Perennial crops reduce atmospheric carbon while delivering food and energy

Climate change and food security are two big monsters that humankind is facing, and we have to battle them together. It is urgent and timeline to look for solutions, and to implement them. I am happy to share with you some good news: We have found strong evidence showing that **under proper management** perennial crops are an efficient land-base climate change mitigation strategy, while also helping to deliver food security, bioproducts and bioenergy. Two mechanisms are behind the scenes: biomass accumulation in plants and an increase in soil organic carbon. Growing perennial crops can indeed help fighting climate change and food security, if we do things properly. **Perennial crops are a tool, and it ultimately depends on us, humans, to use this tool correctly.**

Picture: Coffee plantation - Creative Commons

Agriculture contributes up to one third of human-induced emissions of greenhouse gases, considering the impact of the land use change from a natural system to an agricultural land. Yet, this is the sector which has significant potential for negative emissions, that means, some agricultural practises can reduce greenhouse gasses from the atmosphere (in particular carbon dioxide) and store it in the land via sequestration in plants and soils. Besides, agricultural and forest products can be supply of feedstock for creating energy, thus not only providing us with green renewable energy but also reducing our dependence of fossil fuels. In facts, some products that were traditionally considered waste, like the peps from fruits, can be used to create energy. This use of things that before could have been end up in the bin is what the circular economy is looking for!

Perennial crops are crops that are not fully harvested annually. They can be woody plants, such as tree fruits and nut crops (e.g., apple trees, citrus, almond, coffee), oil crops (e.g., palms), short rotation coppices (e.g. poplar, willow). Or perennial grasses such as sugarcane, switchgrass, *Miscanthus*. The final end-use can be not only food or beverage, also fibre (e.g., cotton) and importantly, bioenergy (e.g., *Eucalyptus, Miscanthus*). Perennial crops represent 30% of the global cropland area, a notable amount. However, the positive effect of perennial crops on the net greenhouse gas emissions has largely been ignored. **With our studies we wanted to give credit and visibility to the important role that perennial crops could play, and to evidence that under proper management, can be an efficient tool to reduce atmospheric carbon while delivering food, goods and bioenergy.**

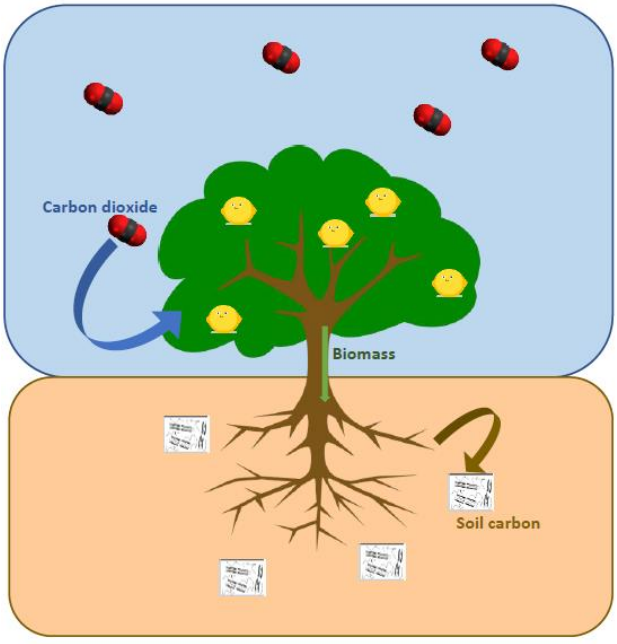
Pictures: Creative Commons

To really understand the potential of perennial crops, we first studied the carbon that perennial plants can take from the atmosphere and store in their bodies. Plants use that carbon to growth. We, humans, also use minerals to growth: our bones are made with minerals. However, we obtain them from our food and not from the air, as the plants do. Plants are cleverer (or lazier, depending on how you look at it). They don't need to go hunting, they can just take the minerals from the atmosphere. Perennial plants growth and thus accumulate carbon during their lifetime, in the shoots, leaves and branches and in the roots. They are also responsible for the increase in organic carbon in the soil, thanks to the root senescence and the incorporation of carbon from litter and other plant residues that fell in the ground, such us fruits that are rotten or little branches that break.

At this point we can see that we are on the correct track, plants take carbon dioxide from the atmosphere and store it on the land. Unfortunately, in real life things are not that simple. Besides, time also matters. The plants take carbon from the atmosphere while are alive, and then what?

If we cut and burn a tree, for example, the carbon that was in its body goes back to the atmosphere. If all the carbon that is once stored in the plant goes back to the atmosphere in a couple of years, we have done nothing, or little. **BUT if some of that carbon that the plants take from the atmosphere can be stored in the land for a long period (let´s say, a hundred years) now, we are talking**.

