**AGRICULTURAL ENGINEERING III**

**SOIL AND WATER CONSERVATION**

**1. Introduction to soil and water conservation**

* Definition
* Process and mechanic of soil erosion
* Factors influencing soil erosion
* Types of soil erosion
* Effect of soil erosion

**2. Soil erosion measurements**

* Universal soil loss equation (USLE)
* Application of USLE
* Soli loss tolerance

**3. Methods of soil and water conservation**

* Biological methods
* Cultural methods
* Physical methods

**4. Water harvesting**

* Importance of water harvesting
* Methods of water harvesting-roof, Rock, weirs, dams, ponds, retention ditches

**5. Design of soil and water conservation structure**

* Factors influencing selection and design of soil structures
* Types of structures-water ways, cutoff drain, terraces, contours

**6. Soil conservation planning**

* Importance of planning
* Process of planning

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| Soil erosion is a naturally occurring process that affects all landforms. In agriculture, soil erosion refers to the wearing a way of a field's topsoil by the natural physical forces of water ([Figure 1](http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm#f1)) and wind ([Figure 2](http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm#f2)) or through forces associated with farming activities such as tillage. Erosion, whether it is by water, wind or tillage, involves three distinct actions – soil detachment, movement and deposition. Topsoil, which is high in organic matter, fertility and soil life, is relocated elsewhere "on-site" where it builds up over time or is carried "off-site" where it fills in drainage channels. Soil erosion reduces cropland productivity and contributes to the pollution of adjacent watercourses, wetlands and lakes.Soil erosion can be a slow process that continues relatively unnoticed or can occur at an alarming rate, causing serious loss of topsoil. Soil compaction, low organic matter, loss of soil structure, poor internal drainage, Stalinization and soil acidity problems are other serious soil degradation conditions that can accelerate the soil erosion process.Land degradation Land degradation caused by agriculture takes many forms and has many causes. Some of the most important types of land degradation (and those that we will focus on) include:**(1)** Degradation related to [overgrazing](http://people.oregonstate.edu/~muirp/overgraz.htm) by livestock**(2)** Degradation related to soil [erosion](http://people.oregonstate.edu/~muirp/erosion.htm) , here related to inappropriate cultivation practices)**3)** Degradation attributable to soil [salinization](http://people.oregonstate.edu/~muirp/saliniz.htm) (a buildup of salts in soil that results from irrigation in certain situations)**(4)** Degradation attributable to [waterlogging](http://people.oregonstate.edu/~muirp/waterlog.htm) (another problem related to irrigation)Another major cause of land degradation is conversion of tropical forests to agriculture (crop or pasture land), HiSoil erosion process and mechanics1. Accelerated Erosion Two steps are recognized in accelerated erosion:
	1. detachment - freeze/thaw, wet/dry, flowing water, wind, raindrops
	2. Transportation - floating, rolling, dragging, splashing, etc.
2. Power of Raindrops Raindrops impact has 3 important effects
	1. It detaches soil - force of falling water.
	2. Beatings tend to destroy granulation at surface - crusting leads to more runoff
	3. Transport soil

