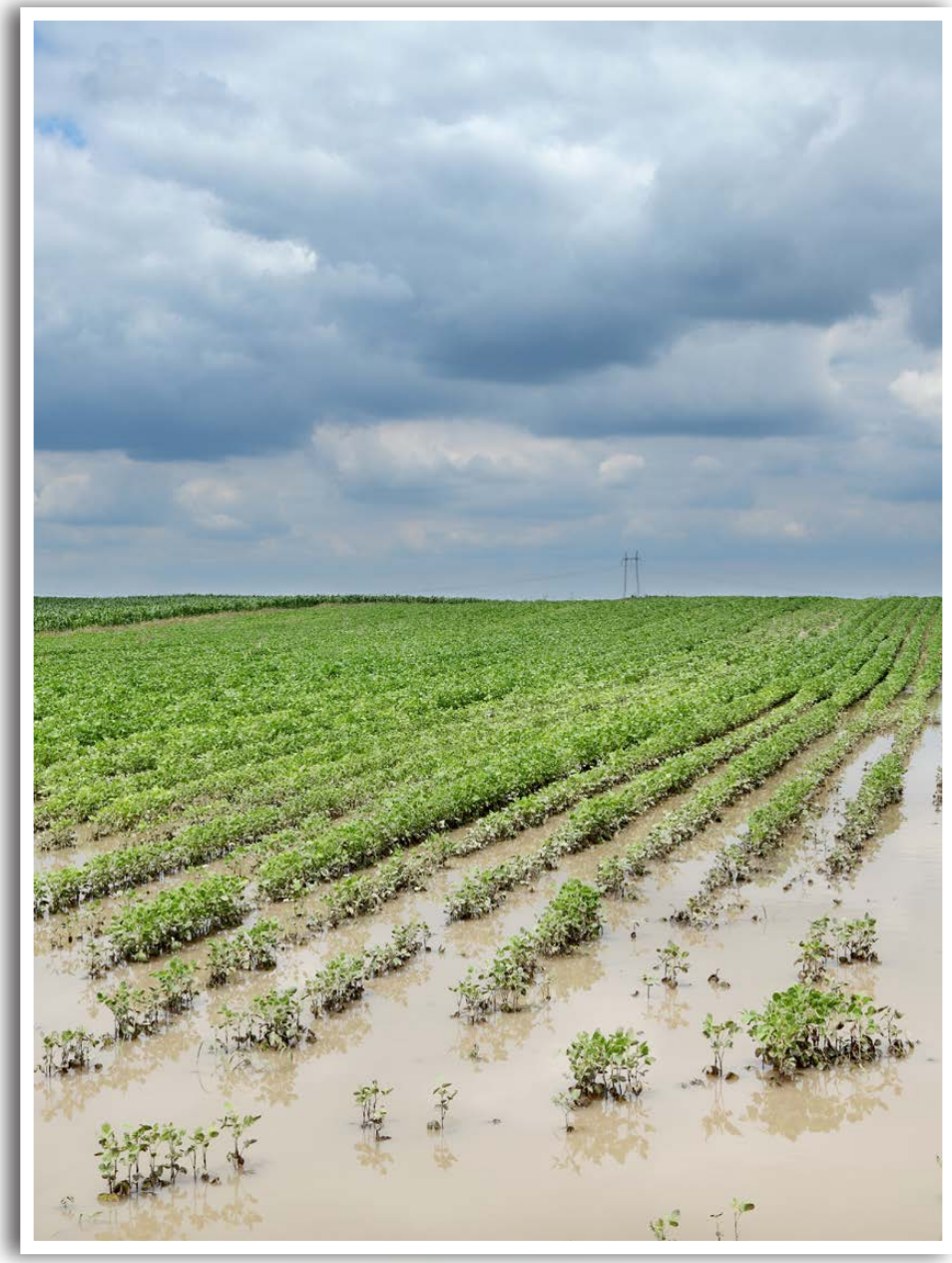
SECTION 3

EXTREME RAINFALL EVENTS

INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC), notes that climate change will bring more frequent and intense, unusual, or extreme weather events worldwide, such as hurricanes, floods, torrential rain, or drought, and will have a direct impact on productive systems. It will also likely have an effect on rainfall and temperature, reducing the sector's productive agricultural potential in extensive areas of the region.[17] The looming effects of climate change, including sea-level rise in particular, are an enormous problem for the Caribbean; there is also the likelihood of more hurricanes reaching Category 4 and 5 in the future.[18] The main hazards associated with hurricanes are storm surges, high winds, heavy rain and flooding. The impact of heavy rainfall can result in increased risk to human life, damage to buildings and infrastructure, loss of crops and livestock, landslides, and disruption of transport and communications systems.

Hurricanes in the Caribbean, the most persistent natural hazards, often bring vast amounts of rain in a short period, causing flash flooding in valleys and erosion. Also, often rainfall persists for extended periods, super-saturating the soils on slopes and leaving them vulnerable to land slippage or catastrophic slope failures/landslides.



17 Community of Latin American and Caribbean States [CELAC], "Regional Strategy for Disaster Risk Management in the Agriculture Sector and Food and Nutrition Security in Latin America and the Caribbean (2018 - 2030)", CELAC: El Salvador, 2018, http://www.fao.org/3/i8919en/I8919EN.pdf

18 Knutson, Thomas R., Joseph J. Sirutis, Ming Zhao, Robert E. Tuleya, Morris Bender, Gabriel A. Vecchi, Gabriele Villarini, and Daniel Chavas, "Global Projections of Intense Tropical Cyclone Activity for the Late Twenty-First Century from Dynamical Downscaling of CMIP5/RCP4.5 Scenarios", *Journal of Climate* 28, 18 (2015), https://doi.org/10.1175/JCLI-D-15-0129.1

In the agricultural sector, extreme rainfall and the accompanying flooding will cause a variety of problems for farmers. These include extensive soil leaching, waterlogging, poor weed control in some areas, and a high risk of flooding along riverbank areas. Excessive rainfall can affect crop productivity in various ways, including direct physical damage, delayed planting and harvesting, restricted root growth, oxygen deficiency and loss of nutrients. It can also expand the risk zone into areas that were previously safe from floods. Also, heavier rain increases erosion and run-off, removing agricultural topsoil and increasing the flow of pollutants into our waterways and affecting water quality. Stormwater run-off, which often includes pollutants like heavy metals, pesticides, nitrogen, and phosphorus, can be deposited in streams and bays, damaging aquatic ecosystems and lowering water quality for human uses.

Flooding results in land becoming unsuitable for agricultural production until waters recede. Additionally, storm surges and flash floods caused by hurricanes and storms might wash out arable land or permanently increase its salinity.[19] Photo 7 demonstrates mulching techniques to reduce the direct impact of rainfall on soils.

> *In 2010, Hurricane Tomas caused major damage to St. Vincent and the Grenadines, with the total loss attributed to the agricultural sector estimated at US$26 million. Similarly, in December 2013, the island was again impacted by a low-level trough system which extensively damaged crops, livestock, farm roads and farmland. In what became known as the 'Christmas Floods', losses in the agricultural sector were estimated at US$12 million.* *(See Situation Analysis, page 8.)*

> *In late 2020 in Jamaica, after several consecutive days of continuous rain, a slow-moving storm that did not directly hit the island caused US$13.7 million in lost agricultural revenue and assets.*

Photo 7: *Mulching with Vetiver grass protects the soil from the direct impact of rainfall during extreme events. By angling grass into drains (as seen above) excess water is directed off the bed.*

19 Sivakumar, M. V. K, "Impacts of Natural Disasters in Agriculture: An Overview", World Meteorological Organization: Geneva, Switzerland, Accessed February 24, 2021, http://www.wamis.org/agm/meetings/anadia06/Sivakumar_Overview.pdf

HOW TO REDUCE THE IMPACTS OF HEAVY RAINFALL

Protective Covering: Plastic cover can be used to eliminate the impact of heavy rainfall on crops and the soil surface. However, it is important to note that when plastic is being used as a cover, such as in a greenhouse, it is important to have good ventilation to avoid heat and disease build up. Insect netting is also an option for reducing the impact of heavy rainfall.

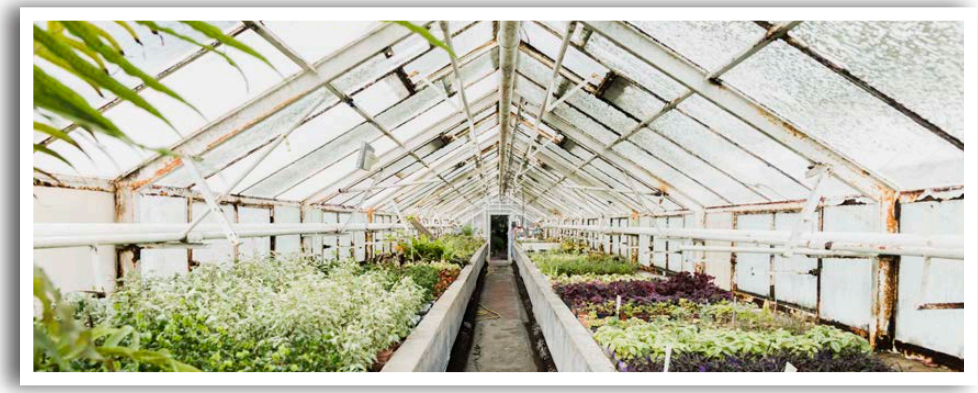


Photo 8: Greenhouse with plastic on top and insect mesh on sides

DESIGNING DRAINAGE SYSTEMS THAT REDUCE EROSION

The right water management system will prevent erosion and landslides during heavy rainfall events and conserves water during dry periods. A good water management system must do the following two things:

- Maximise infiltration rate and water holding capacity
- Move excess water away without causing erosion

1. Maximise infiltration rate and water holding capacity Infiltration is directly related to the presence of non-soil material at the soil surface (mulch) and the holding capacity is related to stable soil aggregates which are created by high levels of organic matter (OM) within the soil. Mulch and OM are covered in later sections.

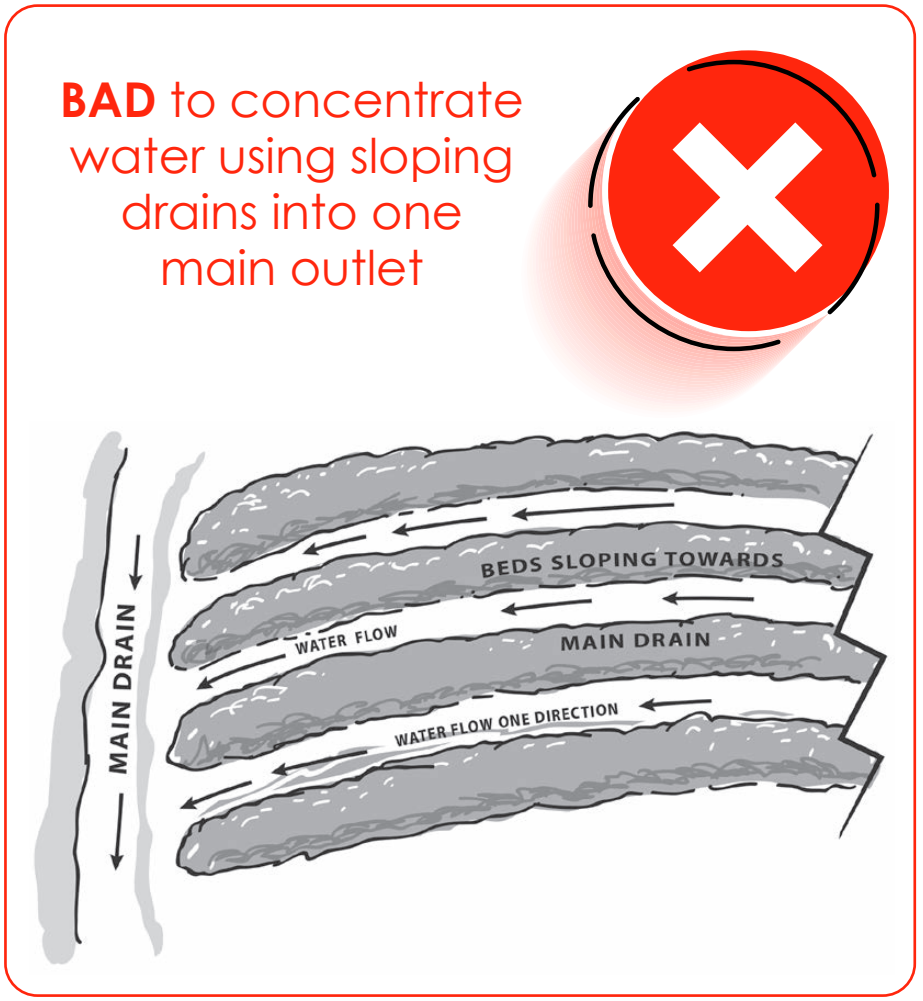


Illustration 8: Incorrect method of designing drains which increases volume and flow rates into one main drain.

2. Move excess water away without causing erosion Erosion is caused by **over-land flow (Illustration 9)** when water cannot penetrate down into the depths of the soil either because of surface compaction and crusting or saturation. Once the soil is saturated, drainage is required to move excess water away, but as slowly as possible!

Drainage without causing erosion must handle the volume of water moving out of saturated soils and move it out of the system in a shallow flow in nearly horizontal drains because as water flows deeper and steeper, it gains speed very rapidly. To reduce the flow volume, splitting the flow up is highly effective. (See Illustration 10)

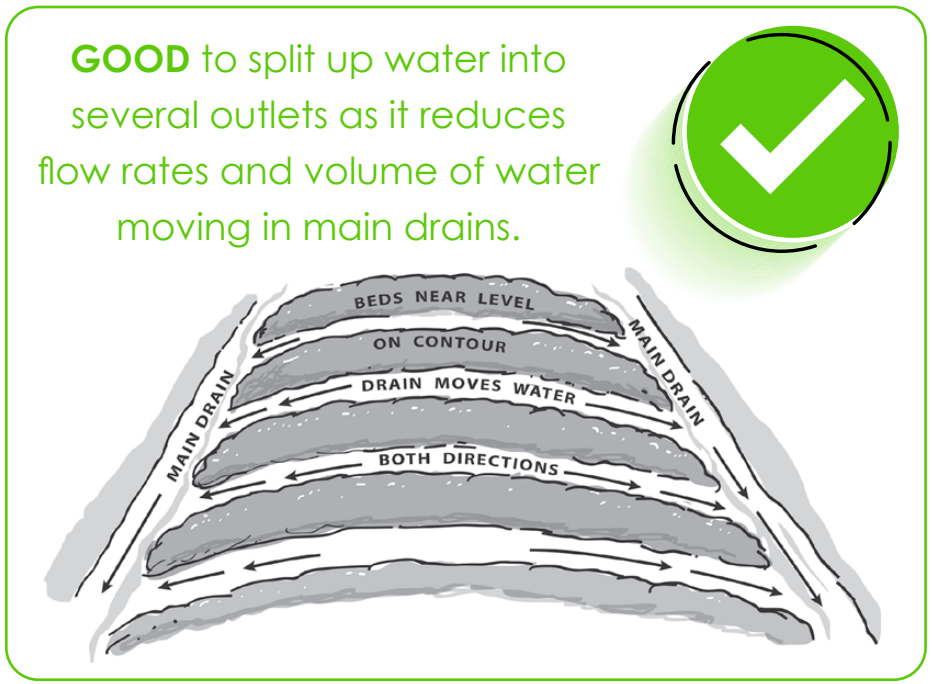


Illustration 9: Designing drains to reduce volume and flow rates into main drains

RE-THINKING HOW WE 'DRAIN'

Bad drainage causes landslides. Roads, walking paths, and farm drainage systems often force too much water into single drains and outlets. During major storms, volume and flow rate in drain structures explode into torrents that can rapidly eat away the foundation of hillsides. Good drainage moves water away at a steady rate that does not have enough power to erode and destabilize. See Figure 9 showing a cross section of beds and inter-bed drains.