In our work we have found interesting cases and evidence that sometimes we can accumulate carbon in the land for long. Let´s take a lemon tree as example, that is a cool perennial crop (and personally, I love lemonade). Imagine that lemon tree is growing, but then some leaves turn yellow and fall. Also, the person in charge of the field cut some branches of the plant (pruning), so the lemon tree will produce more and tastier lemons. We have some plant residues in the plantation now: leaves and branches. Depending on what we do with them, we are keeping the carbon or releasing it back in the atmosphere. For example, of we burn all this, we will put more greenhouse gasses in the atmosphere. However, if we leave the leaves on the ground, and cut and leave the branches on the ground, then the plant parts will decompose and part of the carbon that was in the plant tissues will go to the soil, and there, some carbon can be stored for a very long time. This is great, this is what we are looking for. What is the downside? Well, yes. As we have seen, life is not that easy, and the world can be complicated. In this case, those plant residues could attract pests and diseases, so we must pay attention to them. Thus, perennial crops are not magic climate change savers, we also need to do our bit and take care of them adequately. Then, they will help us.



At this point, you may have probable guessed that reducing carbon from the atmosphere is a two players process: first, we need a plant to take the carbon from the atmosphere and once the poor thing is dying, we need the soil to store the carbon there, the soil is our second player. Plants cannot store carbon for very long without soils, and soils cannot take carbon to store it without plants.

A perfect marriage!

The goal of our second study was to evaluate what happens in the soil after planting a perennial crop and during the perennial's life cycle. To this end, we first had to create a global and unified dataset containing information on changes in soil carbon under perennial crops. Why that? Because such dataset did not exist before (this work of digging information form the web, colleagues, research articles, etc, is one of the most boring works of a researcher, but alas, this has to be done and anyone has to do it). It took us few months…

After those boing months of data mining, it was overly exciting to finally see a good data set. All those data were finally ready to tell us something… actually, spoiling a bit the rest of the post, I can say that the wait was worth it, even the sweat and tears! The results of our analysis were very encouraging, they did overcome my expectations (This is not quite common. All researchers have secretly high expectations about the results and most times what we see after experimenting and/or analysing the data is not that great).

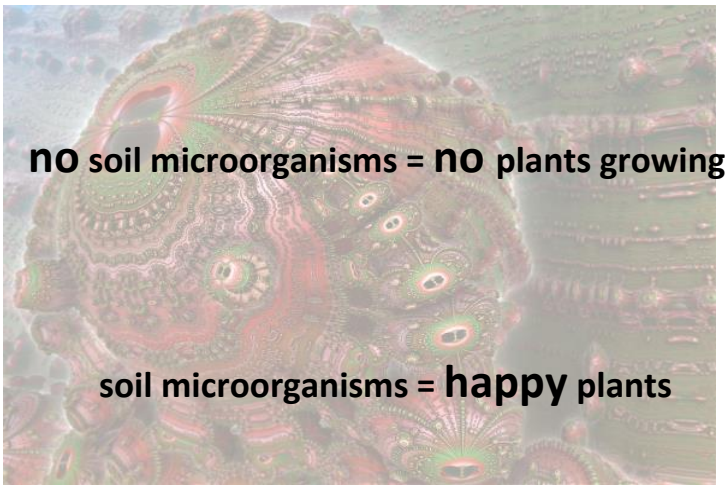
Just a quick note before moving: if you want to check what is exactly the soil organic carbon and why is important, there is a small and easy post about that here https://ekonowsys.net/2020/05/28/what-is-the-soil-organic-carbon-and-why-is-it-important/

Picture: Creative Commons

To understand the effect of perennial crops on soil carbon, we first studied what happens in the soil when you change from having a forest, or a grassland or an annual crop and then you stablish a perennial crop. The consequences of the change are limited and easy to guess: either the soil organic carbon content increases or decreases or stays the same. If the carbon concentration increases, that means that atmospheric carbon that is now stored in the soil – cool! If the soil carbon decreases is the other way around, is bad news. Some carbon that was stored in the soil is released back in the atmosphere, thus increasing the concentration of greenhouse gas emissions. And if stays the same… well, it stays the same. We are not hurting but not helping either, neither fish nor fowl.

