Conservation agriculture

what you should know about ……

hand tools and equipment

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Land preparation

Soil tillage or land preparation is one of the routine activities in most agricultural systems. Often, land preparation starts with burning fallow vegetation or previous crop residues in order to clear the land or to scare away wild animals or snakes.

Plate 1
This farmer is not only cleaning his field, but also 'cleaning his pockets' by burning the potential fertility of his soil.

Burning is usually followed by soil tillage. Depending on the possibilities of the farmer tillage can range from very extensive to very intensive. But why do farmers plough?

In the first place to prepare an adequate seedbed which permits a good germination of the seeds. They think that a soil well tilled, loose, levelled and with a lot of fine particles favours the contact between the seeds and the soil, which in turn lead to sowing at an adequate depth. In second place, farmers plough in order to control weeds. Other reasons for tillage may include enhancement of soil water storage and retention and warming-up of the soil.

Box 1. Functions of soil tillage

- Prepare seedbed
- Manage crop residues
- Incorporate fertilizers and agro-chemicals
- Control weeds
- Decompact dense layers
- Increase water infiltration
- Shape the soil surface (levelling, ridging)

Unfortunately, the method used to achieve any of the above mentioned objectives of tillage might produce a conflict with the other objectives. Each additional tillage operation for weed control also buries more residues and exposes moist soil to the surface, causing additional water loss. As the number of tillage operations is increased, the aggregation of soil is decreased leaving the soil more vulnerable for soil erosion (Godwin, 1990).

In this way, tillage operations have negative effects on the soil productivity and the economic return of the crops. They are responsible for the destruction of the soil and crop residues. Tillage also affects the availability of water and nutrients in the soil. Among the costs of tillage one should also count:

- increased erosion and loss of fertility
- increased evaporation and moisture loss
- decreased capability of the soil to hold water

Eroded soil can move on to other places, like ditches, lakes and reservoirs, water harvesting tanks or to the neighbour's field, taking with it organic matter, nitrogen, phosphorus and pesticides. Preventive measures, like the construction of terraces, are expensive. It is far more effective and cheaper to refrain from tillage and conserve the residues on the soil surface.

Soil tillage

Generally, tillage is defined by the type of activity carried out (Friedrich, 2000):

- **Inversion**: this type of tillage turns the soil in part that is worked. Surface layers are completely incorporated and deeper soil layers are brought to the surface. The argument that ploughing controls weeds is not valid when done every year, as the same amount of weed seeds is brought to the surface.
- **Mixture**: this operation mixes all materials homogeneously to a certain soil depth, which is usually around 10 cm.
- **Ripping**: this type of tillage breaks the soil open, in order to loosen the soil without moving the clods, for instance in soil decompaction operations (subsoiling).
- **Pulverize**: this operation is to crumble the soil clods in order to form a very fine horizon, i.e. the seedbed. It is executed within a few centimetres from the surface.

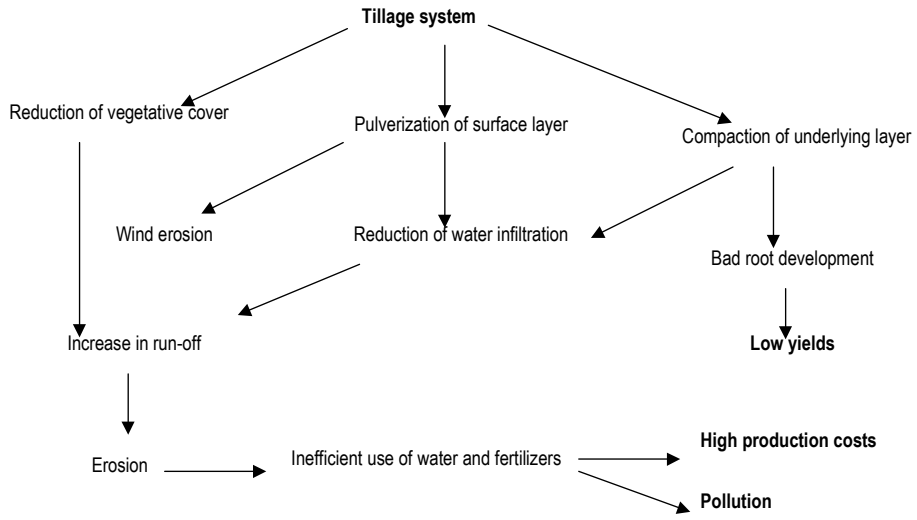
Both inversion and aggressive mixture affect the quantity of residues that are left on the soil surface. Ploughs and discs turn over the soil completely, whereas chisel ploughs break and mix the soil and cultivators only mix. Harrows pulverize the soil in order to prepare a seedbed.