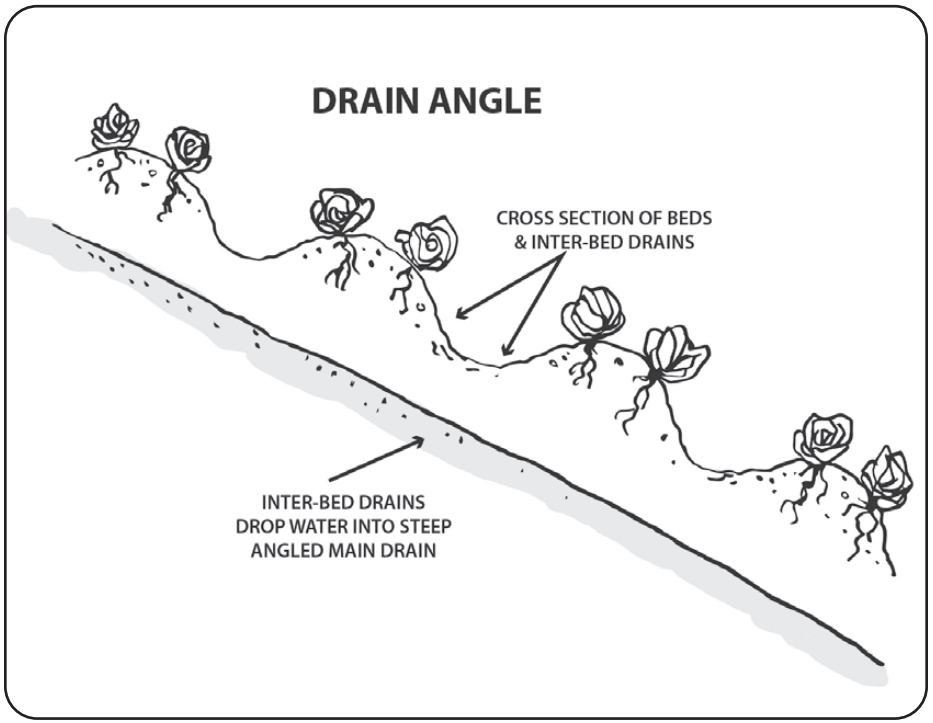


Illustration 10: Illustration of cross section of beds and inter-bed drains.

STEPPED DRAINS

Stepped drains mimic natural river systems. The pristine rivers of Caribbean highlands are like giant staircases and waterfalls and steep rapid areas of flow are slowed by horizontal pools with large rocks to diffuse energy. The aim is to have a steady, slow movement of water. Lining these steps with stone and/or grass also turns a drain into a usable staircase to improve access on steep slopes.

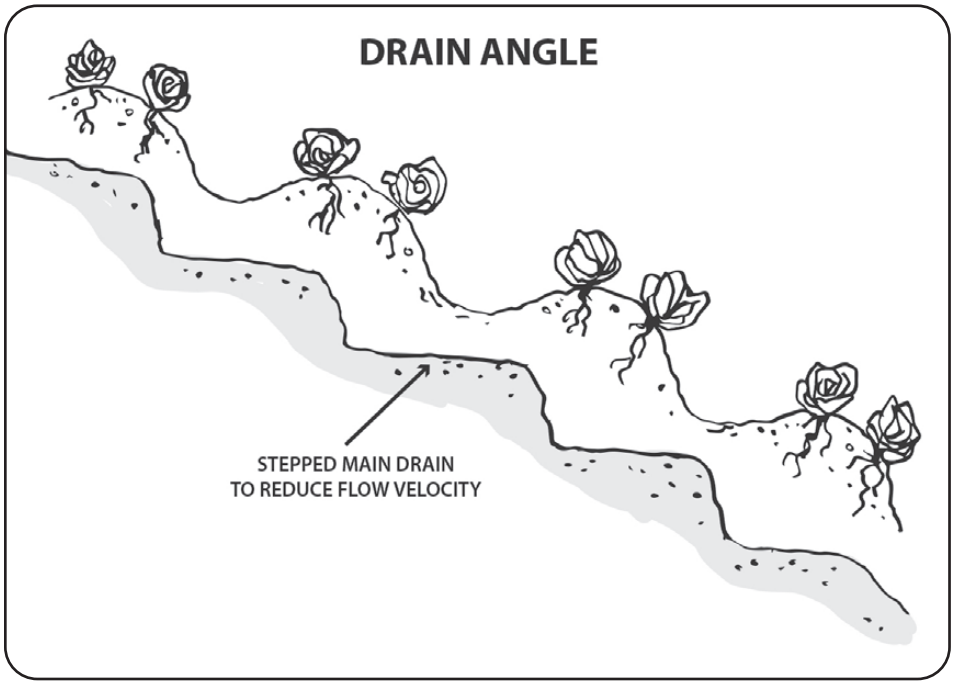


Illustration 11: Stepped drains.

GRASSED DRAINS AND WALKWAYS

Tough perennial grasses can be used in farm drains and walkways to increase surface roughness, slowing down the flow of water, and hold soil in place. These grasses cause less erosion and mud in walkways, reducing the spread of soil-borne disease. Farmers should be cautious against grasses with underground growth that would ultimately invade the bed.

STONE ARMORED DRAINS

Lining main drains with stones prevents gully erosion. Gullies that form after heavy rainfall events erode massive amounts of material. Rivers start as gullies and eventually erode all the material away down to the bedrock. Stones can be used as 'armour' to prevent the flowing water from washing away the soil.

SILT TRAPS OR CLEANOUT AREAS

In natural rivers, the silt traps are the ponding areas where the flow rate of water slows dramatically and can no longer carry larger particles that drop out of the flow. Silt traps can be constructed flat, wide and smooth with easy access to remove valuable material after heavy rain.

DEEP DRAINS VS. WIDE DRAINS

To protect against damage during heavy rainfall events, drainage systems need to handle large amounts of water without overtopping the drain. Illustrations 12 & 13 below illustrate the cross-sections of two drains that both carry similar amounts of water.

WHICH ONE OF THESE TWO IS **LESS** ***EROSIVE***

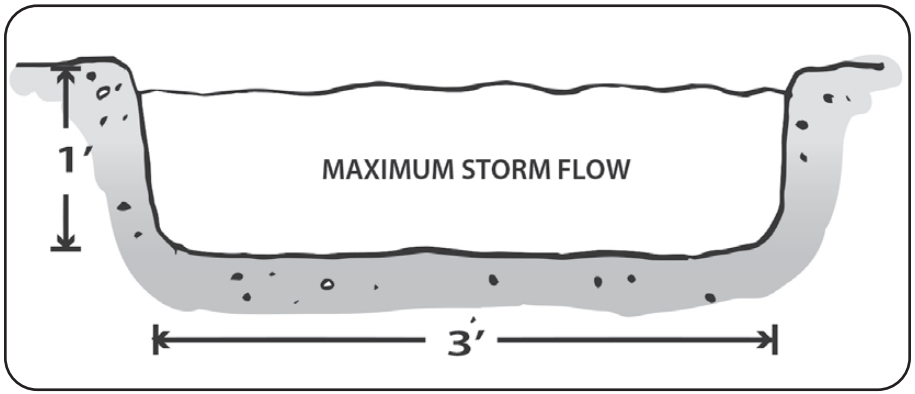


Illustration 12: Wide drain.

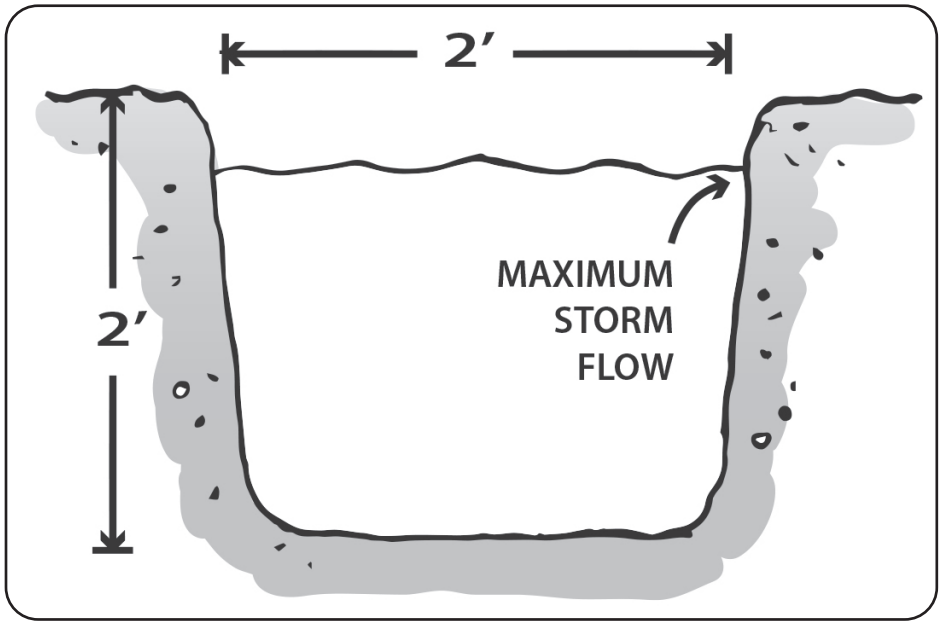


Illustration 13: Deep drain.

CLICK HERE TO VIEW
ANSWER:

TERRACING FOR EROSION AND LANDSLIDE PREVENTION.

Terracing can be used to help reduce slope angle on moderate slopes so that tractors and other equipment can be used. Steeper slopes can be made accessible, safe and non-destructive if terraced.

STONE TERRACING: AN ART AND SCIENCE – STEP-BY-STEP

Well-constructed stone terraces become permanent features. Building terraces requires an understanding of the sub-soil type and structure and how water moves through the area.

STEP 1.
DEVELOPING THE TERRACE

- Terraces are built on or very close to a level contour line
- Level contour lines can be determined with surveying equipment or with a simple A-frame tool (see Illustration 12)
- Dig foundation trench deep enough to cut into clay
- Water will move in this trench even after the wall is built, so give it a slight slope towards the drainage area
- During storms, over-saturation and failure is avoided because excess water can move through the wall
- On most slopes a terrace trench does not pose a significant risk, so the location should simply be close or near to a contour line and wherever makes the best use of the available land. A potential risk exists if the nature of the hillside slope does not allow the trenches to follow the contour closely enough. In this case, a safe runoff angle of less than 2 per cent cannot be maintained for the trench. This would likely lead to gullying in the trench.

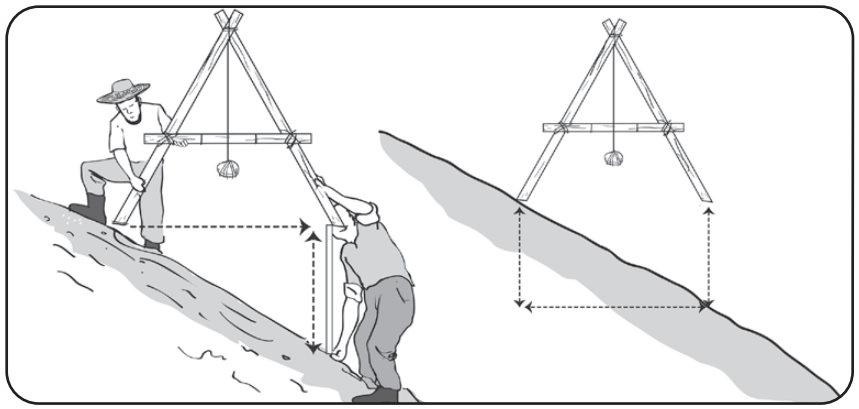


Illustration 14: Illustration using an A-frame to determine slope angle and mark points on a contour line.

Once the string with the rock weight lines up with the center mark, the two feet of the A-frame are at the same height

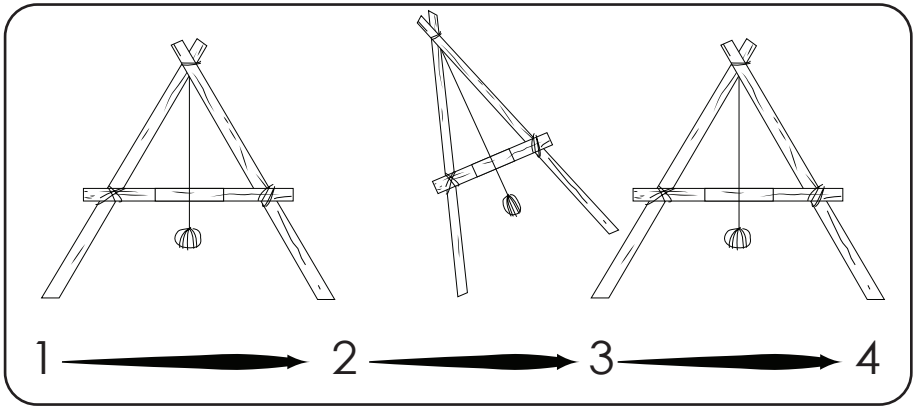


Illustration 15: Using A-frame to mark points on a contour line

Walk the A-frame pivoting it on one leg into a new level position to find the next point on the contour line it is following. Be sure to mark or place a stake at each point before the next pivot is made.

STEP 2.
PITCHING TRENCH AND WALL BACK INTO THE SLOPE.

Both the trench floor and the wall itself should have a slight pitch or angle back into the slope (see Illustration 16).

