Soil Structure Demonstration

Objective: To demonstrate how mulch aids the formation of water stable aggregates in soil.

Tools:
- Two transparent glasses/bottles filled with water
- Clod of soil from frequently tilled land
- Clod of soil from virgin “bush”

Methods:
- Place each clod into a glass filled with water

Results:
- Immediate
  - Frequently tilled: Almost immediately disintegrates and clouds the glass
  - Virgin bush clod: Maintains its structure and air slowly bubbles from the clod

- After several hours
  - Frequently tilled: Little of the clod remaining, and the soils has settled into fine sediment at the bottom of the glass
  - Virgin bush clod: Clod has remained almost perfectly intact

Why:
- The clod from the frequently tilled soil has no structure to bind itself together. The plough supposedly aerates the soil, but there are no bubbles coming from the clod, showing that there is in fact no air in it.
- The clod from the virgin bush has had years of being bound together by roots and organisms beneath the surface. It bubbles away slowly because channels have been formed by burrowing insects and decayed roots, which allows for effective infiltration of water into the soil.
Splash Pan Demonstration
Objective: To demonstrate action of a raindrop falling on soil acting as a hammer causing a splash action to a greater or lesser degree, depending on mulch cover.

Tools:
- Plastic bottle with spray nozzle
- 2 pieces of paper
- Pan 1 (conventional tillage)
  - Tin lid (such as Nescafe lid)
  - Soil
- Pan 2 (using mulch/zero tillage techniques)
  - Tin lid
  - Soil
  - Grass clippings to use as mulch

Methods:
- Place soil in each pan
- Leave soil in one pan bare, cover the soil in the other pan with grass clippings
- Place each pan on a piece of paper
- Spray water on each pan, ensuring that it is sprayed from the same height and that the same amount of water is sprayed on each pan

Results:
- Pan 1 - A lot of soil is splashed out of the pan onto the surrounding paper
- Pan 2 - Very little soil is splashed out of the pan onto the surrounding paper

Why:
- Mulch acts as a cushion for raindrops, reducing the impact of the raindrop, allowing the water to seep into the soil, preventing runoff, and “sheet” erosion.
- On the pan with no mulch, the raindrop causes an explosive action, dislodging soil particles, also allowing for crusting of the soil, preventing water infiltration.
All over the world farmers are tilling their land using tractors and animals. What's wrong with that?

Basically, we don't need to plough the soil to receive a good crop. It is that simple. A natural healthy soil is the best environment for crop production. With tillage we often damage the soil.

That means agriculture contributes worldwide to land degradation and erosion?

Yes, definitely. Arable farming, especially where a plough is used, is a major contributor to the destruction of soil which leads to erosion and the loss of soil.

Does this apply to the developed and the developing countries in the same way?

This applies to all countries. Just look back to the 1930s, when the dust-bowls occurred in the United States. Because of mechanized tillage, huge areas were affected by soil loss.

The difference is that many developed countries are located in temperate zones, whereas the developing countries are in tropical zones, where there is often a very thin soil layer or very fragile soils. This means that the effects of degradation and soil erosion in tropical zones are much worse than in temperate zones. Also, higher temperatures and heavier rainfall in tropical areas contribute to faster soil degradation and erosion.

8. Topping (specifically for Corn)
   - Once fully mature
   - Break off above cobs
   - Use for mulch

9. Post Harvest Stalk Lodging (specifically for Corn)
   - Stand on base of stem and push down between rows
   - Improves mulch and helps reduce weeds
   - Breaks life cycle of maize stalk borer

10. Post Harvest Weed Control
    - Keep lands weed free (1 pigweed produces 600,000 seeds)
    - This years weeds are next years crop failures

11. Rotation
    - Practice crop rotations with legumes
    - Allocate 1/3rd of land area to be under rotation (e.g. beans 1/3rd, 2/3rd corn)
3. **Liming**
   - Based on soil analysis
   - Place evenly across base of hole

4. **Fertilization**
   - Based on yield targets
   - Ensure fertilizer availability before rains
   - 12 ml cup NPK or tin of manure
   - Place evenly across base of hole
   - Cover slightly until required seed planting depth remains
   - Wait until decent rains

5. **Planting**
   - After good rains
   - Soon after rains—within 2 days
   - 3/hole ultimately thinned to 2/hole—44,000 plants/ha
   - In straight row
   - Planting depth—matchbox length (corn)
   - Cover carefully
   - No mulch in the covering or on top of holes

6. **Weed Control**
   - Get them when they are small—1 inch 3 days vs 1 ft 12 days
   - This gives several rest days vs never catching up
   - Weed free throughout
   - 2 hours/day
   - Hoe just below surface—except for creeping grasses

7. **Top Dress Fertilizer**
   - 1st application: when plants are at knee height—depending on yield requirements—5 ml cup Urea
   - 2nd application: before tassling—depending on yield requirements—5 ml cup Urea
   - Minimum of 10 cm from stem base on upside of slope (poke hole in ground, drop Urea inside, cover)

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Are you suggesting that farmers should stop tilling their fields?

