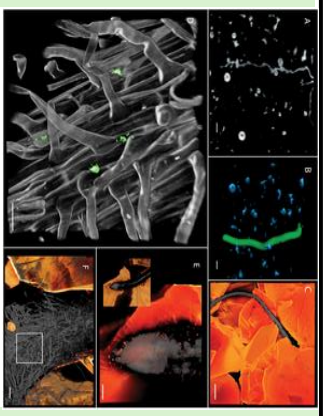
Bio4Ag Toolbox Indicators: litter decomposition

Background

A key agroecosystem function important in sustainable cropping systems is nutrient cycling – the decomposition and mineralisation of nutrients from dead organic matter. Beneficial soil organisms include arthropod detritivores which break down dead plant and animal matter, microbial decomposers which are important in nutrient cycling processes, and symbiotic mycorrhizae and rhizobia which improve plant nutrient availability and uptake. Microbial foodweb diversity also helps regulate pathogen populations by competition with neutral antagonists, enhancing the pest suppressive properties of the soil. Assessment of the soil microbiome and quantification of specific microbial responses to field management requires specialist knowledge and expensive laboratory techniques. However, simple indicators of soil functions can be used as a proxy, most of which focus on estimating rates of litter decomposition by microbes.



Integrated cropping strategies

Soil biodiversity can be enhanced through combinations of reduced tillage intensity and agrochemical inputs, diverse sources of organic matter inputs and crop residue management. No-tillage practices generate more diverse soil pore structure and increased large macropore volume in the top layer (0–5cm), which provide habitat for a greater diversity of soil organisms. Organic matter inputs include compost and dead plant matter from cover crops and weedy stubbles. Crop residue at the soil surface in direct drilled fields also improves physiochemical and microclimate conditions for fungal populations, detritivores and their predators. Combining these strategies as part of a whole-system approach enhances soil biodiversity (macro-invertebrates (carabids, earthworms), micro-arthropods (mites, collembola, nematodes) and microbes (fungi and bacteria), while also increasing C storage, nutrient cycling, reducing nutrient losses and soil erosion. At the CSC, the soil is disturbed only one year in six for potato planting and harvest. Winter wheat is sown into the disturbed soil following potato, but the remaining crops in the rotation are direct drilled. Organic matter inputs include green waste compost applied at 5 t ha^{-1} yr^{-1}. Cover crops are sown immediately after harvest prior to spring crops to provide green cover over winter, helping to retain soil and nutrients and providing organic matter inputs from DOM and root exudates.

Results from the CSC

Litter decomposition rates were estimated using the tea bag method devised by Keuskamp et al. 2013, where 3 replicates of paired red and green leaf tea bags were buried at 9 locations in each crop/treatment just after sowing and retrieved approximately 75 days later after the main harvest period. Sampling was carried out during the cropping seasons 2017, 2018, 2019, 2021 and 2024, six to 13 years from conversion to integrated cropping. Decomposition rates were significantly greater in the integrated system which received organic matter inputs in the form of 5-10 t ha^{-1} yr^{-1} municipal green waste compost, crop residue and cover crop inputs. These treatments resulted in increased soil carbon and greater earthworm abundance which together are known to stimulate microbial biomass and activity, demonstrated here as an increased rate of litter decomposition. Decomposition releases nitrogen resulting in faster rates of nitrification, as indicated by higher concentrations of plant available nitrate compared to conventionally managed crops.

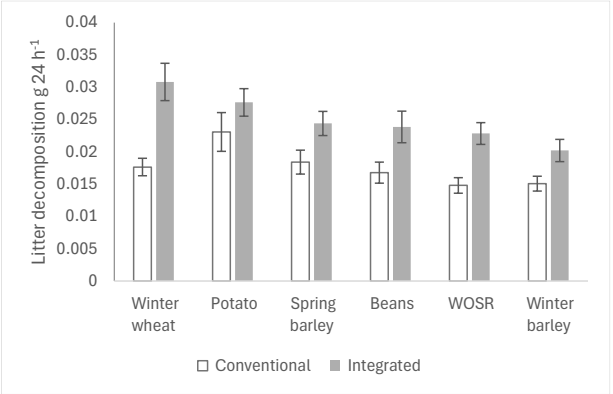


Figure 1. Litter decomposition rate in conventional (open bars) and integrated (shaded bars) cropping system for each crop in the rotation. Kruskal-Wallis H = 18.72, p<0.001, based on mean rank of 19.07 (conventional) and 37.93 (integrated) crops.

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How to measure litter decomposition – tea bag method

Equipment:

30 green tea bags (Lipton EAN no.: 8 722700 055525) and 30 Rooibos Tea (Lipton EAN no.: 8 722700 188438), 60 zip lock sample bags, trowel,10 marker canes and pegs, string, pencil, paper record sheet

Timing:

Install tea-bags after spring crops are sown (April week 3 or 4), retrieve tea-bags immediately after harvest (as close to 3 months from burial as possible)

Location:

Carry out assessments at 10 locations in each field in a W pattern across the field

Procedure:

1. Label tea bags with continuous numbering (1-30) and colour (green G or red R), e.g. 1G, 30R etc. Use a permanent marker on the white side of the tag

2. Dry tea bags at 70°C for 48 hours

3. Weigh to 3 decimal places and note the weight on the tea bags weight on a record sheet.

4. Store weighed tea bags in zip lock bags, one bag for each sample location, until you're ready to bury them.

5. After spring crops are sown, the tea bags can be installed - record date of burial on the attached form.

6. At each location, dig a 10 cm deep pit approx. 20 x 30 cm and place 3 green bags (reps 1-3) equidistantly along one side of the hole. Repeat for red bags on other side.