STEP 3.
PLACEMENT OF FOUNDATIONAL STONES.

For the first layer of stonework, use the large stones. If some smaller stones are needed, alternate with larger ones. These stones should also be angled back into the slope and be oriented so the longest face is perpendicular to the trench.

STEP 4.
WEDGE STONES IN THE GAPS BETWEEN MAIN STONES IN LAYERS.

Wedge smaller stones into the spaces between first layer stones. This side-to-side pressure greatly increases the strength of the wall. Knock these stones with a mallet or other stones to wedge them in securely.

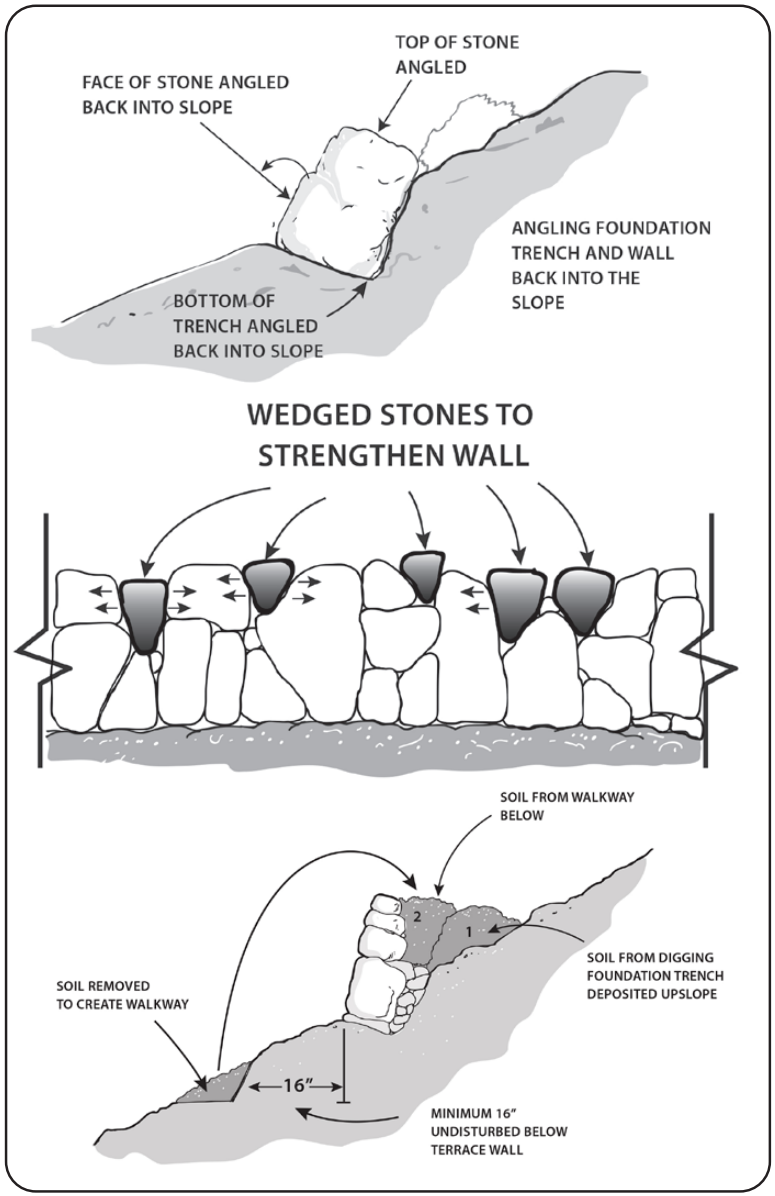


Illustration 16: Demonstrating stone terracing techniques.

STEP 5.
BACKFILL BEHIND WALL WITH SMALL STONES.

Fill the large voids behind the wall with well packed small stones to improve drainage. Large voids behind the wall can be used by rodents and mole crickets to nest.

STEP 6.
LEAVE A MINIMUM 16" OF UNDISTURBED SOIL DOWNSLOPE.

Do not disturb the soil downslope of the terrace wall. Leave a larger undisturbed area below the wall to plant trees and vetiver grass to ensure that the foundation of the terrace wall does not erode over time. Planting or allowing the growth of lawn grasses and legumes on this 'step' is also highly recommended.

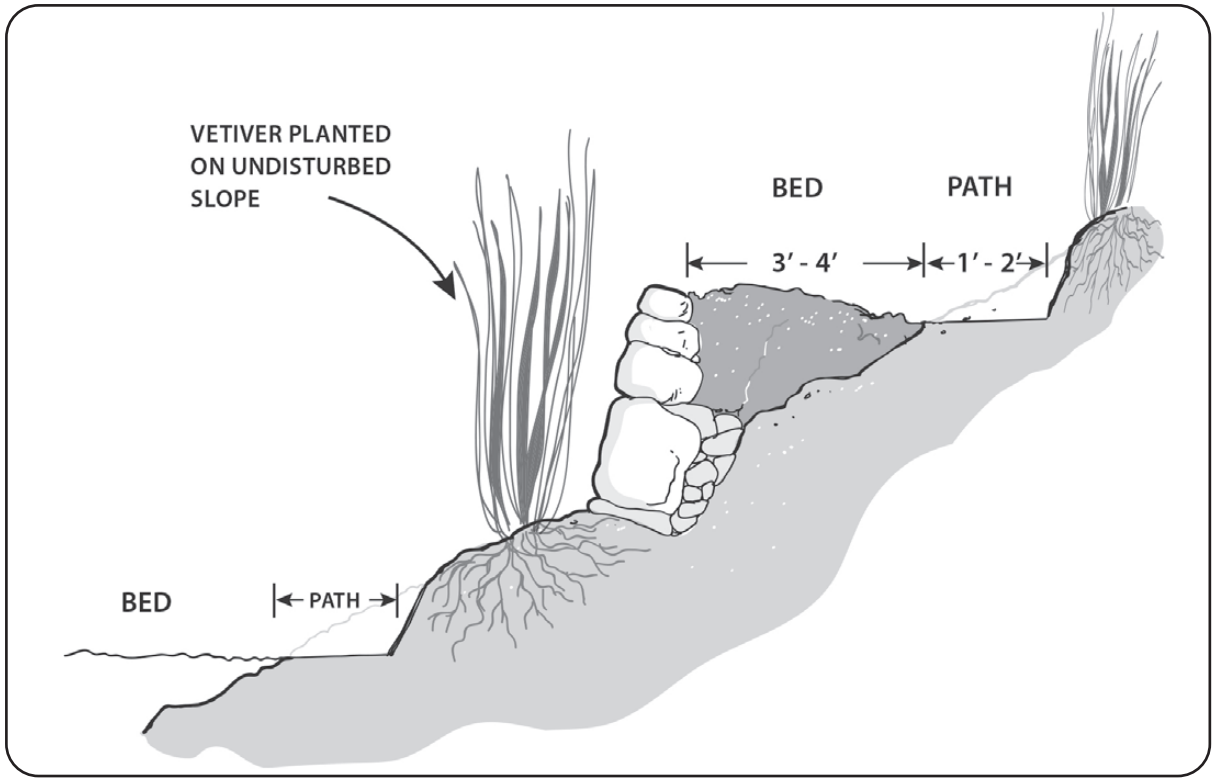


Figure 16: Demonstrating stone terracing techniques. cont'd

MULCHING: PREVENTING SOIL DEGRADATION AND EROSION

Mulching is an invaluable tool to physically protect the soil from erosion and degradation caused during heavy rain events. In nature, soil is rarely exposed. After fire and landslides, exposed soil is quickly covered by 'weeds'. Keeping soil covered is the primary function of weeds. In the region many farmers are continually weeding and exposing the soil. This regional practice has resulted in soil being left exposed and vulnerable for long periods of time. Mulching reduces weed establishment while protecting the soil (see Figure 19). As the mulch decomposes, it adds valuable organic matter back to the soil.

Soil degradation has three major categories:

1. Compaction causing bad soil structure – Good soil structure is loose and crumbly with air spaces. It is not hard and compacted. Compaction can be caused by walking on soil and grazing but is mainly caused by raindrops hitting the soil's surface.

2. Mineral and nutrient loss – Soils exposed to large amounts of intense rainfall and water-logged conditions have their nutrients washed out and lost. This is called nutrient leaching.

3. Organic matter loss – Organic matter in the soil is the most important factor for soil health. Compaction and nutrient loss are both related to organic matter. Organic substances glue together stable soil aggregates and living forms of organic matter convert soil minerals into usable plant nutrients.

Photo 9-10: Mulch used to control grass in Dominica

LIVING MULCH AND RELAY PLANTING TO REDUCE EROSION

In nature, fast growing weeds play a vital role in protecting soil from degradation and erosion caused by heavy rain. Similarly, crops that cover large areas like lettuce or pac choi can be planted in patterns that allow space for the direct seeding of longer establishing crops. Start crops at the same time or establish the second crop at the time of weeding and molding the first crop.

Advantages:

- *Protects the soil and reduces weeding labour*
- *Protects germinating seedlings of the second crop*
- *Can double revenue with little extra work*

Considerations:

- *Avoid crops affected by the same pests and disease*
- *Requires more skill and precision*
- *Greater fertility requirements*

WEEK 1

Transplant 4 rows lettuce at 1' spacing, direct seed cilantro, beets, and carrots between in 3 rows.

Photo 11

WEEK 3-5

Lettuce begins to open and cover soil, and provides shade and protection for slow germinating row crops.

Photo 12

WEEK 6-8

Harvest of lettuce and cilantro already beginning light harvest, but will remain for 4 more weeks of harvest.

Photo 13

WEEK 9-14

Twice weekly harvesting of cilantro. Next crop can be seeded directly in-between row of cilantro!

Photo 14

AFFORDABLE EQUIPMENT TO REDUCE EROSION, DEGRADATION AND CROP LOSS DUE TO HEAVY RAINFALL

Artificial on-farm micro-climates: Greenhouses and shade-houses can be amazingly effective tools at creating micro-climates (see Photo 15). Permanent protected agriculture under greenhouses can play an important and central role within a resilient system. Temporary crop protection apparatus is just beginning to be used widely in the region and is showing great promise.

Benefits of using 50% 'bed covering':

- Similar protection as a greenhouse at 10% of the cost
- Absorbs the impact force of raindrops, protecting soil surface from compaction crusting and erosion
- Assembled and disassembled in minutes, so loss and damage in storms can be completely avoided (See Photo 12)
- Micro-climate (temperature and humidity) can be adjusted to suit growth stage by changing the covering
- Conserve moisture, improving germination and seedling development by reduction in direct sunlight and wind
- Excludes many insect pests completely, and slows the entry and movement of many others
- Reduces damage and theft of produce by animals.

Photo 15: Shade house in Guyana use to create micro climate

Photo 16: Cover cropping to Protect Soil

VARIETY OF MATERIALS AND APPLICATION

Photo 17: Galvanized steel rod arch.

Galvanized steel rods about 3/16ths thick by 6' long are pushed in soil to form supportive arch every 5 feet. Each rod costs about $1 USD. See Photo 17 demonstrating the supportive arch.

- 30 per cent black netting is the most affordable and resilient material. A roll of it is 200' long by 7' wide and retails for about $100 USD.
- Provides some protection from heavy rain, but can be used in combination with mulch to fully protect soil surface
- Best material for use in dry season because it does not hold in heat
- Cucumbers perform extremely well transplanted or direct seeded for the first 3-5 weeks, as plants begin to cover soil surface and commence flowering netting structures are removed for better pollination and harvesting

Photo 18: Direct seeding of arugula.

- 30 per cent White mesh fabric is 2-3 times more expensive and is less resilient and prone to tearing
- Fine mesh structure prevents flying aphids and whiteflies from entering
- Mesh can be laid directly on soil surface for 2-4 days after direct seeding to further conserve moisture and protect soil surface
- If heavy rain is expected after seeding, the 50 per cent stronger material can be placed over top 30 per cent material to completely prevent heavy impact of water on the soil surface. CAUTION: This 50 per cent shade addition would have to be removed after the rain threat has passed. This addition results in 80 per cent shade and plants are likely to etiolate (grow tall and spindly) if left in place.
- At late stages of crop development, replace more expensive and delicate covering material with black 30% mesh, or remove coverings completely

COVER-CROPPING TO PROTECT THE SOIL

Cover-cropping is the use of plants to cover or protect the soil. It is generally done in the rainy season, but can be introduced before, during, and after your main production crop cycle to protect and regenerate the soil.

Characteristics of good cover crops:

- Fast growing spreading plants
- Pest and disease resistant
- Low nutrient requirements or legumes producing Nitrogen
- Effective and aggressive root systems that break through compacted soil and scavenge nutrients

Why use cover crops?

- Prevent soil surface compaction degradation by protecting it from direct impact of heavy rain
- Improve water infiltration by preventing crusting of the soil surface by blocking the sun and rain
- Prevents soil erosion during heavy rainfall or flooding events
- Increase water infiltration by breaking-up sub-soil compaction layer with aggressive taproot systems
- Out compete weeds, and break pest cycles

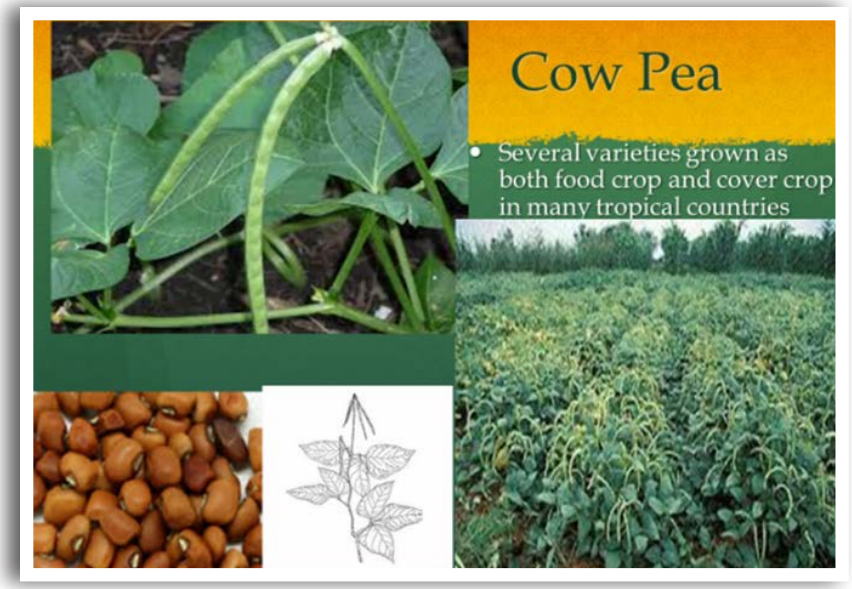


Photo 19: Cow pea intercropped with pumpkin and corn below.