Basically, yes. You certainly have to differentiate according to the types of soil, but generally I would say that we do not need to till our soil as we are doing today.

**What is the alternative?**

Well, we don't simply stop tilling and still produce. We replace tillage by managing the fields.

A soil, left alone, develops a good structure through biological processes. That structure cannot be improved by tillage. Of course, if we have an already degraded and compacted soil, we have to go step by step and assist the process of soil structuring before we can farm completely without any tillage. The first step is usually not to use the plough any more and only to loosen the soil with a chisel. For most crops like grains we don't need to move the soil, we just plant the seeds. It's different with crops such as potatoes, sugar beets or peanuts, here we still have to till in order to get the harvest out.

**But what happens after the harvest?**

After the harvest the soil must be covered with residues, straw, stems, or, even better, other crops should be planted which could be used as a fodder or cover crop. Crop rotation that favours the development of a soil structure is essential.

**What about weed control?**

Many people say, when we till less, we have to use more herbicides. In the beginning this may be right, when we start to move
from conventional tillage to reduced tillage. But after some years
the use of herbicides will decline. It all depends on the crop rota-
tion. With good crop rotation, the use of
herbicides will decrease. Also farmers could shift to very simple
herbicides, if required, with very little damage to the environment.

**Do you have strong financial arguments to convince farmers to shift to conservation tillage?**

The financial arguments are the strongest for our new
approach. The immediate re-
sult for the farmers is, that
with conserva-
tion tillage,
labour and en-
ergy costs are
reduced dramatically. They don't need heavy tractors any more for
soil tillage. Soil tillage is the operation in farming that is most en-
ergy intensive. In many developing countries, where farmers use
animal traction, tillage is the bottleneck to get the seedbed pre-
pared. Reducing tillage means that farmers have more time for
timely planting. This is very important in Africa, for example,
where every day, every week you lose in planting time can lead to
reductions in yield.

**Is animal tillage as controversial as tractor tillage?**

Definitely not. The extreme cases of soil destruction are the result
of mechanized tillage operations, simply because the farmers till
deeper and faster, and the weight of the machines causes soil com-
paction.

“**We are targeting especially poor peasant farmers which account for more than 85% of the population of the continent, who are living undernourished, degraded lives, where food aid is leading to further degradation in self worth & family values. The current maize yields of the continent are between 300-600kg/ha, depending on the climatic cycles, which barely provide for an adult male never mind a family (1,200kg). The continental requirements for importing 21 million tons of grain this year clearly indicate the “begging bowl” status of the continent, whilst also displaying how poorly the continent is doing at realizing her potential.”**

-Farming God’s Way

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Cover slightly & wait for the rains. Or wa-
ter, if you have access to irrigation.
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Ensure mulch is thick & well spread over
the field. Remember this year’s crop resi-
dues are next year’s mulch.
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Keep lands weed free throughout the year.
Cut off weeds at the soil surface, where
they add to the mulch. 1 year of
weeds=7 years of
problems.
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**Mulch/Zero Tillage Method**

1. Mark holes 60 by 75 cm. Dig holes 8 cm deep (15 cm deep if using manure). Place soil heap on downslope side.

2. Place lime in bottom of hole. Use a 5 ml cup & spread evenly across base of hole.

3. Place fertilizer (NPK) evenly on top of lime in bottom of hole. Use a 12 ml cup or a tin of manure per hole.

4. Top dress fertilizer when plants are 30 cm tall & again before tasseling. Place 8 ml of Urea 10 cm from plants, on the upslope side.

5. Plant 3 seeds per hole at 5 cm deep in an evenly spaced line across the hole. Select quality seeds. Thin at 10 cm tall to 2 seedlings/hole.