Deposition Occurs when sufficient energy is no longer available to transport the particles**Factors Affecting Soil Erosion**The factors that influence erosion are: 1. The amount and intensity of rainfall and wind velocity. 2. Topography with special reference to slope of land. 3. Physical and chemical properties of soil. 4. Ground cover its nature and extent. Soil erosion is the wearing away detachment and transportation of soil from one place and its deposition at another place by moving water blowing wind or any other cause. **1. The amount and intensity of rainfall and wind velocity:** Rainfall is the most forceful factor causing erosion through splash and excessive run off.Rain drop erosion is splash, which results from the impact of water drops, directly on soil. Although the impact of rain drops on water in shallow streams may not splash soil, it does cause turbulence, providing a greater sediment carrying capacity. Large drop may increase the sediment carrying capacity of run off as much as 12 times. If rain falls gently, it will enter the soil where it strikes and some will slowly run off, but if it occurs in torrents, as usually the monsoon rains doe, there is not enough time for the water to soak through the soil and it runs off causing erosion. Run off that causes erosion, therefore, depends upon intensity, duration, amount and frequency of rainfall. It is observed that rains in excess of 5 cm. per day always caused run off whereas those below 1.25 cm. usually do not. (The results of soil and runoff losses from air dry deep black and later tic soils with 2 p.e., slope under a rainfall simulator with a constant rainfall intensity of 8.75 cm. per hour indicate that soil loss per 2.5 cm. of siuautated  ram) in case of lateritic soil is 0.25 tons per hectare. Thus the soil loss in case of deep black soil which is heavier than latertic soil is ten times more. **2. Topography will special reference to slope of lands:** Slope accelerates erosion as it increases the velocity of flowing water. Small differences in slope make big difference in damage. According to the laws of hydraulics, a four - time increase in slope doubles the velocity of flowing water. This doubled velocity can increase the erosive power four times and the carrying capacity by 32 times. In one of the experiments in United States of America, it was observed that the loss of soil per hectare due to erosion in a maize plot was 12 tons when the slope was 5 p.c., but it was as high as 44.5 tons under 9 p.c., slope. **3. Physical and chemical properties of soil**: Some soils erode more readily than other under the same conditions. The erodibility of the soil is influenced by its texture, structure, and organic matter, nature of day and the amount and kind of salts present. There is less erosion in sandy soil because water is absorbed readily due to high permeability. More organic manure in the soil improves granular structure and water holding capacity. As organic matter decreases, the erodibility of soil increases. Fine textured and alkaline soils are more erodible. In general, soil detachability increases as the size of the particle increases but soil transportability increases with the decrease in particle size. Clay particles are more difficult to detach than sand, but are easily transported on a level land and much more rapidly on slopes. **4. Ground cover, its nature and extent:** The presence of vegetation ground cover retards erosion. Forests and grasses are more effective in providing cover than cultivated crops. Vegetation intercepts the erosive beating action of falling raindrops retards the amount and velocity of surface fun off, permits more water flow into the soil and creates more storage capacity in the soil. It is the lack of vegetation that creates erosion permitting condition. **Effects of water, wind and tillage erosion on agricultural land**Picture of the point of concentration of surface water runoff flowing across a field.**Figure 1.** The erosive force of water from concentrated surface water runoff.Water ErosionThe widespread occurrence of water erosion combined with the severity of on-site and off-site impacts have made water erosion the focus of soil conservation efforts in Ontario.The rate and magnitude of soil erosion by water is controlled by the following factors:Rainfall and RunoffThe greater the intensity and duration of a rainstorm, the higher the erosion potential. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter are easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amounts are required to move larger sand and gravel particles.Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during short-duration, high-intensity thunderstorms. Although the erosion caused by long-lasting and less-intense storms is not usually as spectacular or noticeable as that produced during thunderstorms, the amount of soil loss can be significant, especially when compounded over time. Picture of an open field showing windblown soil and vegetation.**Figure 2.** The erosive force of wind on an open field.Surface water runoff occurs whenever there is excess water on a slope that cannot be absorbed into the soil or is trapped on the surface. Reduced infiltration due to soil compaction, crusting or freezing increases the runoff. Runoff from agricultural land is greatest during spring months when the soils are typically saturated, snow is melting and vegetative cover is minimal.Soil ErodibilitySoil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Texture is the principal characteristic affecting erodibility, but structure, organic matter and permeability also contribute. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam-textured soils tend to be less erodible than silt, very fine sand and certain clay-textured soils.Tillage and cropping practices that reduce soil organic matter levels, cause poor soil structure, or result in soil compaction, contribute to increases in soil erodibility. As an example, compacted subsurface soil layers can decrease infiltration and increase runoff. The formation of a soil crust, which tends to "seal" the surface, also decreases infiltration. On some sites, a soil crust might decrease the amount of soil loss from raindrop impact and splash; however, a corresponding increase in the amount of runoff water can contribute to more serious erosion problems.Past erosion also has an effect on a soil's erodibility. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were because of their poorer structure and lower organic matter. The lower nutrient levels often associated with subsoils contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil.Slope Gradient and LengthThe steeper and longer the slope of a field, the higher the risk for erosion. Soil erosion by water increases as the slope length increases due to the greater accumulation of runoff. Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water, which permits a greater degree of scouring (carrying capacity for sediment).Cropping and VegetationThe potential for soil erosion increases if the soil has no or very little vegetative cover of plants and/or crop residues. Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of runoff water and allows excess surface water to infiltrate.The erosion-reducing effectiveness of plant and/or crop residues depends on the type, extent and quantity of cover. Vegetation and residue combinations that completely cover the soil and intercept all falling raindrops at and close to the surface are the most efficient in controlling soil erosion (e.g., forests, permanent grasses). Partially incorporated residues and residual roots are also important as these provide channels that allow surface water to move into the soil.The effectiveness of any protective cover also depends on how much protection is available at various periods during the year, relative to the amount of erosive rainfall that falls during these periods. Crops that provide a full protective cover for a major portion of the year (e.g., alfalfa or winter cover crops) can reduce erosion much more than can crops that leave the soil bare for a longer period of time (e.g., row crops), particularly during periods of highly erosive rainfall such as spring and summer. Crop management systems that favour contour farming and strip-cropping techniques can further reduce the amount of erosion. To reduce most of the erosion on annual row-crop land, leave a residue cover greater than 30% after harvest and over the winter months, or inter-seed a cover crop (e.g., red clover in wheat, oats after silage corn).Tillage PracticesThe potential for soil erosion by water is affected by tillage operations, depending on the depth, direction and timing of plowing, the type of tillage equipment and the number of passes. Generally, the less the disturbance of vegetation or residue cover at or near the surface, the more effective the tillage practice in reducing water erosion. Minimum till or no-till practices are effective in reducing soil erosion by water.Tillage and other practices performed up and down field slopes create pathways for surface water runoff and can accelerate the soil erosion process. Cross-slope cultivation and contour farming techniques discourage the concentration of surface water runoff and limit soil movement. Types of Water ErosionSheet ErosionSheet erosion is the movement of soil from raindrop splash and runoff water. It typically occurs evenly over a uniform slope and goes unnoticed until most of the productive topsoil has been lost. Deposition of the eroded soil occurs at the bottom of the slope ([Figure 3](http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm#f3)) or in low areas. Lighter-coloured soils on knolls, changes in soil horizon thickness and low crop yields on shoulder slopes and knolls are other indicators.Picture of a harvested field showing deposits of soil and crop debris at the lower end.**Figure 3.** The accumulation of soil and crop debris at the lower end of this field is an indicator of sheet erosion.Rill ErosionRill erosion results when surface water runoff concentrates, forming small yet well-defined channels ([Figure 4](http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm#f4)). These distinct channels where the soil has been washed away are called rills when they are small enough to not interfere with field machinery operations. In many cases, rills are filled in each year as part of tillage operations.Picture of a harvested field with an obvious path where the surface water runoff has been flowing.**Figure 4.** The distinct path where the soil has been washed away by surface water runoff is an indicator of rill erosion.Gully ErosionGully erosion is an advanced stage of rill erosion where surface channels are eroded to the point where they become a nuisance factor in normal tillage operations ([Figure 5](http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm#f5)). There are farms in Ontario that are losing large quantities of topsoil and subsoil each year due to gully erosion. Surface water runoff, causing gully formation or the enlarging of existing gullies, is usually the result of improper outlet design for local surface and subsurface drainage systems. The soil instability of gully banks, usually associated with seepage of groundwater, leads to sloughing and slumping (caving-in) of bank slopes. Such failures usually occur during spring months when the soil water conditions are most conducive to the problem. Gully formations are difficult to control if corrective measures are not designed and properly constructed. Control measures must consider the cause of the increased flow of water across the landscape and be capable of directing the runoff to a proper outlet. Gully erosion results in significant amounts of land being taken out of production and creates hazardous conditions for the operators of farm machinery.Picture of a cropped field with a large gully running through it.**Figure 5.** Gully erosion may develop in locations where rill erosion has not been managed.Bank ErosionNatural streams and constructed drainage channels act as outlets for surface water runoff and subsurface drainage systems. Bank erosion is the progressive undercutting, scouring and slumping of these drainage ways ([Figure 6](http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm#f6)). Poor construction practices, inadequate maintenance, uncontrolled livestock access and cropping too close can all lead to bank erosion problems.Picture of an eroded drainage channel showing undercut and scoured banks.**Figure 6.** Bank erosion involves the undercutting and scouring of natural stream and drainage channel banks.Poorly constructed tile outlets also contribute to bank erosion. Some do not function properly because they have no rigid outlet pipe, have an inadequate splash pad or no splash pad at all, or have outlet pipes that have been damaged by erosion, machinery or bank cave-ins.The direct damages from bank erosion include loss of productive farmland, undermining of structures such as bridges, increased need to clean out and maintain drainage channels and washing out of lanes, roads and fence rows. Effects of Water ErosionOn-SiteThe implications of soil erosion by water extend beyond the removal of valuable topsoil. Crop emergence, growth and yield are directly affected by the loss of natural nutrients and applied fertilizers. Seeds and plants can be disturbed or completely removed by the erosion. Organic matter from the soil, residues and any applied manure, is relatively lightweight and can be readily transported off the field, particularly during spring thaw conditions. Pesticides may also be carried off the site with the eroded soil.Soil quality, structure, stability and texture can be affected by the loss of soil. The breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter can weaken the structure and even change the texture. Textural changes can in turn affect the water-holding capacity of the soil, making it more susceptible to extreme conditions such as drought.Off-SiteThe off-site impacts of soil erosion by water are not always as apparent as the on-site effects. Eroded soil, deposited down slope, inhibits or delays the emergence of seeds, buries small seedlings and necessitates replanting in the affected areas. Also, sediment can accumulate on down-slope properties and contribute to road damage.Sediment that reaches streams or watercourses can accelerate bank erosion, obstruct stream and drainage channels, fill in reservoirs, damage fish habitat and degrade downstream water quality. Pesticides and fertilizers, frequently transported along with the eroding soil, contaminate or pollute downstream water sources, wetlands and lakes. Because of the potential seriousness of some of the off-site impacts, the control of "non-point" pollution from agricultural land is an important consideration.Wind ErosionWind erosion occurs in susceptible areas of Ontario but represents a small percentage of land – mainly sandy and organic or muck soils. Under the right conditions it can cause major losses of soil and property .Close-up picture of a windblown field showing severe crop conditions.**Figure 7.** Wind erosion can be severe on long, unsheltered, smooth soil surfaces.Soil particles move in three ways, depending on soil particle size and wind strength – suspension, saltation and surface creep.The rate and magnitude of soil erosion by wind is controlled by the following factors:Soil ErodibilityVery fine soil particles are carried high into the air by the wind and transported great distances (suspension). Fine-to-medium size soil particles are lifted a short distance into the air and drop back to the soil surface, damaging crops and dislodging more soil (saltation). Larger-sized soil particles that are too large to be lifted off the ground are dislodged by the wind and roll along the soil surface (surface creep). The abrasion that results from windblown particles breaks down stable surface aggregates and further increases the soil erodibility.Soil Surface RoughnessSoil surfaces that are not rough offer little resistance to the wind. However, ridges left from tillage can dry out more quickly in a wind event, resulting in more loose, dry soil available to blow. Over time, soil surfaces become filled in, and the roughness is broken down by abrasion. This results in a smoother surface susceptible to the wind. Excess tillage can contribute to soil structure breakdown and increased erosion.ClimateThe speed and duration of the wind have a direct relationship to the extent of soil erosion. Soil moisture levels are very low at the surface of excessively drained soils or during periods of drought, thus releasing the particles for transport by wind. This effect also occurs in freeze-drying of the soil surface during winter months. Accumulation of soil on the leeward side of barriers such as fence rows, trees or buildings, or snow cover that has a brown colour during winter are indicators of wind erosion.Unsheltered DistanceA lack of windbreaks (trees, shrubs, crop residue, etc.) allows the wind to put soil particles into motion for greater distances, thus increasing abrasion and soil erosion. Knolls and hilltops are usually exposed and suffer the most.Vegetative CoverThe lack of permanent vegetative cover in certain locations results in extensive wind erosion. Loose, dry, bare soil is the most susceptible; however, crops that produce low levels of residue (e.g., soybeans and many vegetable crops) may not provide enough resistance. In severe cases, even crops that produce a lot of residue may not protect the soil.The most effective protective vegetative cover consists of a cover crop with an adequate network of living windbreaks in combination with good tillage, residue management and crop selection.Effects of Wind ErosionWind erosion damages crops through sandblasting of young seedlings or transplants, burial of plants or seed, and exposure of seed. Crops are ruined, resulting in costly delays and making reseeding necessary. Plants damaged by sandblasting are vulnerable to the entry of disease with a resulting decrease in yield, loss of quality and market value. Also, wind erosion can create adverse operating conditions, preventing timely field activities.Soil drifting is a fertility-depleting process that can lead to poor crop growth and yield reductions in areas of fields where wind erosion is a recurring problem. Continual drifting of an area gradually causes a textural change in the soil. Loss of fine sand, silt, clay and organic particles from sandy soils serves to lower the moisture-holding capacity of the soil. This increases the erodibility of the soil and compounds the problem.The removal of wind-blown soils from fence rows, constructed drainage channels and roads, and from around buildings is a costly process. Also, soil nutrients and surface-applied chemicals can be carried along with the soil particles, contributing to off-site impacts. In addition, blowing dust can affect human health and create public safety hazards.Tillage ErosionTillage erosion is the redistribution of soil through the action of tillage and gravity ([Figure 8](http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm#f8)). It results in the progressive down-slope movement of soil, causing severe soil loss on upper-slope positions and accumulation in lower-slope positions. This form of erosion is a major delivery mechanism for water erosion. Tillage action moves soil to convergent areas of a field where surface water runoff concentrates. Also, exposed subsoil is highly erodible to the forces of water and wind. Tillage erosion has the greatest potential for the "on-site" movement of soil and in many cases can cause more erosion than water or wind.Picture of tractors tilling up and down on a sloped field.**Figure 8.** Tillage erosion involves the progressive down-slope movement of soil.The rate and magnitude of soil erosion by tillage is controlled by the following factors:Type of Tillage EquipmentTillage equipment that lifts and carries will tend to move more soil. As an example, a chisel plow leaves far more crop residue on the soil surface than the conventional moldboard plow but it can move as much soil as the moldboard plow and move it to a greater distance. Using implements that do not move very much soil will help minimize the effects of tillage erosion.DirectionTillage implements like a plow or disc throw soil either up or down slope, depending on the direction of tillage. Typically, more soil is moved while tilling in the down-slope direction than while tilling in the up-slope direction. Speed and DepthThe speed and depth of tillage operations will influence the amount of soil moved. Deep tillage disturbs more soil, while increased speed moves soil further.Number of PassesReducing the number of passes of tillage equipment reduces the movement of soil. It also leaves more crop residue on the soil surface and reduces pulverization of the soil aggregates, both of which can help resist water and wind erosion.Effects of Tillage ErosionTillage erosion impacts crop development and yield. Crop growth on shoulder slopes and knolls is slow and stunted due to poor soil structure and loss of organic matter and is more susceptible to stress under adverse conditions. Changes in soil structure and texture can increase the erodibility of the soil and expose the soil to further erosion by the forces of water and wind. In extreme cases, tillage erosion includes the movement of subsurface soil. Subsoil that has been moved from upper-slope positions to lower-slope positions can bury the productive topsoil in the lower-slope areas, further impacting crop development and yield. Research related to tillage-eroded fields has shown soil loss of as much as 2 m of depth on upper-slope positions and yield declines of up to 40% in corn. Remediation for extreme cases involves the relocation of displaced soils to the upper-slope positions.Conservation MeasuresThe adoption of various soil conservation measures reduces soil erosion by water, wind and tillage. Tillage and cropping practices, as well as land management practices, directly affect the overall soil erosion problem and solutions on a farm. When crop rotations or changing tillage practices are not enough to control erosion on a field, a combination of approaches or more extreme measures might be necessary. For example, contour plowing, strip-cropping or terracing may be considered. In more serious cases where concentrated runoff occurs, it is necessary to include structural controls as part of the overall solution – grassed waterways, drop pipe and grade control structures, rock chutes, and water and sediment control basins.More details on these and other best management practices can be found in OMAFRA publication BMP 26, Controlling Soil Erosion on the Farm.SummarySoil erosion remains a key challenge for agriculture. Many farmers have already made significant progress in dealing with soil erosion problems on their farms. However, because of continued advances in soil management and crop production technology that have maintained or increased yields in spite of soil erosion, others are not aware of the increasing problem on farmland. Awareness usually occurs only when property is damaged and productive areas of soil are lost.The increase in extreme weather events predicted with climate change will magnify the existing water and wind erosion situations and create new areas of concern. Farmland must be protected as much as possible, with special attention to higher risk situations that leave the soil vulnerable to erosion. |
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**Universal Soil Loss Equation (USLE)**



