

To Till or Not to Till
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Why Reduce Tillage: An Ecological Perspective

If you travel through farm country in the late fall you may notice that, whereas farmers used to deep turn their soil in the fall, leaving fields black, nowadays more farmers are leaving their fields blanketed with the residues of the previous summer's crops. They are practicing "conservation tillage", the collective term for tillage regimes designed to reduce soil erosion and soil contamination of natural waters. Some farmers are merely postponing plowing or disking until spring; others will till with a less destructive implement like a chisel plow; yet others will not till at all, seeding into narrow furrows in otherwise undisturbed ground. The primary motivation for such "no-till" methods is to reduce soil erosion. But soil erosion is only one of several problems with tillage, and these are just as much a concern for gardeners managing small plots by hand as for farmers managing large fields.

Tillage destroys soil structure.

One reason why we humans originally developed a tillage-based agriculture was that tillage initially loosens a soil so that we can put our seeds or seedlings into it, and so that our young crops can extend their roots into it unimpeded. But this effect is merely transitory. In the long run tillage destroys soil structure. Soil structure refers to the arrangement of soil particles with pore space between them. Both air and water should easily infiltrate these pores for healthy root growth and for a healthy soil microbial life. Tillage pulverizes larger clumps of soil ("aggregates") into a fine powder, which is easily washed by the next rain down into the soil's pores, clogging them up. The result of many years of repetitive tillage is a soil with poorer drainage and a reduced capacity for holding water and air. Depending on the relative portions of sand and clay in the soil, this problem manifests itself in different ways:

- *soil may be water-logged in the spring and droughty in mid-summer;
- *soil may be compacted, limiting plant root growth;
- *soil may develop a surface crust which impedes water infiltration and seedling emergence;
- *soil will be more easily eroded.

Tillage destroys organic matter in soil.

Organic matter is important for several reasons. 1) Organic matter helps improve soil structure. 2) Organic matter acts like a sponge, soaking up and retaining both moisture and plant nutrients. 3) Organic matter itself is a rich source of plant nutrients, which are slowly released by the feeding of decomposer organisms, primarily bacteria and fungi.

In a healthy undisturbed soil the activity of decomposers is limited by the slow rate at which the oxygen they need for respiration can diffuse to them through sinuous soil pores. Tillage incorporates large amounts of oxygen into the soil, which stimulates a feeding frenzy by decomposer organisms, much like stoking a fire. Decomposer feeding releases nutrients

because they are sloppy eaters: what they don't consume is spilled, and thus becomes available for uptake by plant roots.

These nutrients may in turn stimulate rapid crop growth. Undoubtedly early farmers noticed this, which is part of why we developed an agriculture based on tillage. It is also part of why some farmers and gardeners cultivate in mid-season: crops respond to tillage as they would to fertilizer. The problem is that, whereas in a healthy undisturbed soil this release of nutrients from organic matter proceeds at a pace that roughly matches the ability of plants to take it up, following tillage the nutrients are released faster than the crops can take them up. Nutrients released in excess of the crop's needs are leached away or lost by other mechanisms. Over many decades repetitive tillage can result in soils depleted of both organic matter and nutrients. So, to maintain productive soils, farmers and gardeners who have tilled too frequently must use synthetic or organic fertilizers to replace not just the nutrients removed in harvest, but also the nutrients lost as a result of tillage. Finally, the organic matter that is "burned off" by tillage contributes to the carbon dioxide that is now changing our atmosphere!

Tillage disrupts the ecology of the soil.

Soil is a complex web of life. Even if tillage harmed only one component, its healthy functioning would be compromised. For example, earthworms, which are important for maintaining a porous soil structure, and for mixing organic matter from the soil surface into the soil where it can be worked on by bacteria and fungi, are easily hurt by tillage. So are the predatory organisms that keep in check the populations of other organisms, such as plant-eating nematodes. **The hyphae of fungi, which play many roles in healthy soil ecosystems, are also easily broken by tillage.**

As far as sustainability goes, the less we till the better. That should be intuitive: the most stable natural ecosystems are ones in which the soil is never disturbed. Yet there are many benefits to tillage, or else we wouldn't do it. As already discussed, tillage stimulates the release of nutrients for plant growth. Tillage prepares a soft seedbed for good seed-to-soil contact, which promotes good seed germination, and facilitates transplanting. Tillage is used to incorporate fertilizers and other soil amendments into the root zone, where roots can best access them. Some kinds of tillage, like subsoiling, can break up a hardpan, enhancing water percolation and storage, and facilitating deep root growth. Finally, tillage is invaluable for eliminating some kinds of weeds—though!

A simple way to describe the pros and cons of tillage is that the benefits are primarily short term, whereas the problems are long term. Back when land was abundant, and farmers could simply move to a new site when the old one was depleted, tillage was fine. Nowadays tillage-based systems are only possible because we can maintain the soil with big machines and imported nutrients, either organic "wastes" hauled in from elsewhere, or synthetic fertilizers manufactured with fossil fuels. But for the future, when land and energy will be more scarce, we must develop agricultural systems based on growing our own fertility on site and on maximal conservation of the nutrients already in our soil.

