Technical guide

2026 | No. 1847

Reduced tillage

Protecting soil functions for better climate resilience

FiBL

The pioneers of organic farming followed the rule of thumb "turn shallowly and loosen deeply". This principle still applies today. However, with more powerful tractors and heavier machinery, plough furrows have become deeper. Although deep tillage creates optimal conditions for the seedbed, it has a negative impact on soil structure, soil organisms and organic matter, and leaves the soil uncovered.

Reduced tillage can contribute to soil protection and the preservation of soil fertility by, for example, improving the load-bearing capacity and water balance of the soil. However, completely abandoning the plough poses several challenges, especially in systems without herbicides and readily available mineral fertilisers.

This technical guide describes the advantages and disadvantages of reduced tillage in organic farming. It compares the various methods and machines and provides recommendations for getting started. Suitable solutions are suggested for any difficulties that may be encountered. An assessment from a scientific perspective classifies the effects of reduced tillage on soil humus content and the climate.

Content

What does reduced tillage mean?

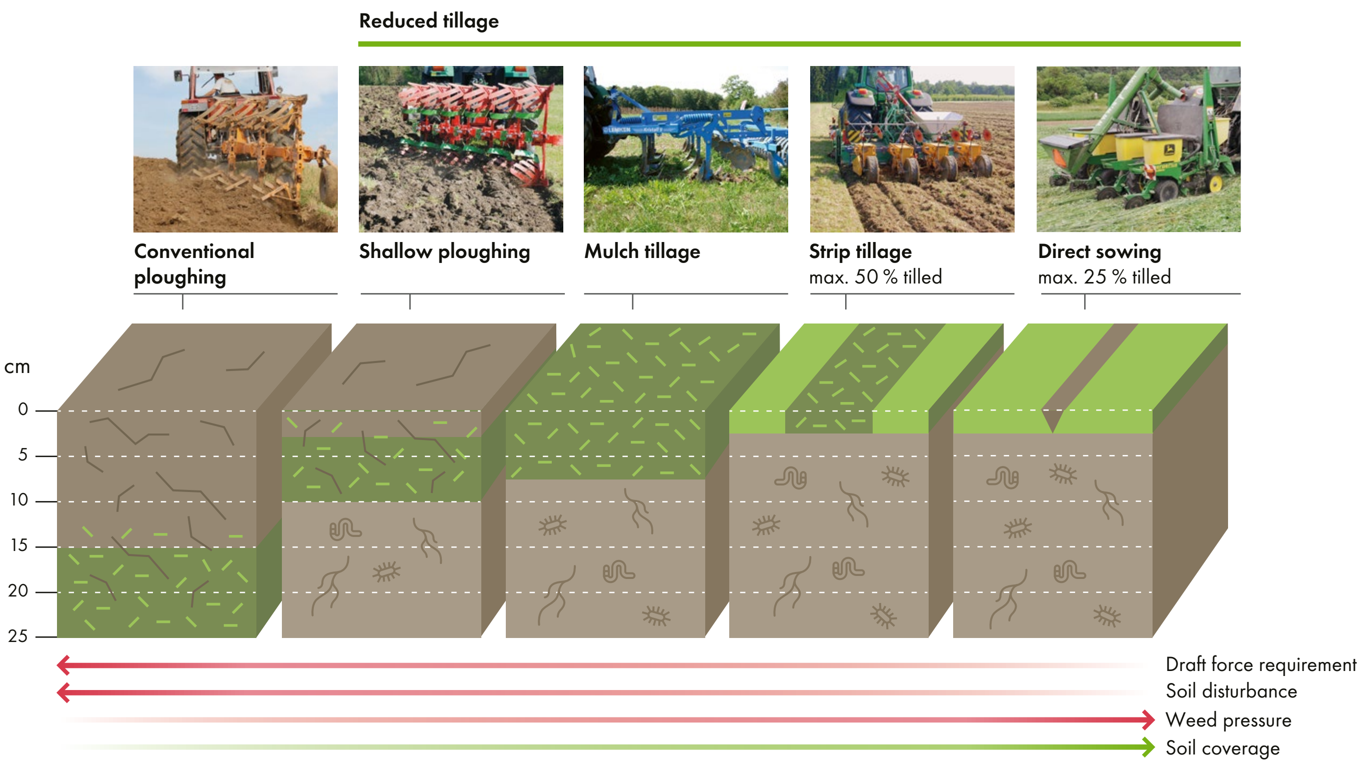
Minimal soil disturbance, maximum soil cover

Reduced tillage refers to methods that work the soil less intensively and/or less deeply than conventional ploughing. The aim of these methods is to work the soil as gently as possible and to maximise soil cover with crop residues and cover crops. This is intended to protect the soil from erosion, minimise the decomposition of organic matter, protect soil organisms and retain soil moisture. Reduced tillage is a key element of conservation tillage systems.

The terms "reduced", "minimal" or "conservation" allow for a certain degree of interpretation, as no maximum depth, number of passes or working methods are defined. In practice, the terms are often used synonymously.

EU Organic Regulation: Focus on soil protection
The EU Organic Regulation (EU) 2018/848 emphasizes the importance of maintaining and enhancing soil health through appropriate cultivation practices. The regulation requires that tillage and cultivation practices maintain or increase soil organic matter, reinforce soil stability and biodiversity, and prevent soil compaction and erosion (European Commission). According to the regulation's principles, producers must maintain and enhance soil life and its natural fertility, stability, water retention capacity and biodiversity (EUR-Lex). Deep or intensive ploughing that disrupts soil structure should be minimised, and cultivation of saturated soil must be avoided. The regulation assumes that maintaining soil health through reduced tillage practices is in the interest of organic producers achieving long-term sustainability.

Figure 1: Reduced tillage systems compared to conventional ploughing



Most reduced tillage methods require less draft force than conventional ploughing. However, fuel consumption is not necessarily lower, depending on the number of passes. As the working depth decreases, the amount of plant residues covering the soil at or near the soil surface increases, which helps to protect the soil. The less the soil is disturbed, the less soil degradation there is. On the other hand, as the intensity of cultivation decreases, weed growth increases.

Reduced tillage methods

Reduced tillage essentially distinguishes between mulch tillage (mulch seeding), strip tillage (strip till) and direct sowing (see also Fig. 1 on page 3). While mulch tillage involves tilling the entire surface, strip tillage only involves tilling narrow strips. Direct sowing only opens seed slots, leaving the soil between the strips untilled.

In organic farming, mulching tillage methods are used almost exclusively. Strip tillage and direct sowing only work in certain cases and require special technology. They must also be implemented without the use of herbicides or readily soluble nitrogen fertilisers, both of which are not permitted in organic farming.

Contributions for soil conservation measures

In **Switzerland**, the Federal Office for Agriculture (BLW) promotes reduced tillage as a measure to improve soil fertility and resource efficiency. All farms can apply for "production system subsidies for soil-conserving tillage" for mulch tillage, strip tillage or direct sowing in main crops in arable farming. The basic requirement for subsidies is that no ploughing is used on at least 60 per cent of a farm's open arable land.

In **Germany**, the national "Federal Action Plan on Nature-based Solutions for Climate and Biodiversity with investment subsidies for machinery to strengthen the natural soil function in agricultural landscapes" promotes, among other things, soil-conserving agricultural machinery. For information, see bfn.de > Forschung und Förderung > Aktionsprogramm Natürlicher Klimaschutz information (only available in German)

Some German federal states have support programmes for climate-friendly farming. As these change regularly, it is worth checking periodically for country-specific support options.

Mulch tillage

Main method

Method

- Superficial incorporation of harvest residues or green manure without turning the soil
- Normally ploughs or disc ploughs are used for weed control in mulch tillage up to a working depth of 10 cm (see Fig. 1 "Shallow ploughing"). Deep loosening is also used without turning the soil.

Advantages (compared to conventional ploughing)

- Lower water evaporation
- Higher biological activity due to organic material in the topsoil
- Better soil structure and load-bearing capacity
- Less soil erosion due to partial soil cover

Possible disadvantages (compared to ploughing)

- Delayed warming of the soil, resulting in less nitrogen mineralisation in spring
- Promotion of slugs by the mulch
- More difficult harrowing and hoeing due to harvest residues on the soil surface
- More volunteer growth or higher weed pressure
- More irregular emergence of crops

Points to consider

- Shred the plant material sufficiently before incorporation.
- Use mulch seeders with higher coulter pressure and disc coulters.
- Avoid seedbeds that are too coarse; roll if necessary.

Strip tillage
Of minor importance

Method
- Narrow strips of living or frost-killed cover crop are tilled into the soil, and the main crop is sown in them.
- The soil between the sown strips remains covered and untilled.

Advantages
- Creates favourable conditions for crop germination in the strips
- Good erosion control due to soil cover between the rows
- Good load-bearing capacity for machinery

Disadvantages
- Without herbicides, the tilled rows can grow back and suppress the main crop.
- The green strips between the rows must be tilled or mulched (e.g. with special 4-row mowers).

Points to consider
- Requires special machinery for sowing (e.g. Striger 100 from Kuhn with 4–12 rows)
- Ensure good soil contact for the seeds with correctly adjusted packer wheels.
- Weeds in the cultivated strips cannot be controlled by hoeing.
- The distance between the strips must be planned so that it is possible to drive on the uncultivated strips.
- General assessment: too labour-intensive for organic farming and associated with a high cultivation risk

Direct sowing
Of marginal importance to date

Method
- Sowing the crop in seed slots directly into the stubble of the previous crop or into a frost-killed or overwintering cover crop without any tillage
- Without herbicide, the cover crop is terminated by mowing and leaving the residue as surface mulch or crushed with a specialised implement, the crimper roller.

