2 Tillage

'Tillage' is the preparation of the soil for the next growing season of a crop. An alternative name used in the literature is 'cultivation'. We prefer to use this latter term only in the strict sense, referring to harrowing the soil. Tillage can be followed by irrigation or by sowing or planting. Tillage includes several processes that can be performed with different implements. The improvements in implements used for tillage have been rapid and diverse. Implements have developed partly independently in different regions, expressing a multitude of shapes and patterns, and are often known by local names only. Their impact on the soil is not straightforward. Implements may combine different kinds of impacts (table 2). Their role in weed control, irrigation, aeration of the soil, and sowing and planting is also not straightforward (table 3). This complicates any standardized description of processes and implements used for this stage of working the field.

Soil tillage method	Implement	Impact on soil			
		Loosening	Turning over	Equalizing	Removing
hoeing	hoe	•			
digging	caschrom/spade/mattock	•	•		
ploughing	ard/plough	•	(•)		
raking	rake	•		•	•
harrowing	harrow/cultivator	•		•	•
rolling	land roller/clod crusher			•	

Table 2: Examples of different methods of soil tillage, their associated implements, and their impact on the soil.

Soil tillage method	Associated agricultural processes			
	Weed control	Irrigation	Aeration	Sowing/planting
hoeing	•		•	
digging	•		•	•
ploughing	•		•	•
raking	•			•
harrowing	•	•		•
rolling		•		•

Table 3: Relation between different methods of soil tillage and some other agricultural processes.

2.1 Hoeing, digging, and ploughing

Hoeing, digging, and ploughing are used to loosen the soil. Loosening is a kind of fragmentation that is aimed at breaking up the clods. It can be done with a variety of implements. The hoe is specifically designed for this kind of soil tillage, whereas other, less specialized implements that can be used for loosening the soil will also have additional impacts on the soil. The hoe has a blade that is connected to the handle at an angle varying between 85° and 90°. The spade has a blade that is in the same plane as the handle and is therefore adapted to both loosening and turning over the soil (Hopfen, 1976). Hoeing, digging, and ploughing can be used to turn over the soil. Turning over the soil (also referred to as undercutting) involves turning the topsoil so that the original ground surface, often with standing vegetation, such as that of a stubble field, becomes buried and a fresh surface, without vegetation, is exposed.

Hoeing, digging, and ploughing can be used for weed control (see also section 6.1) and aeration. Hoeing is done as a process of its own, but digging and ploughing can be combined with other processes. Digging can be combined with planting, whereas ploughing can be combined with sowing (see section 5.1 and 5.2). The effectiveness of cutting arable weeds and then turning the original ground surface upside down as a form of weed control depends on the growth form of the weeds and the

capacity for regeneration of the vegetative plant parts in particular. Arable weeds that can propagate by clonal development by producing rhizomes, root suckers, and tubers, such as Earth almond (*Cyperus esculentus*) and Couch grass (*Elytrigia repens*), will actually benefit from this kind of soil treatment. Turning the soil also exposes diaspores of arable weeds to light, and in some species such exposure will trigger germination, as it breaks the dormancy (Fenner, 1985).

The transformation of organic matter in the soil into humus is positively influenced by oxygen, improvements in soil density, and the maintenance of soil moisture and fertility. Aeration is important because the uptake of groundwater by plant roots is partially an active process that requires oxygen. Aeration is also important because soil organisms use the air that is present in the spaces between soil particles for their metabolism.

Ploughing opens up the soil in long furrows, either pushing away it away to both sides of the blade (for ploughs without a mouldboard, i.e. the ard) or turning it over to one side (for ploughs with a mouldboard). The mouldboard is a curved attachment that turns the soil that is lifted by the ploughshare. It is a typical part of all plough types except the ard. Using an ard for ploughing results in narrow strips of unploughed land between the furrows. To optimize the loosening of the soil of a field ploughed with an ard, the farmer can plough the field a second time at right angles to the first furrows, a practice known as cross-ploughing (Fowler, 2002). Ploughing facilitates weed control of perennial arable weeds lacking vegetative propagation because these weeds are killed when they are turned upside down. The effectiveness of weed control is, however, determined by the deepness of ploughing and the level of turning; if not all the plants are properly turned and covered with soil, some of them may survive and produce new offspring for the next growing season.

