Abandoned but not forgotten: uncovering the soil organic carbon dynamics and sequestration potential of abandoned agricultural lands

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Abstract

Regional cycles of agricultural land expansion and abandonment have been common throughout history in many countries of the world. Following the cessation of agricultural practice, landscapes undergo the spontaneous process of ecological succession resulting in significant above and belowground changes over time. As agricultural lands are often severely depleted of soil carbon, they represent one of the land types with the highest potential to act as carbon sinks through the process of soil carbon sequestration. While best management practices for increasing soil carbon stocks through sustainable agriculture are understandably a key focus point in climate change research today, the lasting effect of the abandonment of agriculture on soil organic carbon has received relatively less attention. However, significant amounts of farmland have been abandoned across the globe in both developed and developing countries, especially over the last several decades. To better understand the ability of old agricultural lands to act as carbon sinks through time, this study compiles field and published data to perform a comprehensive meta-analysis on the impacts of this land use change on soil organic carbon dynamics. Using a chronosequence approach, three study sites in Catalonia, Spain, each with four fields representing different stages of ecological succession post-abandonment spanning roughly 60 years, were sampled at soil depths of 10, 20, and 30 cm. To determine soil carbon stocks at each site, bulk density samples were also collected. Samples were analyzed for organic carbon, nitrogen and pH. Additionally, published chrononsequence and paired-plot data from abandoned agricultural lands throughout the Mediterranean region were also compiled into a database to perform multiple regression analysis. Our findings are not only meant to test the hypothesis that abandoned fields can act as carbon sinks over time, but to also determine the rate of soil carbon stock increase and projected vulnerability in relation to a variety of environmental and land management variables, thereby highlighting the climate change mitigation value of an as of yet understudied global land use change.

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THE BIG QUESTION:

How much soil C lost to agriculture throughout history can be recovered due to abandonment?

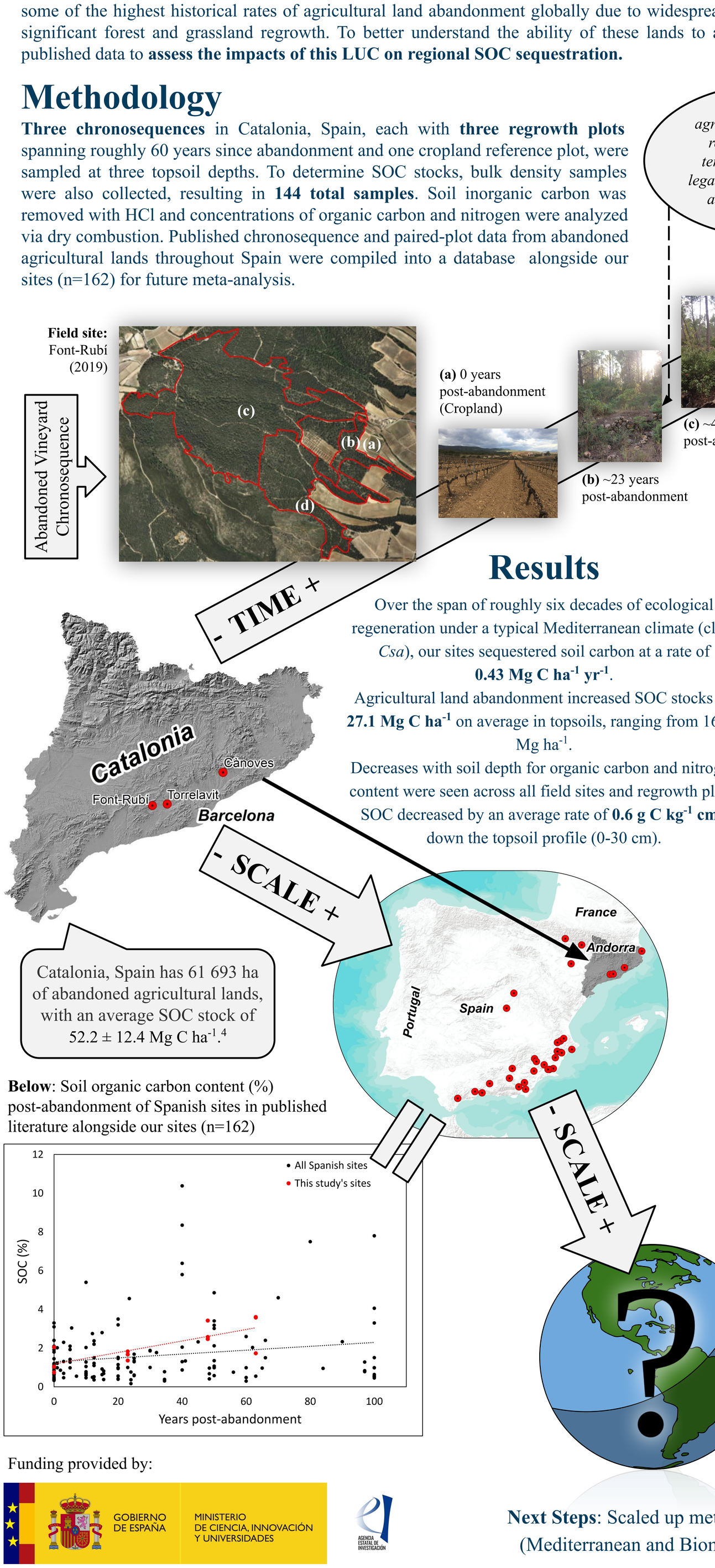
Agriculture's all-time soil C cost is 116 Pg, or approximately 11.7 years of global CO_2 emissions at 2017 levels.[2,3]