Advantages
- Highest degree of soil cover of all methods
- Least interference with the soil
- Preservation of soil structure
- Good soil bearing capacity
- Conservation of soil moisture
- Promotion of soil biodiversity
- Less crow damage (deeper sowing of maize, better rooting, less visibility)

Disadvantages
- Delayed warming of the soil, resulting in less nitrogen mineralisation in spring and delayed crop emergence
- Possible proliferation of slugs under the mulch layer
- Possible regrowth or continued growth of the cover crop
- No mechanical weed control possible

Points to consider
- Choose a cover crop with good weed suppression (e.g. field peas).
- The cover crop must be killed off completely without the use of herbicides (by mowing or crushing during flowering) if it is not frost-killed.
- General assessment: without the use of herbicides and slug pellets, generally high cultivation risk (lower yield compared to mulch tillage)

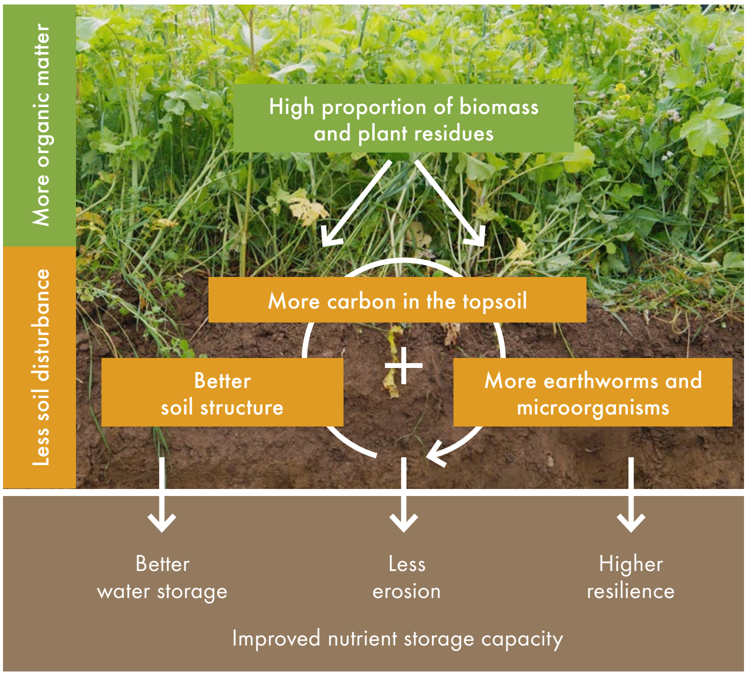
Advantages of reduced tillage

Improved soil fertility

Legumes and cover crops are an integral part of all reduced tillage systems. They serve to improve soil fertility, bind nutrients, suppress weeds, build soil structure, protect the soil from wind and water erosion, and promote above-ground and below-ground biodiversity. Plant residues promote soil life by providing water, food and shelter. This benefits earthworms in particular, as they take on the task of "tilling the soil" instead of agricultural machinery.

Cover crops also promote the development of mycorrhizal fungi, which absorb nutrients and water with their extensive hyphal network and make them available to plants. In addition, the hyphae contribute to the formation of soil aggregates and soil stability.

Figure 2: Dynamics of carbon storage in the soil



With reduced tillage, the biomass is only tilled into the soil superficially and the soil is less disturbed than with conventional ploughing. This improves soil quality in various ways and enriches the topsoil with more carbon.

Less soil disturbance leads to larger and more diverse populations of microorganisms, insects, mites, spiders and earthworms. Greater biodiversity and higher microbial activity promote mobilisation of nutrients in the soil – especially phosphorus, which is difficult for plants to access. This increases the resilience and stress tolerance of soils in response to external factors.

Reduced tillage also increases carbon stocks and water storage capacity in the upper soil layer. These changes in soil properties stimulate biological activity in the topsoil, improve soil fertility and help reduce erosion.

Better water infiltration

Reduced tillage improves water infiltration into the soil through better soil structure, more vertical earthworm tunnels and higher soil cover. At the same time, the higher humus content in the topsoil and denser root penetration boosts the water storage capacity of the soil.

High erosion protection

Reduced tillage in combination with soil cover is an excellent means of preventing soil erosion. An increased water infiltration rate, the capture of precipitation by cover crops and plant residues, and the high stability of soil aggregates due to a higher organic matter content all help to reduce soil erosion caused by heavy rainfall or wind.

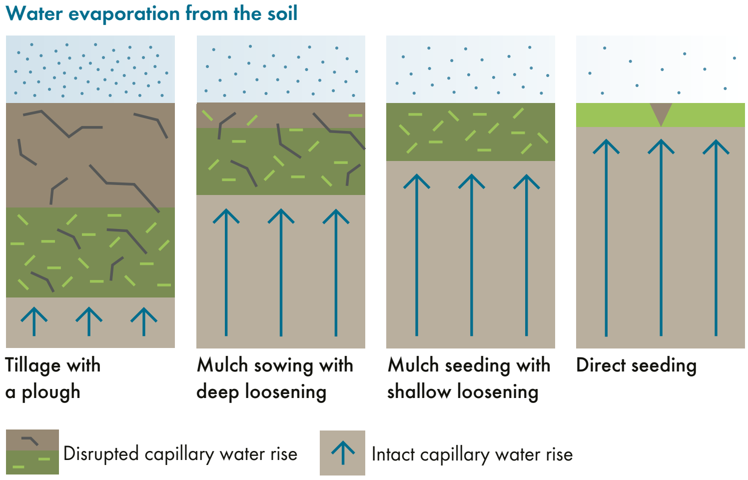
Water storage in summer

The smaller the diameter of the soil pores, the higher the capillary rise of water in the pores. Clay soils, which have the smallest cavities, exhibit the greatest capillary rise of water and are best protected against drying out. Sandy soils, on the other hand, have little to no water storage capacity and therefore dry out much faster than other soils. Sandy soils can, however, be driven on again just a few hours after rainfall.

The depth of tillage also affects water storage in the soil. The deeper the soil is cultivated, the greater the water loss through evaporation.

Stubble cultivation in midsummer cuts through the entire soil surface and stops the capillary rise of water. This preserves the moisture below the tilled layer in the root zone of the crops. In contrast, the area above the tilled depth dries out significantly.

Figure 3: Water evaporation as a function of tillage depth



When tilling the soil with a plough, the 25 cm deep tilled layer dries out faster than with mulch tillage with a tilling depth of 10 cm. Water evaporation is lowest with direct seeding.

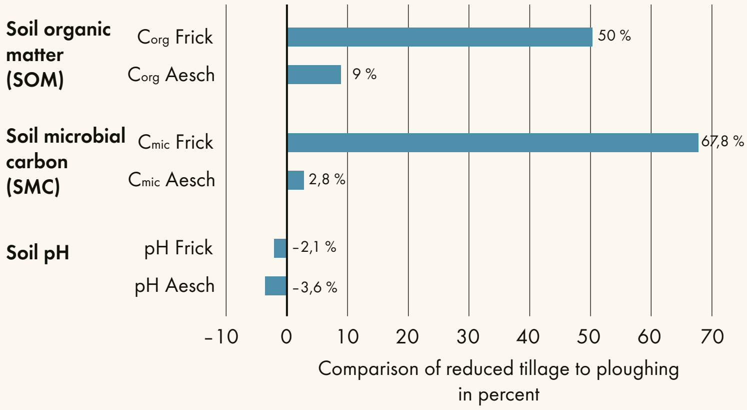
Research results

Reduced tillage enriches humus and microbial biomass on the surface

In two long-term experiments in Switzerland, FiBL is investigating the advantages and disadvantages of abandoning ploughing for soil quality in organic farming systems with different soil textures. In the trials, standard ploughing systems (plough: 17 cm, rotary harrow: 7 cm) and reduced tillage systems (stubble cultivator: max. 8 cm, wing chisel cultivator: max. 7 cm, rotary harrow: max. 7 cm) have been compared since 2002 in Frick and since 2010 in Aesch. The 5- to 6-year crop rotations include a two-year grass-clover ley fallow period. All treatments are replicated four times in the trials.

After 22 years of reduced tillage in Frick and 14 years in Aesch, 50 % more **organic carbon (SOM)** has accumulated in the top 10 cm in the Frick trial and 9 % more in Aesch compared to ploughing. In the 10 to 20 cm layer, the SOM content in the clay soil in Frick was 6 % higher under reduced tillage than under ploughing, whereas in Aesch, with lighter soil, the SOM content was 9 % lower.

Figure 4: Effects of reduced tillage on soil fertility in the topsoil (0–10 cm)



The effects of reduced tillage are more pronounced on the heavy clay soil in Frick than on the loess soil in Aesch (partly due to the longer duration of the experiment).

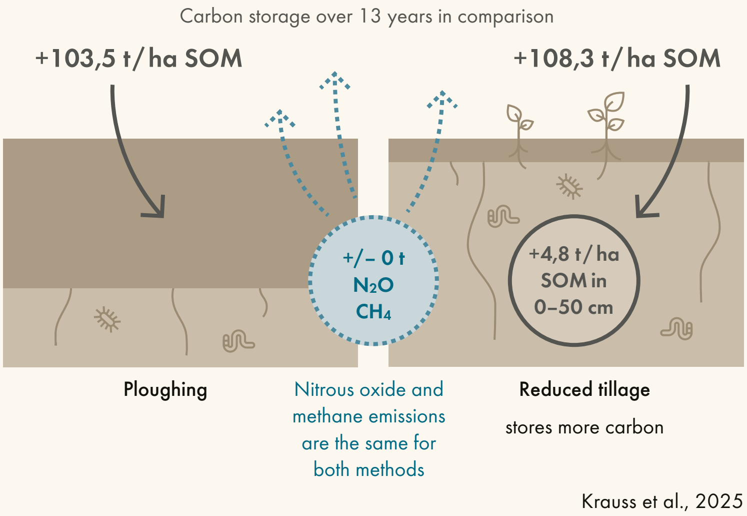
While the **microbial biomass (SMC)** in Frick was significantly higher in the topsoil layer under reduced tillage than in the layer below, the stratification in Aesch was less pronounced. Reduced tillage led to a slight reduction in **pH** in the topsoil at both sites (Frick –2.1 %, Aesch –3.6 %).

Conclusion: Soils under reduced tillage accumulate organic matter in the upper layers. Microbial conversion processes also increasingly take place in the upper tilled layer.

Tillage and climate

According to long-term studies, the humus content in organic farming remains approximately stable under ploughing, while it increases slightly in biodynamic farming thanks to the use of compost. If the soil is tilled to a reduced depth or not at all, humus accumulates on the surface, as it would in a natural grassland. The humus in the lower soil layers, on the other hand, is slowly broken down again. The observation that ploughing breaks up the soil structure particularly severely, makes stored humus accessible to microorganisms and therefore causes humus to be broken down, underlined the recommendation to refrain from ploughing in the climate protection debate.