The USLE, developed by ARS scientists W. Wischmeier and D. Smith, has been the most widely accepted and utilized soil loss equation for over 30 years. Designed as a method to predict average annual soil loss caused by sheet and rill erosion, the USLE is often criticized for its lack of applications. While it can estimate long - term annual soil loss and guide conservationists on proper cropping, management, and conservation practices, it cannot be applied to a specific year or a specific storm. The USLE is mature technology and enhancements to it are limited by the simple equation structure.

**The USLE for estimating average annual soil erosion is:**

***A = RKLSCP***

* **A** = average annual soil loss in t/a (tons per acre)
* **R** = rainfall erosivity index
* **K** = soil erodibility factor
* **LS** = topographic factor - L is for slope length & S is for slope
* **C** = cropping factor
* **P** = conservation practice factor

Evaluating the factors in USLE:

**R - The rainfall erosivity index**

Most appropriately called the erosivity index, it is a statistic calculated from the annual summation of rainfall energy in every storm (correlates with raindrop size) times its maximum 30 - minute intensity. As expected, it varies [geographically](http://milford.nserl.purdue.edu/weppdocs/overview/images/usa.gif).

**K - The soil erodibility factor**

This factor quantifies the [cohesive, or bonding character of a soil type](http://milford.nserl.purdue.edu/weppdocs/overview/images/soiltxt.gif) and its resistance to dislodging and transport due to raindrop impact and overland flow.

**LS - The topographic factor**

Steeper slopes produce higher overland flow velocities. Longer slopes accumulate runoff from larger areas and also result in higher flow velocities. Thus, both result in increased erosion potential, but in a non - linear manner. For convenience L and S are frequently lumped into a single term.