At least four types of tillage operations can be distinguished in a conventional system (Krause *et al*., 1984):

- Clearing of the land and management of residues, including burning of fallow vegetation or residues
- Primary tillage
- Secondary tillage
- Crop management activities, like weeding, ridging, breaking crusts, etc.

But sometimes deep tillage or subsoiling is necessary to break dense and compacted layers deeper in the profile.

Figure 1.
Consequences of badly chosen tillage practices



In tropical and subtropical areas, where the danger of erosion through rainfall is high, the soils are usually poor and eroded and the temperatures are high and thus decomposition is rapid, tillage systems are usually selected with the objective to prepare the topsoil to create a very fine seedbed. And in only attending this objective, tillage systems are applied that bring certain degradation processes with them (Figure 1) (Vieira, 1996).

The type and number of land preparation operations determine the quantity of residues left on the soil surface. For example, ploughing leaves less than 15% on the surface, as a cultivator leaves between 50 and 70% of the residues intact on the surface.

Table 1 Percentage of residues left on the surface with different land preparation activities

Type of land preparation	Resistant residues	Fragile residues
Residues after harvest	80-95	70-80
Plough	0-15	0-10
Plough and chisel	0-10	0-5
Discs (2 operations)	15-20	10-15
Chisel (2 operations)	30-40	20-30
Cultivator (2 operations)	40-50	30-40
Cultivator (1 operation)	50-70	40-60
Direct seeding	80-95	60-80

Box 2. Disadvantages of tillage

- ☹ Loss of soil moisture
- ☹ Limits water infiltration through surface sealing
- ☹ Destroys the soil structure
- ☹ Increases erosion risk
- ☹ Increases operational cost
- ☹ High demand on power, time and equipment

Therefore it is important to choose land preparation practices that protect the natural resources and at the same time improve productivity and reduce production costs. In conservation agriculture systems land preparation practices are reduced to almost no tillage at all.

Zero tillage or no-till practices are those activities in which the seeds are brought into the soil with the least soil disturbance possible. That means planting and sowing into the residues of previous crops and weeds. Therefore, farmers, extensionists and researchers have been developing not only instruments and equipment to seed into the residues, but also tools and implements to manage the crop residues and fallow vegetation.

Handtillage

Hoes and spades in different shapes and weights are the tools used for hand-tillage operation, unless contract ploughing with animals or tractors is used. Tillage depth and intensity with hand tools is very limited, but as it also leaves the soil exposed it will equally lead to soil degradation and erosion. Even the creation of compaction zones (hoe-pans) is known. Tillage tools might still be necessary for some specialized operations even under Conservation Agriculture, such as reshaping beds or maintaining irrigation ditches. However, under conservation agriculture there is no general tillage anymore. With this the main bottleneck of labour availability for land preparation is eliminated.

Cover crop, residue and weed management

The objective of cover crop, residue and weed management is to prepare the area for planting of seeds of the subsequent commercial crop and to manage the weeds so that they cannot interfere with the crop development. In conservation agriculture systems, this management should facilitate the penetration of direct seeding equipment in the field without obstructing the implement and favour the germination of seeds.

It is desirable that the residues form a good soil cover that protects the soil for quite some time against the impacts of rainfall and that liberates allelopathic chemicals to suppress the germination of weeds. The release of these chemicals should be slow and gradually until the commercial crop is able to compete with the weeds. One of the factors influencing the release of allelopathic chemical is the decomposition of organic matter (Almeida, 1988).

Residue/cover crop management can be done either mechanically or chemically, or a combination of the two, depending on the possibilities of the farmer, the topography (slope or flat land), the degree to which the area is invaded with weeds and the development stage of the cover crop.

Mechanical management

Mechanical residue/cover crop management can be done by using machetes, knives or sickles, knife rollers, crushers, mowers, etc. or any derived implement.

Machete or knife
Common practice in Latin America is slashing the weeds and residues of previous crops with a knife or machete before sowing.

Plate 6
The use of a machete or knife is a popular tool to control cover crops in Latin America.
(*T. Friedrich*)

The residues are left on the surface and the subsequent crop is sown into it.

Box 3. Advantages and disadvantages of machete.

