PhD School on Agriculture, Environment and Bioenergy

(http://sites.unimi.it/dottorato_aab/)

(XXXVI cycle, 2020-23)

Project draft

1.Field of interest

*Indicare **il/i** settore/i scientifico disciplinari:*

AGR-02; AGR-10; AGR-13; ICAR-03

2.Project title

Agroecology for rural and urban greening. New materials for maintaining soil fertility

3.Tutor Stefano Bocchi - Co-tutor or external expert: Andrea Schievano (JRC – UE)

4.Relevance of the topic and state of the art:

Large-scale regeneration of ecosystems, including in agricultural land, is urgently needed today to cope with climate change and the depletion of environmental resources. Fertile soil is already a limited resource and different solutions must be urgently found for feeding a growing human population in the coming decades, without damaging ecosystems with intensive agriculture. **Agroecology** paradigms such as **agroforestry** are the most suitable tools to promote simultaneous landscape and environmental **regeneration**, climate and ecological resilience, while responding to the urgent call for food security and social justice.

In parallel, intensive/industrial agricultural productions can be confined to off-ecosystems surfaces (e.g. urban, peri-urban and desertified land), which can be efficiently used for such scopes, while leaving fertile land to more sustainable farming practices (e.g. agroforestry) to promote large-scale ecosystems regeneration. **Soil-less farming** (e.g. cultivation of photosynthetic microorganisms and hydroponic vertical crops can ensure production of nutritional values (e.g. proteins) per hectare of occupied horizontal land, at incomparably higher yields than those of traditional crops (up to 100-200 ton/ha·year versus 1-2 t/ha·year in the case of conventional crops.

However, today's soil-less farming technologies (e.g. photosynthetic microorganisms cultivation or hydroponic farming) still fully rely on the use of mineral fertilizers derived from primary non-renewable resources. In parallel, wastewaters and organic-rich secondary products of food industry are important sources of plant nutrients, which should be valorised as resources, rather than being disposed as waste or dispersed in the environment. Organic forms of nutrients are contained in such recycled streams, while photosynthetic organisms need essentially mineral forms to grow.

Natural soils, instead, are the most efficient circular-economy actors: communities of microorganisms 'regenerate' organic residues by oxidizing organic compounds and releasing mineral forms of nutrients, turning them available for plants growth. A **biomimetic approach** to reproduce this function in soil-less farming would limit their reliance on primary sources of mineral fertilizers.

5. Layout of the project (draft)

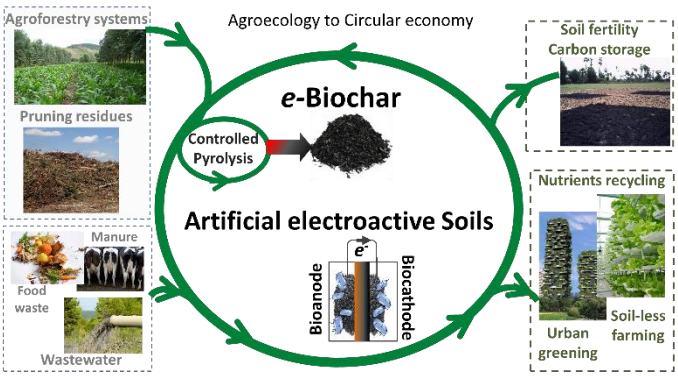
5.1.Materials & Methods:

Artificial soils based on biochar. This project proposes an innovative concept of **artificial soil (AS)**, based on stimulating microbial oxidation towards the mineralization of organic compounds, using **bio-electrochemically active biochar (e-Biochar):**

a) it has several electro-active properties (electrical conductivity, electrocatalytic properties, biocompatibility and the capacity to host microbial communities);

b) it can be produced at large scales (from **green waste and agro-forestry residues**) with a positive energy balance (recovery of syngas);

c) it is fully biogenic/biocompatible and it can be fully recycled as fertility promoter in agricultural soils. Also, the electroactive properties of biochar (in addition to its physical-chemical properties) were recently proposed to play a fundamental role in **influencing soil fertility**. The use of biochar and the re-use of spent bioelectrodes as amendment in agricultural soil opens a new perspective of research on soil microbiology and biogeochemistry: electro-fertilization (**e-fertilization**).



5.2. Schedule and major steps (3 years):

Year 1) – Literature analysis for updating recent reviews. **First studies** at lab-scale the electrochemical properties of commercial biochar, furnished from different stakeholders of the pyrolysis sector.

Year 1-2 - **Urban greening and vertical farming applications**: artificial soils based on e-biochar applied to plant-nutrients recovery from agro-food wastewater (N,P,K,Ca,Fe, etc.). These new bioelectrodes will be coupled to established technologies based on METs, such as i-METlands and e-BioPond, to improve their nutrients recycling capacity.

Year 2-3) **Agroecology applications**: a) biochar origin: agro-forestry systems; b) biochar after-life: carbon sinks in the same agro-forestry systems: what role biochar's electro-active properties (as-it-is or enriched with plant-nutrients) may play in influencing microbial and biogeochemical soil processes?

Year 3 - **LCA study** - The project will evaluate these points as a new circular resource-recovery scheme, with life cycle assessment and economic tools, to simulate possible large-scale application of such concepts.

6. Available funds (source and amount)

- The sources of funds will be the project Funded by Fondazione Cariplo Cariplo Economia Circolare – Progetto e-Biochar (total 168 k€, 10.000 for Pd.D. activities).

7. Literature:

Prado, A., Berenguer, R., Esteve-Núñez, A., 2019. Electroactive biochar outperforms highly conductive carbon materials for biodegrading pollutants by enhancing microbial extracellular electron transfer. Carbon N. Y. 146, 597–609. https://doi.org/10.1016/J.CARBON.2019.02.038

Schievano, A., Berenguer, R., Goglio, A., Bocchi, S., Marzorati, S., Rago, L., Louro, R.O., Paquete, C.M., Esteve-nunez, A., 2019. Electroactive Biochar for Large-Scale Environmental Applications of Microbial Electrochemistry´. ACS Sustain. Chem. Eng. 7, 18198–18212. https://doi.org/10.1021/acssuschemeng.9b04229

Prévoteau, A., Ronsse, F., Cid, I., Boeckx, P., Rabaey, K., 2016. The electron donating capacity of biochar is dramatically underestimated. Sci. Rep. 6, 32870. https://doi.org/10.1038/srep32870

Vaccari, F.P., Baronti, S., Lugato, E., Genesio, L., Castaldi, S., Fornasier, F., Miglietta, F., 2011. Biochar as a strategy to sequester carbon and increase yield in durum wheat. Eur. J. Agron. 34, 231–238. https://doi.org/10.1016/J.EJA.2011.01.006

Marzorati, S., Goglio, A., Fest-Santini, S., Mombelli, D., Villa, F., Cristiani, P., Schievano, A., 2018. Air-breathing bio-cathodes based on electro-active biochar from pyrolysis of Giant Cane stalks. Int. J. Hydrogen Energy. https://doi.org/10.1016/J.IJHYDENE.2018.07.167