**C - The crop management factor**

This factor is the ratio of soil loss from land cropped under specified conditions to corresponding loss under tilled, continuous fallow conditions. The most computationally complicated of USLE factors, it incorporates effects of: [tillage](http://milford.nserl.purdue.edu/weppdocs/overview/tillage.html) management (dates and types), crops, seasonal erosivity index distribution, cropping history (rotation), and crop yield level (organic matter production potential).

**P - The conservation practice factor**

Practices included in this term are contouring, strip cropping (alternate crops on a given slope established on the contour), and [terracing](http://milford.nserl.purdue.edu/weppdocs/overview/images/terrace.gif).

**Erosion index**

The **erosion index** (**EI**, also called the **erodibility index**) is created by dividing potential erosion (from all sources except gully erosion) by the [T value](http://en.wikipedia.org/wiki/T_value), which is the rate of [soil erosion](http://en.wikipedia.org/wiki/Soil_erosion) above which long term productivity may be adversely affected. The erodibility index is used in conjunction with conservation compliance and the [Conservation Reserve Program](http://en.wikipedia.org/wiki/Conservation_Reserve_Program). For example, one of the eligibility requirements for the CRP is that lands have an EI greater than 8.

Erosion index (EI) =RKLS/T

The erosion equation factors are also used to determine an Erodibility Index (EI) for these NRI sample sites. This index is a numerical expression of the potential of a soil to erode, considering climatic factors and the physical and chemical properties of the soil – the higher the index, the greater is the investment needed to maintain the sustainability of the soil resource base if intensively cropped. Highly Erodible Land (HEL) is defined to have an EI of at least 8.

The soil loss tolerance rate (T) is the maximum rate of annual soil loss that will permit crop productivity to be sustained economically and indefinitely on a given soil. Erosion is considered to be greater than T if either the water (sheet & rill) erosion or the wind erosion rate exceeds the soil loss tolerance rate.

**3. Soil and water conservation measures**

Certain conservation measures can reduce soil erosion. Soil / land management practices such as tillage and cropping practices, directly affect the overall soil erosion problem and solutions on a farm. When crop rotations or changing tillage practices are not enough to control erosion on a field, a combination of measures might be necessary. For example, contour plowing, strip cropping, or terracing may be considered.

**Types of conservation measures:**

* Agronomic: such as plant / soil cover, conservation farming methods, contour farming
* Vegetative: such as planting barriers (vegetative strips), live fences, windbreaks
* Structural: such as Fanya Juus, terraces, banks , bunds, cut off drains, barriers
* Overall management: such as area closures, selective clearing

**Conservation agriculture**

**Cultural methods**

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| **Conservation tillage** |
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There are three major principles on conservation agriculture: minimal soil disturbance, permanent soil cover and crop rotations.
Soils under conservation agriculture tend to improve their soil organic matter (SOM) content after applying the technology for certain years. SOM can be considered as the most important soil fertility and quality factor influencing other soil properties as infiltration, water holding capacity or soil structure.

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| http://www.infonet-biovision.org/res/res/files/1370.300x200.jpeg |
| **Good ground cover protects the soil.** |
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Keeping the soil covered is a fundamental principle of conservation agriculture. Crop residues are left on the soil surface to protect soil surface after harvesting. Additional cover crops may be needed if the gap is too long between harvesting one crop and establishing the next. Cover crops improve the stability of the conservation agriculture system, not only on the improvement of soil properties but also for their capacity to promote an increased biodiversity in the agro-ecosystem.

**Cover crops benefits**

* Stabilize soil moisture and temperature
* Protect the soil during fallow periods
* Mobilize and recycle nutrients
* Improve the soil structure and break compacted layers and hard pans
* Permit a rotation in a monoculture
* Can be used to control weeds and pests
* Produce additional soil organic matter and improve soil structure

Example: Cowpea (Vigna unguiculata) is an important grain legume throughout the tropics and subtropics. It has some properties which make it an ideal cover crop: It is drought tolerant and can grow with very little water. It can fix nitrogen and grows even in very poor soils. It yields eatable grains and can be used as an animal fodder rich in protein.
Cropping systems should be designed in such a way that the soil is almost permanently covered with plant canopy. In arable crops, careful timing of sowing and planting can help to avoid uncovered soil being washed away during the rainy season. After the main crop is harvested, a green manure crop may be sown. On slopes, crops should be grown in contour lines across the slopes (along the contour lines) rather than vertically. This can contribute enormously to reduce the speed of surface water.

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| http://www.infonet-biovision.org/res/res/files/1371.300x200.png |
| Minimum tillage effects: Maize grows better where sub soiling and ripping have broken the hardpan (right) than previously (left) |
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In conservation agriculture only minimal or no soil tillage should be applied. It involves crop seeding without mechanical seedbed preparation and minimal or no soil disturbance since the harvest of the previous crop (FAO, 2007).

**Contour farming**

Contour farming involves ploughing, planting and weeding along the contour, i.e, across the slope rather than up and down. Contour lines are lines that run across a (hill) slope such that the line stays at the same height and does not run uphill or downhill. As contour lines travel across a hillside, they will be close together on the steeper parts of the hill and further apart on the gentle parts of the slope.

Experiments show that contour farming alone can reduce soil erosion by as much as 50% on moderate slopes. However, for slopes steeper than 10%, other measures should be combined with contour farming to enhance its effectiveness.
Caution: If contour lines are incorrectly established, then they can actually increase the risk of erosion.

* Contour ridges are used mainly in semi-arid areas to harvest water, and in higher rainfall areas for growing potatoes.
* Trashlines made by laying crop residues or "trash" in lines along the contour. They slow down runoff and trap eroded soil, eventually forming terraces. However, the contour line can be destroyed by termites eating the trash.
* Grass barrier strips planted along the contour. They are planted with fodder grass such as Napier, or are left with natural grass. They are effective soil conservation measures on soils that absorb water quickly, and on slopes as steep as 30%.

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| http://www.infonet-biovision.org/res/res/files/1368.300x200.jpeg |
| Trashlines |
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You may want to mark contour lines (level lines running across a slope) to decide where to plant barrier strips or lay trashlines. Helpful hints: Study the land first and visualize where the contour lines will run. This can be done best by one person directing another person in walking to the other side of the area to be contoure such that he/she stays at the same height as the first person.

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| http://www.infonet-biovision.org/res/res/files/1367.300x200.jpeg |
| Trashlines |

**Physical methods**

**Cutoff drains:**

Cutoff drains are dug across a slope to intercept surface runoff and carry it safely to an outlet such as a canal or stream. They are used to protect cultivated land, compounds and roads from uncontrolled runoff, and to divert water from gully heads.

**Retention ditches**

These ditches are dug along the contour. They catch and retain incoming runoff and hold it until it seeps into the ground. They are an alternative to cutoff drains when there is no nearby waterway to discharge the runoff into. They are often used to harvest water in semi-arid areas.

**Infiltration ditches**

Infiltration ditches are one way of harvesting water from roads or other sources of runoff. They consist of a ditch, 0.7-1.5 m deep, dug along the contour, upslope from a crop field. Water is diverted from the roadside into the ditch, which is blocked at the other end. Water trapped in the ditch seeps into the soil. On soils with an impervious layer (such as a hardpan) below the surface, the water does not sink straight down into the soil. Instead, it moves downslope just below the surface, towards the crops in the field below.