There are many varieties of mouldboard ploughs, differing, among other things, in the presence and number of wheels (swing plough versus wheel plough); the number of blades that produce furrows (single, double, and multi-furrow ploughs); the direction of turning of the furrow slices (both directions versus one direction, the latter variety being especially adapted to the ploughing of hillsides); the shape of the furrow (e.g. ridge plough, adapted to the sowing of seeds); the depth of the furrow (e.g. gallows plough); and the adaptation to stones and trunks in the soil (stump-jump plough) (Partridge, 1973).

To improve the quality of ploughing and also to prevent the digging part from becoming damaged, large stones have to be removed from the field beforehand. These stones can be deposited around the margins of the field, thus serving as a barrier to animals. But it is also possible to pile them up throughout the field, which is an alternative if the parcels are rather large. Piles of stones forming a regular pattern can thus be indicative of fields that were once ploughed.

The earliest implements used for making furrows were human-powered ard-type ploughs (i.e. without a mouldboard). These could be forced down into the soil by the operator kicking his or her foot down on a foot peg, such as is the case with a caschrom (or foot plough), or by pressing his or her breast against a broad piece of wood connected to the beam.

Because moving an ard or plough requires a lot of power, both types of ploughs developed into models that could be powered by draught animals. The use of domestic animals for traction made it possible to cultivate soils that were barely workable using human-powered ploughs—for example, heavy clay soils. The use of draught animals also led to the development of heavier ards and ploughs that could make broader and deeper furrows in soils that could be worked (though less optimally) with human-powered ploughs.

Using animals for draught requires some kind of harness to transmit the animal's power to the implement. The animal's power output is determined by the design of the harness and the way it is attached to the implement. The connection between harness and ard or plough is achieved by a rope, chain, or pole that is connected to a bridle that is attached to the front end of the beam. A whippletree (or swing[le]tree) can be connected between the bridle and the rope or pole to prevent the legs of the animals from hitting the implement. If more than one animal is used for pulling the implement, a set of whippletrees is connected in such a way that the total strength is exerted at a single point. Animals that are used for pulling include horses, mules, donkeys, cattle (oxen), and dromedaries (table 4). The number of animals can differ from one to many.

Harness type		Harness configuration			Animal taxa used	
		S	D	M	equines	cattle
yoke	head	•	•			•
	neck	•	•		•	•
	belly		•		•	•
collar		•	•	•	•	•
breastband		•	•	•	•	

Table 4: Types of harnesses, their harness configurations, and the kinds of animals that can be used with them (S: single harness pulled by one animal; D: double harness pulled by pairs of animals; M: multiple harness pulled by a larger team of animals) (based on Hopfen, 1976).

Commonly used harnesses include the neck yoke, head yoke, collar harness, and breastband harness (Hopfen, 1976). A yoke is a wooden beam that can be connected to different parts of the animal to enable it to pull an implement. If animals are harnessed with a yoke, they can pull singly or in pairs. A belly yoke is typically used for a pair of animals of unequal size.

Various types of yokes exist. Their typology is based on the method by which the yoke is attached to the animal and the number of animals that are connected to the yoke (table 4). Yokes can be fastened to the animal with rope straps, which can be looped around the horns or around the breast. Yokes can also be used in conjunction with a collar harness. The head yoke is adapted to animals with a short neck, such as oxen.

A collar or a breastband can be used for one or many animals. The breastband is only used for equines. Care should be taken not to obstruct the animal's breathing, and the breastband can only be used for lighter work. Collars exist in one-piece or multiple-piece construction. Collars intended for horses can be made in one piece, as they are easily slid over the head. Those used for oxen are made in multiple pieces so that they can accommodate the horns.