6. Cover the hole using the heaped sand leaving a level surface. Ensure no stones & heavy clods cover seeds.

Animal traction is less harmful, but it can still contribute to a certain extent of soil erosion. This is less related to the tillage as such, but to the fact that if the soil is left open and exposed to wind and rain, erosion occurs.

**What type of machines are required for minimum tillage?**

This is actually one of the major constraints for the transfer from conventional tillage to minimum tillage. Despite the clear advantages for the farmer, there is still a need for different machines. Farmers need a planter that can operate on soil which has residues still on the surface. These planters already exist for animal traction and manual mechanization as well, but they are more expensive than conventional planters.

Because of the residues on the surface, farmers probably cannot weed mechanically any more, so they might use herbicides. The equipment for this could be expensive. Cuts may be cut where farmers get together and share equipment.

**Does this concept mean FAO has changed its position on mechanization?**

Not regarding mechanization, but regarding soil tillage.

In the past we rather uncritically favoured all techniques of mechanization and tillage. When we promote animal traction, for example, the first thing we recommend is a plough. This we have to change. We should combine animal traction and reduced tillage, and should introduce a zero-tillage planter.

**Is there any country which already applies conservation tillage?**

Yes, there are several countries, particularly in South and North America. A special example is Brazil with a long history of zero-tillage that dates back more than 20 years. It started with mechanized large farming and then spread down to the small farmers. In Brazil the area under zero-tillage is actually growing, which means...
Ploughing can be bad for the soil. A minority of agriculturalists have been saying so for years and FAO is now adding its voice to the call for a drastic reduction in tillage in order to slow land degradation around the world.

According to the Organization, "with the advent of tractors, the tendency was to increase tillage and farmers started to believe that the more you till the soil, the more yield you get. The truth is that more tillage causes more erosion and soil degradation, especially in warmer areas where the topsoil layer is thinner." Today's conventional ploughing methods cause severe soil loss and desertification in many developing countries. FAO estimates that some 40 percent of land degradation around the world is caused by soil erosion.

The Organization has issued a dramatic warning to farmers: "Parts of Latin America and Africa could become dust-bowls if farmers don't change their tillage practices. Every time a farmer tills land to control weeds, the soil becomes more vulnerable to erosion and the soil structure is destroyed. Conventional tillage with tractors and ploughs provokes soil
Step-by-Step Procedure (also see diagrams on pp 17-19)

1. Tools
   - Hoes
   - Fertilizer Cups
   - Measuring sticks
   - String & bottle tops
   - Fertilizer and/or manure
   - Seed

2. Land Preparation
   - No plowing
   - No burning
   - Clear stumps
   - Keep weed free
   - Rows on contour (perpendicular to slope)
   - Dig out holes @ 60 by 75 cm
   - Holes should be hoe width and 8 to 15 cm deep (deeper if using manure)
   - Dug-out soil goes on downslope side
   - Line bottom of hole with manure

compaction and biological degradation. Even animal traction systems, to a lesser extent, can lead to erosion. The way soils are cultivated today needs to be drastically changed."

FAO is holding a workshop to promote conservation tillage in Harare, Zimbabwe, from 22 to 27 June. The meeting will begin work on the formulation of a code of conduct on soil management and the outline of a regional project on conservation tillage will be prepared. The German Agency for Technical Cooperation (GTZ), the South African Research Council, a Swedish-funded FAO project and the Zimbabwe Farmers Union will participate in the meeting.

In Latin America, RELACO, a network promoting conservation tillage, was established in 1992 and more than 14 million hectares of farmland in the region are now under zero-tillage - in which the soil is disturbed only where the seed is planted. One of the tools specially designed for this is the chisel plough.

In Africa, minimum tillage is mainly practiced only on large estates, but the regional project will be targeting smallholders too. Significantly for smaller farmers, minimum tillage also cuts the costs of land preparation. For example, production costs per acre for soybeans could be cut by US$27 in Argentina, US$14 in the United States and US$11 in Brazil, by introducing minimum tillage techniques.

According to FAO expert José Benites of the Soil Resources Management and Conservation Service, soils in tropical countries do not normally need to be tilled. "The most desirable form of tillage is conservation tillage which leaves a protective blanket of leaves, stems and stalks from the previous crop on the surface. This cover shields the soil surface from heat, wind and rain, keeps the soil cooler and reduces moisture loss by evaporation."
**SOIL TILLAGE**

*From Online Information Service for Non-Chemical Pest Management in the Tropics (OISAT)*

Soil tillage is a method of soil preparation for seedbed preparation, sowing or transplanting, and for crops’ growth.