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| http://www.infonet-biovision.org/res/res/files/1361.300x200.png |
| Infiltration ditch |
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**Broadbeds and furrows**

In a broadbed-and-furrow system, runoff water is diverted into field furrows (30 cm wide and 30 cm deep). The field furrows are blocked at the lower end. When one furrow is full, the water backs up into the head furrow and flows into the next field furrow. Between the field furrows are broad beds about 170 cm wide, where crops are grown.

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| http://www.infonet-biovision.org/res/res/files/787.300x200.png |
| Broadbed and furrow |
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**Fanya juu**

Fanya juu terraces are constructed by digging ditches and heaping the soil, forming bunds in the upper sides of the ditches. Between the ditch and the bund a small ledge prevents the soil from sliding back. Spacing depends on slope and soil depth.

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| http://www.infonet-biovision.org/res/res/files/1919.300x200.jpeg |
| Fanya juu bund in maize field after harvest. Note Napier grass strip on upper part of bund, and maize trash in ditch below. |

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| http://www.infonet-biovision.org/res/res/files/1380.300x200.png |
| New fanya juu terrace |
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| http://www.infonet-biovision.org/res/res/files/1381.300x200.png |
| Fanya juu - Same terrace after 5 years |
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| http://www.infonet-biovision.org/res/res/files/1918.300x200.jpeg |
| Fanya juu terraces in a semi-arid area which have developed over time into benches. Note the well established grass strips along the bunds. |
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**Fanya chini**

A fanya chini is like a fanya juu, except that the soil is put on the lower side of the contour trench, not on the upslope side of it (as in a fanya juu). Fanya chini are used to conserve soil and divert water. The resulting embankment can be used to grow fodder. Fanya chini are easier to make than fanya juu, but they do not lead the formation of a bench terrace over time. They can be used on slopes up to 35%.

**Biological methods**

**Agro forestry**

Agroforestry describes land use systems where trees are grown in association with agricultural crops pastures or livestock - and there are usually both ecological and economic interactions between components of the system. Farmers have practiced agroforestry for years.
Agroforestry focuses on the wide range of working trees grown on farms and in rural landscapes. Among these are fertilizer trees for land regeneration, soil health and food security; fruit trees for nutrition; fodder trees that improve smallholder livestock production; timber and fuel wood trees for shelter and energy; medicinal trees to combat disease; and trees that produce gums, resins or latex products. Many of these trees are multipurpose, providing a range of benefits.

**Proven impacts of agroforestry**:

* Reducing poverty through increased production of agroforestry products for home consumption and sale.
* Contributing to food security by restoring farm soil fertility for food crops and production of fruits, nuts and edible oils.
* Ensuring, through negotiation support, a fairer deal for women farmers and other less-advantaged rural residents whose rights to land are insecure.
* Reducing deforestation and pressure on woodlands by providing fuel wood grown on farms.
* Increasing diversity of on-farm tree crops and tree cover to buffer farmers against the effects of global climate change.
* Improving nutrition to lessen the impacts of hunger and chronic illness associated with HIV/AIDS.
* Augmenting accessibility to medicinal trees, the main source of medication for 80% of Africa's population.

**Vegetative strips / cover:**

Grasses or trees can be used as vegetative strips or cover in various ways. Vegetative strips can be planted to catch soil, excess nutrients, and chemical pesticides moving over the land's surface before they enter waterways. Strips often lead to the formation of bunds or terraces due to "tillage erosion" - the down slope movement of soil during cultivation. The effect of dispersed vegetative cover is multiple, including increasing ground cover, improving soil structure and infiltration, as well as decreasing erosion by water and wind.

**Land use change, area closure and rational grazing**

Management measures are often applied to grazing land in situations where uncontrolled use has led to degradation and where other measures simply do not work without a fundamental change in land management. Enclosures, thus protection from grazing, allow regeneration of vegetation cover. Such measures are often essential for the rehabilitation of badly degraded areas where technical measures and other interventions are not adequate on their own (but can act in a supplementary way). But there are also examples of intensification of grazing land use where fodder crops are planted and used for cut-and-carry feeding of livestock.

One of the major advantages of management measures is that they often do not involve very high investments of money or labour. On the other hand, taking land out of use can lead to increased pressure on neighbouring land, which may also be in poor condition and vulnerable to further degradation. Another disadvantage is that management measures are often not clear-cut; they require great flexibility and responsiveness, not only initially, but over the years that follow. However, there are often implications for land tenure that can complicate decision-making and may sour relationships between neighbours (WOCAT, 2007).

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**Multipurpose trees in Agro forestry**

Agro forestry involves raising trees in combination with other agricultural enterprises, including livestock. Different species of trees can be planted with many types of crops in a variety of patterns. For example, fast-growing trees can be planted when the land is fallow or they can be grown at the same time as agricultural crops.

In addition to providing fodder, fuel, wood, and other products, trees in agro forestry systems promote soil and water conservation, enhance soil fertility, and act as windbreaks for nearby crops.

**Factors to consider when selecting tree species**.

**Environmental adaptation**

A multipurpose tree must be able to adapt to the area's climate, soil, topography, and plant and animal life. This is especially important for exotic species, that is, species introduced from outside the project area or from outside the country.

**Needs of farmers**

The species should meet the needs of farm families. For this reason, it is important to involve farmers, both men and women, in selecting species. They should identify desired tree products and planting locations based on local markets as well as conservation needs.

The cost of acquiring seedlings or cuttings should also be kept in mind. Planting stock of most fruit trees, for example, are expensive.

**Ease of maintenance**

Some species are more difficult to look after than others. Farmers should consider beforehand how much time they have to care for the trees. If they require additional skills and knowledge to grow a particular species, training or demonstration programs should be organized.

**Availability of genetic materials**

Seeds or seedlings of the species being considered must be easy to obtain. If vegetative propagation is required, farmers should receive training in how to do this. Seeds of Gliricidia sepium and Sesbania spp., for example, might not be readily available. Farmers may need help in how to propagate the trees using root cuttings. They may not even have enough time to harvest the cuttings.

**Role of trees in Agroforestry**

**Alley cropping**

When planted as hedgerows between rows of agricultural crops, some tree species reduce soil erosion. When planted on slopes, alley crops slow down runoff rainwater and trap sediment, which can form natural terraces after several years.

Alley cropping means growing hedgerows of closely spaced trees (20cm or less) between rows of food crops. If the land slopes, farmers should plant the hedgerows along the contour, that is, the trees in each hedgerow should be planted at the same level of slope (Figure to come).

Farmers should prune hedgerows regularly to prevent them from competing with nearby crops for sunlight and water. When pruned regularly, hedgerows can provide a reliable source of animal fodder and fuel. Farmers can cut the trees when they become competitive and carry the branches to pens where animals are sheltered. Longer cutting cycles of 4-6 months provide relatively more wood than shorter cycles. Short cycles produce relatively more foliage. Most species should not be pruned more often than every 30 days (see species fact sheets).

If planted in double lines rather than single lines, hedgerows can produce almost twice as much foliage and wood, without greatly increasing the competition with nearby crops for water, nutrients, and sunlight. Where farmers can plant in a north-south rather than east-west direction, this will reduce competition for sunlight. Whether farmers plant single or double rows depends on how much land is available and the slope.

"Green manure" refers to foliage and twigs that are spread among food crops as mulch and organic fertilizer to improve their growth. To obtain green manure, farmers can prune the tops of the hedgerows every 6-8 weeks.

**Desirable characteristics of species**

* **Easily established:** require minimum labor for planting and maintenance.
* **Fast growing:** benefits become available to the farm family as soon as possible.
* **Good sprouting:** hedgerows continue to grow regularly after pruning.
* **Nitrogen fixing:** leguminous (nitrogen-fixing) species can contribute to crop nutrition.
* **Heavy and palatable foliage**: provide more green manure and acceptable fodder.
* **Deep root system:** nutrients and water are drawn from lower soil layers.
* **Easy to propagate:** generally, growing hedgerows from seed requires less labour than vegetative propagation.
* **Adaptable to close spacing:** hedgerows require dense planting.