Figure 5: Carbon storage with ploughing and reduced tillage in clay loam soil in a long-term trial in Frick



In this experiment, not using a plough resulted in an accumulation of humus in the top 50 cm of soil. In the clay loam soil in Frick, reduced tillage stored 4.8 t/ha more carbon than ploughing over 13 years. During this period, the differences in nitrous oxide and methane emissions were negligible.

Carbon storage in the soil depends on various factors

Long-term experiments have shown that replacing deep ploughing with shallower and mostly non-inversion tillage in organic farming can significantly increase the humus content in the topsoil, exceeding the levels achieved with ploughing. More recent measurements, which consider the entire soil profile, show that humus dynamics with reduced tillage depend on soil type and climate. In addition, bulk density must be taken into account for correct classification.

Depending on the location, carbon storage in the entire soil profile can be higher or lower with reduced tillage than with conventional ploughing. According to a study comparing long-term experiments at different locations and sampling to a depth of 1 metre, reduced tillage can achieve an average annual gain in organic carbon of 90 to 270 kilograms per hectare compared to ploughing.

Problematic nitrous oxide formation

The impact of tillage on climate change should also consider nitrous oxide emissions, which are significantly more harmful to the climate than carbon dioxide. Compact and poorly aerated soil tends to promote nitrous oxide emissions. The depth and intensity of tillage have less of an impact on nitrous oxide formation than soil moisture. To minimise nitrous oxide formation, soil should only be tilled in rather dry conditions and not immediately before rain.

Greater resilience to climate change

The accumulation of organic carbon in the topsoil through reduced tillage contributes to better soil structure and more active soil life. This also offers some potential for mitigating the effects of climate change, such as extreme rainfall events and drought.

Organically bound carbon also contributes to resilience to climate change. As the main component of organic matter or humus (dead organic matter), it positively affects soil structure and increases its water retention capacity. On the soil surface, it protects against wind and water erosion. It also forms the basis for conversion processes, providing “food” for soil organisms.

Consistent avoidance of ploughing despite challenges

In Müntschemier in the Bernese Seeland of Switzerland, I run an arable farm covering around 40 hectares. Around 33.5 hectares of the surface are under crop rotation. The crop rotation mainly consists of grain maize, peas/soybeans/sunflowers, oats and winter wheat, followed by grass-clover. However, the crop rotation can vary depending on the market. The soils are very diverse, ranging from mineral to light, humus-rich peat soil. In 2019, I converted the farm to organic farming and at the same time stopped ploughing.

The Kerner Corona star wheel cultivator with harrow roller has performed extremely well.

Success with the right combination of machinery and patience

Initially, I cultivated all areas with a disc harrow to a depth of approximately 5 centimetres and a cultivator with double heart shares. The load-bearing capacity and water storage capacity of the soil improved quite quickly. This motivated me to continue with reduced tillage. On the other hand, root weeds such as thistles, but also black grass and knotweed, millet and goosefoot slowly but steadily increased. So, I started looking for new machines and methods.

Four years ago, I tested a Kerner universal cultivator with a harrow roller as a rear-mounted implement for the first time. After the first year, I was so impressed that I bought the machine and have only used it since then. The advantage is that this cultivator can be converted from a wing chisel cultivator to a shallow sweep cultivator/chisel plough in 5 to 10 minutes thanks to a quick-change system.

The long harrow tines of the rear roller bring the root weeds to the surface, where they wither and die. So far, this has worked quite well against thistles and couch grass. I am satisfied and the weeds are under control again everywhere, except on one plot where black grass is still causing problems.

On that plot, I am currently in the process of repeatedly covering the seedlings with an intensive weed control phase with repeated soil tillage until the end of October. Since most black grass seeds do not germinate until October, I am even prepared to postpone sowing winter wheat until November.

The only disadvantage of reduced tillage compared to ploughing is the ploughless termination of grass-clover leys. With a plough, termination of leys is much faster and can be done in a single pass. Without a plough, on the other hand, I need a window of about three weeks of dry weather and 2 to 3 passes.

I do the shallow tillage with flat goosefoot sweeps, first very shallow like with a scalpel. This works better on hard, mineral soils than on soft organic soils. With my cultivator, which has a row spacing of 30 cm, this results in correspondingly wide sod strips. That's why this year I've added a front-mounted disc harrow, which breaks up the sod in advance and divides it into smaller strips.

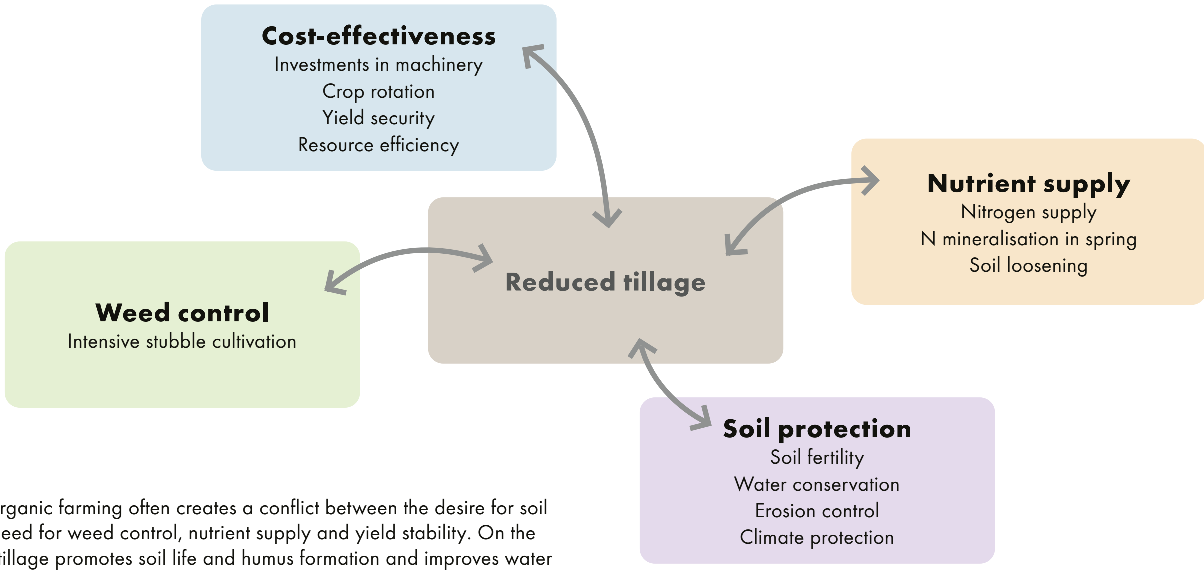
For me, ploughless tillage is a key element in creating an ideal seedbed for the main crops so that the seeds germinate evenly. On the other hand, reduced tillage helps to reduce weed pressure. So far, I have been quite successful in both respects. Small improvements are still possible, but the essentials have been achieved, and the soil structure has improved significantly.

Marcel Herren, Müntschemier, Berner Seeland

Challenges and solutions

The biggest challenge with reduced tillage in organic farming is increased weed pressure. Solutions are usually based on a combination of measures, including adapting the crop rotation, targeted cultivation of cover crops, the use of specific machinery and adapted nutrient supply.

Figure 6: Conflicting priorities in reduced tillage



Reduced tillage in organic farming often creates a conflict between the desire for soil protection and the need for weed control, nutrient supply and yield stability. On the one hand, reduced tillage promotes soil life and humus formation and improves water balance, but on the other hand, it usually leads to increased weed pressure, can impair nutrient supply and requires adapted crop rotations and investment in machinery.

Weed pressure and volunteer growth

The weed population in a field adapts quickly to new conditions. With reduced tillage, weed pressure can increase for various reasons:

- Shallow tillage with a harrow or light cultivator encourages the germination of seeds, especially small-seeded light-dependent germinators such as loose silky-bent, black grass, millet, thistles and dandelions.
- Failed seeds that did not have enough time or moisture to germinate and are then buried by premature stubble cultivation and fall into what is known as secondary dormancy, in which they can survive for years.
- This leads to an accumulation of seeds in the topsoil.
- Deep-rooted weeds, as well as alfalfa and tussock-forming grasses, are not sufficiently severed and are able to regrow.

Preventive reduction of weed pressure

Low weed pressure before switching to reduced tillage is crucial for crop success during the transition. The following measures contribute to efficient preventive weed control:

- Crop rotations with cereals, maize, sunflowers, protein peas in mixed cropping, as well as field beans are easier to convert to reduced tillage than less competitive crops such as soybeans, protein peas in pure cultivation, sugar beet, millet, flax or potatoes. For good weed suppression, choose tall-growing, nitrogen-efficient varieties with rapid early development.
- Clover grass content of at least 20 per cent in the crop rotation (increase in case of high weed pressure).
- Alternate between cereal and broadleaf crops and summer and winter crops.
- Perform clean-up cuts in the forage cover crop.
- Prevent weeds from setting seeds. Remove seed heads of docks and thistles before harvest at the latest.

Consistent stubble cultivation

Stubble cultivation is of central importance in organic farming. It should be done at the optimal time for controlling weed seeds and, above all, root weeds. Prolonged dry weather after harvest makes it possible to drive relatively heavy machinery over the soil, cultivate it several times and allow the weeds to dry out on the surface. Sowing cover crop directly after the rapeseed or cereal harvest and foregoing stubble cultivation is not recommended in organic farming.

Objectives of stubble cultivation

- Interruption of capillarity so that moisture remains in the soil
- Regulation of root weeds
- Reduction of volunteer grain and weed seeds
- Incorporation and distribution of straw
- Introduction of oxygen into the soil to promote decomposition
- Breaking up wheel ruts

How to proceed?

- If weed pressure is low, it is sufficient to till the stubble as superficially as possible with a fine cultivator, disc harrow or skim plough.
- Two passes are usually necessary: the first to stimulate weed seeds and volunteer grains to germinate, the second in combination with sowing to establish a cover crop and cover the emerged seedlings again.
- If weed pressure is high and there is a lot of volunteer grain, further passes may be necessary.
- Wait 7 to 10 days between passes to allow the seeds to germinate.
- After the last pass, sow a cover crop if possible.

Important to know

- Stubble cultivation only works if sufficient moisture rises in the soil capillaries to the seed layer so that the weeds and fallen grains can germinate in the cultivated layer.
- Seeds that have not germinated will be buried.
- Allow the seeds sufficient time to germinate on the surface.

