How-to… set up a cover crop strategy to recover degraded agricultural land?

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Many agricultural lands have been severely degraded. This is often caused by multiple years of heavy tillage, chemical fertilizers, pesticides, and compaction. In these lands, topsoil has been depleted of soil organic matter. Also, there often an accumulation of soluble salts from excess fertilizer use, which damages soil microbiology. Together, this leads to a loss of yield and an even stronger dependence on those methods that caused degradation in the first place.

Using cover crops is a strategy for recovering these farmlands and rebuilding the soil organic matter reserve. In this guide, you will learn what makes cover crops effective. The step-by-step plan will then help you set up your own cover cropping strategy.

This How-to Guide is made by Daniel Fourie with support of Roos from the 4returns.earth team. If you have any follow-up questions, please don't hesitate to contact Daniel.

Intercropping in action: a field of rosemary, protected from weeds by an auxiliary cover crop. Photo by Daniel Fourie

Why is cover cropping effective?

If degraded land would be left alone, an abundance of weeds would sprout and disease-causing organisms would dominate the soil. So to recover these soils and grow a healthy crop in them, they need a great deal of input, such as organic matter and crop residues that rebuild soil structure, compost to reactivate soil microbiology, and minerals to fix imbalances in soil chemistry. The most effective way to provide this input is to rebuild the soil along the channels of natural secondary succession, just like we see in healthy ecosystems.

Cover crops are an ideal tool to build up this succession. This is because you plant species that fall into these successional steps, but also have at least some agricultural benefit.

But aren't weeds bad?

Weeds are pioneer plants: they rapidly colonise open spaces and create a huge amount of biomass in a short amount of time. When they die, they incorporate all that biomass into the soil.

How do they do this? To be successful in their short life cycle, weeds need to out-compete all the other 'weeds' in the same space. Weeds use nutrients in a very efficient way. For example, they can use soluble salts that are in an oxidised form (such as nitrates or sulphides) that would normally damage slower growing later successional plants.

Another weed strategy is to produce phytochemicals ('plant chemicals'). These supress the disease-causing organisms that are usually abundant in these recently disturbed areas. An added benefit: the weeds are now less appetising to grazing animals, so they are more likely to survive until they seed. So, weeds are good, but only in the right time and place.

To sum up:

- Weeds are fast growing, highly efficient plants that use up nutrients in a oxidising, highly soluble form which would damage other plants.
- They produce chemicals that supress disease.
- They also generate a lot of good ground cover and biomass to rebuild soil organic matter.

The roadmap

So, how to start and which crops to use? This depends on your local soil and climate conditions. The amount of options can be overwhelming. But keep in mind that there is no perfect solution - the best thing you can do is just to start. This guide helps you with that. Just follow the steps, and keep learning from your land.

The guide assumes that we are starting with severely degraded land, that has compaction problems, an imbalance of inorganic nutrients, an accumulation of soluble salts, and high levels of anaerobic plant pathogenic organisms.

Stage 0

Determine the successional state of your land

Typically, after a severe disruption to a natural ecosystem such as a flood, fire, or landslide, the ecosystem is pushed back to an early successional stage. Luckily, there is a way to find out how far along your system is in ecological succession. The trick is to look at the ratio of fungi to bacterial biomass in the soil (see figure 1).

For a degraded piece of farmland, the system would typically have a fungi to bacteria ratio of 0.1 or lower. If we would leave this land alone, only weeds would dominate. Have a look at figure one to determine in which state your system is. Is it in the 'weeds' state or lower? Then this guide could help you; continue to step 2.