**Types of soil tillage:**

*Conventional tillage*

The cultivation of the soil using plow, harrow and other farm tools or mechanical implements to prepare the field for crop production.

**Advantages**
1. Destroys pests’ shelters and disrupts their lifecycles
2. Exposes pests to predators and unfavorable conditions
3. Distributes soil nutrients throughout the soil
4. Aerates the soil
5. Controls weeds
6. Makes other farm cultural practices easier to undertake
7.

**Disadvantages**
1. Destroys the soil cover and its structure
2. Enhances soil erosion
3. High moisture loss
4. Disrupts the lifecycle of beneficial soil organisms
5. Needs more labor cost for the soil preparation

*Conservation tillage*

The planting or sowing in the previous crop's residues that are purposely left on the soil surface.

**Advantages**
1. Conserves water. The mulch reduces water to evaporate.
2. Reduces erosion because the topsoil is protected.
3. Reduces soil compaction.
4. Protects impact from rain and wind.

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**Zero Tillage Combined with Mulching**

*(based on “Farming God’s Way”, a publication of the Harvest Church, Zimbabwe)*

<table>
<thead>
<tr>
<th>Technology</th>
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<tbody>
<tr>
<td>- Mulch/zero tillage instead of slash and burn</td>
<td>Mulch/zero tillage instead of slash and burn</td>
</tr>
<tr>
<td>- 30-100% decaying plant residue surface cover</td>
<td>30-100% decaying plant residue surface cover</td>
</tr>
<tr>
<td>- Reduced raindrop impact &amp; crusting</td>
<td>Reduced raindrop impact &amp; crusting</td>
</tr>
<tr>
<td>- Reduced runoff—from 90% with conventional tillage vs 6% with mulch/zero tillage</td>
<td>Reduced runoff—from 90% with conventional tillage vs 6% with mulch/zero tillage</td>
</tr>
<tr>
<td>- Better infiltration (10% with conventional vs 94% with mulch/zero tillage)</td>
<td>Better infiltration (10% with conventional vs 94% with mulch/zero tillage)</td>
</tr>
<tr>
<td>- Reduction in soil erosion—30 t/ha vs 0.6 t/ha</td>
<td>Reduction in soil erosion—30 t/ha vs 0.6 t/ha</td>
</tr>
<tr>
<td>- Reduced evaporation</td>
<td>Reduced evaporation</td>
</tr>
<tr>
<td>- Moderation of soil temperatures—better germination and seedling growth</td>
<td>Moderation of soil temperatures—better germination and seedling growth</td>
</tr>
<tr>
<td>- Soil fauna &amp; flora encouraged</td>
<td>Soil fauna &amp; flora encouraged</td>
</tr>
<tr>
<td>- Plants develop better root system close to surface</td>
<td>Plants develop better root system close to surface</td>
</tr>
<tr>
<td>- Organic nutrients available</td>
<td>Organic nutrients available</td>
</tr>
<tr>
<td>- Improved yields</td>
<td>Improved yields</td>
</tr>
<tr>
<td>- Stable yields in dry seasons</td>
<td>Stable yields in dry seasons</td>
</tr>
<tr>
<td>- Reduction in weed population</td>
<td>Reduction in weed population</td>
</tr>
</tbody>
</table>

**Zero Tillage (No plowing)**

- Little soil disturbance
- Improved soil structure
- Increased soil water holding capacity
- Reduced erosion
- Improved soil fauna & flora—both aerobic & anaerobic
- Reduced effort
- Reduced cost—input costs halved and tractor costs 1/3rd
- Plant soon after rains
inclusion of a tillage operation for the purpose of weed control. Regardless of the type of conservation tillage system, all will result in lower seedbed disturbance/fewer passes than in a conventional tillage system.

*Low disturbance openers* are narrow openers such as knives, narrow spoons, narrow hoes and slightly offset discs (not including a discer). The openers should not disturb more than 33% of the soil surface area (eg. If the opener row spacing is 9 inches (22.9 centimetres), then the width of disturbance created by a single opener should not exceed 3 inches (7.6 centimetres).

*High disturbance openers* are medium and wide openers, such as wide hoes, narrow sweeps or shovels, wide spoons, wide shovels and discers. These openers disturb more than 33% of the soil surface.

5. Improves the soil condition with the increased organic matter content.
6. Natural enemies have places to stay.
7. Lessens the overall production cost.