Advantages
☺ Easily available
☺ Cheap
☺ Common tool

Disadvantages
☹ Heavy and time consuming
☹ Regrowth of weeds

Knife rollers or chopping rollers

The knife roller is used to bend over and crush the weed or cover crop vegetation prior to planting of the commercial crop, resulting in the death of the cover crop. It is usually known as tool for animal traction or for tractors, but the same principle could be applied to small rollers or similar tools being dragged by humans. This operation is best carried out after flowering but before maturity of the seeds of the cover crop. This way there is no need to apply a herbicide to desiccate the vegetative cover, and will substantially reduce the cost of production. In this case it is important that the knife roller only breaks and crushes but does not cut the cover crop plants so that they dry out and die. If the plants are cut the stubble might stand up again and re-sprout. Mechanical planting is also easier if the residues are not cut but still in contact with the soil.

The knife roller is a simple and relatively cheap piece of equipment that can be made on the farm. It consists of a cylindrical body that rotates freely over a horizontal axle. The blades are arranged around the cylinder with equal distances apart. The distance between the blades determines the crushing length. Staggered knives and knives set at an angle to the radial of the cylinder improve the action and reduce the impact on the drawbar. The body is placed in a frame which might also provide transport wheels and a protection for the operator. When pulled the cylinder rolls on the knife-edges, bending over and crushing the vegetation (Araújo *et al*., 1993).

A simple knife roller can be made of a tree trunk, adorned with "knives" at a distance of 22-25 cm apart around its circumference. The knives can be made of strips of hardened steel, e.g. the leaf springs of an old motorcar (Bertol and Wagner, 1987).

It needs proper management to avoid regrowth. In case of bending and crushing the vegetation it is important that the cover has a uniform development stage and that no regrowth or seeding occurs after the operation. Therefore it is recommended to use the knife roller in the following growth stages of the cover crop (Calegari, 1992):

- for legumes: between full flowering and formation of the first pods;
- for grass species: during the milky stage;
- for other species, like oil radish: between flowering and maturing of the seeds.

If mixtures of cover crops are used, it is important to choose those species with a more of less uniform growing cycle (Monegat, 1991).

Plate 7
Knife roller is a popular tool on small to medium farms in southern Brazil.
(*T. Friedrich*)

Mowers
Another form of slashing cover crops is with the use of manual or mechanical mowers. Operator carried moterized mowers are in some countries becoming an alternative to using the machete. The result is a good cover, because the greater part of the biomass remains intact after cutting.

Plate 11
A mechanical hand mower to control the vegetation.

Chemical management

Chemical management of fallow vegetation or cover crop is done by spraying herbicides. Herbicides are applied to desiccate or "burn" the vegetative cover and thus facilitates the subsequent planting of the commercial crop. This practice is normally carried out when the green manure/cover crop is not yet in the full flowering or milky growth stage, and it is necessary to sow the next crop, or when the farmer is too late for using the knife roller.

Different types of sprayers have been developed. The lever operated knapsack sprayer is probably the most commonly used manual sprayer. The sprayer is carried on a person's back and therefore be easily transported around the farm and used in different terrains.

The tank makes up the largest part of the sprayer and can contain between 10 and 15 liters of liquid when full. A hand lever on the side of the tank, which is moved up and down, is used to create the required pressure (Moeller, 1997). The pressurized liquid is released through a nozzle at the end of a hand lance and broken down into small droplets forming the spray.

As the use of a knapsack sprayer is quite tiresome because of carrying and walking for long periods, other sprayers have been developed, based on the same principle.

Plate 13
The knapsack sprayer is probably the most common sprayer in the world.
(*T. Friedrich*)

The tank is placed on a chassis of a wheelbarrow or a frame to which two bicycle wheels are attached. For human traction the tank can contain between 20-50 liters of liquid. The wheels are also used to operate the pump. For this, the lever is connected to a hydraulic piston that is being activated by the movement of the wheel. As the sprayer is no longer carried, but pulled the area sprayed can also be extended through the use of a boom to which the hose containing the nozzles is attached. This way up to 5 meter wide can be treated at the same time. Labour is reduced to 0.6-1 hour per hectare (Araújo *et al*., 1999).

Plate 14
An adapted knapsack sprayer for manual traction.
(*T. Friedrich*)

Water availability is a serious limitation for applying herbicides in some regions. In this case low volume technologies using rotary nozzle sprayers are a viable alternative. Necessary application volumes can be reduced from 150-200 l/ha down to 10-20 l/ha.

Plate 15
Operator carried rotary nozzle herbicide sprayer.
(*T. Friedrich*)

Box 4. Different sprayers

- Hydraulic nozzle
- Rotary nozzle/low volume

- Point sprayer (single nozzle)
- Boom sprayer
- Shielded sprayer/row crops

Weed wipers are relatively simple tools to apply herbicides by contact to the weeds. Important is to use the right concentration of the herbicide and that the weed wipers produce a constant flow rate throughout the use. As there is no problem with drift weed wipers can be used for interrow weed control without danger to the crop, provided a minimum care is taken not to touch the crop rows.