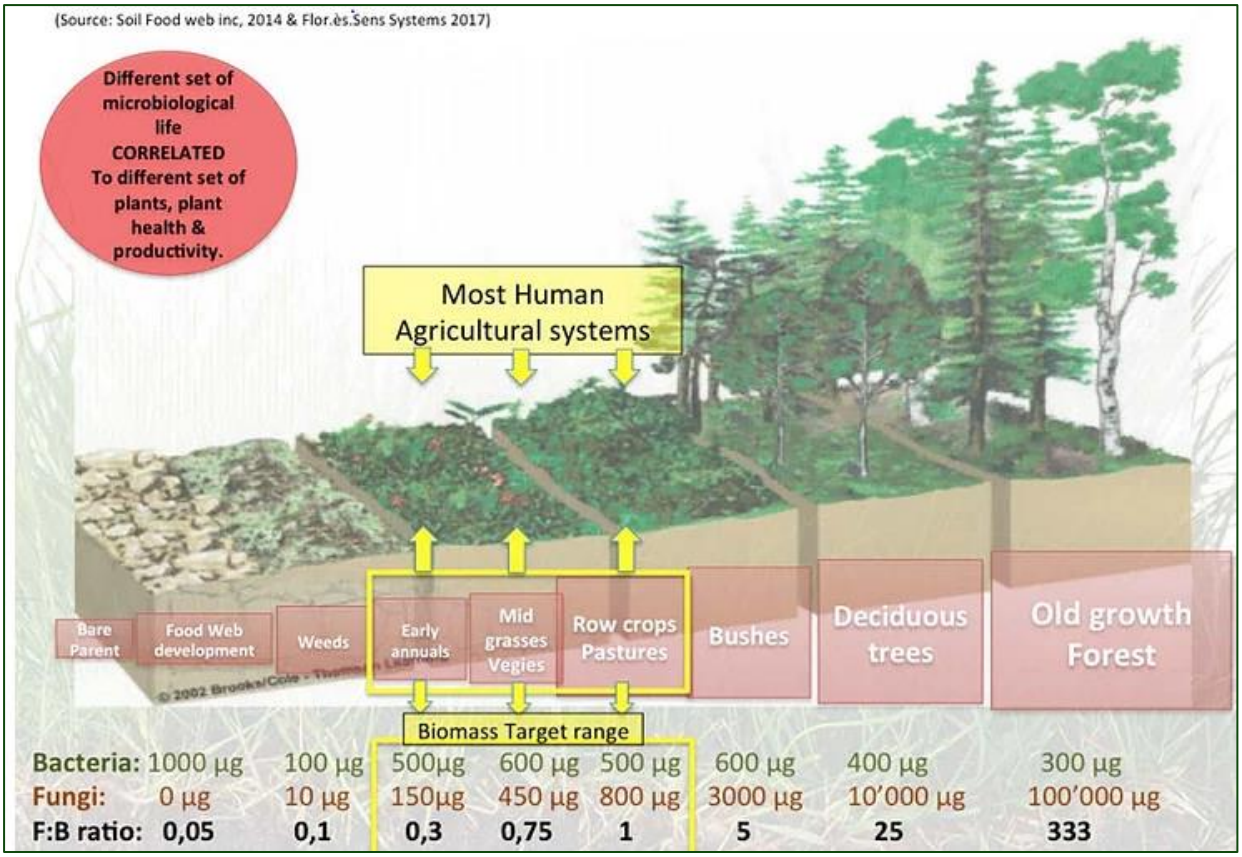


Figure 1 - Succession in natural ecosystems as measured by looking at above ground carbon storage and below ground fungal to bacterial ratios.

Stage 1

The first successional group: weedy plants

A cover crop rotation starts with plants that can be classed as 'weedy'. An excellent choice are the Brassicas: box 1 gives more information on this plant group.

Other cover crops to include in the mix would be fast but low growing grasses such as annual ryegrass and teff. Both accumulate the oxidising, highly soluble nutrients from the soil and have a growth-supressing effect on other weeds.

After picking out your crop mix, follow these steps:

1. Till (prepare a seedbed). Then, plant in the cover crop mix as soon as possible. This will give them the best chance of getting ahead of the other weeds that would naturally come up after tillage.

2. Grow them out to a decent size - they can produce huge amounts of biomass (up to 20-ton DM/HA).

3. Graze down very heavily with an ultra-high stock density (UHSD) grazing system. The livestock will waste a lot of material, but this is what we want.

4. Allow the cover crop to regrow.

5. Incorporate the plants into the ground if possible, by disc harrowing the plants into the soil (how to disc harrow). This will boost a natural biofumigation effect to kill any remaining pathogenic soil organisms. It will also add a lot of valuable organic matter to the soil.