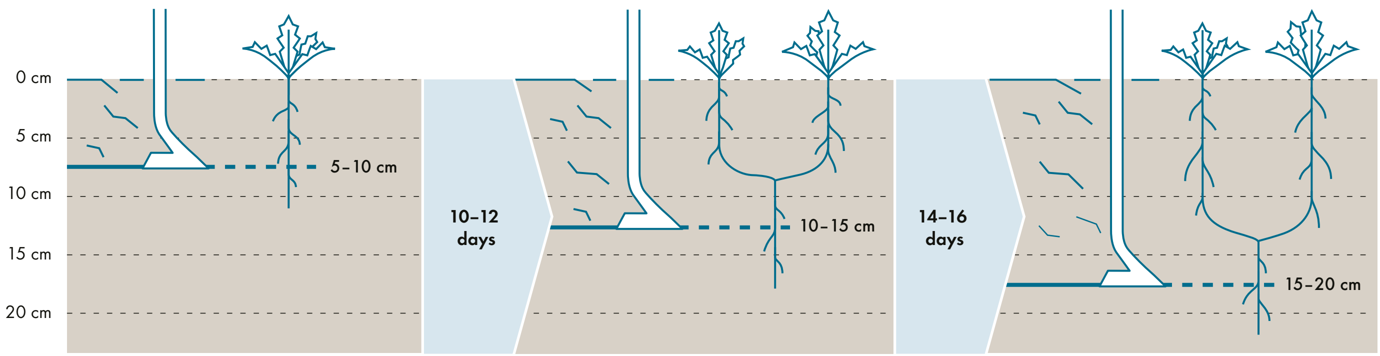
When switching to reduced tillage, there may be an increase in annual weeds at first and later also in grasses (left: conventional ploughing, right: reduced tillage).

- To control creeping thistles, at least three passes with a shallow cultivator are necessary in dry conditions, with each pass undercutting 5 centimetres deeper than the last. In wet conditions, smeared layers can form.
- Ideally, use a rear roller during the first pass. This promotes the germination of the fallen seeds by pressing them down. During the second pass, omit the rear roller so that the newly germinated plants can be pulled out and dry out.
- In the case of docks, shallow stubble cultivation should be avoided, as this would lead to the roots being broken up and the individual root pieces sprouting again individually.
- Shallow tillage with soil reconsolidation can also be counterproductive for couch grass or bindweed, as most of the buds are located in the upper part of the rhizomes, which can lead to propagation. Rotating implements should be avoided, if possible, as high speeds fragment root weeds and promote propagation.

Table 1: Stubble cultivation with a focus on controlling perennial weeds

Without root/ perennial weeds	After cereals (without black grass*): • First, very shallow (5 cm deep) stubble cultivation as soon as possible after harvest • Second, slightly deeper (up to 10 cm deep) tillage, possibly in combination with sowing a cover crop or grass-clover ley * For cereals with black grass, proceed as after rapeseed.	After rapeseed: • First, superficial stubble cultivation approximately 3–6 weeks after harvest (allow volunteer rapeseed and black grass to germinate) • Allow rapeseed to germinate again, then carry out a second, slightly deeper stubble cultivation in combination with sowing a cover crop or a grass-clover ley.
With creeping thistles	In addition to the above procedure: • Further passes with the shallow cultivator at a depth of 10 and 15 cm (see Fig. 7) • For large thistle patches, continue passes until sowing the main crop (forego greening). • Sow a long-term grass-clover ley.	
With dock	• Cut the taproots once or several times across the entire area to a depth of 12–15 cm using a heavy spring tine cultivator with goosefoot sweeps, a shallow cultivator or a skim plough, and bring them to the surface with a star harrow roller to expose and clean rootstocks. • Repeat the process until all roots are on the soil surface. • Ideally, collect the roots, as they can sprout again when they come into contact with moisture in the soil.	
With couch grass	• Cut through the soil across the entire field with a spring tine cultivator with strong tines and a large clearance (9–12 cm in light soils, 7–9 cm in medium soils and in heavy soils 6–8 cm deep). • Repeat the process, as the runners will sprout again below the working horizon. • Bring the runners of the couch grass to the surface with a harrow with a large tine spacing (no clogging), where they will wither. • Alternatively, use the "Kvik-up" from Kvikagro in Denmark to open the soil to a depth of 10–15 cm in a single pass with the long winged shares and bring the rhizomes to the surface with the rotating tines (180 rpm).	
With field bindweed	• No clear recommendation possible. There is a tendency towards more field bindweed with reduced tillage. If there is a lot of field bindweeds, plough relatively deep and bury the weeds. Sow cereals at hoeing distance and hoe. • Sow long-standing grass-clover leys and manage it intensively with a dense sward.	

Figure 7: Stubble cultivation in summer: gradually cutting the thistle deeper

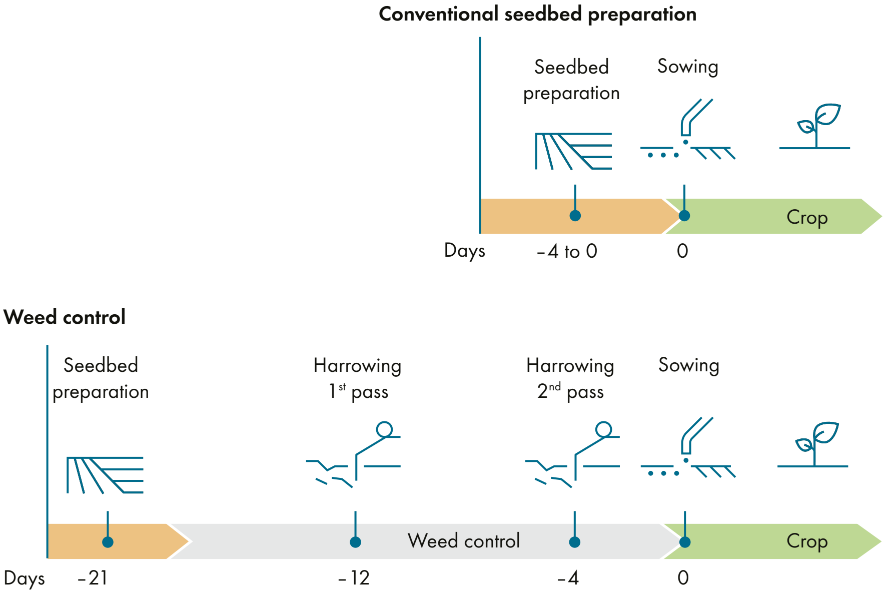


In the case of large-scale thistle infestation, stubble cultivation can be carried out from the end of June after an early harvest until the beginning of August. Repeated, gradually deeper, full-area undercutting with a disc plough or a full-area wing chisel cultivator with overlapping coulters can starve the thistles, as they are dependent on building up reserves during this period.

Weed control against annual weeds

Weed control should be carried out when there is a high pressure of weed seeds and weakly competing main crops. Weed control works on the same principle as stubble cultivation. The seedbed is prepared 2 to 4 weeks before the planned sowing date so that the weed seeds can germinate. Afterwards, the soil is harrowed as superficially as possible, which buries the seedlings. Caution: Deeper harrowing brings seeds back to the surface and tends to increase rather than decrease weeds.

Figure 8: Weed control



For weed control (also known as "false seedbed"), the seedbed is prepared 2 to 4 weeks before sowing. The weeds are then allowed to germinate and are repeatedly incorporated shallowly (2 cm deep) with a harrow at intervals of 7 to 10 days. Surface tillage encourages new seeds to germinate.

Continuous soil cover

Continuous soil cover with green manure and (undersown) cover crops not only protects the soil from erosion but also suppresses germinating weeds in patchy stands and reduces late weed infestation. In addition, undersown cover crops can fix nitrogen, enable faster feed utilisation after harvesting the crop and improve the structure and load-bearing capacity of the soil. If an undersown cover crop remains as a grass-clover ley, one tillage pass can be saved and the growing season can thus be more efficiently utilised.

How to proceed?

- Depending on the crop and the undersown mixture, the cover crop can be broadcast (or drill) sown at the same time as the main crop, after the last harrowing or hoeing pass (for winter cereals between tillering and booting) or with a drone into the ripening crop.

Optimally deployed undersown crops, such as here in wheat, can offer numerous benefits.

- For small-seeded undersown crops, use a pneumatic seed drill for better seed distribution.
- For forage cover crop or grass-clover leys, carry out a clean-up cut before the weeds go to seed.

Important to know
Competition for water and nutrients can have a negative effect on the main crop under certain circumstances.

Grass-clover ley termination

Terminating a grass-clover ley without a plough is a challenge. Without conventional ploughing, it is not possible to prepare a "clean canvas". Grass clods (especially from ryegrass) and alfalfa can grow back. What the plough does cleanly in one pass can require several passes over a longer period with mulch cultivation. In addition, success depends heavily on the weather conditions, the composition of the grass-clover ley, the machinery used and experience.

With shallow tillage, several passes and a longer dry period are usually necessary to prepare the soil for the next crop. Periods of heavy rainfall in spring and autumn make non-turning ley termination extremely difficult.

Three options for ploughless ley conversion
Instead of a conventional plough, a temporary ley can be tilled with a disc plough, a cultivator or a rotary tiller.

Ploughless ley conversion should be carried out in summer, if possible, as the undercut grass withers at high temperatures. However, this may require an adjustment to the crop rotation.

As an alternative to conventional ploughing, a grass-clover ley can be terminated with a skim plough.

Option A: shallow turning
The simplest replacement for the plough is the skim plough. It undercuts the turf to a maximum depth of 10 centimetres and turns it over. Although this does not usually result in a "clean canvas", maize, cereals and grain legumes can then be sown.

Option B: full-area paring
Another option is full area paring with a shallow cultivator. Like the control of creeping thistle, 2 to 3 passes with gradually increasing working depth are necessary when breaking up a grass-clover ley.

The wing chisel cultivator and disc harrow do not usually achieve good results, as they cannot cut under the entire surface of the sod.

Option C: gradual tilling
Following the same principle as in option B, the turf can also be damaged in stages using PTO-driven equipment in at least two passes. Various rotary tillers are suitable for this purpose. Here too, several passes may be necessary, depending on the density and composition of the vegetation.

Incorporating harvest residues and green manure

Working in straw and volunteer seeds

Some harvest residues and seeds remain on the surface. Due to the increased risk of clogging the seeder, harrow and hoe, mechanical weed control and sowing of the main crop can be difficult. In case of much organic material, a sowing technique suitable for mulch tillage with disc coulters is necessary.

