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Phosphorus recycling from biogas slurry and manure in Denmark

Improving the local phosphorus balance by evaluation of recycling potential, recycling and redistribution costs under different technology and policy regimes to reduce phosphorus pollution

Master Thesis

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Abstract:

Phosphorus (P) is a not substitutable, essential element for plant growth, which in its current form of use, derived from phosphate rock, can be regarded as non-renewable. Around 80% of all P are lost in the supply chain, while only 20% reach the end consumer (Cordell et al., 2011). The largest flows of P can be found in the agricultural sector (Klingmair et al., 2015), while livestock manure is the largest secondary recoverable P source (Withers et al., 2015). Large differences in P distribution exist in Denmark and constitute an important part of the environmental pollution problem, as well as the inefficient use of that resource. Therefore, a regional and local P balance is constructed on the smallest statistical unit of a parish. Animal distribution and manure P content serve as a basis for P supply, while the P demand is based on spatial and statistical analysis of crop demand. The results show an east-west gradient of P distribution, with largest P oversupply levels in Jutland, which decrease towards the east and turn into undersupply. In the light of the Danish Energy Strategy 2050, which intends to increase the throughput of manure up to 50% through the biogas sector, P recycling and redistribution potential is analysed by translating the concept of Levelized Cost of Energy (LCOE) to Levelized Cost of Recycling (LCOR) and applying it to different low-tech recycling technologies. Uncertainty analysis of model inputs allows for scenario building and the construction of different supply curves for recycled P, which are based on the LCOR and the regional P balance. The results show that P recycling is competitive with rock phosphate for most recycling options and that recycled P can be provided at €152 - €446/Mg. Under the implementation of the Danish Energy Strategy 2050, nearly full substitution of mineral P and a P balance reduction of up to 9.26 kg/ha can be achieved in average. This represents a promising approach for reducing environmental pollution. Regulatory measures such as a mineral P tax or P concentration permit markets are not necessarily needed to achieve price competitiveness of recycled P, but could play a role for accelerating the dissemination of P recycling and reduce environmental pollution. Further research should focus on P recycling dissemination problems outside pure price effects, followed by a more in depth regulatory analysis to improve P recycling and harmonization of the Danish P balance.

Key words: Sustainable phosphorus, recycling, manure, biogas slurry, Denmark, phosphorus balance, regulation, environmental management