Low-impact tillage

There are many benefits to tillage, or else we wouldn't do it. The challenge is to reap these benefits without doing long-term damage to the soil.

Not all tillage methods are equally harmful. Mold-board plowing (also called "bottom plowing") is one of the most harmful methods because it inverts the soil layers and because it often forms a "plow pan" at the depth where the plow runs. The surface layer may be relatively loose, but beneath it is a compacted zone of very low permeability. Disking also produces compaction, because it bears down on the soil with a lot of weight. Rototillers are also harmful: they are very hard on earthworms, they break up too many soil aggregates, and they incorporate too much air into the soil.

Recommended implements include the chisel plow, cultivators, and harrows. With long curved metal shanks, a chisel plow can break up a moderate plow pan and aerate the soil moderately with a lifting action. Where the soil surface is already soft, field cultivators or spring-tooth harrows can prepare a seedbed without much damage: they are light and confine their disturbance to the surface layers of the soil.

Most home-scale gardeners do most of their tillage by hand, using a spade or fork and a rake. These are much easier on earthworms and other soil life, and do not have the problem with soil compaction that large tractor-drawn implements may have. But gardeners still need to avoid inverting the soil, breaking up aggregates too zealously, or incorporating too much air into the soil. Of course there are some soils that need to be aerated. Double-digging is a good method for aerating already-compacted or shallow soils. If you cannot push a digging fork all the way into the soil without major effort, I recommend double-digging. (See [John Jeavons, How to Grow More Vegetables or Lazy Bed Gardening](#) for a description of how to double-dig, as well as other good gardening ideas.)

Tillage is least harmful under the right soil moisture conditions. Soil structure is most harmed when the soil is either too wet or too dry. This depends on how much sand or clay your soil has. A crude test for determining the right moisture content for tilling is to try to form the soil into a ball in your hand. It is just right if you can form a loose ball that falls apart when tossed in the air or prodded with a finger.

No-till gardening--my experience

I have been practicing no-till gardening with permanent raised beds and thick mulch for 17 years in Minnesota, using methods I first tried in the red clay soil of North Georgia. My system is not strictly "no-till" because it requires a lot of digging to set it up, but once it is established it requires only surface-level soil disturbance, and much less work, I believe, than conventional systems.

In Minnesota I was fortunate to inherit a community garden plot with deep rich soils (13% organic matter!) thanks to generous compost additions by previous gardeners. It was also relatively free of perennial weeds, which otherwise would have had to be dug out. So the initial work was light. To build raised beds I scooped the soil from my pathways, which normally would be wasted underfoot, and piled it on the beds where it would be of more use to the crops. Thus I increased the depth of top soil in the beds with less work than double digging. Also, the raised beds clearly delineate where to walk. (Boards or logs can also serve this function, but I find them more bother than they are worth.) Eliminating foot compaction in the root zone is essential for maintaining a light tilth.

The recommended height of the beds depends on climate and soil type. In Minnesota's cold wet springs, higher beds help the soil dry out and warm up faster in the spring. The surface of

my beds, which are six to eight inches tall, is often dry enough to plant before the snow is melted from the pathways. But in warmer climates or on droughty soils this additional surface area for drying might be a liability; lower beds are better there. The beds should be made as wide as you can reach across easily. Mine are about three feet across, though sometimes I wish I'd made them narrower. Because I have very limited space, I made my paths extremely narrow, only about a foot across at the base, tapering outwards, which makes walking difficult, because crops tend to sprawl into the paths! I recommend making them wider if there's enough room.

Once the raised beds are built, soil disturbance is minimal. Every three or four years I dig out the pathways, where the soil has been enriched by decomposed mulch, to build up the raised beds from the top, or maybe I simply rake it up. But most years I do no major shovel work. To plant, usually all I have to do is rake aside the mulch, which has kept the soil beneath it in a friable condition, scratch a furrow in the soil, and seed. For large-seeded crops, I may simply poke the seeds through the mulch with a dibble stick. The mulch maintains good surface moisture for excellent germination. For transplants, I use a trowel to dig a hole just large enough for the root ball. If the soil is too hard to do this easily (the force of rain can compact it over time) I may use a fork to loosen it gently, without turning. I do not incorporate residues from spent crops. Instead I cut them off, leaving their stumps to rot in place and using their tops as mulch or compost fodder. (An exception is if they had a disease or insect pest problem, in which case I take them to my municipal compost collection site, because only large-scale composting systems can attain the high temperatures needed to kill all disease spores and insect eggs.)