Background

Vast expanses of **previously cultivated lands around the world are currently regenerating** as a result of agricultural land abandonment. Upwards of 472 Mha, or over half of the land area of the USA, is estimated to have been abandoned over the last three centuries.[1] As agricultural lands are often severely depleted of soil organic carbon (SOC), they have the **potential to act as carbon sinks** through long-term sequestration. The Mediterranean region in particular has experienced some of the highest historical rates of agricultural land abandonment globally due to widespread rural depopulation and agricultural policy changes resulting in significant forest and grassland regrowth. To better understand the ability of these lands to act as carbon sinks through time, this study compiles field and published data to **assess the impacts of this LUC on regional SOC sequestration.**

Methodology

Three chronosequences in Catalonia, Spain, each with **three regrowth plots** spanning roughly 60 years since abandonment and one cropland reference plot, were sampled at three topsoil depths. To determine SOC stocks, bulk density samples were also collected, resulting in **144 total samples**. Soil inorganic carbon was removed with HCl and concentrations of organic carbon and nitrogen were analyzed via dry combustion. Published chronosequence and paired-plot data from abandoned agricultural lands throughout Spain were compiled into a database alongside our sites (n=162) for future meta-analysis.

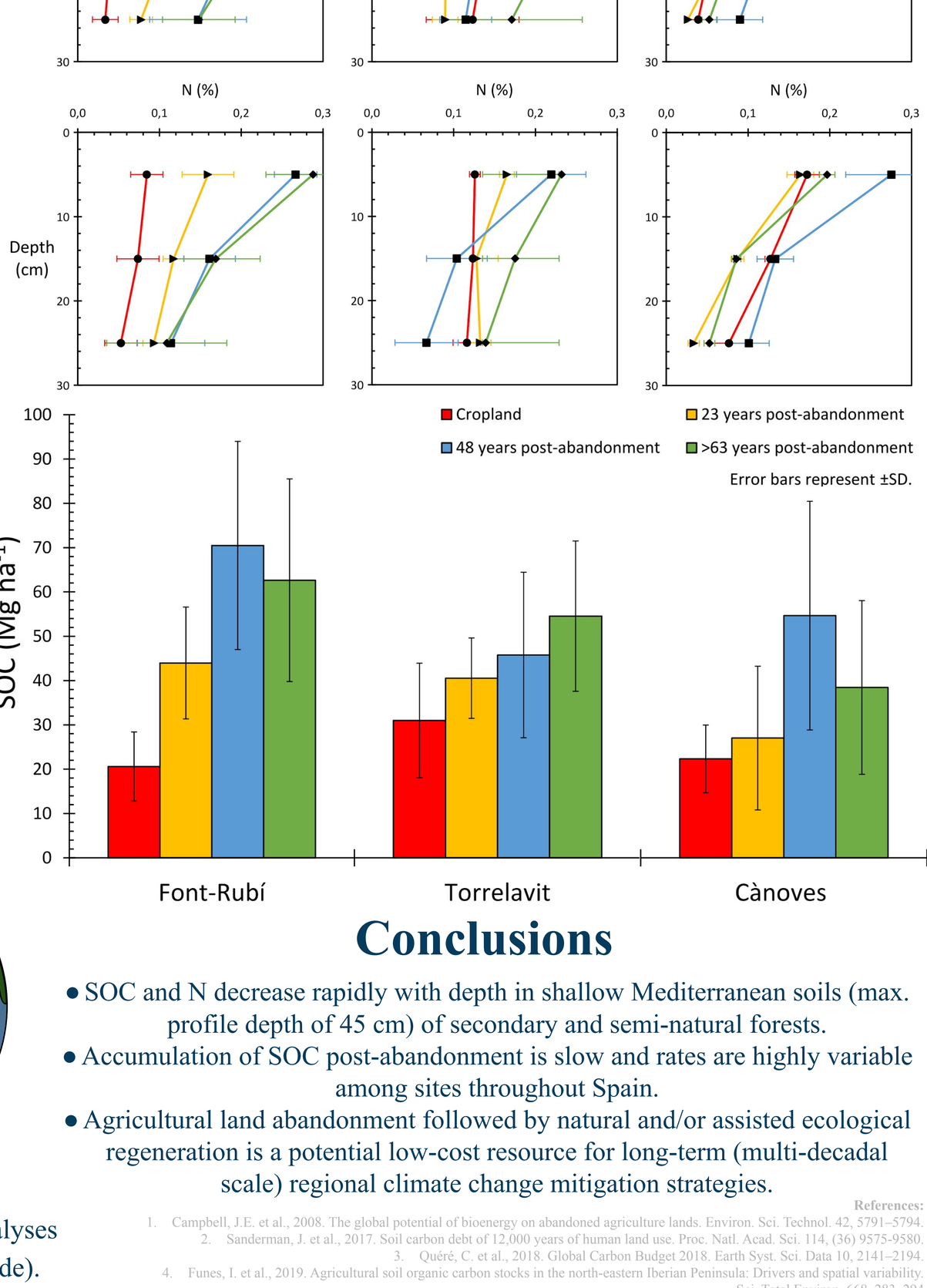


Results

Over the span of roughly six decades of ecological regeneration under a typical Mediterranean climate (class *Csa*), our sites sequestered soil carbon at a rate of **0.43 Mg C ha^{-1} yr^{-1}**.

Agricultural land abandonment increased SOC stocks by **27.1 Mg C ha^{-1}** on average in topsoils, ranging from 16-42 Mg ha^{-1}.

Decreases with soil depth for organic carbon and nitrogen content were seen across all field sites and regrowth plots. SOC decreased by an average rate of **0.6 g C kg^{-1} cm^{-1}** down the topsoil profile (0-30 cm).



Conclusions

- SOC and N decrease rapidly with depth in shallow Mediterranean soils (max. profile depth of 45 cm) of secondary and semi-natural forests.
- Accumulation of SOC post-abandonment is slow and rates are highly variable among sites throughout Spain.
- Agricultural land abandonment followed by natural and/or assisted ecological regeneration is a potential low-cost resource for long-term (multi-decadal scale) regional climate change mitigation strategies.

Catalonia, Spain has 61 693 ha of abandoned agricultural lands, with an average SOC stock of 52.2 ± 12.4 Mg C ha^{-1}.[4]

Below: Soil organic carbon content (%) post-abandonment of Spanish sites in published literature alongside our sites (n=162)

Next Steps: Scaled up meta-analyses (Mediterranean and Biome-wide).

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