So, what we observed? That a change from an annual to a perennial crop crops led to an average 20% increase in soil organic carbon in the upper 30 cm in 20 years. This is a lot and is indeed good news! Annual crops are crops that we plant every years, such us potatoes, tomatoes, lettuce, peas, and many other crops that are very important in our diets. Annual crops are not very friendly with the soils, but it turned that perennials aren´t doing it that badly. Why? In annual crops there are annual disturbances in the soil, such us tillage. This breaks the organic and inorganic compounds in the soil and some of the carbon that was trap in those compounds is released to the atmosphere. Same next year, and next year, next year and so on if we tillage every year before planting the annual crop. Also,

in most cases annual crops requires a higher user of fertilisers, which changes bio-chemical properties in the soils and help to release carbon. On the other hand, perennial soils are not tilled in years and (maybe more importantly), perennials have bigger roots and the parts of that roots that die are directly going into the soil (well, they are already there). The roots of perennial crops pierce also deeper, so these new carbon inputs occur in a wider soil area. Besides, avoiding tillage helps the soil bacteria and other micro-organisms to develop and thrive, and those guys play a key role in creating and maintaining a good quality soil. We don´t fully know how many types or fungi and bacteria are out there, but we do know they are they essential to have good soils.



Picture: Bacteria Spore Fungal - Free image on Pixabay

Results from the other two land changes, forest or grassland to perennial crop, the news are not that exciting: we did not obtain any robust result. A change form grassland to perennial seems to decrease the carbon and a change from forest to perennial seems to increase carbon in the first centimetres of the soil but decrease carbon at bottom layers. Those are observed trends but not supported enough with the statistics, so we can only say they may be true.

Finding that perennial crops can remove some carbon from the atmosphere was a particularly good new. And this way of removing atmospheric carbon will also deliver goods… not to mention products such as coffee or wine!

Picture: Creative Commons

Our soil study identified the temperature as the main factor explaining changes in soil carbon: in tropical and Mediterranean areas carbon accumulation is slower than in temperate regions. This is probably because soil bacteria and microorganisms are more abundant and more active, so they eat more. As a consequence, those plant residues that could have stay in the soil are delicious dishes for our soil micro-friends instead. They use this food for having energy, and in the process, they release carbon dioxide back to the atmosphere (then again, there´s more info about this in post about soil carbon https://ekonowsys.net/2020/05/28/what-is-the-soil-organic-carbon-and-why-is-it-important/). Another second factor that is important to help storing carbon in the soil is the quality of the soil itself. When the soil is in good condition, it can store more carbon, because it has the structures that are needed to capture that carbon. In poor soils, without those structures, the carbon cannot be fixed. It will likely go away the next day is very windy or it rains.

Those are some basic clues; the process is not that easy and guessing correctly what may happen in every case is not that straightforward. But I want to show you that we do have the knowledge to manage our land properly to increase carbon, or at least not to lose it. I want to show and remark to you that good management is they key and will help us achieve not only environmental-friendly practices but also help mitigating climate change! **The power is in our hands**.

Picture: Creative Commons

This article is focused on the clear benefits of perennial crops. Yet, I don't want to finish it without an **important disclaim: This is not a cornucopia.** First an importantly, crops management has to be the adequate. A second key factor, which will limit the carbon storage benefits of perennial cropping system is that most perennials require quite a lot of water. Planting, for example, almond crops in arid areas will likely result in drainage of natural underwater sources. This will be disastrous for the population nearby, not to mention will result in a poor soil, which won't have as many bacteria and will highly reduce the capacity to store carbon and nutrients. A third factor worth mentioning is that if we change a natural ecosystem into a man-made ecosystem, which is cutting down a forest to plant perennials, not only will biodiversity and present wildlife be reduced but the benefits of the natural ecosystem will be lost.

This is the home-take message:

Perennial crops can be an effective climate change mitigation tool because they can remove greenhouse gas emissions from the atmosphere. But (there´s always a but) only if the management is correct and the plantation area is the appropriate. Mainly, if plant residues and the soil are managed properly, as we have seen before, and water scarcity is not a problem. **So, perennial crops are not magic entities that will save the planet, is us, humans, who can help on this issue if we manage the crops properly.** Perennial crops are a tool, but if we don´t use the tool correctly if won`t work**. At the end of the day, is us who must do things properly.** We can and I hope we will 😊

Picture: Creative Commons

PS: Those articles I have been talking about haven´t been possible without the help and support (both scientific and personal) of my co-authors. Many thanks to them again!

If you want to check our scientific papers:

Changes in soil organic carbon under perennial crops – *Global Change Biology, 2020* https://onlinelibrary.wiley.com/doi/10.1111/gcb.15120

A global, empirical, harmonised dataset of soil organic carbon changes under perennial crops

https://www.nature.com/articles/s41597-019-0062-1

Perennial-GHG: A new generic allometric model to estimate biomass accumulation and greenhouse gas emissions in perennial food and bioenergy crops - *Environmental Modelling & Software, 2018*

https://www.sciencedirect.com/science/article/abs/pii/S1364815217310496

(the first and second is open access, the later can be downloaded from my web page, www.alicialedo.com)