Hello everyone,

Today I will introduce the context of my internship by reviewing the long-term goal of this research project, and explaining why it is an important step towards that goal.

The carbon cycle in natural ecosystems is composed of two main fluxes : photosynthesis, primarily carried out by terrestrial plants and marine eukaryotic algae, and respiration by auto and heterotrophic organisms. As such, it is imperative to quantify their contributions to global CO2 fluxes in order to estimate future atmospheric CO2 concentrations, especially since their balance determines if land ecosystems act as sources or sinks for CO2.

A new method has received growing attention over the last decade, which uses the uptake of carbonyl sulphide (or COS), a trace atmospheric sulfur gas, as a proxy to estimate gross primary production at the ecosystem scale. In leaves, COS is taken up along CO2 through the activity of the same enzyme : carbonic anhydrase (or CA).

CA is an ubiquitous enzyme for exchanging and equilibrating CO2, and as such, it is shared between a wide range of organisms.

including auto and heterotrophic bacteria, fungi, lichens, moss, plants and even animals. Within them, the main roles of CA are carbon fixation and sulphur metabolism. CAs are diverse, they include six known classes that can thereafter be subdivided in clades. These different families have different affinities to CO2 and COS and different expression rates. Therefore, COS fluxes linked to CA activity are dependent on community composition since it will affect the kind of CAs found within the communities.

Now that this has been said, it probably isn’t surprising to hear that soils, just like plants, also consume COS.

They house a high number of microorganisms that can consume COS, through that same enzyme shared between microbes and plants, CA.

But it is worth noting that soils also emit COS, through both biotic and abiotic pathways that remains to be fully determined.

The consumption of COS by soil microorganisms depend on many parameters

Starting with local COS concentration. There is a direct correlation between it and the consumption of COS by soil microbes. The higher the concentration, the higher their consumption, until a threshold is reached, around 2 ppb. To give an idea, the mean athmospheric concentration of COS is around 0.5 ppb.

Temperature is also a major factor, as it affects the activity of the enzyme. For CA, the optimum is around 15 degrees Celsius.

In addition to these two, soil moisture also plays an important role. On the one hand, water is an essential component for the chemical reaction catalysed by the enzyme to take place. But on the other hand, the water retained by the soil affects the penetration of COS into the soil. A soil that is too wet will allow less COS to penetrate, thus reducing the potential consumption by the microorganisms. This means, like with temperature, that there is an optimum.

And finally, light. The study of its effects is still recent, but the results are very encouraging and suggest that we may have greatly underestimated its impact on both soil microbial communities and the resulting COS fluxes. On the figure on the left, we can notice that light impacts the COS balance mainly through its effects on the living fraction of the soil. In this study, the highest consumption of COS took place in the soil on the far right, rich in easily decomposable organic matter, and in the dark. To explain this result, the authors argued that light stimulates the decomposition of organic sulphur compounds by certain specialized organisms, turning the soils from net-sinks to net-sources of COS in this experiment.

Let's move on to another study, with contrasting results. During this study, different soils were incubated either in the light or in the dark for several weeks. After that, the abundances of the different groups of microorganisms were estimated with a QPCR. The y-axis of this figure represents the relative abundance of phototrophic organisms in microbial communities altogether, relative to the x-axis, which represents soil pH. The treatment here is darkness. This means that in the first soil, the most acidic, phototrophs accounted for 1% of microbial communities. So in the dark, microbial communities are clearly dominated by bacteria and fungi.

And here is the same figure for fungal organisms, and we can see that the relative abundance of fungi is higher in acidic soils.

Now, let's go back with the phototrophs and turn on the lights. The difference is obvious as their abundance is way higher in soils incubated in the light. They also do best in soils with relatively high pH levels.

Now, let's also turn on the light for the fungi. The result is a little more unexpected than for the phototrophs. Despite their preference for slightly acidic soils, the abundance of fungi increases in alkaline soils, BUT only in the light, when they are in the presence of phototrophs. This could be explained by relationships of parasitism, predation, or because phototrophs release organic compounds into the environment through photosynthetic reactions that could be used by fungi.

In addition, in this study, fungi were associated with increased COS consumption. This figure represents the balance of COS on the Y-axis, going down means COS consumption, and relative to the number of fungal gene copies detected by QPCR. Thus, fungi abundance was associated with the consumption of COS, leading to soils being potent COS sinks in the light. Since the abundance of fungi in the different soils was indirectly impacted by light, through the presence of phototrophs, it seems that the differences in COS fluxes cannot be explained alone by the abundance of the different organisms. It is also necessary to study the different interactions within soil microbial communities.

Phototrophic organisms are at the heart of many interactions involving other members of microbial communities. The example of the rhizosphere is often used, but these interactions also take place in marine environments. Free phytoplankton cells exude organic compounds, creating an area around them that is enriched in these compounds and in which marine bacteria tend to accumulate. It is called the phycosphere.

And it seems likely that this mechanism could be applied to terrestrial environments, with free-living soil phototroph playing the role of phytoplankton. It is of the many ways through which light could impact the microbial communities, and thus soil COS fluxes.

An additional reason to take into account the photosynthetic fraction of the soil is that an increasing number of tools are being made available to research for this purpose. For example, Djemiel and colleagues have recently published a new database dedicated to photosynthetic organisms called microgreen-db. This tool, which we used for our study, is tremendously useful for a more targeted and therefore more reliable identification of soil phototrophs.

And finally, one last point to continue to illustrate the importance of studies focused on soil photrophs is that most arid areas around the globe are covered by a thick layer known as the biocrust, composed of bryophytes, cyanobacteria and other microorganisms. And these biocrusts have a considerable impact on their ecosystem. To begin with, most of the organisms in these crusts are diazotrophic, which means that they are able to fix atmospheric nitrogen. Moreover, these organisms can even directly shape the geology of their environment, since they are able to form or dissolve limestone. To this day, despite their importance, the role of phototrophs organisms in soils has greatly been underestimated

By taking them into account for this study, we aimed, first, to describe their diversity in soils. Second, to determine whether light affects phototroph, bacterial and fungal community composition, and to explore the potential interactions between members of these different groups. And finally, to evaluate whether changes in microbial community composition would lead to changes in ecosystem function, more specifically COS exchange.