7. Lay the strings to one side and carefully fill in the hole. Tie each string to a central cane and peg the cane securely to the ground so that bags can be easily re-located after harvest.

8. Leave teabags until just after harvest.

10. Locate marker cane and carefully dig up each tea bag by lifting the soil, taking care not to damage the bag. Do not pull the bags up by the string.

11. Make a note on the record sheet if any of the bags are damaged, or you found them at the surface, or any labels are missing.

12. Place each tea bag in a separate plastic bag to prevent loss of contents. If any labels are missing or have become illegible, work out what the label should be by comparing with the neighbouring bags. Write this label on a piece of paper in pencil and place inside the plastic bag with the relevant tea bag.

13. On return to the lab, remove any loose soil, roots etc and dry the tea bags at 70°C for 48 hours.

14. Clean off all remaining soil and roots. If there are roots growing into the bag that cannot be removed, note this on the attached form and discard.

15. Weigh the dried tea bags to 3 decimal places and record weight of each bag.

16. Enter the starting and end weights of each tea bag into a spreadsheet along with the exact number of days each was buried.

17. Calculate the rate of litter decomposition using the formulas 1-3 given in Keuskamp (2013). A spreadsheet is available to do this automatically from Cathy.Hawes@hutton.ac.uk or, for a very rough relative measure, take the end weight of each tea bag away from its start weight and divide by the number of days it was buried, then work out the average for the 3 green and 3 tea bags at each sample location (sum of weight/6).

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How to measure litter decomposition – cotton strip assay

The following is a simpler estimate using cotton strips instead of tea bags, to measure the relative difference in microbial decomposer activity between fields.

This method is adapted from: https://conversations.echocommunity.org/t/simple-proxy-for-soil-life-cotton-strips/5480

Equipment:
trowel, marker cane (so you can find your samples at the end of the season), 20 cotton strips per field, each sealed in a labelled mosquito net bag (so you know which strip is which when you dig them up again). The mosquito net is to stop larger insects shredding the cotton so that the decomposition rates estimated are just a result of microbial activity.

Timing:
Bury cotton strips as soon after planting as possible in the spring (for spring sown crops) and around the same time in winter sown fields (April). Retrieve them after harvest when it's easy to access the field.

Location:
20 sample points should be located across the field in the usual W shape, but make sure they are away from tramlines, so tractor movement and harvest operations don't get in the way.

Procedure:
1. Cut 20 strips of unbleached, 150 GSM cotton calico measuring 20x10 cm.
2. Dry at 70 ^{0}C for 24 hours to standardise the starting weights, then weigh and place each one inside a bag made out of mosquito netting (or similar fine mesh), labelled bag with a unique identifier, noted alongside the starting weight.
3. Bury each bag 4-5 cm below the ground surface and mark the location with a cane. Record the date of burial.
4. Leave for whole the growing season.
5. After harvest, locate and carefully dig up the samples, making sure not to damage the mesh bag. Record the date of retrieval.
6. Spread the bags out on a bench to dry, then gently roll something heavy over them to break up any clods of earth. Shake to remove as much soil as possible. Then rinse off any remaining debris in water.
7. Dry the bags again at 70 ^{0}C for 24 hours
8. Carefully tip out each cotton strip (or what's left of it) onto a dish and re-weigh (making a note of the weight of the empty dish).
9. Take the final weight away from the starting weight and the result is the amount of cotton that has decomposed. This gives a relative measure of overall microbial activity and can be used to detect change over time or differences between different fields.

Useful links

- Keuskamp, J.A., Dingemans, B.J.J., Lehtinen, T., Sarneel, J.M. and Hefting, M.M. (2013), Tea Bag Index: a novel approach to collect uniform decomposition data across ecosystems. Methods Ecol Evol, 4: 1070-1075. https://doi.org/10.1111/2041-210X.12097
- Hawes, C., Iannetta, P.P.M., Squire, G.R. (2021). Agroecological practices for whole system sustainability. CAB Reviews, 16, no. 005.https://doi.org/10.1079/PAVSNNR202116005
- https://csc.hutton.ac.uk
- https://csc.hutton.ac.uk/resource/Handbook_of_indicators_v1.pdf
- Decomposition study using tea bags: https://orgprints.org/id/eprint/30717/1/fertilcrop-tn-wp4-teabag_english.pdf
- Global litter decomposition study: https://www.teacomposition.org/approach/
- Soil Your Undies Challenge: https://www.nrcs.usda.gov/state-offices/montana/soil-your-undies-challenge
- https://conversations.echocommunity.org/t/simple-proxy-for-soil-life-cotton-strips/5480

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