Plate 15
Weed wiper
(*T. Friedrich*)

Even if only herbicides of low toxicity might be used, the application of agrochemicals requires always maximum care and knowledgeable operators. The sprayers used must not leak and be in good working conditions, the nozzles regularly cleaned and replaced. Operators should be trained in calibration and handling of sprayers to make sure that a maximum result is achieved with a minimum of herbicides.

Direct seeding

Planting stick or hand hoe

Direct seeding is practiced in a lot of places in the tropical world, although the terminology is not used as such.

Plate 16
A farmer in the steeplands of southern Honduras using a planting stick to sow his maize.
(*A.J. Bot*)

Plate 17
"Frijol tapado" or braodcast beans, sown over the residues of the former vegetation in Costa Rica.
(*A.J. Bot*)

Seeding or planting in large parts of Africa is done by using a hand hoe. The hand hoe used for planting purposes usually differs from the one used for tillage and weeding in that the blade is thin and narrow. Basically we are talking about direct seeding/planting if planting is done without any land preparation prior. In Latin America a planting stick (*huizute - El Salvador*) is commonly used to plant maize and sorghum and usually beans are broadcasted over the covered surface, without any land preparation. Making sure that the seed falls through the mulch cover, it germinates on the moist soil under the mulch without problems.

Manual direct seeder or hand jab planter

In order to speed up the process of planting a hand jab planter (or *matraca* in Spanish) was developed. It is a hand-held tool that allows the farmer to plant from a standing position and faster than with any other hand tool (average 2 days per hectare). The tool is made of two long levers joined with a hinge to form a V with a pointed tip. The pointed tip is pushed into the soil. By closing the V shaped levers the tip is opened to release the seed into the soil. At the same time new seed and eventually fertilizer is charged into the metering mechanism. The planter is pushed into the soil at every step, allowing a regular spacing. Disadvantages include:

- ☹ "arms" are sometimes too weak and easily damaged by powerful farmers
- ☹ tip gets clogged with soil, when not properly designed or handled and used in very moist clayey soils.

There are two types of jab planters: with broad tip and with narrow pointed tip. The former type is used on prepared land, for example when the planting line is ripped. The second one with the narrow pointed tips is designed for manual no-till planting and thus more recommended for conservation agriculture.

One of the modifications to the planter is a second box, opposite of the seedbox to contain fertilizer. This allows the farmer to fertilize and plant at the same moment. If the jab planter is provided with a second hopper to apply fertilizer and seeds in one operation, it should ideally have two separate delivery tubes and points to make sure the seed and fertilizer is not deposited too close to each other.

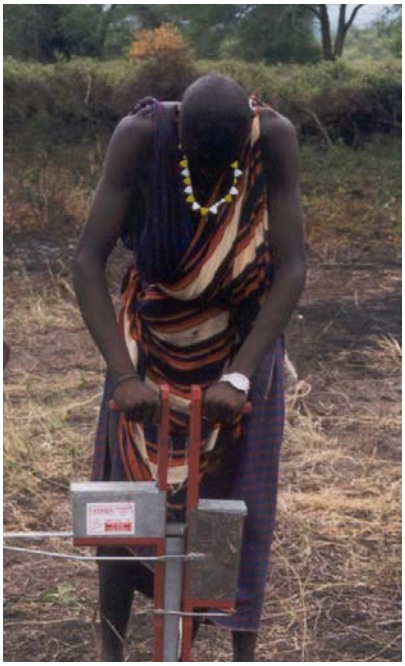


Plate 18
A Maasai in Northeastern Tanzania evaluating the hand jab planter.
(*A.J. Bot*)

Plate 19
The distance between seeds and fertilizer deposited in the soil by a hand jab planter is about 2 cm wide and 1-2 cm deep.
(*A.J. Bot*)

Other information on direct seeders

Already a lot of manufacturers of zero tillage equipment have posted their products together with information on the Internet. FAO Agricultural Service tries to bring as much information together as possible in their on-line database on Conservation Agriculture Technology, which is accessible through: http://www.fao.org/ag/catd/index.jsp

The database provides information on different models of conservation agriculture equipment for manual use, animal and mechanized traction. Technical, agronomic and commercial information for direct planters and seed drills, rippers, equipment for residue handling and specially developed sprayers can be viewed from this site. Complete addresses are provided, including links directly to webpages of the manufacturers.

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