Incorporating green manure

Green manures can be worked into the soil a few centimetres using a cultivator, rotary tiller or Geohobel (implement with rotating planer blades).

Seed combinations with a roller crimper at the front and a spring tine harrow combined with a roller can easily incorporate green manure in a single pass without a PTO-driven implement.

How to proceed?

- **Timing:** Green manures with high biomass are preferably mulched and incorporated approximately two weeks before sowing the main crop. Terminating green manure immediately before sowing the following main crop is not recommended due to the onset of surface decay (degradation process).
- The optimal **stage of development** for mulching is before the green manure is in full bloom, when the plants are not yet lignified.
- The work should be carried out **early in the morning or in the evening** when pollinators are not yet active.
- **Shredding the green manure** with a roller crimper or a mulcher before incorporating it into the soil makes it easier.
- **Incorporating the green manure into the soil** to a depth of approximately 3 to 5 centimetres is best done with a rotary tiller or a Geohobel. However, with these PTO-driven machines, the speed must be adjusted to the conditions to maintain the crumb structure of the soil (Coin-Test: approximately 20 clods larger than a two-pound or two-euro coin on an area measuring 40 × 60 centimetres) and to avoid a smear layer on the working horizon.

For green manure with low biomass, incorporation and sowing of the subsequent crop can be carried out in a single operation.

Incorporating the crushed or shredded plant material with the soil triggers decomposition by soil microorganisms. With good mixing and sufficient moisture in the soil, decomposition takes place in 1 to 2 weeks. Decomposition is complete when a sweet smell is noticeable.

Delayed nitrogen mobilisation in spring

Many crops depend on a good supply of nitrogen in spring for their development. With reduced tillage, this can be limited because nitrogen mineralisation is lower or delayed compared to ploughing. This can result from the lack of "aeration" by the plough and the usually longer soil cover and associated higher moisture content with lower soil temperatures.

In organic farming, readily available mineral N fertilisers may not be used for short-term nitrogen supply. However, slurry (or liquid recycled fertiliser) can replenish nitrogen deficits relatively quickly.

Regenerative agriculture for humus formation and climate protection?

The regenerative agriculture movement focuses on the soil. The key principles of regenerative agriculture are:

- Permanently covered and well-rooted soil
- Maximum promotion of biodiversity
- Minimal tillage
- Incorporation of green manure by means of surface decomposition and with ferments (e.g. effective microorganisms – EM)
- Deep loosening of the soil

There are various forms of regenerative agriculture. The lack of a clear and binding definition makes research into this form of farming difficult. However, based on previous experience, no measurable humus formation is to be expected in the short term from regenerative agricultural practices. The cover crops cultivated promote humus formation in the long term by adding additional above-ground and below-ground biomass. However, humus stocks also depend on the addition of other organic substances such as farmyard manure, compost or biochar, crop rotation in general, and particularly the integration of perennial crops such as grass-clover leys. These practices have been less of a focus of regenerative practices to date.

It is still unclear whether regenerative practices can build up larger humus stocks than organic farming, for example. Initial measurements showed a slightly higher conversion of the incorporated cover crops through the application of decomposition starters at the beginning of the surface composting periods.

Total nitrous oxide emissions were not affected by regenerative practices. Organic matter with a narrow C/N ratio can release more nitrous oxide. The amount and nitrogen content of cover crops determine the level of nitrous oxide emissions.

Soil compaction

Natural soil reconsolidation and traffic on the soil under less mechanical loosening can, especially in the transition phase from conventional to reduced tillage, lead to increased soil compaction below the tilled horizon. Compaction can have a negative short-term effect on crop yields.

In most cases, compaction develops below the 10-centimetre horizon, where reduced tillage is most common. Even the old plough pan can remain a compaction zone for some time after switching to a reduced tillage system.

How to recognise compaction?

- Compaction in the topsoil can be easily assessed with a soil probe or spade test or recognised by roots that do not penetrate deep and are curved.
- Above ground, compaction is often noticeable by a light colour and stunted growth of the crops (and, as a result, often lower yields). Weakly rooting crops such as grain legumes are particularly sensitive to compaction.
- Compaction in deeper layers (e.g. caused by heavy harvesting machinery) can promote the growth of creeping thistles along the compaction horizons.

Field thistles, broad-leaved plantain and dandelions indicate soil compaction in the field.

Assessing the risk of compaction

Important to know

- The risk of compaction is greatest on soils low in organic matter.
- The cultivation method, depth, frequency, timing (wet or dry) and the tractor and tyres are decisive factors in the degree of soil compaction.
- Optimal soil conditions at the time of cultivation with good load-bearing capacity are the most important measure against soil compaction!

Terranimo Online-Tool

Terranimo® is a simulation model for calculating the risk of soil compaction when using agricultural vehicles.
terranimo.world

Spade test from soils with different tillage methods (left: reduced tillage, right: ploughing). The reduced tilled soil has a good soil structure in the topsoil and good root penetration, whereas the ploughed soil is coarser and clumpier with undecomposed, buried crop residues. However reduced tillage also reveals compaction or densification in the subsoil.

Avoiding compaction

Before using any machinery, the soil should be assessed for passability to avoid compaction. Wide tyres with low tyre pressure can help to reduce compaction. It is also crucial to distribute the weight as evenly as possible across the wheels. As a rule, light machinery should be used in preference to heavy machinery.

Subsoiling in case of compaction

Deep cultivation with a chisel plough/subsoiler can help to restore compacted soil after the use of heavy equipment (wheel ruts) or to break up a hardpan layer.

- If subsoiling takes place after harvesting a crop, fast-growing and deep-rooted plants must be sown at the same time or immediately after subsoiling so that the loosened soil is rooted as quickly as possible and does not collapse again.
- Subsoiling can also be carried out immediately before sowing or in a green manure crop. When loosening in a growing crop, the roots can cover the cavities more quickly.
- When subsoiling is carried out at the same time as sowing a green cover crop or a main crop, the germinating plants can make direct use of the cavities.
- Regular subsoiling is problematic as it can lead to new compaction below the loosened horizon, especially if the subsoil is not completely dry.
- Carry out a spade test before subsoiling!

Subsoiling

Working method

- Heavy cultivator with good penetration and few blades that lift the soil
- Non-overlapping blades
- Working depth: 20–50 cm, depending on soil type
- Depending on the type of tines, cracking is horizontal and/or vertical.

Advantages

- Does not clog, large passage
- The soil structure is preserved, only loosened
- Preserves the soil-covering mulch layer
- Breaks up soil compaction below the plough pan
- Preserves carbon stored in the soil
- Moisture in the lower soil layers is retained
- Deep drainage promotes water infiltration

Disadvantages

- Subsoiling machines require powerful tractors. However, the traction requirement also depends on the design.
- High resistance when pulling into heavy, dry soils
- Often requires several passes

Points to consider

- The soil should be neither too wet (smearing) nor too dry (large clumps).
- The working depth of the tines must be below the compacted soil layer.

Manufacturers (selection)
Alphatec Weaving TL, Amazone TL, Bremer TG, Imants Culter, Kuhn subsoiler, Kverneland CLI, LM-Tech AERE TG, Löwenzahn, Maschio Gaspardo TL, Rolmako TL, Saphir TL Plowstar

Investments in mechanisation

The transition to reduced tillage requires suitable equipment to replace the plough and for supplementary measures, as no single tillage implement can completely replace the plough. The necessary diverse mechanisation results from the following measures:

- Stubble cultivation requires powerful equipment that is adapted to local soil conditions and can work at different depths.
- Mulching equipment, roller crimpers or PTO-driven equipment is required for incorporating green manure.
- If harvest residues are only incorporated superficially, it may be necessary, for weed control, to switch from tine-drawn to rotary implements (i.e. in addition to the harrow, it may be necessary to purchase a tine harrow or star weeder).
- The larger amount of organic material in the topsoil requires a suitable sowing technique.

Share equipment instead of buying

Instead of making large investments in implements for various tasks, joining machine pools or purchasing implements jointly with neighbouring farms can help to save costs.

The time window for soil cultivation is slightly larger than for weed control equipment. Before making large investments, equipment should first be tested on your own fields, as the quality of a machine's work can vary depending on soil conditions.

Disease and pest pressure

Pests and fungal pathogens can survive for long periods on crop residues. If the crop residues are not shredded and incorporated into the soil, the pathogens can continue to multiply and may even overwinter. This can lead to them infesting the subsequent crop.

Fusarium can easily be transferred to wheat if maize stubble is not incorporated or is incorporated insufficiently.

Minimising disease and pest pressure

Consistent prevention of diseases and pests reduces the risk of infestation during conversion.

How to proceed?

- Observe crop-specific cultivation breaks.
- Choose disease-resistant varieties.
- Promote rapid decomposition of crop residues: mulch crop residues such as straw and work them into the soil surface.
- To control the corn borer, mulch the corn stubble cleanly after harvesting and work it into the soil as superficially as possible.
- To prevent the transmission of Fusarium diseases, do not grow wheat or triticale after maize when using mulch and direct sowing methods.
- Avoid thick layers of mulch as this encourages slugs.
- In the event of wireworm infestation, a short period of black fallow (stubble cultivation) in summer reduces the number of larvae.

Practical example 2

Machinery and crop rotation must be compatible

» In Flaach, Canton of Zurich, Switzerland, I run a 15-hectare arable farm. I also manage two other farms in Hünikon, each covering 16 hectares, which I run according to my philosophy of minimal tillage and permaculture.

The switch to direct sowing and mulch tillage took place back in 1996. With the switch to organic farming in 2011, pure direct sowing was no longer possible due to the ban on glyphosate. Nevertheless, the "Treffler" shallow cultivator enabled ploughless tillage. The machine works the soil to a depth of about 4 to 6 centimetres over the entire area before the crops are sown with the direct seed drill. The shallow cultivator can also be used to terminate grass-clover leys.

Optimised cultivation system

The crop rotation with alfalfa, grain maize, winter wheat, winter barley-protein pea mixed cultivation and sunflowers is adapted to my machinery. Sugar beet or potatoes would not work in this system.

