Review of: "Wollastonite addition stimulates soil organic carbon mineralization: Evidences from 12 land-use types in subtropical China"

Rafael Santos[1]

1 University of Guelph

Potential competing interests: I am a non-remunerated Scientific Advisor of Everest Carbon, and I scientifically collaborate with Canadian Wollastonite and UNDO Carbon.

It is important to study the soil application of wollastonite in the context of being an alternative to limestone-based amendments for liming application, and in the context of carbon drawdown via enhanced weathering and pedogenic carbonate formation mechanisms. To this end, the study titled "Wollastonite addition stimulates soil organic carbon mineralization: Evidences from 12 land-use types in subtropical China," by Yan et al. (2023), holds potential to be used to further this scientific and technological endeavor. However, the use of this article's conclusions and data should be taken with caution, as a significant point of weakness in experimental design and subsequent data interpretation can lead to erroneous conclusions. This starts with the article's title, aggressively suggesting that wollastonite, generally, leads to soil organic carbon (SOC) losses, with the contents of the abstract also unilaterally pointing to such a conclusion, and the paper's conclusion section furthering this view. Yet, within the article lies data that does not support this outcome outright, and discussion that provides, though sparingly, a more moderate viewpoint. This will be further discussed below, with the more correct data interpretation made more obvious.

The main issues with the study include:

i. the study uses a 10 wt% amendment rate, which is very high for wollastonite given how basic and reactive a mineral it is compared to other candidate rocks such as basalt and olivine;
ii. the study used an unamended control, but the study should have also had a limestone control to investigate whether limestone would have had the same SOC mineralization effect on such acidic soils at such a high amendment rate;
iii. in agriculture, liming is done to enable certain crops to grow on less suitable soils, so the initial loss of SOC is something that happens when a natural soil becomes a crop soil, before SOC rebound and eventual greater accumulation occurs on well-managed soils;
iv. the study used tropical soils from largely non-crop fields (mostly forested areas), so making over-reaching statements with regards to wollastonite causing SOC mineralization is not appropriate;
v. the study is based on lab tests without plants, and it is known that every soil loses SOC under such conditions, so it is not surprising that with wollastonite boosting microbial activity, as the paper states, it acted as a nutrient source for microbes that decomposed accumulated SOC, which further highlights how the study should have had more tests to compare wollastonite's effect versus other mineral amendments, including limestone.

In fact, there exists abundant literature about the effect of liming (with limestone) on agricultural soil SOC, both in the short and in the long term. One such study is that of Paradelo et al. (2015). The following are quotes from the abstract of this paper:

- *"The net effect on SOC can be the result of several factors: first, liming increases the soil biological activity, thus favoring the mineralization of organic matter, which should result in CO_2 losses and a decrease of the SOC stocks."* (Paradelo et al., 2015)
- *"Second, liming ameliorates soil structure, increasing the stability of clay assemblages and clay-organic matter bonds, which should bring an increase in SOC physical and physicochemical protection."* (Paradelo et al., 2015)
- *"Finally, as liming ameliorates soil conditions for plant growth, plant productivity increases and also the return of C inputs to soil, thus potentially increasing SOC concentrations."* (Paradelo et al., 2015)
- *"The net effect of these processes is not well understood yet. Still, some overall trends can be deduced from data currently available in the literature. Liming does modify SOC stocks, increasing them in most cases, which seems to be caused by higher C inputs to limed soils due to increased productivity. Reductions in SOC have also been reported, probably in connection with increased mineralization, whereas the role of improved soil structure remains unclear."* (Paradelo et al., 2015)

It becomes clearer that in the study of Yan et al. (2023), wollastonite simply displayed the liming effects described above, but given they were short-term lab experiments, only the mineralization was measured. To be fair, the paper of Yan et al. (2023) actually points to these effects of liming deep in its Discussion section on page 4, with the following statement: *"Many other studies involving lime application also have published similar results as indicated by the increased soil MBC and respiration as the soil pH increases (Fuentes et al., 2006; Wu et al., 2021)."* (Yan et al., 2023) But this correlation is not at all reflected in the article's concluding and summarizing statements in its Abstract or Conclusions sections, meaning that a casual reader will be unlikely to realize that liming studies exist that show the same effect when soils are over-limed.

Over-liming is another issue of the paper, in terms of experimental design. Figure 1 in Yan et al. (2023) shows that soil pH values increased from less than 5, on average, to over 7.5, on average. An increase in soil pH of nearly 3 units is bound to cause significant effects on soil microbes and result in rapid SOC mineralization. The authors actually mention this, but again only in passing, in its Discussion section, as follows: *"Second, more recalcitrant C has been translated to labile form, an easily utilized fraction of soil C for microbes, as a response to the soil pH increase. The release of DOC from organic soil layers has been positively related to soil pH before (Andersson and Nilsson, 2001; Jokinen et al., 2006)."* (Yan et al., 2023). Moreover, when the soil pH is rather low (below 5), wollastonite will weather rapidly (Haque et al., 2023), as would limestone; hence, the pH increase is not only large but also rapid, basically shocking the soil microbes to re-adapt to a very different biogeochemical condition.

While the work of Yan et al. (2023) does not contain errors, and the data presented in the paper is apparently accurate, the issue is the message that the study sends out to its readers when it makes broad statements without the relevant comparisons to other minerals, and based on experiments that exacerbated SOC mineralization due to high amendment rate, low soil pH, lack of plants, short duration, among other limitations. Dedicated liming studies are needed to understand how to use silicate minerals in place of carbonate minerals: what dosage, how often, what pH correction target to set, and other agronomic considerations.

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