Nano-enabled agriculture and circular economy. Nature-derived materials as smart-delivery systems

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Nano-Enabled Agriculture and Circular Economy. Nature-Derived Materials as Smart-Delivery Systems

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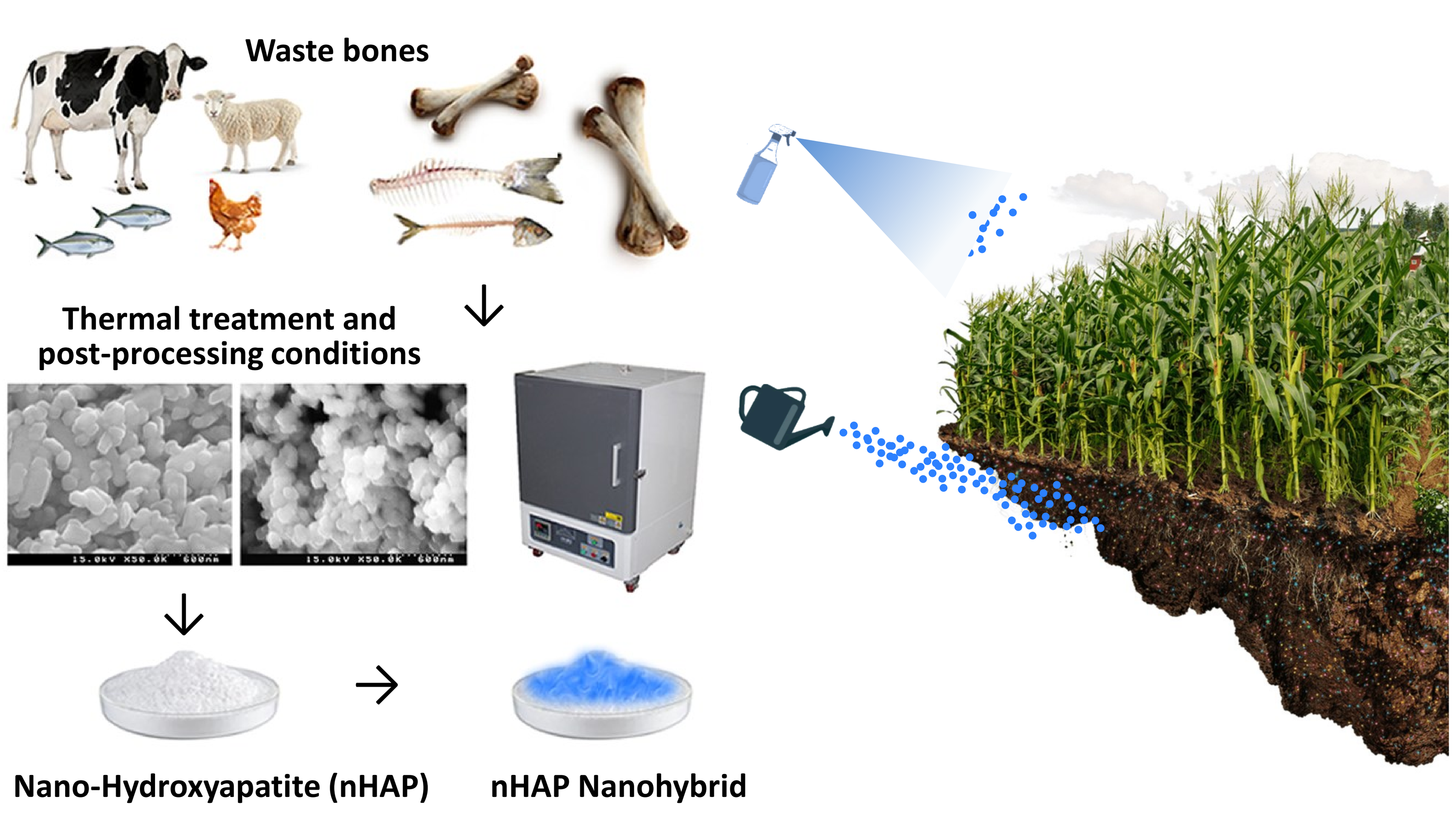
Nano-enabled agriculture (NEA) describes the application of nanotechnology in agriculture to improve the performance of agrochemicals. NEA mainly focuses on improving the agrochemical uptake efficiency by crops, enhancing plant growth and food safety, and mitigating the environmental impacts of agriculture. But the real expected innovation will be the significant reduction of the overall applied doses of nanostructured materials compared to conventional fertilizers, herbicides, and pesticides (Zhang et al., 2021).