After harvesting, I sow a green manure as soon as possible. I have experimented a lot with undersowing cover crops in sunflowers, but without achieving the desired result. I consistently sow sunflowers with a row spacing of 75 centimetres and a starter fertiliser application of around 30 kilograms of nitrogen per hectare. The chosen row spacing creates great synergies when hoeing, as the work for sunflowers and grain maize overlaps and the hoeing machine does not have to be constantly repositioned.

I have been working with a Geohobel since 2023. Here, too, I work to a depth of 4 to 6 centimetres. Compared to a shallow cultivator, the Geohobel works in crop residues or green manure better. This means that the decomposition process starts earlier, which makes harrowing easier. The lower speed compared to a rotary tiller reduces wear and energy consumption.

Hanspeter Breiter, Flaach (breiterga.ch)

Incorporating green manure into the soil with a Geohobel.

Choosing suitable equipment

General criteria

The choice of suitable equipment depends on the intensity of soil cultivation and the following conditions:

- **Required seedbed conditions:** Winter crops such as cereals thrive on coarse and shallowly prepared soils, while shallow- or weak-rooted crops, such as peas and soybeans, require deeper loosening of the soil. Crops with small seeds need a fine seedbed for good soil contact.
- **Amount of biomass to be incorporated:** The more biomass that needs to be incorporated into the soil, the higher the tillage intensity must be. Fields planted with grass-clover leys or alfalfa are particularly demanding.
- **Prevailing soil conditions:** To determine the depth and intensity of tillage, it is necessary to correctly assess the condition and current moisture status of the soil. On medium-heavy soils, tillage is usually carried out with discs, coulters or simple tines, while on heavy soils it is carried out with skim ploughs or PTO-driven harrows and rotary tillers.
- **General and specific weed pressure:** The existing or expected level of weed growth and the type of weeds are important factors in determining the depth and timing of tillage.
- **Soil compaction:** The soil structure should be preserved as much as possible and heavy agricultural machinery should be avoided.
- **Registration for soil-conserving cultivation:** To qualify for CAP eco-scheme payments supporting conservation agriculture/reduced tillage in some EU member states, farmers may need to minimise tillage to prevent soil erosion with specific depth restrictions that vary by country. Most member states apply GAEC 5 requirements to arable land on slopes and have introduced bans on ploughing, required direction of ploughing, or mandatory plant cover to control erosion. Some national CAP strategic plans offer additional payments for reduced tillage practices that go beyond basic conditionality requirements. However, tillage depth requirements and restrictions differ significantly across member states based on local soil conditions and erosion risks.
  If the specific requirements are too restrictive for your farming system or would compromise crop establishment, you may choose to forego the voluntary eco-scheme payments while still meeting mandatory GAEC standards, allowing for a more flexible tillage approach suited to your operational needs.

Choice of implement according to field capacity (work rate)

On large farms with relatively flat fields, the area work rate is 5 to 6 hectares per hour thanks to high working speeds of 15 to 18 kilometres per hour with a working width of 6 metres. In countries with uneven topography and relatively small plots, only 3-metre-wide tillage implements are usually used – trailed implements achieve an area performance of approximately 1.5 hectares per hour here.

Table 2: Work rate of tillage implements in ha/h

Three-share plough	0.47
Four-share plough	0.62
Five-share plough	0.78
Six-share plough	0.93
Spading machine, 3 m	0.45
Subsoiler, 3 m	0.55
Cultivator with trailing roller, 3 m	1.40
Short disc harrow with rear roller, 3 m	1.42
Short disc harrow with rear roller, 4 m	1.92
Spring tine harrow with crumbler roller, 3 m	1.58
Spring tine harrow with crumbler roller, 6 m	3.07
Rotary tiller with rod crumbler, 2.5 m	0.76
Rotary harrow with packer roller, 3 m	1.09
Roller crimper, 6 m	0.50

Source: Swiss cost catalogue 2025, Agroscope Transfer, 598, 2024

Larger farms, on the other hand, mostly use combinations of implements to achieve high performance. On large arable farms with medium-heavy soils, combinations with trailed or ground-driven implements are often used.

When using a combination of implements, the soil is first broken up and loosened, then the straw is spread and mixed with the soil and tilled in. Finally, a packer roller/scraper is used to reconsolidate the soil, depending on the working purpose.

Individual implements or combinations

Despite all the advantages, implement combinations should not make us forget that sometimes it can be more sensible to carry out individual operations with lighter machines.

The more implements in the combination, the higher the purchase costs. For this reason, large combinations are mainly purchased by contractors, as they achieve a sufficiently high work rate.

Selection according to area of application

Traditionally, soil cultivation methods are divided into one of three categories: primary tillage, stubble cultivation or seedbed preparation. Today, however, this division is no longer so decisive, as many implements can be given a different function by quickly converting them or adjusting the hydraulics. This was not possible in the past.

Primary tillage

Primary tillage traditionally involves mixing and loosening the soil to a depth of 15 to 25 centimetres. With the help of a plough or cultivator, harvest residues, weeds and farmyard manure are tilled into the soil. This can be done with or without turning, using trailed or PTO-driven implements.

In reduced tillage, tillage deeper than 10 cm with a traditional reversible mouldboard plough is not carried out.

Stubble cultivation

Stubble cultivation is usually carried out with cultivators or ploughs, which are set to a shallow depth, but they can also be used for basic soil cultivation when set to a deeper depth. Cultivator models differ mainly in terms of row spacing, tine shape and the number of rows and tines. Quick-change systems allow them to be easily converted from a wing chisel cultivator to a shallow cultivator.

Seedbed preparation

Seedbed preparation follows primary tillage or stubble cultivation. The top layer of soil is tilled more finely and prepared for sowing. The most important implements are spring tines or rotary harrows.

There are a variety of cultivators that can be used for both stubble cultivation and seedbed preparation.

The different types of implements and how they work are presented on pages 24–29. Due to the wide variety of implement combinations available, only selected combinations are described. Today, the major machine manufacturers offer an almost overwhelming selection of types and models with different tools. These can be individually combined and adapted. More detailed information on the weight, width and purpose of the implements can be found on the manufacturers' websites. Prices can vary greatly depending on the equipment and must therefore be requested individually.

Table 3: Assessment of reduced tillage implements in comparison to conventional ploughing

The table provides an overview of the main types of implements used for soil cultivation. It helps to select a suitable type of implement based on the working method and conditions. The equipment is arranged according to method and type of drive system. Area performance, suitability and incorporation of material into the soil, and effect on the soil structure depend largely on the tillage depth. For the assessment, a standard tillage depth for low disturbance tillage was defined. Detailed descriptions of the most important implements can be found on the following pages.

Implement	Method	Working method			Suitability for					Effect on	
		Minimum working depth (cm)	Method of operation	Drive system	Field capacity	Terminating grass-clover ley	Incorporation of straw, harvest residues, manure	Incorporation of mulch (above-ground green manure)	Control of thistles	Soil structure and erosion control	Water storage
Mouldboard plough (standard)	PT	20	I	T	●	●●●	●●●	●●	●	–	–
Skim plough	PT/SC	<10	I	T	●●	●● (●)	●●	●	●●●	●	●●
Wing chisel cultivator/plough	PT	15	NI	T	●●●	●	●●	●●	●	●	●
Rotary cultivator	PT	15	NI	PTO	●	○	●●●	●●●	○	○	○
Spading machine	PT/SC	<10	NI	PTO/ TGD	●	●	●●	●	–	●	●●
Shallow cultivator (shallow sweep cultivator)	SC/PT	<10	NI	T	●●●	●●	●	●	●●●	●●	●●●
Light cultivator	SC/SBP	<10	NI	T	●●●	○	○	○	○	●●●	●●●
Disc harrow	STB/SBP	<10	NI	T	●●●	●	●	●●	–	●●	●●
Rotary tiller	SC/PT	<10	NI	PTO	●	●	●●●	●●●	–	○	●●●
Geohobel (implement with rotating planer blades)	SC/PT	<10	NI	PTO	●	●	●●●	●●●	–	●	●●●
Roller crimper		0	NI	TGD	●●●	○	○	●●●	○	○	○
Spring tine harrow	SBP	<10	NI	T	●●●	○	●	○	●	●●	●●
Rotary harrow	SBP	<15	NI	PTO	●	○	●	○	○	●	●

Method
- Plough (not reduced)
- PT Primary tillage
- SC Stubble cultivation
- SBP Seedbed preparation

Working method
- I Inversion tillage
- NI Non-inversion tillage

Drive
- T Towed
- PTO PTO-driven
- TGD Towed ground-driven

Suitability/Effect
- ●●● very good, high, positive
- ●● medium
- ● low, minimal
- ○ none, neutral
- – negative

Equipment for reduced tillage

Primary tillage

Turning, with removal of root weeds

Skim plough

Working depth
8 – 12 cm

Working method
- Cuts through the entire surface of the soil
- Working depth can be adjusted to conditions (as shallow as possible, as deep as necessary)

Advantages
- Good incorporation of biomass for rapid decomposition
- Can terminate a grass-clover ley in a single pass
- Conserves moisture in the subsoil
- Requires less traction than a conventional plough, more powerful
- On-land (depending on the mode), drives without ploughing furrows

Disadvantages
- Complete turning not possible at working depths <10 cm
- Risk of regrowth with deep-rooted grasses and alfalfa
- On uneven plots, slopes and wheel ruts, working depths greater than 10 cm are required.
- Difficult to pull in a shallow depth on heavy, dry soils

Technology
- Towed
- Usually 6 – 8 coulters (up to 11 coulters possible)
- Working width: 2.5 – 3 m
- Draft force requirement depending on width: 120 – 220 HP
- Support wheel for precise depth control
- Reversible plough (smaller models) or ridge plough (one way)

Manufacturers (selection, alphabetical)
Bugnot Rapid Lab, Escudero Ecologic, Köckerling Trio, Kverneland Ecomat, Einböck Ovlac mini, Stubble cultivator Zobel

Non-inversion tillage as an alternative to ploughing

Wing chisel cultivator (heavy cultivators, few coulters)

Working depth
15 – 25 cm

Working method
- Steep wing shares that tear open the soil, mix it thoroughly and loosen it
- The share point and wing share at different depths
- Depth control via packer roller

Advantages
- Good mixing and incorporation of harvest residues
- No risk of clogging due to large clearance with non-overlapping coulters
- High field capacity
- Lower draft force requirements than a plough
- No additional deep loosening necessary

Disadvantages
- In most cases, the soil is not cut through completely (no control of root weeds)
- Several passes are necessary for complete undercutting (e. g. for clover grass cultivation).