**Home gardens and other multistory systems**

Home gardens, mixed plantings of annual and tree crops around dwellings, are a common type of multistory agro forestry system.

Multistory means that there are at least two layers of plants growing to different heights in the system.

In home gardens, the lowest level often consists of vegetables or root crops; the second level includes fast-growing trees or crops such as bananas, spices, and cacao; a third higher level may consist of large trees that provide fruit, timber and shade.

Home gardens also provide a pleasant shaded living area.

Many farmers already grow multipurpose trees in their home gardens for flowers, fruits, and seeds. If farmers want to grow a tree for its food rather than its wood or leaves, they should plant seedlings at least 5m from each other.

Also, trees grown mainly for food should not be pruned regularly for fodder or fuel. Pruning can interfere with flowering and fruiting. Instead, farm families can collect fallen branches for fuel wood.

Women make many of the decisions on how to tend the home garden. They often choose the species to be grown. Attempts to improve the use of trees in home gardens should involve discussions with women and men farmers to better understand how they use trees and what products should be optimized.

Other multistory systems include those where trees in farmlands are left to grow amid the food crops (Figure 19). In coffee or cacao plantations, grower’s plant fast-growing species to provide shade.

**Desirable characteristics of species**

* **Cast the desired amount of shade:** understory crops need the right amount of light for optimum growth. Typically, the crown should be high, small, open, and foliage sparse.
* **Deep rooted:** they can draw nutrients and water from deeper soil layers and will not compete with shallow-rooted crops.
* **Roots should not spread laterally too far from the trunk:** to minimize competition with nearby crops.
* **Nitrogen fixing:** to grow well under adverse conditions and help improve soil fertility.

**Living fences**

In many places, farmers plant multipurpose trees in rows along farm boundaries as "living fences". In addition to providing fodder and fuel wood, living fences provide privacy and protection from browsing animals.

**Desirable characteristics of species**

* **Tolerate minor "injuries":** living fences are susceptible to frequent injuries from pruning or animals and should tolerate them well.
* **Fast growing:** provide benefits to farm families as soon as possible.
* **Compatible with annual and perennial crops:** should not have adverse effects on other tree species or crops they are associated with.
* **Provide fodder:** serve as a source of animal feed.
* **Fire resistant:** act as a fire break.
* **Thorns:** stiff branches, thorns, spines, nettles, or irritating latex help keep animals out if that is a problem.
* **Vegetative propagation:** ensures fast establishment while reducing the chance of spreading to pasture and cultivated areas.

**Windbreaks**

Windbreaks are strips of trees, shrubs, and vines planted closely together along the edges of croplands perpendicular to winds, prevailing. Especially in dry areas, windbreaks can provide protection to crops and soils from the detrimental effects of wind.

**Some examples of MPTS as windbreaks and living fences**

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| **Species** | **Climate** | **Other uses** |
| *Acacia nilotica* | arid, semiarid tropics | beverage, fuelwood |
| *Azadirachta indica* | semiarid tropics | timber, lumber, manure, essential oils, fuelwood |
| *Casuarina equisetifolia* | humid tropics | fuelwood, timber |
| *Eucalyptus camaldulensis* | humid tropics | fuelwood, timber |
| *Gliricidia sepium* | humid tropics | food, fuelwood, poles, fodder |
| *Grevillea robusta* | subhumid tropics, humid tropics | timber, fuelwood, building materials |
| *Leucaena leucocephala* | humid subtropics, humid tropics | fuelwood, poles timber fodder |
| *Sesbania grandiflora* | humid tropics | fodder, fuelwood, food |

Windbreaks provide protection to crops over a distance equivalent to 15-20 times the height of the trees in the windbreak. For large areas, windbreaks shouls be planted at this distance from each other. For example, windbreaks comprising trees that grow to a height of 8m should be planted not more than 120-160m apart.

Farmers should replace dead trees from time to time. As the trees in the windbreaks grow larger and compete with each other, farmers should remove some of them.

**Desirable characteristics of species**

* + **Wind resistant:** withstand strong winds.
	+ **Deep spreading root system:** adds stability to the windbreak by making the trees less susceptible to wind damage.
	+ **Small open crown:** reduces the risk of wind damage.
	+ **Easy to propagate:** minimizes labour inputs.

**Improved fallow systems**

In many regions, population increase has resulted in faster rotation cycles of crop cultivation and shorter fallow periods. In some instances, fallow time is simply too short to allow the soil to recover. Blocks of fast-growing trees, particularly species that fix nitrogen in the soil, can help the soil recover as well as provide fuel, poles and fodder. Farmers can plant stump cuttings in the fields at the same time as the harvest of the last annual crops before the fallow period. The cuttings do not shade other crops until after 4-6 months.

**Desirable characteristics of species**

* **High nitrogen content in tissue:** hastens soils rejuvenation, since nitrogen is the most important deficiency of tropical soils.
* **Fast biomass production:** litter from the tree, especially foliage, can add important nutrients to the soil.

**Trees and raising livestock**

Farm systems that combine tree plantations with livestock that graze beneath them are found generally in drier areas, where natural grasslands and farm sizes are larger. In such systems, farmers graze sheep or cattle on forage grasses or in stands of trees.

In wetter areas, which tend to have smaller land holdings, alley cropping and other "cut and carry" methods for procuring fodder are more important.

**Some advantages of MPTS as sources of fodder**

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| **Species** | **Climate** | **Other uses** |
| Acacia tortillis | semiarid tropics | fuelwood |
| Albizia lebbek | humid tropics, semiarid tropics | fuelwood, timber |
| Calliandra calothyrsus | humid tropics | lumber, fuelwood |
| Dalbergia sissoo | semiarid tropics | timber, fuelwood |
| Gliricidia sepium | humid tropics | food, fuelwood, poles |
| Leucaena leucocephala | humid subtropics, humid tropics | fuelwood, poles, crop shade, timber |
| Prosopis cineraria | semiarid tropics, arid tropics | windbreak |
| Sesbania grandiflora | humid tropics | fuelwood, food |
| Ziziphus mauritiana | semiarid tropics, sub-humid tropics | food, shade |

Advantages to integrating tree growing with livestock production include:

* Increasing the production of meat protein without sacrificing large tracts of agricultural land.
* Reducing surface soil erosion by preventing open grazing and reducing dependence on grasses.
* Using animal manure to fertilize the soils and intercrops, reducing reliance on inorganic fertilizer.
* Providing additional income through sale of livestock.

**Desirable characteristics of species**

* **High protein and nutrient content:** improve livestock nutrition.
* **Palatable:** livestock are selective about what fodder they will eat.
* **Free of toxic substances:** some fodder species contain toxic substances that can be consumed only in small amounts. Leucaena spp, for example, contain mimosine which, in large dosed, is harmful to animals. It must, therefore, be used in combination with other fodder sources.
* **Sprout well:** recover rapidly after pruning.

**Stabilizing stream banks and gullies**

Trees can help reduce soil erosion along streams and gullies. They should be planted at the medium to high-level water mark. Their roots serve to hold the soil in place and reduce the impact of storm water.

**Suitable species**

Some tree species suitable for stabilising stream banks and gullies are *Paraserianthes falcataria*, *Gmelina arborea*, *Leucaena leucocephala*, *Sesbania grandiflora*, and *Moringa oleifera*.