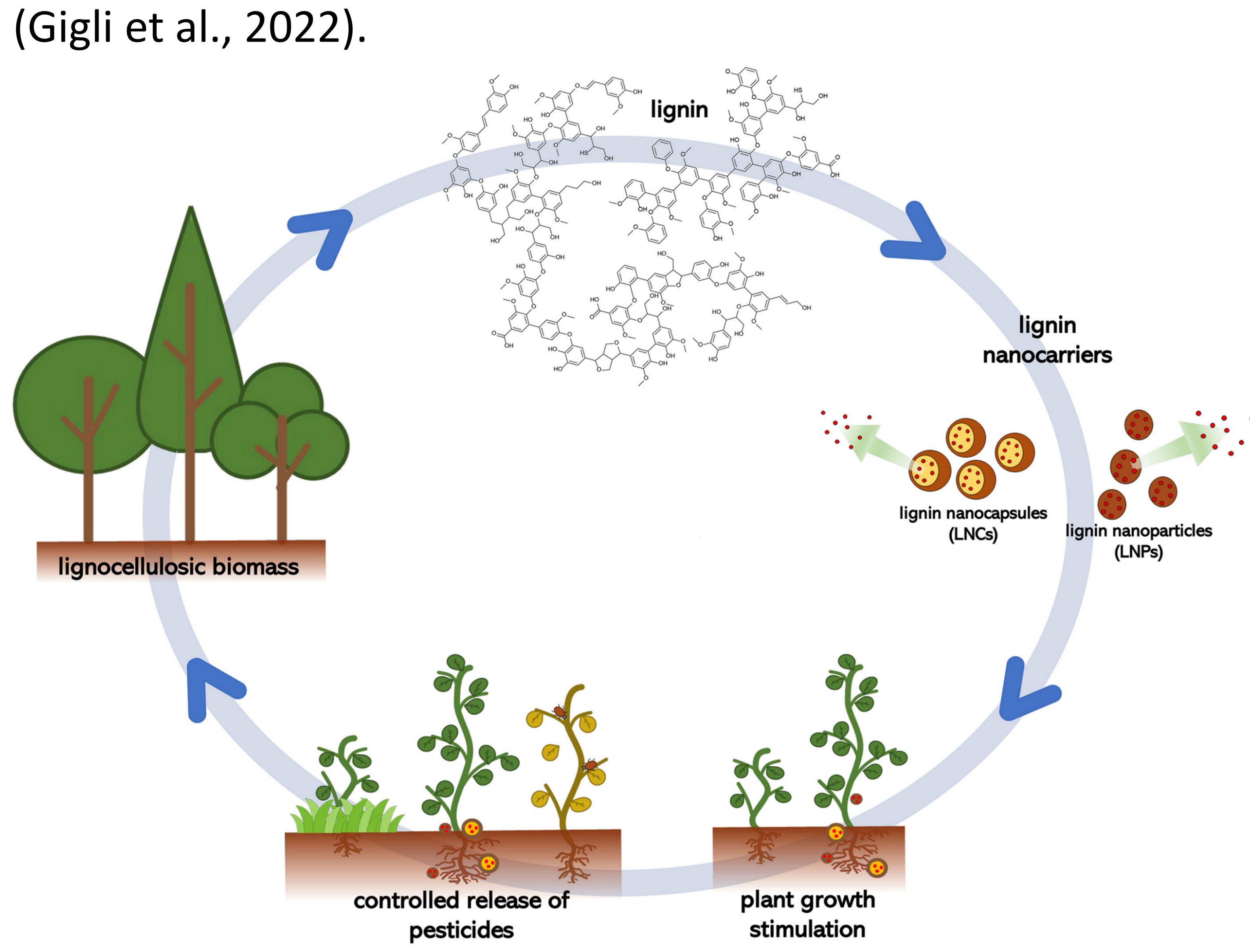
The use of nanomaterials in agriculture deals with their use in the field, their dispersion in the environment, and of course, the human and animal consumption of agricultural products. The safety of nanomaterials must be tested for human consumption beyond their effects on plant nutrition against plant pathogens or weeds. For this reason nature-derived nanostructured materials are more promising than synthetic nanomaterials (Sampathkumar et al., 2020).

The use of renewable materials deriving from plant and animal waste biomass to produce nanosized delivery systems in NEA, represents a crucial step towards the fulfilment of circular economy paradigms. Two examples demonstrate how concrete this scenario is.

The first one concerns the valorisation of hydroxyapatite ($Ca_{10}[PO_4]_6[OH_2]$) extracted from biowastes, such as bovine, horse and chicken bones, fish bones and scales (Maschmeyer et al., 2020). Compared to stoichiometric synthetic HAP, biological HAP contains other ions such as Na^+, Zn^{2+}, Mg^{2+}, K^+, Si^{2+}, Na^+, and $^{2}CO_3$. The interest in NEA stems from the potential of nano-hydroxyapatite (*n*HAP), such as an alternative P-source for crops or as a smart carrier for macro/micronutrients and plant protection products (Fellet et al. 2021).



The second example concerns lignin. Lignin is the second most abundant organic compound in plants, a biopolymer representing 30% of the non-fossil organic C on earth. Its polyphenolic structure is of high interest towards the design of nanomaterials. Lignin-based nanocarriers can be divided into lignin nanoparticles (LNPs) and lignin nanocapsules (LNCs). Ongoing studies indicate the great potential of lignin nanocarriers as bio- and eco-compatible materials for NEA (Gigli et al., 2022).



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CIRCULAR ECONOMY AND SUSTAINABLE AGRICULTURE: Hydroxyapatite from Biowastes as Smart Nanofertilizer

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