Photo 20: Cover-cropping technique.

COVER-CROPPING TO PREVENT SOIL EROSION AND DEGRADATION STEP-BY-STEP:

Step 1. Immediately after cultivation, direct seed the cover crop in straight furrows beside the furrow location to plant the next production crop, so cover-crop roots do not have to be removed to plant next crop (see Figure 26).

Step 2. Ensure quick and strong germination of cover-crop. It is also good to fertilize, and even give a quick weeding to speed early development.

Step 3. Periodically observe and remove undesired weeds. Monitor pests and beneficial insects.

Step 4. Mow cover-crop with weed-eater leaving material spread evenly over soil surface.

Step 5. Prepare furrows beside cover-crop furrows made at planting time. Do not remove cover-crop root systems.

- Reduce disease and pest severity: Some species such as marigold, sesame seed, castor bean, mucuna bean, jack bean, sunn hemp, mustards and oil seed radish are known to suppress certain plant parasitic nematodes and soil borne diseases. In contrast, most legumes are highly susceptible and can increase nematode populations. Information on pests and diseases prevalent in an area must be considered before choosing cover crops. This information can usually be accessed from the Ministry of Agriculture and extension officers.

Photo 21 & 22: Examples of cover crops.

Photo 21: Mucuna Bean

Photo 22: Sun Hemp

MUCUNA BEAN

- Considered the most important Tropical Leguminos Crop-cover
- Fights Nematodes
- Fastest most aggressive legume

SUN HEMP

- A multipurpose tropical and subtropical legume
- Legume with an upright growth habit, produces large amounts of seed
- Fights nematodes

PREVENTING SOIL DEGRADATION AND EROSION THROUGH CONSERVATION CULTIVATION

Reduced and Strategic Weeding

It is necessary to remove weeds that are very close to crops. However, over-weeding exposes soil to heavy rain for too long. Soil can be conserved by weeding less in the rainy season.

No-till agriculture

No cultivation is done after a crop. The new crop is sown directly in undisturbed soil. Soil heals fastest when organic matter is allowed to build up in the soil. Regeneration is accelerated by discontinuing ploughing and tilling. This is called 'no-till' farming.

Why no-till?

The cultivation of soil greatly accelerates the break-down of certain key forms of organic matter. While this breakdown releases nutrients for crops, it also transforms soil carbon into carbon dioxide (CO_2). It is now established that the biggest source of CO_2 is the cultivation of agricultural soils around the world. The FAO notes that agriculture accounts for 13.5% of global greenhouse gas (GHG) emissions, mainly in the form of methane (CH_4) and nitrous oxide (N_2O) from fertilized soils, enteric fermentation, biomass burning, rice production, as well as manure and fertilizer production.[20]

Ancestral no-till farming systems: The Three Sisters – corn, beans, and squash – have been planted together for thousands of years by all of the indigenous peoples in the Americas. The Three Sisters system (Figure 28) was planted in St. Lucia without ploughing. The cover-crop of water grass was mowed to bare soil by a weed-eater, and then narrow furrows were made to plant corn and holes were dug every two feet for squash and beans.

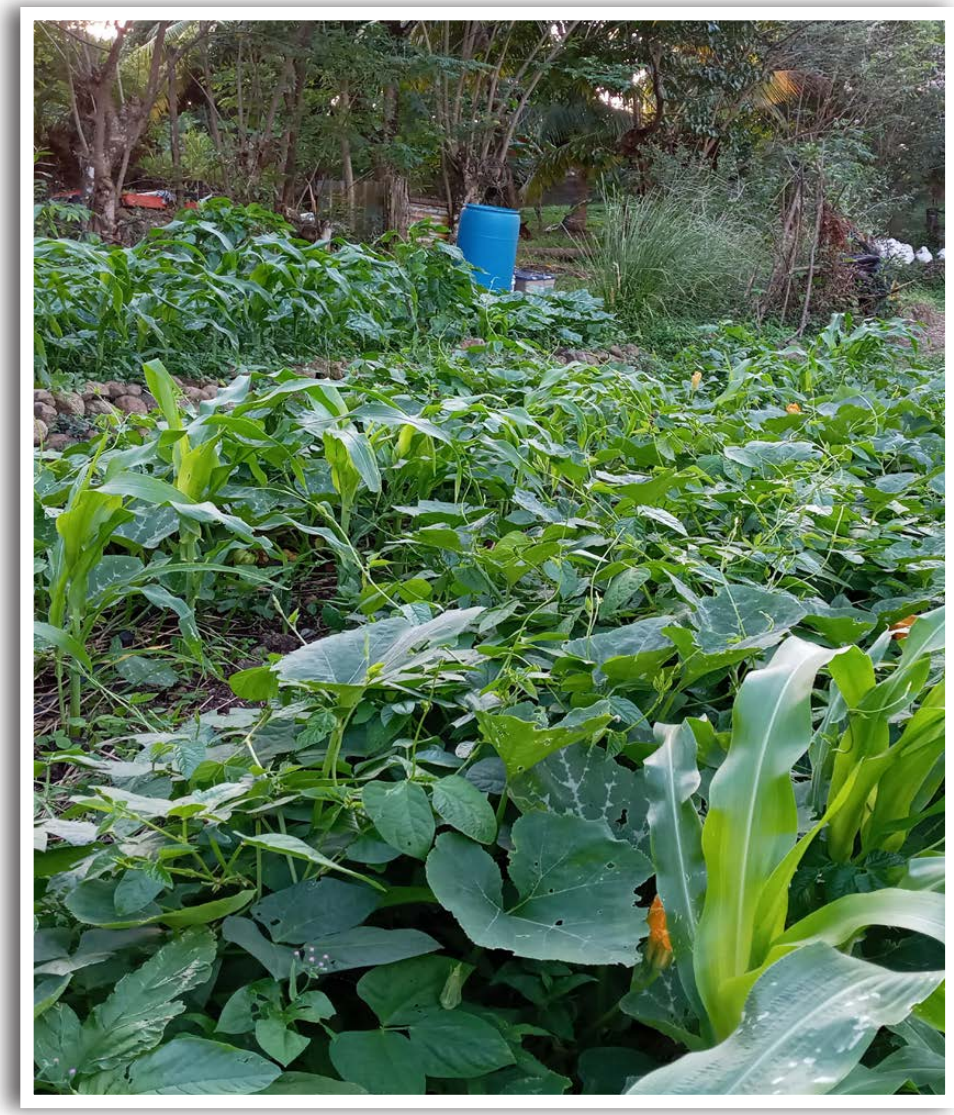


Photo 23: No Till Agriculture

20 Food and Agriculture Organization of the United Nations [FAO], Profile for Climate Change, Rome, Italy, http://www.fao.org/3/i1323e/i1323e.pdf

MINIMAL-TILL SYSTEMS

The smallest number of cultivation operations are done before planting the next crop. For example, planting in furrows that are minimally cultivated instead of ploughing and tilling the entire bed improves soil quality by creating an undisturbed zone where on-bed composting occurs, directly feeding soil-life and the nearby crop root systems. Developing a crop rotation system that requires minimal interventions between crops has multiple benefits, including: ***reduced labour, breaking of pest and disease cycles, weed control, and overall improved soil health.***

1. Weed fallow: Water-grass (Commelina diffusa) and callaloo are allowed to establish/seed previous crop while maturing. Less desirable weeds are removed.

Photo 24: Minimal-till systems.

2. Weed-eating: Callaloo plants are cut out with a cutlass (machete), leaving roots in soil. Water-grass is cut down to bare soil. Material is raked into a mound down the center of the bed.

Photo 25: Minimal-till systems.

3. Furrows 8-12" wide on bed-edges were lightly ploughed first: Leaving about a 2' wide strip in the middle of the bed undisturbed and mulched with water-grass will feed the soil life and the adjacent crops as the water-grass decomposes.

Photo 26: Minimal-till systems.

4. Planting of lettuce on furrowed bed edges: Place a handful of compost at each drip emitter on drip-tape.

Photo 27: Minimal-till systems.

5. Mulched with Vetiver grass: Lay Vetiver down carefully in one direction, following a careful pattern. To prevent damage to leaves, ensure that leaves do not touch the transplants. Seven (7) clumps were cut to mulch this area (10' x 35').

Photo 28: Minimal-till systems.

6. Covered with 30% protective netting for 2 weeks: Protects transplants from direct sun and also prevents contact from pests and birds.

Photo 29: Minimal-till systems.

7. Side-dressing with fertilizer and Weeding: After 2-3 weeks re-growing water-grass is removed, lettuce is side-dressed with fertilizer and composting water-grass is pulled from under vetiver on the center of the bed, then extra mulch is added.

Photo 30: Minimal-till systems.

SECTION 4

EXTREME WIND EVENTS

INTRODUCTION

Just as water management is critical to the success of any farming enterprise, putting in place programmes to adapt to wind conditions is just as important to farming operations, especially for fruits and vegetables.

Agricultural production is adversely affected by hurricanes and tropical storms. Hurricanes cause severe damage to farm housing, irrigation infrastructure, feeder roads, crop and livestock production and forest reserves. The accompanying winds can have devastating and long-lasting effects on agricultural produce. The winds can break limbs, remove leaves and fruit, or even topple trees, leading to long-term crop losses. Perhaps the most evident damage following hurricanes and storms is that of fallen trees. This type of damage occurs when soils become saturated after heavy rain and lose the soil structure needed to support the trees. While the prevention of natural hazard events might not be possible, the resultant disastrous effects can be considerably reduced through proper planning and effective preparation. Several interventions can be implemented to mitigate or lessen the damage strong wind events can cause.

Planning, early warning and well-prepared response strategies are the major tools for mitigating agricultural losses. Wind and airflow can be viewed as a resource for farmers and can be designed to allow for good air movement through and around sensitive crops. Tomatoes, cocoa, citrus, and even bananas benefit greatly from good airflow as they are then far less susceptible to fungus and other microscopic pathogens and diseases.

Storm- and hurricane-force winds can be deflected and interfered with enough to reduce damage dramatically. Buffer strips designed as windbreaks can be highly effective and provide food, direct income, and indirect income by generating materials for compost, mulching and other invaluable services to the farming system.

> *In Grenada, the devastation caused by Hurricane Ivan in 2004 resulted in significant losses to the agricultural sector. The World Bank (2017) estimated that Hurricane Ivan destroyed up to 90 per cent of forest vegetation and resulted in the loss of topsoil and nutrients crucial to agricultural production. Additionally, up to 85 per cent of the island's nutmeg crop was lost, with 60 per cent of the trees having been completely destroyed. Similarly, 60 per cent of the cocoa tree stock was destroyed. Other tree crops such as citrus, avocado and mango were damaged, as were the vast majority of shade crops such as bananas. More than 3,000 farming families were impacted. Losses for the overall agricultural sector were projected at US$37 million.* (See Situation Analysis, page 7-8.)

HOW TO REDUCE THE IMPACTS OF HEAVY WINDS

Greenhouse structure design

Wind management general principles and design

A direct hit from a Category 3 hurricane (with wind speed of 111-129 mph or 178-208 km/h) or higher creates devastating wind conditions that very little can be done to mitigate. However, for most wind events, windbreaks or shelter belts can greatly reduce the force of the blow and improve resilience and recovery from wind disasters.

Wind management principles:

1. **Making the surface of the farm 'rougher'** reduces wind velocity by absorbing wind energy. Roughness or friction can be increased by including trees, bushes and structures throughout the cropping area in strips (alley cropping) or clumps (permaculture guilds). Mixing annual market crops with trees and perennials is known as agro-forestry and is commonly practiced in the region.

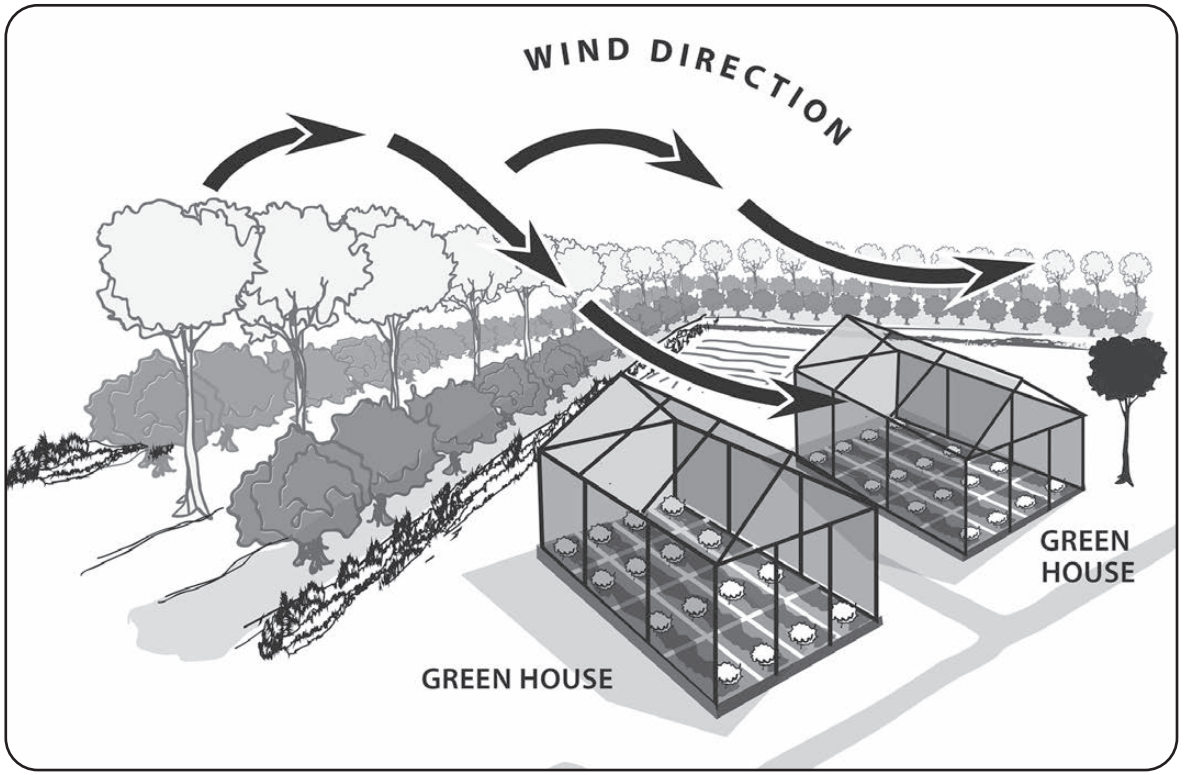


Illustration17: Wind Flows.