Technology
- Towed
- Various combinations with 2 or 3 beams/tines possible
- Wing share with stone protection, concave discs and roller
- Frame height approx. 80 cm, approx. 10 tines for 3 m width
- Quick-change system with various cultivator tines: straight or curved wing shares, narrow-point shares, double heart shares

Manufacturers (selection, alphabetical)
Amazone Cenio, Bremer Schwergrubber, Carre Culti, Einböck Hurricane, Kuhn Cultimer, Horsch Terrano, Pöttinger Synkro, Lemken Kristall, Maschio Gaspardo Terremoto, Saphir Terrastar, Väderstad Opus or Cultus

PTO-driven, with incorporation of large amounts of organic biomass

Rotary cultivators

Working depth
15–30 cm

Working method
- Non-inversion tillage
- Flat, long tines rotate vertically and mix the soil and crop residues in the working horizon.

Advantages
- Good mixing
- Large quantities of crop residues and green manure can be incorporated
- Also suitable for heavy soils, but can also lead to a smear layer

Disadvantages
- High energy requirements, heavy implements, high draft force and power needs of up to 300 HP required
- Good field capacity in combination with other implements, moderate field capacity when used alone
- The incorporation of large quantities of straw and finely chopped material can lead to nitrogen blockage in the subsequent crop
- The soil structure can be damaged at higher speeds, especially during deep cultivation

Technology
- PTO driven
- Tines available in various sizes
- Compared to a rotary harrow, where the tines are attached in a trailing position, rotary cultivators have longer, more stable tines that are slightly forward-facing. This helps to more thoroughly mix the soil.

Manufacturers (selection)
Amazone KX rotary cultivator

PTO- or ground-driven, for incorporating green manure

Spading machines

Working depth
8–15 cm

Working method
- Complete cutting through the root system with a spade and loosening/turning of the soil
- Lightly firming the soil with a roller after mixing
- Bomford Dyna Drive double tine rotor with two rotor shafts connected by a heavy-duty drive chain (front shaft with many spade tines, rear shaft with a smaller number of tines). The triple speed of the rear shaft ensures thorough mixing and incorporations of the loosened soil. The machine has a minimum draft power requirement of 135 HP at a working width of 3 m.

Advantages
- Slow-rotating and shallow-working spade shaft, therefore no smearing of the soil possible as with rotary tillers
- Good mixing and incorporation of harvest residues
- Clean seedbed
- Brings oxygen into the soil
- Large clearance, no clogging
- Suitable for all soil types

Disadvantages
- No control of root weeds
- Low area work rate (ha/h)

Technology
- Horizontally rotating tines with interchangeable spade blades, depending on soil type
- Combination with subsoiler, harrow roller and seed drill possible
- Width: 3 m, draft force requirement with PTO without subsoiler coulter: 90 HP

Manufacturer
Imants, Celli (PTO-driven), Bomford Dyna Drive (with ground drive instead of PTO)

Stubble cultivation

With regulation of root weeds or
shallow skimming grass-clover ley

Shallow cultivator (precision cultivator)

Working depth
5–10 cm

Working method
- Full-area shallow skimming and mixing of the soil with harvest residues using overlapping tines with goosefoot weeps

Advantages
- Can be used on all soils, high field capacity
- Minimum working depth of 5 cm possible on level plots
- Soil moisture is retained beneath the topsoil layer.
- Control of root weeds such as thistles possible (3 passes necessary according to Fig. 7 on page 11)
- For control of dock, work to a depth of at least 12–15 cm
- Suitable for terminating a grass-clover ley (under-cutting of the grass-clover in the first pass, 5 cm deeper in each subsequent pass, usually 3 passes necessary)

Disadvantages
- Risk of clogging with large amounts of biomass
- The shallower the working depth, the lower the mixing effect

Technology
- Towed, working width 3–6 m
- Rigid goosefoot sweeps with stone protection, quick-change system, 2 or 3 beams/tines possible
- Relatively heavy implements with dual wheels
- Hydraulic depth adjustment
- Usually in combination with discs or star wheels (which expose root/perennial weeds) and a following implement (packer/roller or harrow)

Manufacturers (selection, alphabetical)
Bremer Mulchgrubber, Carre Urasi precision scalper, Einböck Razor, Güttler Super Maxx Bio, Horsch Cruiser, Kongskilde Delta Flex, Köckerling Vario, Kuhn Cultimer, Kverneland Turbo, Lemken Koralin, Pöttinger Terria, Saphir Tinestar Profi, Treffler precision cultivator

With intensive weed control phase

Fine cultivators (spring tine cultivators, precision spring tine harrows, straw harrows, heavy spring tine harrows)

Working depth
5–10 cm

Working method
- Full-surface cultivation of the soil
- The vibrations of the long spring tines bury weeds and mix them into the soil.
- Suitable for controlling couch grass (tears out rhizomes) and annual weeds
- More suitable for light to medium soils; suitable for second stubble cultivation on heavier soils
- Transition to seedbed preparation

Advantages
- Preserves soil moisture under the working horizon
- Ideal for weed control before sowing
- Lighter than other cultivators
- High field capacity

Disadvantages
- Risk of clogging; cannot incorporate large amounts of straw or weeds
- Not suitable for ley termination

Technology
- Offset overlapping double spring tines with or without goose foot sweeps at the tip
- Compared to spring tine harrows, stronger and higher frame as well as longer and stronger tines
- Precise depth control via dual wheels, rear roller and harrow (hydraulically adjustable)

Manufacturers (selection, alphabetical)
Bremer Vibro spring tine cultivator, Carre Pentasol fine cultivator, Einböck fine cultivator Vibrostar, Horsch Finer, Kongskilde Vibro Flex, Kerner Stratos ultra-cultivator, Köckerling Bio Allroud classic, Kuhn Prolander, Kverneland Oeko cultivator, Pöttinger Plano, Saphir straw harrow Clearstar, Saphir large spring tine harrow Allstar, Treffler precision spring tine harrow, Väderstad Swift

With incorporation of straw, volunteer seeds

Disc harrows (short disc harrows, spade roller harrows)

Working depth
5–10 cm

Working method
- Surface scratching of the soil with heavy, serrated, discs set at an angle
- Mixes soil and crop residues

Advantages
- Suitable for light to medium soils with little to no root/perennial weeds
- Suitable for quickly working stubble and annual weeds into the soil
- Moisture is retained beneath the working horizon
- Does not clog
- Very powerful

Disadvantages
- Risk of spreading root/perennial weeds, such as couch grass or thistles, by cutting them into small pieces that can sprout again
- Less effective in dry conditions and heavy soils

Technology
- Towed
- Front-mounted implement, disc unit and trailing roller
- Compact disc harrows in widths of 3–4 m
- In combination with a front-mounted roller crimper, also suitable for incorporating green manure

Manufacturers (selection, alphabetical)
Amazone Catros compact disc harrow, Bremer Columbus, Einböck Rebell, Horsch Joker, Kuhn Optimer, Kverneland Qualidisc, Lemken Rubin 10, Maschio Gaspardo Veloce, Pöttinger Terra Disk, Saphir Discstar short disc harrow, Väderstad Carrier

Incorporation of green manure with PTO-driven implements

Rotary tillers

Working depth
4–10 cm

Working method
- Angled blades rotate around the axis and till up the soil.
- Depending on the working depth, the soil is skimmed shallowly and/or mixed with harvest residues.
- Mulched plant material rots on the surface.
- Often used in combination with a subsoiler.

Advantages
- Incorporation of even larger cover crops or grass-clover ley is possible, even in heavier soils
- The mulch layer protects the soil from erosion and drying out.
- The moisture under the tilled horizon is preserved.
- Combination with sowing is possible but only recommended when incorporating small amounts of crop residues.
- For large quantities of green manure, sow seeds in a separate second pass after completion of the rotting process.

Disadvantages
- No control of root/perennial weeds
- Low area coverage with separate sowing
- High fuel consumption
- High wear
- Damage to soil structure and earthworms possible at high speed
- Risk of smear layer formation
- Fragmentation and proliferation of root/perennial weeds possible

Technology
- Tilling with angled tines

Manufacturers (selection, alphabetical)
Celli Fixed rotary tiller, Konskilde Howard Biocircle rotary tiller, Kuhn Biomulch rotary tiller, Maschio Gaspardo rotary tiller, Vortex VE A250 rotary tiller

Incorporation of green manure with PTO-driven implements

Shallow surface-planing implement (Geohobel)

Working depth

4 – 10 cm

Working method

- Cutting through the entire root system with patented planer blades (Geohobel) or spades (Imants) and turning the soil
- Lightly compacting the soil with a roller after tilling

Advantages

- Low speed and special coulter shape, therefore almost no smearing of the soil as with a rotary tiller
- Good mixing and incorporation of crop residues
- Can be combined with sowing, but only recommended when incorporating small amounts of crop residues
- Clean seedbed
- Brings oxygen into the soil
- High clearance, no clogging
- Suitable for all soil types

Disadvantages

- No control of root weeds
- Annual seed weeds are incorporated and can germinate again.
- Low operation speed (ideal: 6 km/h, usually less) and low area work rate (ha/h)
- Two passes may be necessary if there is a lot of biomass.
- If there is a lot of biomass, sowing must be done in a separate pass
- High draft force requirement

Technology

- Blade shape based on the garden hoe
- Spade blades can be changed for different soils
- Usually combined with seed drill and roller

Manufacturer
Rath Geohobel

Incorporation of green manure with trailed implements

Roller crimper in combination with flat or spring tine cultivators

Working depth

Roller crimper: on the soil surface, flat cultivator: <10 cm

Working method

- The roller in front-mounting runs on the soil surface and chops cover crops and harvest residues.
- Incorporation and mixing of the biomass with the soil by the following flat cultivator

Advantages

- Towed, ground-driven or PTO-driven versions for the roller
- Erosion protection: the implements work less intensively than mulchers, which means that the biomass takes longer to decompose.
- No smearing possible
- High field capacity (approx. 5 ha/h at a width of 6 m)

Disadvantages

- The coarse structure of the crushed or chopped green manure can hinder subsequent sowing.
- Allow sufficient time before sowing the main crop.
- Less suitable for heavy soils

Technology

- Straight or spiral cutting elements on a roller

Manufacturers (selection, alphabetical)
Agrisem, Dal-BO, Horsch Cultro, Kerner x-cut Solo, Saphir, Vibrocut, Wallner

Seedbed preparation

With trailed implements

Spring tine harrows (also spring tooth harrows)

Working depth

5 – 15 cm

Working method

- Mixing and loosening the soil with spring tines that cut through the surface
- The vibration of the spring tines causes the soil to break up along its natural fracture lines; larger soil aggregates remain on top, smaller crumbs underneath.