2.2 Raking, harrowing, and rolling

Raking and harrowing are processes related to weed control, sowing, and planting that have a similar impact on the soil. The term raking is mostly applied to small plots, such as kitchen gardens, whereas harrowing mostly refers to larger surfaces, such as fields. The implements used for raking are therefore usually hand tools, whereas those used for harrowing can be drawn by animals. Each process has additional functions. Harrowing can be used to equalize the soil—an essential step in fields that are to be under irrigation in order to ensure that the water flows evenly over the field. Raking can also be used for collecting the remaining harvest (such as hay or reaped or mowed cereals) from the land surface (see section 8.1). Rakes used to collect the harvest can be either hand tools or large implements drawn by animals.

Harrowing that is aimed at equalizing the soil surface can be performed with rather simple tools. In Egypt, for example, some farmers still use a *zahhafa*, made from a trunk of a Date palm (*Phoenix dactylifera*). The farmer stands on the beam to make the implement heavier. Using a plate made of wood or metal, the farmer moves some soil to spots that have to be filled in. A more advanced tool for this purpose is the earth scoop. It consists of a three-sided wooden box that is open in front and is used to scrape off the mounds and fill the hollows. In this way the surface becomes smooth and the distribution of water during irrigation is improved.

A harrow is also used to harrow down drills. If this is done after sowing, it helps to cover the seeds, so that loss to predation is reduced. Initially, harrows were simple frames with straight tines. Over time, these developed into more advanced implements, with hooked tines and rotating discs. These modern harrows are also known as 'cultivators'. The disc harrow is sometimes also called a 'disc plough'.

Rolling is aimed at equalizing the soil surface by crushing any clods of soil. This produces a smooth and compact surface for sowing. Smoothing the soil surface may also improve the quality of irrigation, provided that the entire surface has also been levelled. Under these conditions, flooded water can be distributed equally over the field. Fields with loose soils benefit of rolling after sowing; the resulting compaction of the soil allows for better contact between the soil and the sowed seed. Rolling can be done with a 'land roller', which contains a cylinder with a smooth surface, or with a 'clod crusher', which contains a cylinder with a toothed surface.

Figure 19: Hoe with a heavy metal blade that is attached to the handle with plant material. The end of the handle is thicker to optimize the balance. Length handle: 63 cm; size metal blade: 5 × 21 cm (unknown provenance; DF).

Figure 20: Wooden hoe with metal blade. The wooden part is made from a forked branch. Length: 56 cm (unknown provenance; DF).

Figure 21: A digging hoe is primarily used to loosen the soil, to create drills, and to control field weeds; the soil is not turned. The shape and size of the blade can differ depending on the local soil type. This hoe, with its pointed blade, is typical of the type of hoe used for farming and gardening on loose, mostly sandy, soils. Length: 72.5 cm (provenance Germany; 20th century; DF).

Figure 22: The blade of this digging hoe has a broad cutting edge. Length: 96 cm (Çağlayan, Turkey; May 2015; DF).

Figure 23: Spade with a handle consisting of a long wooden stick with some of the bark still present. The small triangular blade has a socket that enables it to be attached to the handle. A metal bar with a triangular cross-section has been welded to the top of the socket, creating two foot rests. Length triangular bar: 22 cm (Taşköprü, Turkey; August 2015; RC).

Figure 24: New and second-hand pull hoes offered for sale. The handle is secured either perpendicular to the blade or obliquely to the blade. The hoes also differ in the absence or presence of a stem between the blade and the handle (Kochin, India; January 2015; RC).

Figure 25: Straight hoe blades offered for sale in a shop (Gop, India; September 2014; RC).

Figure 26: Stemless pull hoe with a slightly curved blade, resting on a stone in the courtyard of a farmhouse. The handle is inserted into the blade (Jaypur, India; September 2014; RC).

Figure 27: Pull hoe with a short stem between blade and handle, in the courtyard of a farmhouse. The handle has been inserted into the blade and fixed in place by pushing some wood chips and a piece of a reinforcing bar between the metal ring and the handle (Thekkady, India; January 2015; RC).

Figure 28: Pull hoe in a courtyard of a farmhouse, with bundles of threshed plants of Rice (*Oryza sativa*). These processed plants are used as fodder (Puani, India; October 2014; RC).

Figure 29: Farmer with a spade (Dilo Kotir, Iraq; June 2014; RC).