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| **Remember****Agro forestry** is an approach to land use that combines raising trees together with agricultural crops and/or animals. Multipurpose trees in agro forestry can yield wood for construction, fuel wood, fodder, and fruits.**In alley cropping**, rows of trees are planted closely together between rows of agricultural crops. These hedgerows can reduce soil erosion, and, when pruned regularly, provide valuable fuel and fodder.**Home gardens** and other multistorey tree systems can provide a large range of tree and other crops such as vegetable, banana and fodder. The upper story provides shade, protection from strong winds, and litter to enhance soil fertility.**Living fences** of multipurpose trees can serve as boundaries; provide valuable products, offer privacy, and protection from browsing animals.Windbreaks of multipurpose trees protect crops from destructive winds and reduce the effects of wind erosion. |

**Conservation Agriculture with Trees (CAWT)**

Conservation Agriculture with trees (CAWT) harnesses and combines the synergies of rapid improvement of livelihoods from conservation agriculture with the longer-term but sustained crop productivity and environmental resilience derived from “fertilizer and high value trees”. CAWT derives its strength from the complimentary principles of *Conservation Agriculture* and *Agroforestry*. Conservation Agriculture with trees is poised to revolutionalize the way farming is practiced in Africa and other parts of the world.

CAWT is based on **five important principles**;

i) *Minimizing soil disturbance,*

*ii) Maintaining land/soil cover,*

*iii) Practicing crop rotation,*

*iv) Good agronomic management practices,*

*v) Incorporating nitrogen fixing trees and high value trees (e.g. fruit, medicinal and timber)*

***1. Minimum soil disturbance***

Whether the farmer is using a hand hoe or sophisticated equipment, tilling the soil is costly in terms of labour and fuel. Organic matter is the substrate for soil life. In addition to disrupting biological processes, tillage also exposes the soil to loss of carbon through rapid mineralization of organic matter (due to an increase of oxygen content in the soil) as well as soil loss through water and wind erosion. In CAWT practices, only the spots where seeds are sown need to be prepared. This leaves the rest of the land intact. Minimum tillage enhances soil biodiversity and allows soil organisms to perform the task of tilling the soil, and this process can be called **"biological tillage,"** which also enriches the soil in the process.

***2. Permanent soil cover***

when soil is exposed, it is vulnerable to sun baking and wind/water erosion. Soil cover is necessary and may be achieved with use of crop residues, fertilizer trees and other legumes. In CAWT, crop residues are left on the land to serve as mulch. To reduce greenhouse gas emissions crop residues should not be burnt at all. Fertilizer trees and cover crops can also be grown in rotation or between rows of crops to smother weeds, increase activity of soil fauna and reduce soil compaction. The fertilizer trees also shade the land during the dry season, thereby reducing soil surface temperatures.

***3. Crop Rotation***

Crop rotation helps to interrupt the propagation of crop pests between subsequent crops while also helping to diversify food crops.  A well balanced rotation involving cereals and legumes (e.g. maize and beans) can reduce pest build-up and increase the diversity of beneficial organisms that maintain the “checks and balances” in terms of insect pests, disease and weed control.

***4. Good management practices***

Smallholder farmers are often skilled in crop management. However, they need quality seed and useful information on weather conditions. With appropriate timing of planting, weeding and overall efficiency of crop management, they can minimize crop failures. The spacing and management of trees is another important consideration. Trees spaced and managed optimally will provide the necessary nutrients to maximize crop productivity. The control of pests and weeds is crucial in minimizing production and post harvest losses.

***5. Incorporating nitrogen fixing trees***

Growing legume trees helps to improve soil fertility through the fixation of atmospheric nitrogen, thus enriching the soil with nitrates. With appropriate selection of tree species and good management we can substantially reduce the requirement for inorganic fertilizers. In addition to this, incorporating pruning materials (leaves and litters) of these nitrogen fixing legumes in the soils enables better retention of water as well as increasing the content and efficiency of fertilizer use. Pruning materials used as mulch also reduce the soil temperature, thereby enabling a better build up of soil fauna that helps crop productivity. Therefore, a the integration of tested trees into farming practices (Agroforestry) has the potential to sustain land productivity in addition to providing useful tree products such as firewood and fodder

## 4. The basis of water harvesting

As land pressure rises, more and more marginal areas in the world are being used for agriculture. Much of this land is located in the arid or semi-arid belts where rain falls irregularly and much of the precious water is soon lost as surface runoff. Recent droughts have highlighted the risks to human beings and livestock, which occur when rains falter or fail.

While irrigation may be the most obvious response to drought, it has proved costly and can only benefit a fortunate few. There is now increasing interest in a low cost alternative - generally referred to as "water harvesting".

Water harvesting is the collection of runoff for productive purposes. Instead of runoff being left to cause erosion, it is harvested and utilized. In the semi-arid drought-prone areas where it is already practiced, water harvesting is a directly productive form of soil and water conservation. Both yields and reliability of production can be significantly improved with this method.

Water harvesting (WH) can be considered as a rudimentary form of irrigation. The difference is that with WH the farmer (or more usually, the agro-pastoralist) has no control over timing. Runoff can only be harvested when it rains. In regions where crops are entirely rainfed, a reduction of 50% in the seasonal rainfall, for example, may result in a total crop failure. If, however, the available rain can be concentrated on a smaller area, reasonable yields will still be received. Of course in a year of severe drought there may be no runoff to collect, but an efficient water harvesting system will improve plant growth in the majority of years.

**Importance of water harvesting**

* Provide drinking water
* Provide irrigation water
* Increase groundwater recharge
* Reduce storm water discharges, urban floods and overloading of sewage treatment plants
* Reduce seawater ingress in coastal areas.
* Reduce soil erosion

**Method of Water Harvesting**

**Inter plot water harvesting**: - In this method harvested water is directed to the crop. This method is suitable for area where rainfall is scanty (< 500 mm) and even there is difficulty of maturing a single crop. In this technique a portion of the area is cultivated & remaining area is used for harvesting water. Usually the uncultivated area is compacted or treated in such a way that runoff would be induced. Surface modification may be required to get runoff. Such method is suitable for arid regions. Runoff may be induced by using cover films (plastic or rubber) preparing hydrophobic layer (wax) compacting surface or spreading sodic soil on surface.

Inter row water harvesting: - There may not be enough rain to support a crop in some areas & therefore by conserving more water in furrows and planting the crop in furrows may give some yields.

Water harvesting in farm Ponds: - A portion of the excess runoff water after allowing maximum in situ moisture conservation is collected in farm ponds. As far as possible the pond should be located in the lower patches of the field to facilitate better storage and less seepage losses. The size of the farm pond should be worked out considering annual rainfall probable runoff and the catchments area. Generally, 10 to 20 per cent of the seasonal rainfall is considered as runoff in medium and deep black soils. A farm pond of 150 m3 capacity with side slopes of 1.5: 1 is sufficient for each hectare of catchments area in black soils. The farm ponds may be circular, square or rectangular. However square or rectangular ponds are more convenient for harvesting of runoff water.