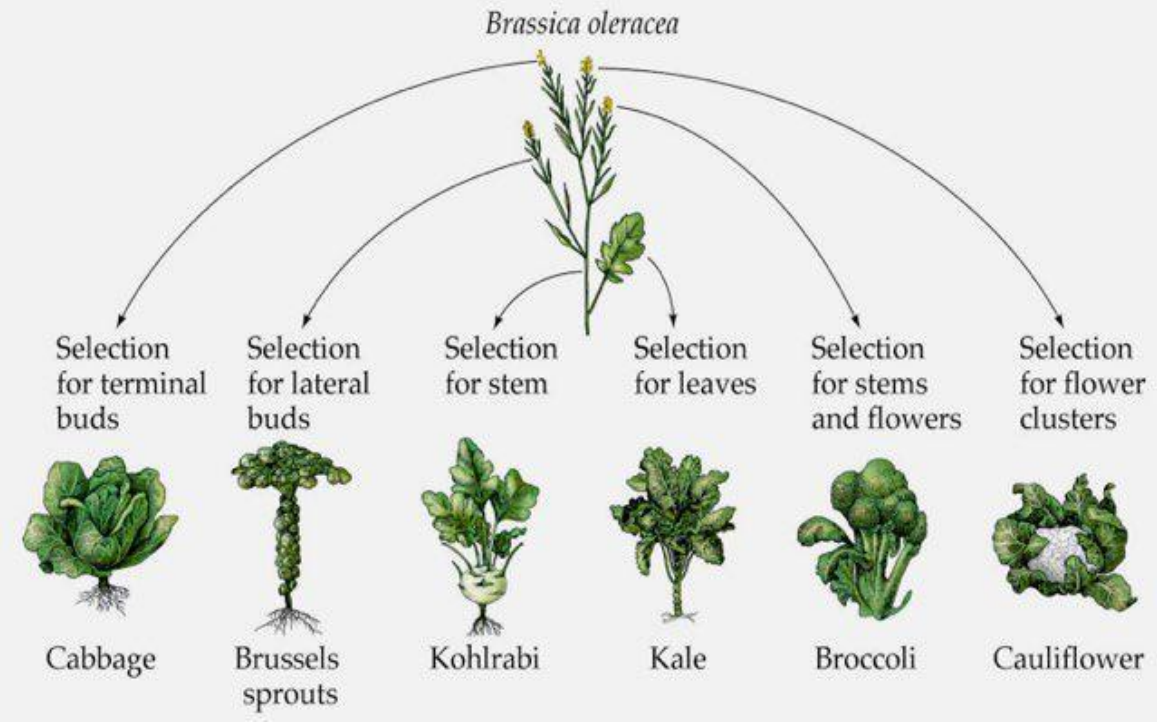
6. Compost. The bio-fumigation will have wiped out all the soil life. So, after the first treatment, insert as many beneficial soil biota as possible by applying good quality compost, compost extracts, compost teas and any other magic microbiological mix you have.

Brassicas

Common Brassicas are the (tiller or fodder) radish, fodder turnip, canola, and kale. All these plants have been selected from the wild mustard (*Sinapis arvensis)* that many farmers would be familiar with as a common weed in their fields.

This group of plants produce phytochemicals called glycosides (sugar + poison if translated directly) as a defence mechanism. Fun fact: this gives the 'hot' taste of mustard seeds. These chemicals are secreted through the roots of the plants. When they encounter oxygen, it breaks down into glucose (sugar) and cyanide. Cyanide is a deadly gas that kills micro-organisms in the soil.

Isn't it bad to kill all the microbes in your soil? Usually, yes. But in damaged ecosystems you will have high levels of disease-causing organisms. So it's good to pasteurise the soil of pathogenic organisms and start inoculating beneficial organisms again. The brassicas also love those highly oxidising nutrients, compete well with other weeds through allopathic mechanisms, and are at least slightly beneficial as fodder crops for livestock.



Selection of different brassicas from the common wild mustard ancestor

Stage 2

The second successional group: mid-grasses & vegetable-like crops

The next step in succession will be to grow out the mid-grasses and vegetable-like crops. The aim of this step is to produce as much root exudates (fluids emitted through the roots of plants) as possible. This will support the formation of a healthy soil food web. The mix will also produce good above-ground biomass that will help contribute to the total organic matter content in the soil. From this point forward it is ideal to move towards no-till growing to preserve the fungal community and start building good soil structure.

