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CONVERTING AGRICULTURAL BY-PRODUCTS INTO VALUE: BIOCHAR TECHNOLOGIES FOR A CIRCULAR APPROACH

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Introduction

According to conventional production models used in agriculture, the by-products resulting from primary production processes were traditionally considered as waste remained unexploited, lacking integration into new value-adding production systems. Nowadays, within the current legislative and policy framework, both globally (*Transforming our world: the 2030 Agenda for Sustainable Development*) and at the European level (The Green Deal, the new Circular Economy Plan, Zero Pollution Action Plan), ensuring the resource efficiency through the application of circular economy principles, agricultural by-products are recognized as key inputs in sustainable production models. According to ESDAC (European Soil Data Centre) definition “biochar is a carbon-rich material produced from biomass sources such as crop residues, green waste, wood chips and others”. Thus, the main benefit provided by biochar application is carbon sequestration and also enhancing soil properties (water and nutrient retention). Not at least, by replacing the conventional agriculture inputs with biochar has a long-term positive impact for soil health and crop productivity. This paper aims to summarize the potential benefits of biochar application in relation to the specific needs identified within the agricultural sector, highlighting how this approach can contribute to soil status improvement, waste reduction and the overall transition towards a circular economy.

Materials and methods

The methodological framework of this paper integrates several scientific techniques, including but not limited to analytical and synthetic methods, computational simulations, structural system analysis and formal reasoning.

Results and conclusions

In order to highlight biochar application as a sustainable practice option, promoting measures regarding biochar application should include the natural and socio-economic conditions of the target area or farm. Moreover, ensuring long-term sustainability requires preliminary modelling that considers how climate, land use, farming practices, and socio-economic conditions are expected to evolve over the period during which biochar remains active in the soil. Equally important is raising awareness among farmers and agricultural producers about the positive impact that valorizing by-products through biochar production technologies can have, from environmentally and economically perspective.

While traditional production techniques involved slow burning process with significant CO₂ emissions, modern pyrolysis methods allow environmentally

friendly biochar production by capturing harmful emissions. Beyond improving soil health and fertility, ensuring a nitrogen optimal level both in terms of soil and water quality is also a positive aspect related to biochar application. According to recent statistical data (Eurostat, 2023), the consumption of inorganic fertilizers (nitrogen) remains high, particularly in France, Poland, Germany, and Spain (Figure 1). It can be observed that the agricultural sector continues to rely on chemical fertilizers to achieve the productivity levels necessary for meeting both domestic consumption and export demands.

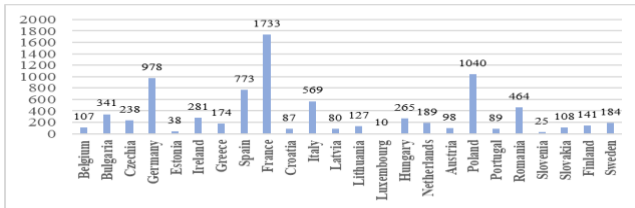


Figure 1. Consumption of inorganic fertilizers (thousands of tonnes), *Nitrogen*, in UE countries, 2023

According to the specialized literature, the nitrogen content identified at biochar level is not very high, ranging between 0.1% and 6.7%, depending on the feedstock used, the biochar production process, and other factors (Paiva, O., de Moraes, E.G., Jindo, K. et al., 2024). However, the long-term application optimizes productivity levels by improving soil health as well as water retention capacity in agricultural lands. The initial investment costs associated with establishing a biochar production pyrolysis line can be substantial, potentially discouraging agricultural producers. Thus, achieving economic viability of such an investment depends on the type of feedstock employed as well as the specific farm characteristics (Figure 2).

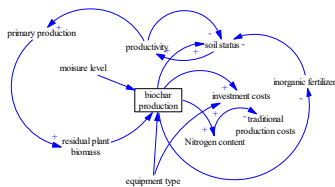


Figure 2. Shaping the links between the main biochar production factors

Thus, biochar production directly contributes to the agricultural operator’s efforts in conserving natural resources, while indirectly generating additional income by reducing costs associated with conventional fertilizers and by achieving higher primary production through improved soil productivity.

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