2. Wind can be deflected around or upward above vulnerable areas by shelter belts or windbreaks composed of strategically placed plants and trees. Deflecting and diffusing can reduce wind velocity enough to greatly reduce its destructive power. The difference between a 50 and 70 km per hour wind gust could be the difference between life and death or between some farm damage and farm destruction.

3. Managing trees and crops to be wind resilient. Pruning and strategic crop management can also greatly reduce damage by extreme wind events and is the most direct mitigation effort producing immediate improvements.

WINDBREAKS AND SHELTER BELTS: AGRO-FORESTRY STRATEGIES AND TECHNIQUES

The diagram below (Illustration 18) illustrates wind being deflected upwards over a windbreak and not returning to ground level at full velocity. Generally, the distance from the base of the windbreak with significant reduction in wind speed is 2 – 5 times the height of the trees. There is some slight reduction for up to 20 times the height of the windbreak. The composition and design of the shelter belt significantly impact effectiveness.

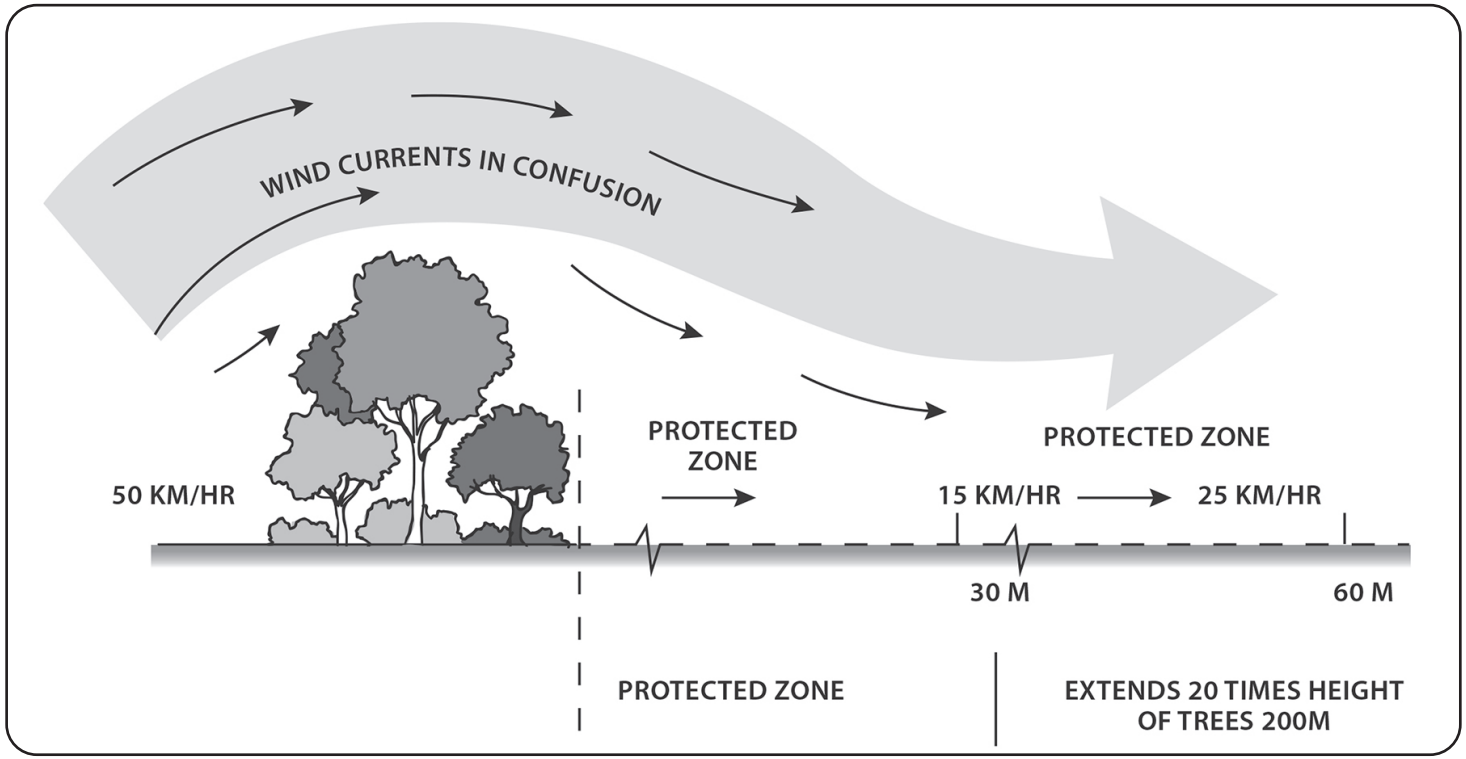


Illustration 18: Windbreaks and shelter belts.

WINDBREAK/ SHELTER BELT DESIGN FACTORS

1. Height of windbreak – Taller windbreaks will provide longer areas of protection. The higher the wind is 'squeezed' or deflected up, the greater the flow is confused or made turbulent.

2. Interval or spacing between windbreak strips – Multiple strips and short distance between consecutive 'rows' of windbreaks greatly reduce wind speeds. If your wind break is 20 feet tall, 200 feet of crop beds until the next windbreak row is good spacing. An acre is approximately 208 feet x 208 feet. ***Therefore, a significant measure of protection is achieved by surrounding each acre of production with shelterbelts.***

3. Density – This is the number of leaves, branches, and tree trunks that interfere with the wind over the area that the windbreak occupies. To get 100 per cent density, several rows or layers of trees and plants are required. An effective windbreak has 40 – 60 per cent density. The goal is not to create zero air flow, but rather to interfere with and deflect damaging wind gusts.

4. Continuity or the uniformness of windbreaks – Large holes in the windbreak, such as a road, will create a channeling effect, increasing wind velocity in this area. Roads or holes in the windbreak should be done diagonally.

5. Orientation – Is the angle at which the windbreak is laid out. It should be perpendicular or at a 90° angle opposite the wind direction. This is problematic when designing for hurricane events as wind direction is often different than the usual prevailing winds.

6. Length – Similarly to the height of the windbreak, the length of the windbreak directly affects the amount of wind protection on the down-wind cropping area. Windbreaks should be at least as long as the field being protected: longer is better

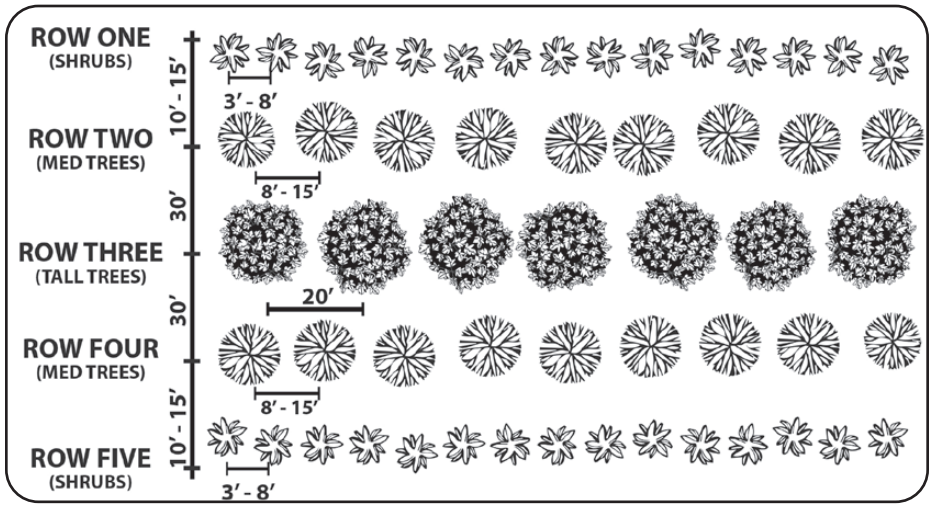


Illustration 19: Shelter belt design

> *The species chosen to use in the shelter belt will vary based on the conditions experienced in the area and local market demands. As the shelter belts are establishing, plant Vetiver and Elephant grass to offer some wind protection to establishing trees and to build up organic matter in the system.*

AGROFORESTRY AND ECOSYSTEM SERVICE PROVIDERS (ESP)

Many of the trees and plants around us provide support in maintaining/ enhancing our daily existence. These are called Ecosystem Service Providers for this reason. Besides the fact that plants provide oxygen, which is essential to human survival, plants also provide, food, medicine, shelter, building materials etc., while creating habitats for other creatures as well. The table below shows the value to be derived from a range of the tropical plants we know.

Tree or plant	ESP – Wind resilience and positive services and characteristics	Special considerations and design concerns
Bamboo	• Arguably the best tropical plants for wind breaks • Fastest growing plant on earth, clumping root ball creates a mound several feet above original soil level • Builds up an enormous amount of organic matter	• Leaf litter contains substances that can prevent or limit the growth of some other plants (allelopathic) • Not commonly intercropped
Banana **Plantain** **Macambo**	• The most important food security plant family for recovery after disaster • Mandatory in all sustainable agro-forestry systems as a tool to intercrop with young fruit trees for their protection while providing food, shade and cooling to other plants around	• Macambo is the best for agro-forestry, as it has the most aggressive growth habit and best resilience to disease, and most reliable producer
Vetiver	• The second fastest growing grass and has been used as a thatch roofing material for generations in the region • Drought tolerant, deep rooting (10 ft +), and long-lived • Often grown on slopes to stop erosion • Tough straw-like leaves are excellent long-lasting mulch • Decomposing leaves release chemicals that are both anti-fungal and nematocidal • Roots contain an essential oil used in high-end perfumes	• When grown densely and not maintained can harbour field pests including rats, snakes, and mongooses and become a significant fire hazard • Can irritate skin and cause cuts, therefore it is challenging to cut and carry • Seeds are generally not able to germinate, so it is very unlikely to spread and behave like a weed
Elephant grass	• Becomes a windbreak faster than any other plant • Fastest growing and tallest clumping grass, indestructible • Best cut and carry cattle feed with high nutritional profile • Wide, thick, long and tough leaves can be used as mulch • Disease, pest, drought resistant and can persist in an area for decades without any maintenance	• High silica content that dulls metal quickly and wears out weed-eater cord extremely fast • Spreads by both seeds and cuttings • Difficult to control and invasive

Table 3: Value added received from different providers

Tree or plant	ESP - Positive services and characteristics	Special considerations and design concerns
Glircidia (Glory-cedar)	• Fastest establishing living fence posts, leguminous nitrogen-fixing plant, good animal feed, medicinal, excellent in compost	• Often almost completely defoliated by caterpillars several times a year
Leucaena	• Fastest growing tree to produce strong wood and branches • Legume with leaves breaking down quickly into nitrogen-rich manure • Deep tap root, thrives in dry areas and is the only tree that can completely regenerate any degraded area by itself	• Left to seed it will become invasive and difficult to kill and remove • Seeds remains viable for years, will re-grow after fire and cutting
Moringa	• Fastest growing tree, grows easily from branches, can be used as living fence post, thrives in dry conditions • All parts edible and nutritionally valuable, highest nutritional density of all green leaves, known as the miracle tree • Excellent for compost, green manure, manure teas and animal feed, high value-added production potential	• Planted posts remain weak until over a year old due to very soft wood, becomes leggy and elongated, and therefore vulnerable to wind damage and uprooting, sparse canopy structure, limited lifespan
Neem	• Strong drought-tolerant evergreen, very decorative and dense canopy, very fast growing, all parts are anti-nematode, anti-bacterial and anti-fungal. Used to make botanical pesticides repelling a broad spectrum of pests and is a growth regulator and reproductive cycle breaker for leaf eating caterpillars	• Seeds have high viability and are spread by birds. Can become slightly invasive • Valuable wood, medicines and care products are made from it
Coconut	• Fast growing, drought-tolerant, excellent wind resistance, thrives on all soil types, used as a high-level windbreak. • High value-added production potential, consistent revenue generator and food security plant	• Evasive root system making inter-planting other crops around difficult. Requires considerable maintenance and fertility to remain productive
Mango	• Fast growing drought-tolerant hardy evergreen, resistant to all extreme weather conditions, re-grows vigorously after heavy pruning. Long standing windbreak creating ideal micro-climates for farming and leisure activities. Leaf and fruit litter create vibrant microorganism community. High value-added production potential	• Can harbour rodents, birds and other farm pests, vulnerable to theft. Root system can spread far beyond the drip line of the tree

Table 3 cont'd: Value added received from different providers

Tree or plant	ESP - Positive services and characteristics	Special considerations and design concerns
Tamarind	• Extremely strong and flexible wood making branches almost completely wind resistant • Fruit is very high in vitamin content (super food) • Long standing, tall growing with dense branching/canopy structure, great value-added production potential	• Invasive and very strong root system, make inter-planting difficult after established • Prone to pests and disease that can compromise fruit
Guava	• Strong wood good for tool making and coal production • Drought-tolerant evergreen, producing multiple fruit yields • Medicinal compounds in leaves, animals do not eat so can be planted in pasture areas	• Sparse canopy structure makes it less than ideal in a windbreak
Breadfruit	• Fast-growing, high-rising, grows well in a range of conditions and will compete to dominate the upper canopy • Their thick, giant leaves hide giant fruits that have been providing food security to communities for thousands of years	• Can be dangerous when planted too close to houses and if not well pruned and maintained
Acerola (Barbados) Cherry	• Dense foliage on evergreen bushy low growing tree provides excellent low-level windbreak • The fruit is the most vitamin C rich fruit in the world! • Excellent value-added superfood potential	• Seems to require full sun to produce large fruit harvests, so may be limited as an understory agro-forestry tree
Fat Poke	• Thick evergreen leaves and very dense branching structure makes this an ideal hedgerow shrub, with direct sun tolerance and able to thrive in poor soils • Produces consistent yields of fruits that can be sold locally and in value-added products, gaining popularity because of potential medical benefits and high protein content • Potential super food, more research required	• Used extensively as an ornamental hedge crop in southern Florida • This lowland tropical plant requires a lot of sun to fruit abundantly and should be used on the sunnier side of buffer zones

Table 3 cont'd: Value added received from different providers

Most trees can be managed and trained to become significantly more resistant to damage in major wind events. Beginning this training and control of the growth habit and shape, like with all living creatures, is far more effective when started as early as possible. In general, shorter is better for both wind resistance and production efficiency. Management of the branching, canopy density and other factors is extremely important to both protecting the plant and ensuring its sustained productivity.

PRUNING TECHNIQUES AND RELATED FACTORS

1. KEEP TREES SHORT

Tall trees exert much more leverage on their root system and are much more likely to be uprooted and fatally injured. Reducing a tree height from 20 feet to 15 feet can improve outcomes by 50 per cent.