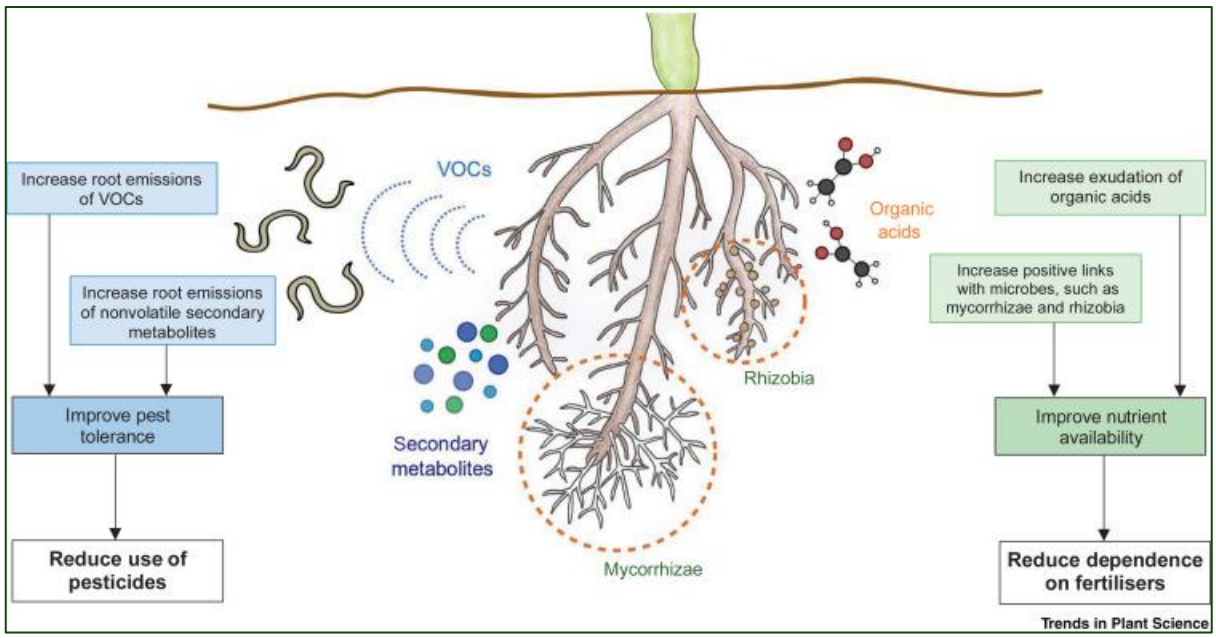


Figure 2. Root exudate benefits in the soil food webs formation and a decrease in the dependency on external inputs.

Which crops to plant?

- Legumes are especially important. Pick annual legumes and some perennial legumes such as cow peas, berseem clover, peas, lentils, lupins and vetch. These crops accumulate organic nitrogen in the soil through the symbiosis with Rhizobia that fix atmospheric nitrogen into a plant available form.
- Millets, sorghums, sudan grass, and other hybrids of these summer grain crops. They produce lots of simple sugars that they excrete through their roots to feed the soil PGPR's (plant growth promoting rhizobacteria).

- Winter small grains such as oats, wheat or rye are all good mid-height grasses that also produce huge amounts of sugars for the soil microbiome.
- Crops such as beets, plantain, chicory and buckwheat add diversity and fulfil different ecological niches such as nutrient accumulation, pollinator support and other soil health building functions