Advantages

- Powerful, working speed of 8 – 12 km/h
- Relatively low draft force requirement
- Leaves a level soil surface
- Working depth adjustment via rear roller
- Suitable for weed control before sowing
- Also suitable for stony soils
- Low risk of smearing compared to rotary tillers
- Leaves a good soil structure in light to medium soils

Disadvantages

- May become clogged depending on the condition and spacing of the tines
- Often leaves the seedbed too coarse on heavier soils (coin test); use additional clod and crust breakers or use a disc harrow.

Technology

- Spring tines made of hardened steel (flat iron on a tine with or without goose foot sweeps)
- Width: 3 – 12 m, 30 – 120 tines
- Often used in combination with discs and rear rollers

Manufacturers (selection, in alphabetical order)

Bremer Vibro spring tine cultivator, Einböck Vibrostar, Köckerling Allrounder, Kverland TLG, Maschio Gaspardo Grator, Pöttinger Universal, Väderstadt Mounted

With PTO-driven implements

Rotary harrows

Working depth

10 – 15 cm

Working method

- Non-inversion tillage
- Vertically rotating tines, in contrast to rototillers with horizontally rotating tines

Advantages

- Good surface mixing and incorporation of harvest residues
- Suitable for heavy soils, also for breaking up coarse clods
- Rotary harrow usually used in combination with a seed drill after stubble cultivation or ploughing

Disadvantages

- High energy consumption
- Good performance in combinations, moderate when used alone (approx. 1 ha/h at 3 m width)
- Risk of soil surface crusting after rainfall if tillage is too intensive
- Moderately good incorporation of mulch by the rotary harrow

Technology

- Less heavy and less stable than the rotary cultivator
- Tines available in various sizes
- Relatively high power requirement depending on implement width (1.3 – 10 m, standard: 3 m) and number of blades (10 – 80)

Manufacturers (selection, alphabetical)

Amazone Rotamix rotary harrow, Kuhn rotary harrow, Kverneland M or H Series, Maschio Gaspardo, Pöttinger Lion Classic, Lemken Zirkon

Changing soil cultivation method takes time and patience. These pay off over time in the form of improved soil fertility (left: reduced tillage, right: conventional ploughing).

Getting started with reduced tillage

Interest in low-disturbance tillage is growing steadily. The potential advantages of reduced tillage can convince many farmers. On the other hand, as collective experience increases, the challenges and risks of the methods become clearer. Even though reduced tillage is still under development, the experience gained provides valuable information for beginners.

1. Clarify requirements and assess risks

It is worth assessing the farm-specific conditions, such as soil, climate, topography, crop rotation, weed pressure, etc., for reduced tillage: What are the pros and cons of reduced tillage? How should the risks be assessed?

Nearby farms with similar conditions and experience in reduced tillage can provide valuable information on suitable methods. Enquiries about machinery are also helpful: What equipment is available in the region and/or could be rented?

2. Start with simple methods

As a rule, it makes sense to introduce reduced tillage gradually and not to sell the plough immediately after making the switch. The success of reduced tillage depends heavily on experience. Damage to the soil such as compaction and smear layers, the proliferation of root/perennial weeds and high yield losses must be avoided. Farmers with no experience in this area should keep the risks as low as possible and start with simpler, proven methods and crops. Cereals are among the simpler crops. Initial difficulties can usually be overcome with minor adjustments, which can subsequently lead to success. Initially, only individual plots should be cultivated using reduced tillage. If successful, reduced tillage can be extended to more demanding crops such as rapeseed, soybeans, flax or sugar beet.

Examples of different risk levels

In autumn

Simple
- Cereals after stubble cultivation
- Cereals after potatoes
- Winter field beans or barley/protein peas after cereals or rapeseed

Somewhat more demanding
- Rapeseed or winter flax after stubble cultivation of cereals

In spring

Simple
- Summer field beans after maize

Somewhat more demanding
- Maize, sunflowers, protein peas or lupins after cereals with frost-killing or overwintering green manure

Demanding
- Soybeans, sugar beet, potatoes, hemp, millet or summer rapeseed after cereals with overwintering green manure or after maize
- Maize after grass-clover ley/alfalfa

3. Optimise the system

Reduced tillage is ideally seen as an approach to improving soil fertility and resilience. Reduced tillage should be used wherever possible, especially in organic farming, while ploughing should be used where its benefits are greatest and its disadvantages are minimal, for example in late autumn when the biological activity of the soil is reduced and the decomposition of organic matter is limited due to low temperatures.

A flexible system as a solution?

Some organic farmers have been successfully using reduced tillage for years. Many have approached the system cautiously and made a gradual transition, starting with simple applications. Many organic farmers have established a flexible system in which the plough is only used where it makes most sense, for example when ploughing a grass-clover ley, before demanding crops or when there is a heavy infestation of problematic weeds. Such systems, in which reduced tillage and the use of the conventional plough complement each other, are called “flex systems”.

Practical example 3

Acting optimally in any situation with a flexible system

» We run an organic farm in Bätterkinden, Bern, Switzerland, with 62 hectares of agricultural land. In addition to arable farming, we keep 2,000 laying hens and 16 suckler cows. The farm also includes 1 hectare of cherries and 180 nut trees. Per hectare of fertiliser-eligible area, we maintain around 1.6 fertiliser large livestock units.

The soils vary greatly: from gravelly, sandy and humus-rich to heavy clay soils. This means we must be flexible in how we till our soils.

Better soil fertility thanks to reduced tillage with trailed implements
Reduced tillage is an important part of how we maintain soil fertility. The improved soil structure, together with the mulching of crop residues, provides good protection against erosion and smearing. Reduced tillage also generally requires less effort.

Where possible, we use towed implements for soil tillage. Various machinery cooperatives provide us with a wide range of implements such as star wheel cultivators, heavy spring tine harrows and disc harrows. The grass-clover ley is ploughed with an on-land plough. Thanks to the wide selection available, we can choose the most suitable implement for each situation. This type of cooperation gives us the flexibility we need.

With the dam forming plough, primary tillage, sowing and weed control can be carried out with a single pass in crop cultivation.

Ploughing as required
Despite all the advantages of reduced tillage, there are situations on our farm where the plough is justified. It is important for us to be able to carry out tillage flexibly and not according to rigid principles.

Heavy clay soils on our farm are easier to work with trailed implements after several years of mulch seeding. However, after several wet years, weed grasses can become problematic. In such situations, we use the plough as needed.

Based on our positive experiences with trailed tillage implements, we decided in 2024 to purchase a dam forming plough for growing root crops. This implement allows us to carry out primary tillage, sowing and weed control. Our initial experiences have been positive in terms of root growth and soil structure. We still grow our cereals using conventional shallow tillage methods.

Our aims is to continue our reduced tillage approach, achieving a good cost-benefit ratio while maintaining intact soil structure throughout the entire crop rotation and keeping weeds at an acceptable level.

Adrian Kuchel, Bio Chratte, Bätterkinden, Switzerland

Further information

Publications

Basic Guide "The basics of soil fertility":
shop.fibl.org > 4002

Fact sheet "Soil and climate: Climate impact of organic soil management": shop.fibl.org > 1349

Practice abstract "Autumn cover crops":
organic-farmknowledge.org > 32948

Practice abstract "Cover crop mulches and no-till maize":
organic-farmknowledge.org > 32610

Videos (selection)

Humus management: Building humus – maintaining soil fertility (2024) (German with english subtitles)
youtube.com > FiBLFilm > Humuswirtschaft

Incorporating green manure with rotary tillers and trailed implements (2019) (German with english subtitles)
youtube.com > FiBLFilm > Einarbeitung Gründüngung

Minimum tillage: Experiences from Kampars organic farm in Finland
organic-farmknowledge.org > 56549

Imprint

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Translation: Translated by DeepL, January 2026, revised by Lauren Dietemann, Meike Grosse, Nicolas Lefebvre and Gilles Weidmann (all FiBL)

Design: Sandra Walti (FiBL)

Photos: Thomas Alföldi (FiBL): pages 2, 4, 6, 17 (2), 27 (1); Amazonen Werke, DE: pp. 25 (1), 29 (2); Daniel Böhler (FiBL): pp. 18, 28 (2); Hanspeter Breiter: p. 20; Hansueli Dierauer (FiBL): pp. 1, 3 (4), 5, 9, 11, 13, 14, 15, 16, 17 (1), 19, 22, 24, 26, 27 (1), 29 (1); Meike Grosse (FiBL): p. 30; Django Hegglin: p. 28 (1); Imants BV: p. 25 (2); Adrian Knuchel: p. 31

FiBL Art. No. 1847 **Permalink:** orgprints.org/id/eprint/56627

Recommended citation: Dierauer H. & Grosse M., Reduced tillage. Protecting soil functions for better climate resilience (2026). Research Institute of Organic Agriculture FiBL, Frick. Available at: shop.fibl.org.

Funding: This technical guide was produced as part of the KLIMACrops project (Strategies for adapting arable farming systems to climate change and their contribution to climate protection in the Upper Rhine region) with co-financing from the Interreg Upper Rhine programme with support from the European Union from the European Regional Development Fund (ERDF), Interreg VI, the Swiss cantons of Basel-Land, Basel-Stadt, Solothurn and Aargau, as well as the Regio Basiliensis, and as part of the NBSOIL project (Nature-Based Solutions for Soil Management) with support from the European Commission, the Swiss State Secretariat for Education, Research and Innovation (SERI) and UK Research and Innovation (UKRI).

Kofinanziert von der Europäischen Union
Cofinancé par l'Union Européenne
Oberrhein | Rhin Supérieur

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

UK Research and Innovation

This work has received funding from UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee grant number 10061997.

Project funded by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI).

The English translation of the original German edition was realised with support of the OrganicClimateNET project. The project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement no. 101136880 and by the Swiss State Secretariat for Education, Research and Innovation (SERI).