**Disadvantages**
1. Needs a thorough understanding of the concept and requires careful farm management practices to be successful.
2. Most soil pests populations are increased.
3. Weeds compete with the main crops.
4. High tendency of a carryover of the insect pests and diseases from the crop residues.
5. Organic matters are not evenly distributed or are concentrated at the topsoil.
6. It needs patience and waits a longer time to have an excellent soil.

**Methods of conservation tillage**
- Zero tillage (no-till, minimum tillage, or direct seeding). A system where the soil is not disturbed between harvesting one crop and planting the next. It is a crop production where the soil is not traditionally tilled or cultivated although sticks or other planting equipments are used to make the openings for seeds.
- Ridge tillage. A specific form of no-till wherein a new crop is planted on pre-formed ridges or hills or bunds from those of the previous crop. After harvest, the crop residues are left until the planting time. The seeds are sown along the ridges. Sticks or other farms tools are used to make the openings for seeds.
- Mulch tillage (stubble mulch tillage). Any system that ensures a maximum retention of crop residues (30% or more) on the soil surface. The soil is prepared in such a way that plant residues or other mulching materials are specifically left on or near the surface of the farm.
There are two main types of tillage systems: conventional tillage and conservation tillage.

**Conventional tillage** is a system that traditionally uses moldboard plows or chisel plows with sweeps, followed by disk, harrowing or other secondary tillage operations to incorporate residue, prepare a seedbed and control weeds.

**Conservation tillage** systems, which include reduced tillage and zero tillage, produce benefits such as soil quality enhancement (increased soil organic matter levels over time), moisture conservation, erosion control, reduced use of fossil fuels and reduced labor requirement. Weed control in these systems may require increased use of herbicides. There are a variety of conservation tillage systems, as described below.

**Reduced tillage** systems involve the removal of one or more tillage operations to increase residue cover on the soil, reduce fuel costs and to use standing stubble to trap snow to increase soil moisture and permit the winter survival of winter wheat. Three examples of reduced tillage systems:

- **Direct seeding** is a type of reduced tillage where the only tillage operation occurs at seeding. Maximum surface residue is maintained until seeding, at which time high disturbance seed openers are used for seedbed preparation, residue management and weed control.

- **Ridge till** is a type of reduced tillage where row crops (such as corn) are planted on pre-formed ridges. During the planting operation, crop residues are cleared from the row area and moved to the furrow between rows. The planted rows are on a raised ridge 3 to 5 inches (7.6 to 12.7 centimetres) above furrows between rows. Ridge height is maintained with cultivation. Weeds are controlled with cultivation and/or herbicides.

- **Minimum tillage** is a type of reduced tillage that employs a reduction in one or more tillage operations from conventional practices (such as no fall tillage) and uses low disturbance seed openers.

**Zero tillage** (or no-till) is a type of cropping system in which crops are planted into previously undisturbed soil by opening a narrow slot of sufficient width and depth to obtain proper seedbed coverage. No tillage operation for the purpose of weed control is conducted, but this allows for tillage with low disturbance openers (knives, spikes, etc) for fall banding of fertilizer, filling in ruts, and the use of heavy harrows for crop residue management.

Zero tillage is often thought of as the “ultimate” in conservation tillage. The use of narrow, low disturbance openers (knives, discs) on the seeder results in minimal seedbed disturbance. All of the other tillage systems produce higher soil disturbance, either from wider, high disturbance openers (sweeps, spoons) or from the

### Comparisons of various tillage systems

<table>
<thead>
<tr>
<th>Tillage System</th>
<th>Fall Tillage</th>
<th>Spring Tillage</th>
<th>Soil Disturbance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall Openers</td>
<td>Spring Openers</td>
<td>Overall System</td>
</tr>
<tr>
<td>Conventional</td>
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<td>Yes</td>
<td>Low or High</td>
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<tr>
<td>Conservation</td>
<td>Reduced</td>
<td>Direct</td>
<td>High</td>
</tr>
<tr>
<td>Tillage</td>
<td>Ridge</td>
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<tr>
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<td>No</td>
<td>Ridge planters</td>
</tr>
<tr>
<td>Minimum tillage</td>
<td>Spring OR</td>
<td>Fall</td>
<td>Low</td>
</tr>
<tr>
<td>Zero tillage</td>
<td>No</td>
<td>No</td>
<td>Moderate</td>
</tr>
</tbody>
</table>