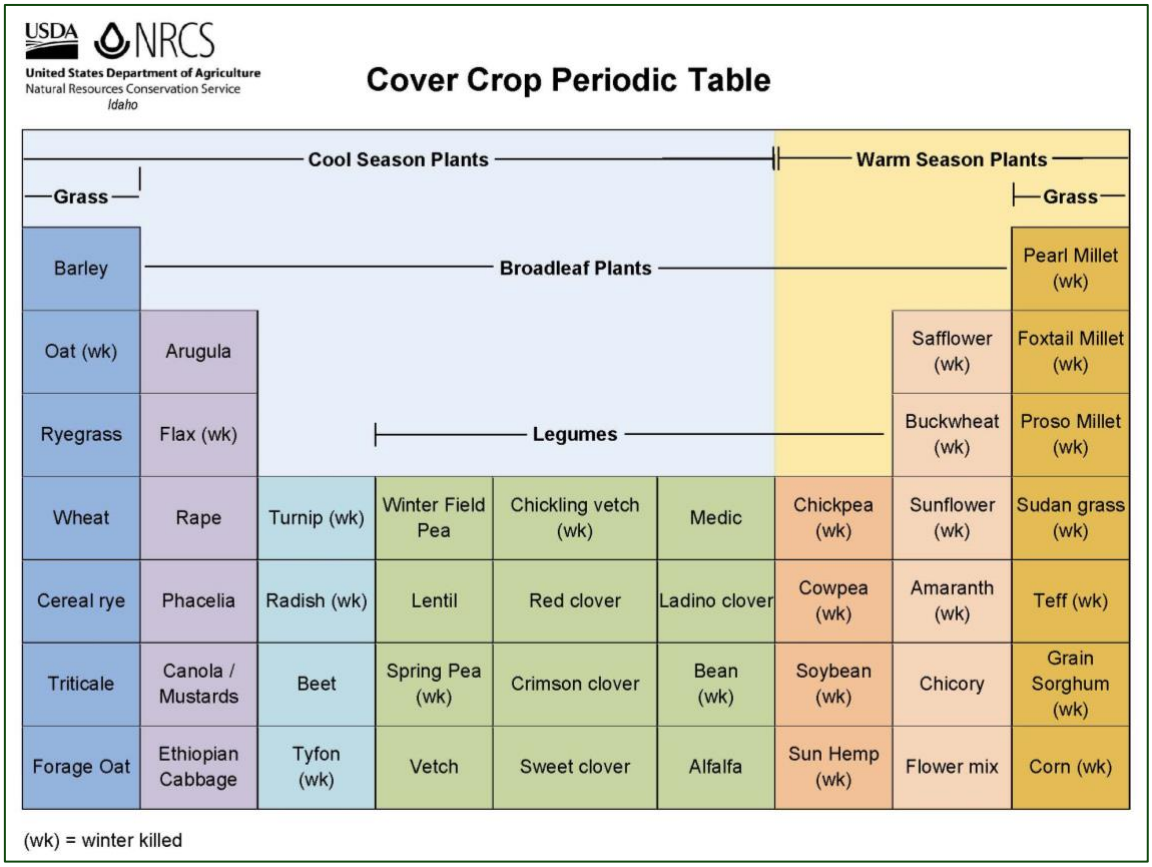


Figure 3. Chart of cover crops and their growth conditions. For the second successional crops consider medium height annuals and reduce brassicas. Perennials are more suited to the third successional group. Source: USDA.

Table 1 - Advised plant groups and ratios for the second step.

Plant group	Suggested % in mix
Legumes	30-35%
Grasses and grains	60%
Brassicas	<4%
Other	1-5%

Steps to follow:

1. Plant into the residues of the first successional mix. But plant only after at least six weeks: that's how long it usually takes for the poisons that are released during the first successional step to be broken down.

2. Graze. The crop should be raised up to the right height for grazing. Then is should be grazed down several times with an ultra-high stock density (UHSD) grazing system to incorporate manure and residues into the soil.

3. Winter / summer kill. At the end of the growing season allow the cover crops to grow out a final time and be killed by shifting into the next season (winter / summer kill). This ensures that the plants develop woody stems that are high in lignans. This is a type of compound that can feed the fungi and ensure movement to the third successional stage (with a fungi : bacteria ratio of 1 or higher).

4. Repeat. It may be necessary to repeat the second successional group a few seasons in a row, especially if the soil organic matter was exceptionally low to start with. This will allow the build-up of sufficient nutrient reserves to move to third successional crops.

Stage 3 Third successional group & future strategy

After the second successional cover crop cycle, the future strategy depends on the type of cropping that you'd like to employ on your land. The field may be put into perennial pasture and continue to build on the soil health though managed grazing, used for vegetable production or cash crops like cereals, or moved into perennial shrubs or trees. Depending on this choice, different cover crop strategies can help maintain soil health. This time, you'll have a strong foundation to build on!