### Microcatchments (rainwater harvesting)

(Sometimes referred to as "Within-Field Catchment System")

**Main characteristics:**

- overland flow harvested from short catchment length
- catchment length usually between 1 and 30 metres
- runoff stored in soil profile
- ratio catchment: cultivated area usually 1:1 to 3:1
- normally no provision for overflow
- plant growth is even

**Typical Examples:**

Negarim Microcatchments (for trees)
Contour Bunds (for trees)
Contour Ridges (for crops)
Semi-Circular Bunds (for range and fodder)

### External catchment systems (rainwater harvesting)

(Long Slope Catchment Technique)

**Main Characteristics:**

- Overland flow or rill flow harvested
- runoff stored in soil profile
- catchment usually 30 - 200 metres in length
- ratio catchment: cultivated area usually 2:1 to 10:1
- provision for overflow of excess water
- uneven plant growth unless land leveled

**Microcatchment system: Negarim microcatchment for trees**

Typical Examples:

Trapezoidal Bunds (for crops)
Contour Stone Bunds (for crops)

**External catchment system: trapezoidal bunds for crops**


### Floodwater farming (floodwater harvesting)

(Often referred to as "Water Spreading" and sometimes "Spate Irrigation")

**Main Characteristics:**

- Turbulent channel flow harvested either (a) by diversion or (b) by spreading within channel bed/valley floor

- Runoff stored in soil profile

- Catchment long (may be several kilometres)

- Ratio catchment: cultivated area above 10:1

- Provision for overflow of excess water

Typical Examples:

Permeable Rock Dams (for crops)
Water Spreading Bunds (for crops)

**Floodwater farming systems: (a) spreading within channel bed; (b) diversion system**

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**Summary chart of main WH techniques**

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| --- | --- | --- | --- | --- | --- | --- |
|  | **Classification** | **Main Uses** | **Description** | **Where Appropriate** | **Limitations** |  |
| negarim microcatchments | microcatchment (short slope catchment) technique | trees & grass | Closed grid of diamond shapes or open-ended "V" s formed by small earth ridges, with infiltration pits | For tree planting in situations where land is uneven or only a few tree are planted | Not easily mechanised therefore limited to small scale. Not easy to cultivate between tree lines |  |
| contour bunds | micro catchment (short slope catchment) technique | trees & grass | Earth bunds on contour spaced at 5-10 metres apart with furrow upslope and cross-ties | For tree planting on a large scale especially when mechanised | Not suitable for uneven terrain |  |
| semi circular bunds | micro catchment (short slope catchment) technique | rangeland & fodder(also trees) | Semi-circular shaped earth bunds with tips on contour. In a series with bunds in staggered formation | Useful for grass reseeding, fodder or tree planting in degraded rangeland | Cannot be mechanised therefore limited to areas with available hand labour |  |
| contour ridges | microcatchment (short slope catchment) technique | crops | Small earth ridges on contour at 1.5m -5m apart with furrow upslope and cross-ties Uncultivated catchment between ridges | For crop production in semi-arid areas especially where soil fertile and easy to work | Requires new technique of land preparation and planting, therefore may be problem with acceptance |  |
| trapezoidal bunds | external catchment (long slope catchment) technique | crops | Trapezoidal shaped earth bunds capturing runoff from external catchment and overflowing around wingtips | Widely suitable (in a variety of designs) for crop production in arid and semi-arid areas | Labour-intensive and uneven depth of runoff within plot. |  |
| contour stone bunds | external catchment (long slope catchment) technique | crops | Small stone bunds constructed on the contour at spacing of 15-35 metres apart slowing and filtering runoff | Versatile system for crop production in a wide variety of situations. Easily constructed by resouce-poor farmers | Only possible where abundant loose stone available |  |
| permeable rock dams | floodwater farming technique | crops | Long low rock dams across valleys slowing and spreading floodwater as well as healing gullies | Suitable for situation where gently sloping valleys are becoming gullies and better water spreading is required | Very site-specific and needs considerable stone as well as provision of transport |  |
| water spreading bunds | floodwater farming technique | crops & rangeland | Earth bunds set at a gradient, with a "dogleg" shape, spreading diverted floodwater | For arid areas where water is diverted from watercourse onto crop or fodder block | Does not impound much water and maintenance high in early stages after construction |  |

##### Soil conservation planning

##### Conservation Plan

A Conservation Plan is a written record of your management decisions and the conservation practices and systems you plan to use, develop, and maintain on your farm or ranch. Carrying out your plan will help achieve the goals of protecting the environment and your natural resources. After soil, water, air, plant, and animal resources are inventoried and evaluated, Certified Conservation Planner review and offer possible alternatives for you to consider. The alternatives you decide are recorded in a conservation plan, which becomes the road-map to help you achieve your goals and maintain the resources of your land.

##### What is in a Conservation Plan?

* An aerial photo or diagram of your farm or ranch
* A map of the soils on your farm or ranch and descriptions of those soils
* Information on grasses, trees, and broad-leafed plants that grow on your farm or ranch
* Resource inventory data which can include crop production potential, engineering designs and support data, and potential livestock and wildlife carrying capacity
* The location and schedule for applying conservation practices
* A plan of operation and maintenance for conservation systems of practices
* Job sheets and fact sheets

##### How it Helps the Land

Conservation of the natural resources (soil, water, air, plant, and animal resources) is important that it can provide help with issues as animal waste management, water quality, soil erosion, grazing land management, engineering, and other conservation needs.

**Conservation planning process**

Conservation planning process includes 9 steps. Each step is designed to provide parts that will eventually result in a fully implemented conservation plan. These steps do not necessarily occur in a sequential order and many steps may occur simultaneously.

##### The Nine Steps of Conservation Planning

* Preplanning
The conservation planner prepares for a site visit by anticipating the conservation problems that may be encountered. This may require research and self improvement study. They also assemble the basic information for the planning area such as soil surveys, plant yields, water quality issues, and other related information.
* Step 1. Identify Problems
The conservation planner assists the client in determining the resource problems, opportunities, and concerns in the planning area. This includes an early identification of all natural resource problems. This will be further clarified as the process continues.
* Step 2. Determine Objectives
The conservation planner must record the client's objectives. This might include how the area is to be used, what is the intended use of the property over the long term, what are the family considerations, and other factors that might influence the choice of conservation practices to be applied.
* Step 3. Inventory Resources
A comprehensive inventory will be completed of the natural resources, such as the soils, plants, animals, physical structures, available labor, equipment, and anything else that might be needed to solve the conservation problems.
* Step 4. Analyze Resource Data
The information gathered in Step 3 will be analyzed to clearly define the conditions of the natural resources along with the economic and social issues. The causes and effects of conservation problems will be summarized.
* Step 5. Formulate Alternatives
One or more conservation alternatives are prepared that will achieve the client's objectives, solve the natural resource problems, and take advantage of opportunities to improve or protect resource conditions. Clients will be provided any products explaining the details of the conservation practices being considered. This would include job sheets, fact sheets, standards, or similar materials.
* Step 6. Evaluate Alternatives
Each of the alternatives is evaluated to determine if it is addressing the client's objectives and the natural resource problems. The effects of the alternatives should be evaluated both for on-site and off-site impacts. The alternative should also be acceptable to the client. Special attention will need to be given to those ecological values protected by law or Executive Order.
* Step 7. Make Decisions
The client selects the alternatives that will best serve their business. The conservationist then prepares the conservation plan of operations (CPO) for the client which includes the practices to be implemented and the schedule. The CPO is a record of conservation decisions made by the client.
* Step 8. Implement Plan
The conservation planner delivers the plan to the client and reviews it for accuracy and clarity. The plan contains a listing of the conservation practices and a schedule for implementation. Included with these practices should be a description of the impacts of the selected practices on their natural resources. Plans usually include a map, field boundaries, soil map, and other items specific to the client’s property. The conservationist may also include other alternatives that the client has not or is not ready to make a decision on, but are needed to protect the resource. The client then requests needed assistance from the NRCS to implement the practices.
* Step 9. Evaluate the Plan
The client is assisted to evaluate the effectiveness of the plan as it is implemented. Conditions often change and may bring about the need to adjust the plan. Information gathered during evaluations is used to "fine-tune" our conservation practices in meeting natural resource needs.

**References**

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