2. SINGLE MAIN STEM/TREE TRUNK

Competing main trunks compromise the strength of a tree in two ways:

1. In strong wind events, trunks can shear and split apart, causing serious injury.
2. Multiple trunks are thinner than a single trunk and more likely to break

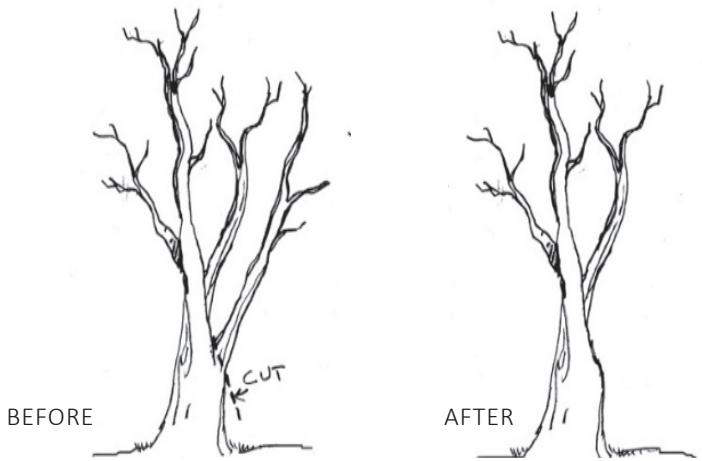


Illustration 20: Before & after trunk cutting.

3. ALTERNATING BRANCHING STRUCTURE

Two branches should not grow at the same height, prune to maximise distance from one branching point to the next Ideally, branches should spiral up the tree.

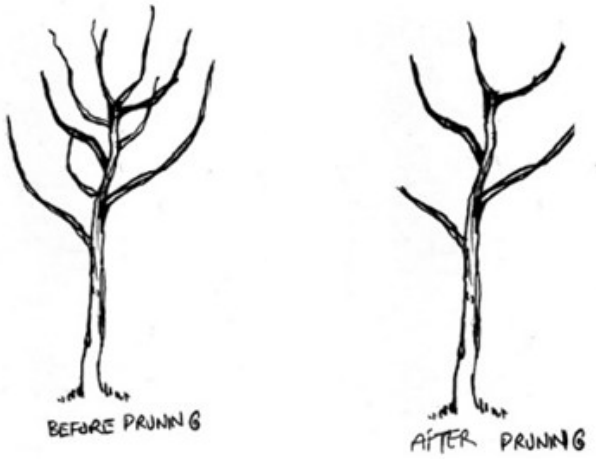


Illustration 21: Before & after pruning

4. REMOVE CROSSING BRANCHES

Branches should occupy their own space and move in strong winds without rubbing or touching other branches. Crossing branches can catch the force of the wind like a net.

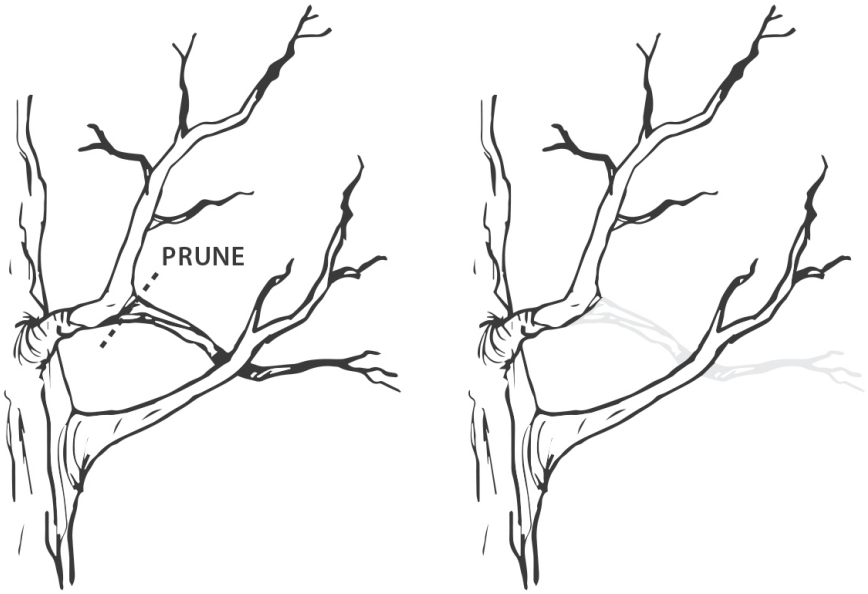


Illustration 22: Before and After Crossing Branches Pruning

5. REMOVAL OF BRANCHES GROWING INTO CENTRE

Pruning-out clutter in the centre of trees reduces wind leverage while allowing for ease of climbing, airflow within the canopy structure to prevent disease, and ease of picking fruit from the ground with tools.

6. 40 PERCENT RULE

When doing major pruning, try never to remove more than 40 per cent of the canopy (leaf surface area). Trees can be shocked, causing irregular and unpredictable responses and often produce poorly for years afterward or start sending suckers instead of fruiting.

7. PRUNING AT THE RIGHT TIME

Most fruit trees are pruned after they bear fruit, and as they are starting to push-out new growth.

Every tree species is different, and it is best to consult several sources to develop a pruning schedule and plan.

8. ESP PRUNING

Pruning can be used to train trees into the best possible shape, size and characteristics of a production tree for an agroecosystem or provide other services. Over time they can be contorted to occupy the spaces we need them in, to avoid shading crops while creating shade for harvest and other off-field activities.

WIND RESISTANT CROPS AND PLANT CARE PROCEDURES

Wind events are very difficult to predict. An approaching storm may or may not have winds that will cause damage, and often we only know when it is too late. However, if there is a strong likelihood that a wind event is approaching, there are measures that can be taken.

Preparing the farm for extreme wind events:

1. REMOVE FRUIT FROM TREES:

- Even green fruit needs to be harvested
- Some green fruits can be processed and can be useful in times of food shortage
- Flying fruits can be dangerous

2. CLEAN COCONUT TREES:

- All nuts removed and 50 per cent of leaves removed

3. CUT BACK AT LEAST 50 PER CENT OF BANANA/ PLANTAIN STOCK:

- When whole clumps are uprooted, regrowth is delayed

4. REMOVE TRELLISES AND STAKED PLANTS:

- Disconnecting trellised crops like tomatoes and laying them on the ground may save the crop

5. COLLECT SEEDS, SLIPS, AND TAKE CUTTINGS:

- Rare or high-value plants can be completely wiped out: secure planting material

6. PRUNE AND CUT BACK:

- Prune back all crops that can be cut back and re-grown: peppers, tomatoes, eggplant, tania, okra, rosemary, basil, pigeon pea, cassava

7. SECURE MATERIALS AND EQUIPMENT:

- Carefully secure dangerous debris, chemicals,
- farm animals, tools and equipment
- Remove greenhouse/shade-house coverings

SECTION 5

POST-DISASTER RECOVERY AND CONFRONTING CLIMATE CHANGE

INTRODUCTION

The Caribbean community has recognised that it is possible to build resilience through a number of actions. The Caribbean Disaster Emergency Management Agency is working with Member States, CARICOM Institutions and Associate Institutions to advance resilience through Comprehensive Disaster Management. The Comprehensive Disaster Management (CDM) Strategy 2014 - 2024 with its goal of **"Safer, more resilient and sustainable CDEMA Participating States through Comprehensive Disaster Management"**[21] is core to the achievement of a resilient Caribbean Community. Achieving this goal will contribute to an increased quality of life for all Caribbean citizens. As referenced in the introduction to this manual, Caribbean countries are among the 25 most vulnerable nations in terms of disasters per capita or land area, with their frequency and damages exceeding those for countries in other regions.

As noted previously, climate change is expected to intensify and/or exacerbate many of these vulnerabilities. Climate change is expected to increase sea-water temperatures, potentially fueling more storms. With many Caribbean populations living in high-risk areas exposed to sea-level rise and countries' weak infrastructure and heavy reliance on weather-sensitive sectors such as tourism or agriculture, the risks are expected to worsen through damage to biodiversity, coastal erosion, risk to food and water security, and increased health risks.[22]

Natural hazards such as drought, hurricanes, earthquakes and floods have had devastating impacts on the socio-economic and environmental landscape of the Caribbean within the last decade.

21 https://www.cdema.org/CDMStrategy2014-2024.pdf

22 Otker-Robe, Inci, "Building a More Resilient Caribbean to Natural Disasters and Climate Change", Let's Talk Development (World Bank Blogs), February 12, 2019, https://blogs.worldbank.org/developmenttalk/building-more-resilient-caribbean-natural-disasters-and-climate-change

The agriculture sector has not been spared this dislocation and devastation. The sector has been severely affected by these weather-related and seismic events, impacting the region's food and nutrition security. These impacts include, *among others*, loss of crops and livestock, reduced agricultural productivity, destruction of housing for livestock, increased migration of fish from the region, high food prices and loss of livelihoods of affected farmers and fisherfolk.[23]

The region has put measures in place to respond more efectively to the challenges posed by natural hazards and climate change. To help the agriculture sector recover effectively and quickly after a disaster, several important measures can be implemented. Biodiversity reserves are key to this, as well as planning ahead. It is critical to have a strategic plan in place, and therefore the biodiversity action plans for the region developed under the Convention for Biodiversity (CBD) must be implemented.

The FAO notes that building resilience requires that we "grasp the dimension of multiple challenges" (High-level Panel on Global Sustainability, 2012). An examination of the diversity of natural hazards affecting agriculture and food security indicates that, even without climate change, a multiplicity of hazards are already eroding livelihoods and compromising gains made in food security. These hazards are contributing to the difficulties in meeting the Sustainable Development Goal (SDG) 2 to end hunger, achieve food security and improved nutrition and promote sustainable agriculture by 2030. These hazards will negatively impact the SDGs if hazard mitigation or climate adaptation measures are not put in place. All hazards are included: geological hazards, such as earthquakes, tsunamis and volcanic eruptions; human-induced hazards, such as conflict, economic crises, high food prices;

and weather-related hazards, such as floods, drought and storms.[24] This manual will assist regional small farmers in strategically implementing disaster risk management.

DISASTER PREPARATIONS AND RECOVERY STRATEGIES

Designing and building resilient systems is a long-term effort. This section will cover short-term activities to prepare for potential or imminent climate-related disasters and explore mechanisms that could be put in place to help recover effectively and quickly after a disaster.

23

24 Food and Agriculture Organization of the United Nations [FAO], "Climate-Smart Agriculture", http://www.fao.org/climate-smart-agriculture/resources/publications/en/?page=11&ipp=5&tx_dynalist_pi1%5Bpar%5D=YToxOntzOjE6IkwiO3M6MToiMCI7fQ%3D%3D

Photo 31: CPDC Situation Analysis

> *Post-disaster livelihood recovery…is marked by prolonged periods of difficulty in accessing technical and financial support, particularly from government entities. These combined impacts of repeated exposure to natural disasters also cause psycho-social effects such as feelings of despair."* (See Situation Analysis, page 4.)

> *In Dominica, the majority of the small farmers reported a dramatic increase in pests and diseases post-Maria…This problem has caused farmers significant losses in plant varieties, time, and income, while attempting to recover and restore their farming operations to normalcy. Post-Maria, Dominica's biodiversity has been altered.* (Situation Analysis pg 14)

TOPICS TO BE COVERED IN THIS SECTION:

- Seed saving: varietal selection and improvement, and best practices for long-term seed storage
- Water storage and purification
- Planning and designing for disaster recovery
- Creating a farm recovery plan
- Adapting to and confronting changes in pests and disease following natural disasters
- Creating and protecting biodiversity 'safe-zones'Seed saving: Varietal selection and improvement, and best practices for long-term seed storage

A simple way to get and save seeds is as follows:

1. **Remove seeds from the fruit/vegetable**
2. **Wash off as much of the fleshy part as possible from the seed**
3. **Dry the seeds for three days or more**
4. **Place in a sealed plastic bag**
5. **Store in a cool part of a refrigerator (not freezer)**

In the Caribbean, there was a legacy of seed saving and adapted Caribbean varieties. Unfortunately, generational achievements in specialized varieties have been severely compromised by near complete dependence on imported hybrid seeds. This has left farmers more vulnerable to climate-related disasters. A number of the varieties that are currently sold are still open pollinated types. The seed would be 'true to type' (i.e., grow and bear fruit identical to the parent plants) when harvested. One would just have to note which ones and recommend them.

BASICS OF SEED GENETICS:

Hybrid vs. GM vs. Heirloom seeds – **Hybrids** occur naturally when pollen from one plant that is genetically different pollinates another plant. **Genetically Modified (GM)** seeds are formed from unnaturally combined genetic material (DNA) that is inserted into the reproduction process. **Heirloom** varieties are hybrids that became 'stable' self-pollinators that produce viable seeds yielding virtually identical off-spring to themselves.

Seed saving can only be done reliably using heirlooms. However, hybrid seeds can be 'de-hybridized' by growing the seeds out several times and selecting the characteristics that work better.

Photo 32: Heirloom seeds

Adapting and improving varieties:

- Plants change or adapt their growth pattern to better suit their environment to improve survival
- Miraculously, these adaptations slightly modify their genetic composition after each generation
- The more times we grow plants in an environment, the better they adapt to growing there
- Selecting and breeding 'improved' varieties and removing all others creates improved, stable heirlooms

Seed saving and long-term storage:

- Seed saving is a critical skill for human survival.
- Plant seeds have specific sets of best practices to dry them at the ideal rate and to the right moisture content.
- Seeds are dormant living things. Consistent control of humidity and temperature allows for long-term storage.

WATER STORAGE AND PURIFICATION

Securing both drinking water and irrigation is the most important consideration before a disaster and the first step in recovery. An important lesson to be learned from previous disasters in Haiti and throughout the world is that contaminated drinking water often causes more death and suffering than the initial disaster itself. Storage of large amounts of clean water before a disaster is critical. **As the climate changes, farmers need to expand water storage capacity continually and aggressively.**

HOMEMADE FILTRATION SYSTEM TO PURIFY WATER

STEP 1.
Removing sediments from murky water: Modify 55-gallon plastic shipping barrels into a large filtration system by adding a tap at the bottom, and adding clean stones, gravel, sand, and a cloth filter. This will remove the majority of sediments. Periodically change the filter-bed contents and/or wash filtration materials.

STEP 2.
Natural chemicals to clarify cloudy water: Pound the seeds of moringa into powder/paste to add to filtered water and shake to further chemically clarify water (moringa seeds contain chemical precipitants).

STEP 3.
Removing contaminants and bad tastes: Modify a 5-gallon bucket into a charcoal water filter system to remove some contaminants and bad odors/taste from drinking water, as shown in Figure 34. Figure 35 shows crushed moringa seeds clearing up murky water.

