The dynamics of soil Carbon and how it connects with Nitrogen.

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Biome Services- An independent source of evidence-based soils information

Venue: Wagga Wagga

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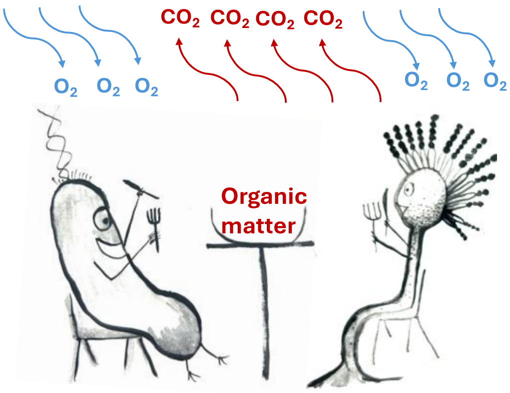
Everyone that relies on the soil for food and fibre is a Carbon farmer; what sets us apart is the end goal and what motivates us to get there.

The simplest way to explain the dynamics of soil C is to assume (correctly) that soil biology drives the Carbon (C) cycle *and* consider i) the needs of the biology to function (in this case, the microbiology) and ii) the soil (texture & structure) as a habitat.

Firstly, to the 'needs of soil microbes'; the bacteria, archaea and fungi. In general, these function best when there is moisture, gas exchange, a workable pH range and quality food. Most (above 90%!) soil microbes use C 'food' as an energy source to respire.

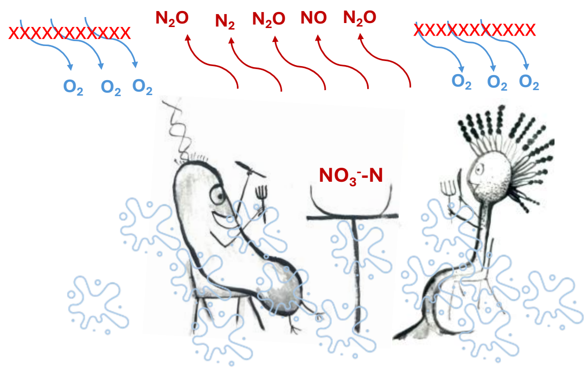


Like us, they capture Oxygen (O_2) and expire Carbon dioxide (CO_2) to grow and decompose plant residues to release nutrients and sugars (for plants & soil structure). Another critically important process is photosynthesis; the capture of CO_2 using light energy from the sun and the production of O_2. Plants are the major players here, but soil microbes are also very effective photosynthesisers. Living in a surface 'biocrust' they can capture CO_2 and generate their own N source (in N_2 fixation) to fuel the process.

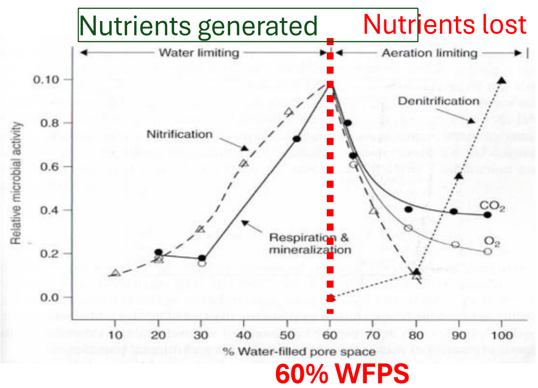
Generally, if the soil is moist (60-70% water filled pore space), not too acidic (pH_{ca}> 5.5) and has a lot of small pores (<<30-micron pore neck) to protect bacteria from predation, microbes can function at their best in a diverse community. The quality, accessibility and supply of food (for energy) is also important. Carbon as food comes mainly from plants; shoots and roots which may be pre-processed (as manure and compost) or supplied directly as root exudates. Such readily available C is described as particulate organic matter (POM) or the fast C turnover pool. Regardless of whether C food is simple (e.g.

sugars) or complex (e.g. melanin), microbes rely on enzymes to break them down. This is important because enzymes are proteins and microbes require an N supply. In other words, microbes, like plants, require Nitrogen to function. If they cannot fix their own N, they source N from plants, other microbes or even directly or indirectly from fertiliser. Here C:N ratios of residues is important but that's another story....

The soil condition described above is part and parcel of achieving a healthy soil. This condition however will change seasonally. During a rainfall event or 'wetting up cycle' soil water pores fill with water and remain that way for extended periods. This excessive water or waterlogging (no O_2) happens in some soil types (e.g. Chromosols) where sandy-loam surfaces overlay clay (e.g. perched water tables) or where soil structure has been compromised (sodic soils or by compaction or wetting/drying cycles). Where O2 is scarce, the highly adaptable soil microbes can switch to the 'no or little O_2 mode' and either use C or 'another energy' source. If they use C they can produce the gge of methane in methanogenesis. More microbes however can use C and convert nitrate (NO_3-N) to gas; nitrogen gas (N_2), nitrous oxide (N_2O), nitrogen dioxide (NO_2), and ammonia (NH_3). Those that produce N_2O are known as denitrifiers. These are very common in wet soil, especially after urea fertilisation and contribute significantly to greenhouse gas emissions (gge).



To recap, the amount of soil water and/or air is a critical switch that turns on microbial N_2O and CH_4 loss pathways. According to some scientists this can occur at about 60-70% water filled pore space. This will depend on the texture (composition of clay, silt and sand), structure (porosity & aggregate stability) and management (compaction, plants, fertiliser rates & timing). How we manage in the confines of our soils and climates can influence the extent of gge.



Graphics modified from Soil Microbiology, Ecology & Biochemistry third edition, editor Eldor A. Paul

Secondly, to soil texture & structure as a (micro) habitat. The percent clay, silt and sand are a fundamental property of soil and one that can be readily determined in the field using the 'ribbon test'. The clay content is particularly important as the charged and large surface area of these particles means that plant residues, minerals, water & microbes are concentrated here. Further the coating of these residues and microbes by charged clay particles (or platelets) renders these hard to access and therefore decompose (and release back to CO_2). Soils typical in the Riverine Plains farming region are Chromosols, Dermosols and Sodosols. All of these have at least 20% clay in surface soils and in the case Chromosols ('texture contrast soil'), up to 35% in subsoils. Depending on the plant types (root architecture), the clay can protect organic material so that it enters the 'slow turnover pool'. This is referred to as the 'Mineral Associated organic matter' or MAOM pool.

So recapping, depending on soil clay content, the soils on our farms have different capacities to protect and trap organic matter so that it more slowly expires as CO_2.

A final word on C sequestration. The capacity to increase the storage of C in our soils means promoting C capture via plant & microbial photosynthesis. The type of plant (when and how it grows through the soil profile) will influence the quality, quantity and location of the C deposition. More challenging is the notion of prolonging C passage through soil especially if waterlogging events lead to denitrification and methanogenesis. In the meantime, efforts to understand mechanisms, to develop and apply reliable, relevant measures that can be used to monitor and record soil C storage are advised.

References:

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