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Bio-based strategies in agriculture: perspectives for environmental pollution reductions

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Introduction

Agriculture has been contributing considerably to air and water pollution given nitrogen emissions to air in the form of ammonia, nitrogen oxides and nitrous oxide, and nitrogen and phosphorus emissions to water via leaching and runoff. Agricultural runoff being rich with nutrients enters rivers and is further exported to seas, affecting aquatic biodiversity. In many regions, agricultural crop and animal production is not sustainable, having substantial adverse impacts on climate and water quality. In Europe, existing policies facilitate the use of renewable resources such as bio-based fertilizers (BBFs) to support the circular economy and reduce environmental impacts. BBFs are often produced from processed organic waste such as animal manure, and sewage sludge. BBFs also facilitate nutrient recovery and re-use technologies to improve nutrient efficiencies. The integrative effects of BBFs to reduce both air and water pollution simultaneously are however not well studied, as well as their contribution to the spreading of antibiotics and pathogens.

Methodology

In this study, we synthesize the knowledge on the role of BBFs in agriculture and identify perspectives and lessons for air and water pollution reductions. For this, we systematically review the relevant literature. We used the ISI Web of Science (WoS) database for the period of 01.01.2014 - 31.12.2024. For each perspective, two separate search strings were developed and a combination of two search string blocks was conducted. After each combination of searches, we scanned the search results based on the title and abstract that were relevant to this study. For the articles that were judged as relevant, we then reviewed the full text to assess recent literature regarding each perspective (environment, agronomy, technology, scale, and policy) on the role of BBFs in air and water pollution control.

Results and discussion

We identified five main perspectives including (1) environment, (2) agronomy, (3) technology, (4) policy and socio-economy, and (5) scale and integration. BBFs may contain multiple pollutants that may increase environmental pollution (e.g., pathogens, heavy metals), and this should be considered before the adoption of BBFs in agriculture (perspective 1). In general, the agronomic efficiency of BBFs may be somewhat similar or different from synthetic fertilizers (perspective 2). There is no "golden" technology to process waste and produce BBFs. This implies that technologies vary greatly in terms of processes influencing their cost and implementation efficiency (perspective 3). BBFs are often subject to legal limitations for their production and adoption. This varies among regions in the world (perspective 4). Most of the knowledge base regarding the role of BBFs focused on agronomic effects and has been derived from small-scale lab and field experiments. The BBF implementation on a larger scale (e.g., continental, global) and its impact on air and water quality is still unknown(perspective 5). Models can help to explore the effects of upscaling BBFs in the world and assess their effects on air and water pollution reductions. BBFs are promising strategies to improve agricultural efficiencies. Their implementation should consider effects not only on agronomy but also on multiple pollutants, policy, and technology in time and space.

Conclusion

We derive five main conclusions. First, environment, agronomy, technology, policy, and scale are five perspectives identified. Second, bio-based fertilizers may have multi-pollutant issues. Third, the content variability of bio-based fertilizers could be overcome by precision techniques. Fourth, models can help understand the role of bio-based fertilizers in pollution control. Fifth, the upscaling of the application of bio-based fertilizers needs further research attention and the integration of other perspectives.

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