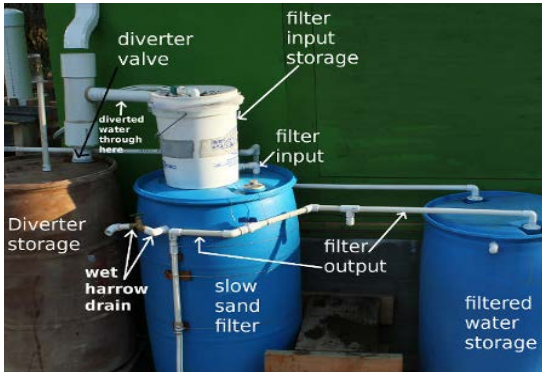


Photo 33: Barrels used to collect, filter and store water.

Photo 34: Crushed moringa seeds will clarify murky water

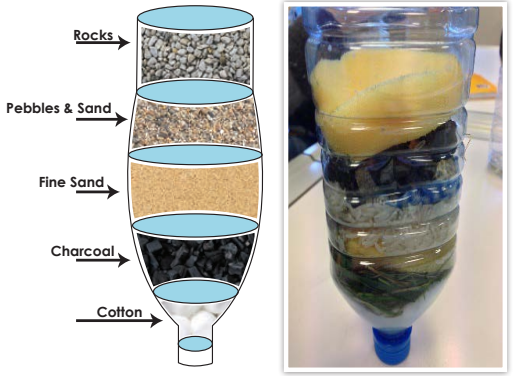


Illustration 23: Homemade water filtration system

Effective water filters can be made with charcoal and other household materials.

PLANNING AND DESIGNING FOR DISASTER RECOVERY

Every resilient farm dedicates a significant portion of its land-space to biological reserves required to survive and recover after disaster. These areas do not have to be within main production areas: pockets and fringes are fine and near or within windbreaks/shelter belts is ideal.

Suggested composition of biological reserve areas Figure 36 shows examples of plants that can contribute to improved resilience for farmers.

- Vetiver: Erosion prevention, mulch, compost, and building/ roofing material
- Native flowering perennial plants: Beneficial and pollinator insect habitat, natural pesticides
- Living fence posts: Glircidia, moringa, psychic nut, corn plant: repairing/building perimeter fencing
- Neem trees: Creation of cooler micro-climates and production of a variety of insect treatments
- Mango trees: Micro-climate, food, micro-biology
- Traditional root and food crops: Yam, tania, dasheen, cassava, eddoe, banana
- Native vining beans: Hyacinth bean, cow pea

Farm Recovery kit:

In recovery from a disaster, it would prudent and useful to have a kit with items that can help restore normal activity on the farm and in the wider ecosystem. Essential components of the kit would be:

- Planting bags and containers (1,000 minimum)
- Chemical fertilizer and pesticides
- Neem seeds for production of pesticides
- Moringa seeds for water purification and planting
- Charcoal for cooking and water purification

Photo 35: Vetiver grass

Photo 36: Bee pollinating passion fruit flower

Photo 37: A live fence using glyricidia

Photo 38: Corn in a field (in background)

Photo 39: A moringa tree (above) and fruit (right)

Photo 40: Cowpea pods on a plant

CREATING A FARM RECOVERY PLAN

After a major disaster that affects large portions of the country, farm planning becomes survival planning. Farmers battle on the frontline for community and national recovery. Based on the accounts of those recovering after the 2019 hurricane in Dominica, we learn that technical support is either unavailable or unreliable, and that many farmers began planting the same traditional 'market crops', putting a glut on the market. Recovery is not business as usual. The following list of activities prioritizes survival crops to secure food in the household and community:

1. **SECURE SEEDS, CUTTINGS OR PLANTING MATERIAL FOR FOOD CROPS FIRST!!!**
   - *Plant or re-plant calorie rich food crops first: banana, dasheen, yam, cassava, corn, sweet potato, carrots, squash and beans*
   - *Don't plant market crops first: tomato, cucumber, lettuce which have little value as survival food!*
2. **PLANT GREENS, GRAINS AND BEANS**
   - *Leafy greens provide vital vitamins and minerals: plant callaloo, spinach, kale and others first*
   - *Flour for baking can be derived from: cassava, breadfruit, plantain and other grain substitutes*
   - *Plant perennial or 'wild-type' climbing beans: fast growing, disease resistant, and reliable producers of both green beans and dry beans for protein include: cow pea, long or 'bora' beans, wing bean, pigeon pea and jack bean*
3. **BUILD A PLANT NURSERY AND NURSERY BUSINESS!**
   - *After securing vital survival food crops in the ground, build a nursery to propagate and sell plants in the community*
   - *Recovering from disaster brings out the farmer in many, and it is therapeutic for healing the community*

- **CREATE A CROP ROTATION PLAN**
  - *Create a crop plan that focuses on food crops first, shifting more and more to market crops while producing survival food for your family.*

CREATING AND PROTECTING BIODIVERSITY 'SAFE-ZONES'

One important benefit of agroforestry is the creation of micro-climate and protected zones where beneficial insects can thrive. Insects that become crop pests can adapt their breeding cycles to the conditions of their target crops. Beneficial insects or pest predators are generally not as specialized and do not breed as easily within open field conditions. Instead, they require:

- Protected areas adjacent to fields to move in and out of, seeking food and avoiding danger
- Consistent supply of water and pests to feed on, or alternative food source (normally pollen)
- Protection from extremes in climate
- The resources and habitat required for breeding

THE IRONY OF MAINTAINING PEST PREDATORS

Generally, to maintain a healthy population of pest predators on a farm, you must have a healthy population of pests. This means that the goal cannot be the complete elimination of pests but rather managing pests at the level where ecological balance is maintained without significant loss in crop yield.

Natural enemies are the "friends of the farmer" because they help farmers to control pests or diseases in crops. Natural enemies of pests and diseases do not damage plants and they are harmless to people. They can be divided into four groups:

Predators (eating pest organisms): spiders, lady beetles, ground beetles, praying mantis, stick bug, firefly, predator bug, and syrphid flies. Predators usually hunt or set traps to catch prey to feed on. Predators can feed on many different species of insects. (See appendix for photos and descriptions.)

Parasitoids (parasitizing pest organisms): commonly wasps or flies. Only the larvae are parasitic and they develop on or inside a single insect host. Parasitoids are usually smaller than their host. There is a parasitic wasp for every insect pest, but it takes a skilled observer to know when they are present.

Pathogens (causing a disease in pest organisms): fungi, bacteria, or viruses that can infect and kill insects. Pathogens require specific conditions (e.g., high humidity, low sunlight) to infect insects and to multiply. Commonly used insect pathogens are Bacillus thuringiensis (Bt), and NPV virus.

Nematodes (microscopic worms that destroy soil pests): these microscopic worms generally live in the soil, although there are species that spend part of their lives patrolling plant surfaces aboveground. Nematodes are best known as soil pests (root-knot nematodes) but there are several important varieties that are bred in laboratories as pest predators.

ADAPTING TO AND CONFRONTING CHANGES IN PESTS AND DISEASE FOLLOWING NATURAL DISASTERS

Emergent pests: Some pests only become a problem after a disaster. As insect ecosystems are thrown out of balance, some pests will emerge and dominate and even appear as a 'new pest'.

Exotic pests are occasionally introduced by storm systems that carry pests and disease from distant areas; there will be no natural enemies to keep populations in check.

STEPS TO COMBAT PESTS AFTER A DISASTER:

STEP 1. MONITORING

- Be extra observant and make pest monitoring and research part of the daily routine

STEP 2. CREATING AND MAINTAINING INSECT SANCTUARIES

- Plant flowers that bear pollen, since pollen is food for not only bees but also wasps, which are important insect predators and also feed on pollen

STEP 3. COLLECTION AND BREEDING OF PEST PREDATORS

- Create beneficial insect sanctuaries (insect zoos) on farm. One can use the permaculture zoning approach for setting up such areas. Zone 5 in permaculture-based planting layout is like a wilderness where wild plants and animals can be encouraged. In a Zone 2 area, where crops are not visited as often, the right assortment of flowering plants (e.g., basil) could be planted as well.

STEP 3. COLLECTION AND BREEDING OF PEST PREDATORS CONT'D

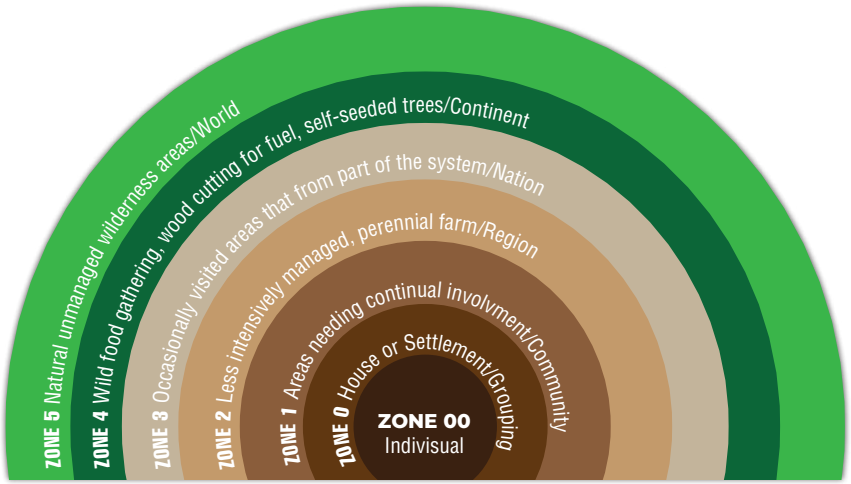


Illustration 24: Example of what is planted in different permaculture zones on a farm

- National and regional centres for breeding pest predators should be an industry priority

Ladybugs, or lady beetles

(Hippodamia convergens)
Most ladybugs have oval, dome shaped bodies with six short legs. Depending on the species, they can have spots, stripes or no markings at all. Ladybugs are classified as beneficial insects and feed on a wide range of insects and their eggs. Both the adults and larval stages feed on soft bodied bugs. Plants that have nectar and pollen attract ladybugs and they will stay in the garden as long as a food source is present. The adults lay bright yellow eggs which hatch within one week that will pupate after three to four weeks.

Photo 41: Ladybug

Eggs

Photo 42: Ladybug eggs

Larva

Photo 43: Ladybug larva

Pupa

Photo 44: Ladybug pupa

Leafminer Parasite

Leafminer Parasite (Diglyphus isaea) is a small, black, non-stinging wasp that searches out leafminer on which to lay its eggs. The leafminer parasite is deadlier to leafminers than the pesticide sprays as the leafminers hide in the tunnels and are protected from the spray. The leafminer parasite tracks down its prey by rapping its antennae on the mine to locate the miner.

Photo 45: Leafminer Parasite

Mealybug Destroyer

The Mealybug destroyer (Cryptolaemus montrouzieri) is a very effective pest controller, as two to five mealybugs per plant will control pest outbreaks. The mealybug adults and larvae feed on the eggs and young crawlers of the invading pests. Adult females will lay around four hundred eggs over their two month life span. The Mealybug destroyer loves to eat mealybugs, especially citrus mealy bugs. The MD was first introduced into the United States from Australia in 1891. One MD will destroy up to 250 mealybug larvae and is considered to be an effective biological control agent.

Photo 46: Mealybug destroyer

Photo 47: Mealybug

Soldier Bug

Soldier Bug (Podisus maculiventris) is a very important predator as it feeds on some of the most damaging insects and bugs. The soldier bug penetrates its victims with its large, weapon-like proboscis and sucks out its bodily fluids. The beetles are elongated, soft bodied, and about half an inch long. Colour may vary from yellow to red with brown or black wings.

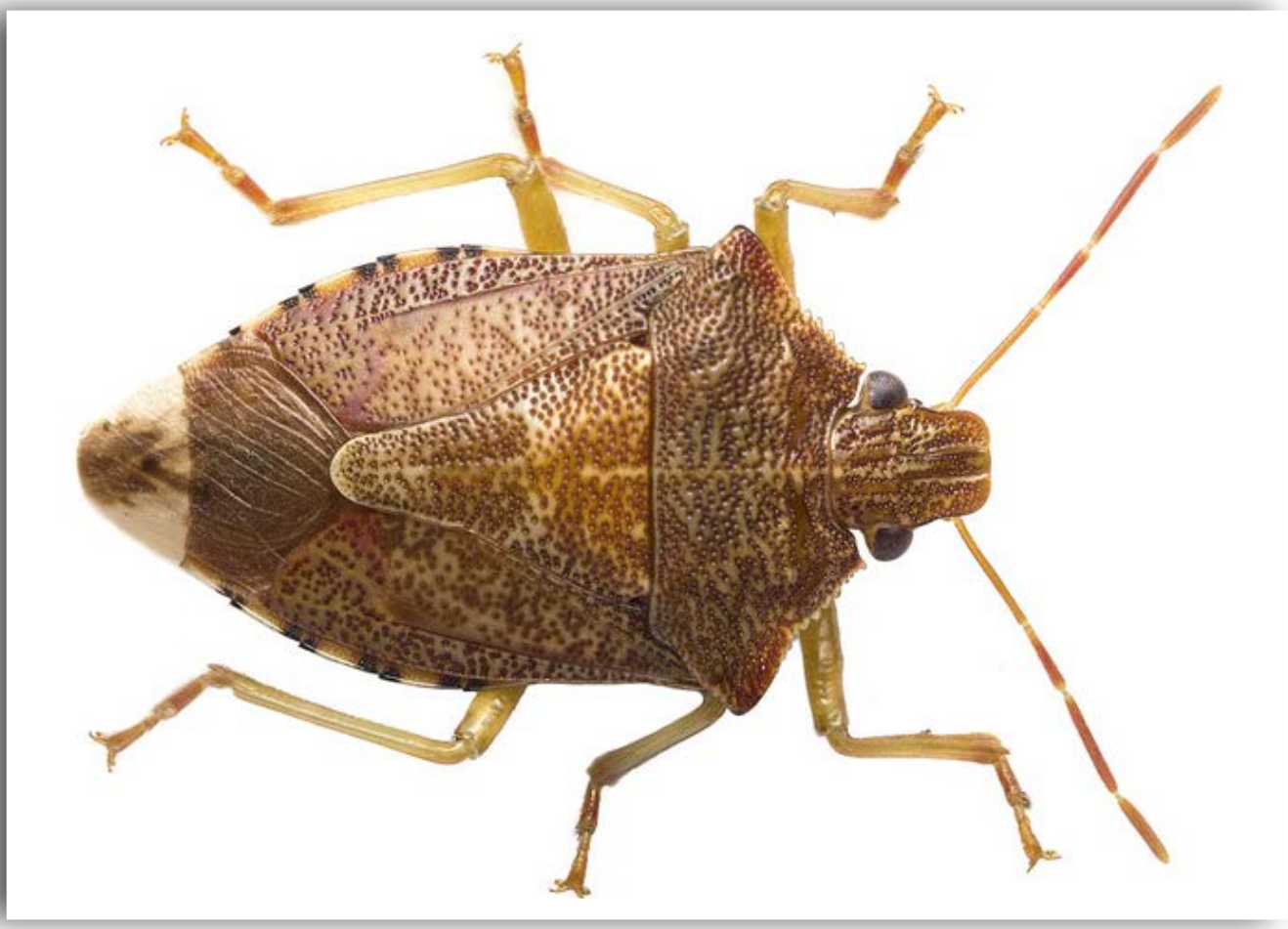


Photo 48: Soldier Bug

Gall Midge

The Gall Midge (Aphidoletes aphidimyza) is predator to a wide range of aphids. It is considered a night feeder and is especially deadly in its larval stage. Unlike many of its compatriots, it spends its pupal stage in the ground. The Gall Midge is a delicate insect (Order Diptera) characterised by beaded, somewhat hairy, antenna and a few veins in the short haired wings. The brightly coloured larvae live in leaves and flowers, usually causing the formation of tissue swellings (Galls).