Need a little refresher on deciding what your next step could be? Check out the choice help on the next page.

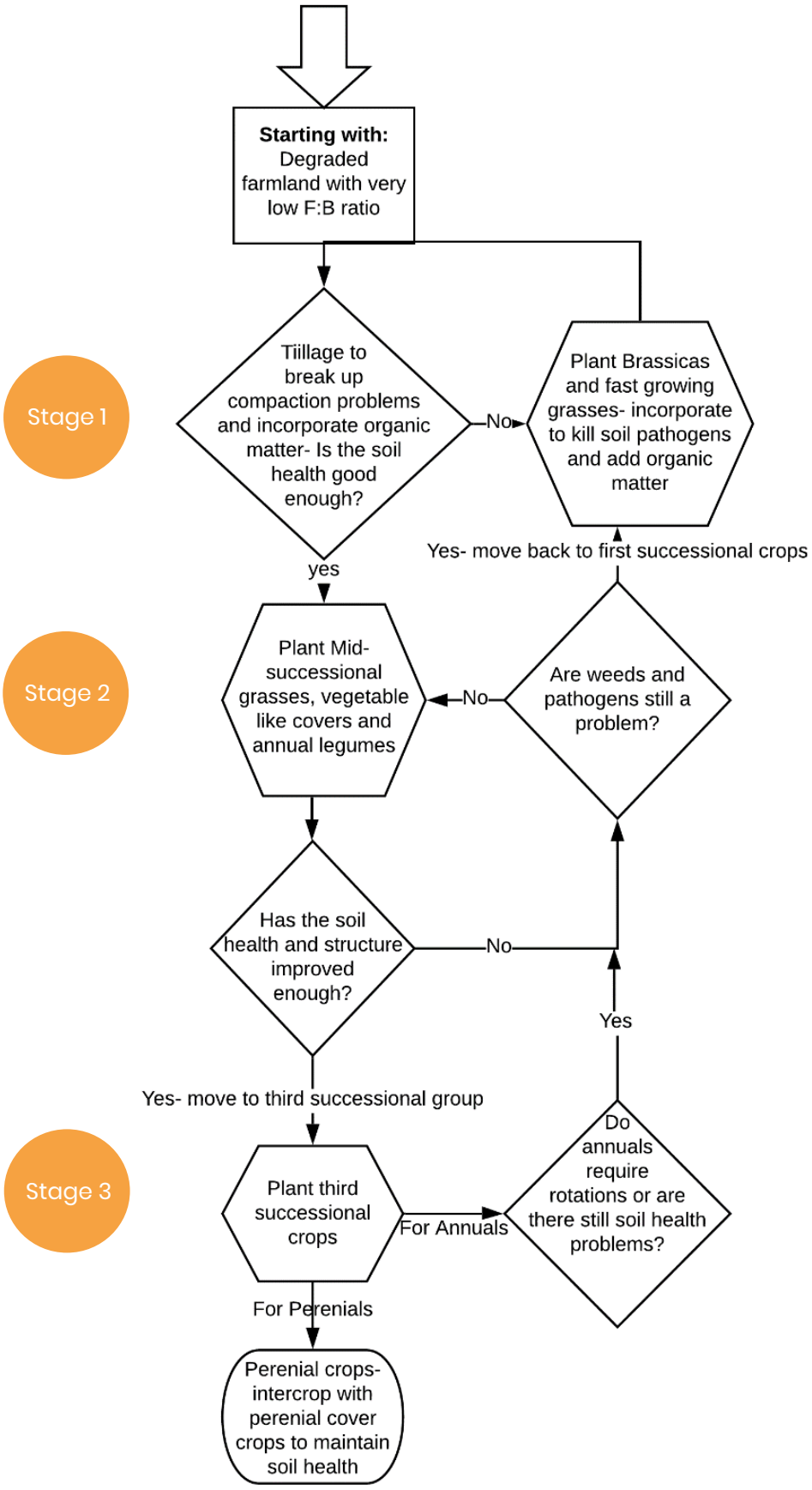


Figure 4. Cover crop decision tree to guide progress through successions.