I have found that weeds are less of a problem in my no-till system than in conventional gardens. Because I am not uncovering buried weed seeds with annual tillage, the only new weed seeds would come from weeds allowed to go to seed, but since I don't allow any to go to seed, I only have to contend with those that blow in on the breeze—if you don't count the dill, sunflowers, cosmos, marigolds and hairy vetch, which I have purposefully allowed to reseed! But these weedy crops and other small weeds are easily eliminated with a sharp hoe when they're at the two-leaf stage. I slice them off right at the soil surface, without gouging the soil at all. It's a quick job if I get to it early and often enough. Surface hoeing one or two times early in the season is all that is necessary before I lay down a thick layer of mulch, after which I need to do hardly any weed control the rest of the season. The exception is rhizomatous weeds such as quackgrass, which are a major problem in a no-till system. It is best to dig them out before you start, and to watch lest they re-invade at the garden's edge!

Mulch is a key component of my system, providing weed control, moisture conservation, and fertility. According to Cheryl Long (How to Fertilize Your Garden, Organic Gardening, July/Aug 2000, pp. 46-51) once an optimum fertility level is attained, a one-inch thick layer of grass clippings per year is all that is needed for maintenance of fertility in a vegetable garden; that is, all that is needed to replace the nutrients removed in harvested vegetables. Grass clippings are easy to spread, high in nitrogen, and break down so quickly that there's no reason to incorporate them. Straw and rotten hay also work well. I generally wait until June to start spreading mulch, to allow the soil to warm up first and to allow the vegetables to get large enough to avoid smothering them with the mulch. Some people spread the mulch first and plant into that, which also works, though it may delay soil warming.

When I have empty or near-empty plots in the fall, I plant cover crops, either oats, peas, and hairy vetch in August, or rye in September/October, scattering seeds beneath squash, tomatoes and beans, and raking them in wherever there is bare soil. Watering helps get them established. The following spring, I either hand pull or hoe the cover crops out before planting small seeded crops, or plant directly into them for larger seeded crops and transplants, later smothering them out with a thick mulch. This is a little tricky in Minnesota, where the growing season is barely long enough for two crops. If I had a large enough garden to take plots completely out of production for a season, I would rotate cover crops with my vegetables

Lasagne or deep mulch gardening.

The methods I've described above work well for gardens that already have good soil and are free of perennial weeds. But what if you're starting with a lawn or other ground cover? Eliminating perennial vegetation before you start is essential, and is often accomplished with tillage. But smothering it out with deep mulch, a method sometimes called lasagna gardening, can be even more effective at eliminating some kinds of perennial weeds than tillage. For example, tillage merely breaks up quackgrass rhizomes into multiple small fragments, all of which regrow, making for an even larger weed problem.

The key to killing perennial weeds is to layer the mulch on thick enough to completely block out sunlight. Placing cardboard (without the plastic) or thick layers of newspaper on the bottom helps. Water it to keep it in place, then cover it with layers of whatever organic material you can get your hands on—straw, crop residues, old hay, autumn leaves, manure, compost -- it doesn't even have to be mature compost--, you name it. Try to make sure there is a good mix of "green" and "brown" material similar to what you would put in a compost system, to ensure the optimal carbon-to-nitrogen ratio which is needed for effective decomposition. Also avoid making any layer too thick to ensure that the different components come into contact with each other.

It is best to put the courser material on the bottom and finer material on top, because fine-textured material will be best at holding moisture, which will be needed for seed germination and for young transplants to get established. Unless you can top the beds with soil or well-finished compost, in the first year it is best to only plant large-seeded crops, such as beans or potatoes, or vegetables grown from transplants. Tomatoes and squash work well the first year, because they have deep roots capable of growing through the coarse lower layers and through the cardboard, which rots quickly after it is wet. After the first year, beds built this way can be managed as I described above.

The lasagna method is how I established my entire "guerrilla garden, which has grown into an informal community garden, with up to eight families in some years. Abundant rocks were the impetus for avoiding digging. The guerrilla garden started out as four long parallel beds on a lawn, the width of my pick-up truck apart because I simply shoveled the organic material off the sides of the truck. The only thing I would have done differently was not to leave the alleys in grass, because quackgrass kept invading the beds from the sides until we filled in between the beds with more compost. More recently we've expanded the garden towards the woods by layering organic material on top of stumps of buckthorn and other weedy shrubs, which would have been very difficult to dig out by hand!

Experiment!

What I have described is not the only way to do no-till gardening, or even the best way. You will have to adapt to your own situation, especially to what kinds of organic material you can find.

My system has a major short-coming in that it depends on lawn clippings that are imported with a pickup truck. They are available to me because the people who throw them away do not appreciate that they are better kept on the lawn. Basically I am harvesting the fertility of their lawns to enrich my garden. Eventually they will learn, and I will have to find another mulch source. I've been trying to grow my own, by planting rye as a cover crop, and by seeding clover around the perimeter, but so far I haven't produced as much as I need.

Responsible soil stewardship calls for no-till where possible. I would like to challenge those of you who have a bent for experimentation to give some of the ideas I have presented a try. As a gardener you may not manage much land, but the little bit you do manage is precious, and it will become more precious in the future.