Photo 49: Gall Midge

Photo 50: Gall Lava

Parasitic Wasp

The Parasitic Wasp (Aphidius colemani) starts its life as a parasite, in or on the body of a host, but they end up as predators, eating the host entirely. This wasp is able to detect the aphid's honeydew secretions, and after they track the aphids down they inject an egg into the aphid. When the eggs hatch, they consume the pest from the inside.

Photo 51: Parasitic Wasp

STEP 4. NATURAL NON-LETHAL METHODS TO AVOID PESTS

- DO NOT plant crops prone to insect pests!
- Produce pest deterrent sprays using: neem (leaves and/or seeds), hot pepper, garlic, etc.
- Build 'insect traps' to install and monitor around the farm (many simple designs can be found online) E.g., Durable Yellow card with Vaseline or non drying glue pasted on it will attract and catch insects such as aphids and white flies.

STEP 5. PESTICIDE PRODUCTION AND APPLICATION

- Chemical products may be unavailable for long periods of time following a major disaster
- After a disaster, extra care must be taken in the application of any pesticide, natural or chemical
- As insect ecosystems are recovering, any further die-offs could have severe impacts

NATURAL PESTICIDES

Apricot

Photo 52: Mammy apple tree

Apricot (St. Lucia) (Mammea Americana) Mammy Apple – Seeds in liquid or powder are effective against ants, aphids, cockroaches, cucumber beetle, diamondback moth, flies, imported cabbage worm and several others. Dry seeds are crushed into a powder and sprinkled on cabbage plants to kill caterpillars.

Chile Pepper

Photo 53: Chile Pepper

Chile pepper (Capsicum frutescens) – Collect two handfuls of chillies and dry. Grind into a fine powder (use eye protection). Mix in water, and allow to stand for several hours, strain, add soap and spray.

Garlic

Photo 54: Garlic

Garlic (Allium savitum) – Use a mixture of finely chopped heads of garlic with 10 litres of water to deter pests. It stores for two weeks unstrained but remains effective for only for 1-3 days.

Glory Cedar

Photo 55: Glory Cedar (Gliricidia sepium)

Glory Cedar (Gliricidia sepium) – Prepare a poison bait for rats and mice by boiling several large pieces of bark in water with 8 kilos of maize. Scatter treated maize in rodent infested areas.

Marigold

Photo 56: Marigold plant

Marigold (Tangetas indica, erecta, minuta) French, African and Mexican. All these varieties can be utilised to make sprays to deter attacks from a wide variety of biting/pricking insects. Most importantly, marigold contains substances that kill nematodes.

Moringa

Photo 57: Moringa tree

Moringa (Moringa oleifera). Leaves have fungicidal properties effective against damping-off disease. To protect seedlings from fungal attack, work moringa leaves into the soil one week before sowing.

Neem

Photo 58: Young Neem Plant

Photo 59: Mature Neem leaves

Photo 60: Neem seeds

Neem *(Azadiracta indica)*. Contains several insecticidal compounds. The main active ingredient is azadiractin, which both deters and kills many species of caterpillars, thrips and whitefly. Both seeds and leaves can be used. Neem seeds contain a higher amount of azadiractin, but leaves are available all year. In addition to being an insecticide, nematicide and bactericide, neem oil (from seeds) is a fungicide. Commercial products made with neem are available in the region. The active ingredient in neem mimics an insect hormone and repels insects, as well as inhibiting their digestion, metamorphosis and reproduction. It has been used effectively on over 100 leaf-eating insects. Neem is also unique because it has been proven to act systemically, meaning it can be absorbed by roots and leaves of crops and incorporated into their cells, thereby affecting pests that feed internally, such as leaf-miners.

Deterrent - Use a half bucket of neem leaves blended or just left to soak overnight, strain, add soap, and spray.

Systemic Pesticide - Collect mature seeds, remove the husk, and allow to dry completely. Pound into a powder using a mortar and pestle. Use 50 grams neem kernels to 1 litre of water. Mix and leave overnight. The next morning, filter the solution through a fine cloth and use it immediately for spraying. It should not be further diluted.

Oleander

Photo 61: Oleander

Oleander (Nerium indicum) – WARNING! Considered poisonous to humans. All parts of the plant contain substances poisonous to ants, flies, beetles, diamond-back moth, weevils, and rice brown leaf spot fungus. Oleander also has nematicidal properties. Crush any part of the plant and soak for 30 minutes in water, filter and spray.

Onion

Photo 62: Onion

Onion (Allium cepa) – Solutions made from onion peels, leaves and bulbs can repel most biting insects and fungal diseases, including damping off, late blight, and tomato leaf spot. Mix 10-100 grams of onion peel and leaves per litre of water, allow to sit for 4-7 days covered, filter and spray. Can be used mixed with other plants (marigold, neem, etc.) to broaden the deterrent capabilities.

Papaya

Photo 63: Papaya

Papaya (*Carica papaya*) – Leaves contain fungicidal properties. Can fight coffee-rust, powdery mildew and rice brown leaf spot. Directions: Vigorously mix one kilogram of finely shredded leaves per liter of water. Filter the solution and dilute with soapy water (100g soap flakes per 25 liters water) and spray.

Physic Nut

Photo 64: Barbados nut

Physic nut (*Jatropha curcas*) Barbados nut, Biodiesel plant – Living fence plant. Soak any part of the plant in water and strain to make a spray effective against leaf eating larvae and snails. The use of poisonous seed oil makes a stronger pesticide that can treat weevils and bollworm.[25]

25 Elwell, H. A., and Anita Maas. *Natural Pest and Disease Control*. Zimbabwe: Natural Farming Network, 1995.

Tobacco

Photo 65: Tabacco

Tobacco (*Nicotiana tabacum*) – WARNING! Tobacco is a poison and can kill humans if ingested: do not breathe the vapours or allow to touch the skin. Because of this, the use of nicotine is generally no longer allowed in organic farming. Only real tobacco, Quassia Africanna Amarna contains nicotine, the substance acting as an insecticide. Collect healthy, fresh leaves which are free of spots. Mix 80 grams of dry leaves and stems per litre of water and soak for two days.

Urine

Photo 65: Cow urine

Urine (Cow or goat) – Urine is used as fertilizer. However, one has to be cautious in applying this to plants for which the leaves are eaten raw (e.g., lettuce) and edible underground parts. It is usually recommended, for health safety, that urine is applied in subsurface irrigation rather than sprinkling on the plant foliage. Collect cow or goat urine and mix with a small amount of soil. Allow to ferment for two weeks. Dilute with 2–4 litres of water per litre of urine. Urine is very high in nitrogen and thus can burn tender leaves. Do not apply in full sun and dilute further if necessary. Human urine can also be used.

Glossary

AGRICULTURE EXTENSION OFFICERS: Agricultural extension officers are intermediaries between research and farmers. They operate as facilitators and communicators, helping farmers in their decision-making and ensuring that appropriate knowledge is implemented to obtain the best results with regard to sustainable production and general rural development.

AGROFORESTRY: Agriculture incorporating the cultivation of trees.

BUNDS: A containment area where water is slowed down and filtered.

CLIMATE CHANGE: A long-term change in the average weather patterns that have come to define global climate.

CLIMATE-SMART AGRICULTURE: Climate-smart agriculture is an approach to achieve short- and long-term agricultural development priorities in the face of climate change and serves as a bridge to other development priorities.

DISASTER: Disasters are serious disruptions to the functioning of a community that exceed its capacity to cope using its own resources. Disasters can be caused by natural, man-made and technological hazards, as well as various factors that influence the exposure and vulnerability of a community.

DISASTER RISK MANAGEMENT: The application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.

DRAINAGE: A system by which water is drained from the soil to enhance production.

DROUGHT: A prolonged period of abnormally low rainfall leading to a shortage of water.

ECOLOGICAL BALANCE: The equilibrium between, and harmonious coexistence of, organisms and their environment.

ECOSYSTEM SERVICE PROVIDERS: Species or populations that provide specific ecosystem services. E.g., mango, coconut and breadfruit trees provide food, shelter, useful materials and other support to us as humans. Bees and birds provide pollination services.

EROSION: The gradual destruction of earthen materials by natural forces (such as water or wind

EXOTIC PESTS: Organisms that are introduced into an area beyond their natural range and become pests in the new environment.

FOOD SECURITY: The state of having reliable access to sufficient affordable, nutritious food.

GENETICALLY MODIFIED: The results of the process of altering the genetic makeup of an organism.

NATURAL HAZARD: A natural hazard is an unexpected and/or uncontrollable natural event of unusual magnitude that might threaten people and infrastructure. (e.g., floods, storms, hurricanes, tsunamis and droughts)

HEIRLOOM: A traditional variety of plant or breed of animal which is not associated with large scale commercial agriculture. Seeds are saved and passed on from each generation within communities (local selection). Since they are open pollinated, the seeds will produce plants that are identical to the parent plant.

HYBRID: The offspring of two plants or animals of different varieties.

HYDRO RAM PUMP: A configuration of two water reservoirs at different elevations that can generate power as water moves down through the turbine.

INSECT SANCTUARIES: An area dedicated to preserving insect habitats, allowing them to survive and flourish.

INTER-PLANTING: The practice of planting a fast growing crop between a slow growing one to make the most of your land space.

INVASIVE SPECIES: A species that is non-native to the ecosystem which usually spreads very quickly.

MICRO-CLIMATE: Any climatic conditions in a relatively small area, within a few feet or less above and below the Earth's surface, and within canopies of vegetation.

MULCHING: The process or practice of covering the soil/ground to make more favourable conditions for growth, development and efficient crop production.

NATURAL PESTICIDES: Pesticides made from natural ingredients, such as minerals mined from earth, bacterial extracts, or plant extracts.

NO-TILL AGRICULTURE: No mechanical manipulation of the soil (ploughing harrowing, etc.) takes place between the harvest of one crop and the planting of the next.

PERENNIAL: A plant lasting for three seasons or more.

PURIFICATION: The act or operation of separating and removing from anything that is impure or noxious.

RESILIENT: The ability to recover from setbacks. Adapt well to change and keep going in the face of adversity.

SEISMIC: Relating to the vibrations of the Earth.

SHELTERBELT: A line of trees planted to protect an area, especially a field of crops, from fierce weather.

SUPER-FOOD: A nutrient-rich food considered to be especially beneficial for health and well-being.

SUSTAINABLE AGRICULTURE: A type of agriculture that focuses on long-term production of crops and livestock while having minimal effects on the environment as well as maintaining economic stability of the farm.

SUSTAINABLE DEVELOPMENT GOALS: The Sustainable Development Goals (SDGs), set up in 2015 by the United Nations General Assembly and to be achieved by 2030, are 17 global goals with 169 targets designed to be a blueprint to achieve a better and more sustainable future for all.

TRELLIS: A framework of light wooden, plastic or metal bars chiefly used as a support for fruit trees and climbing plants.

VULNERABLE: The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

WINDBREAKS: A linear planting of trees and shrubs designed to slow the wind and its impact on crops, soils, livestock and people.

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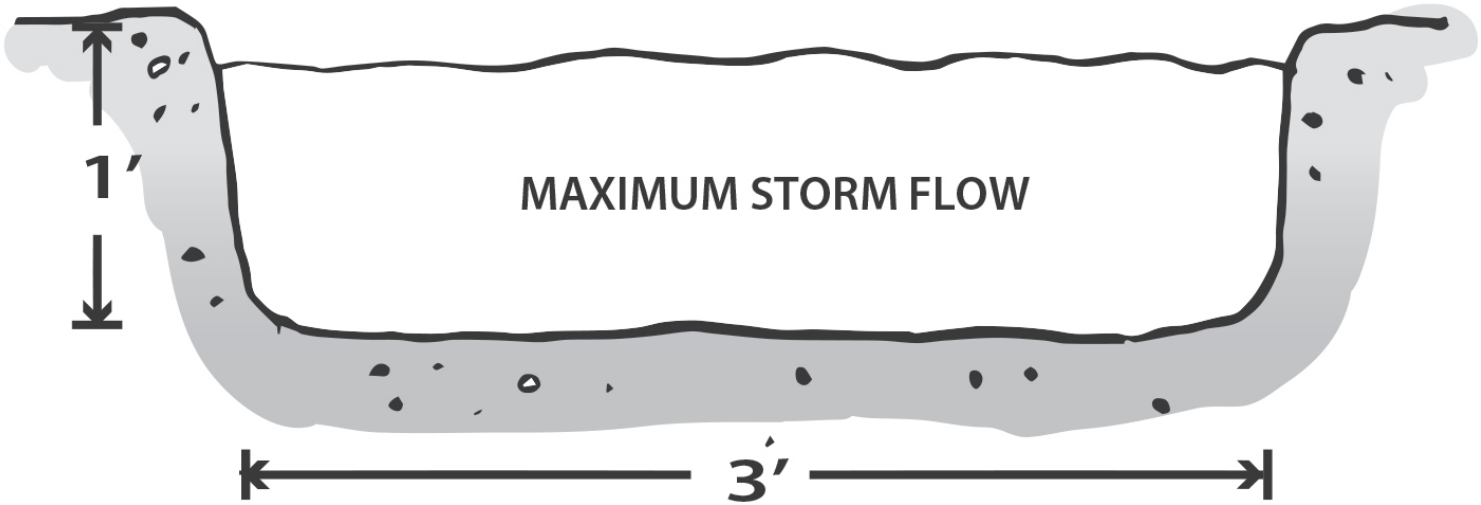
WHICH ONE OF THESE TWO IS **LESS** *EROSIVE*

ANSWER

Wide drain.



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