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Farmer perceptions and use of organic waste products as fertilisers – A survey study of potential benefits and barriers

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ABSTRACT

Processing of organic waste can improve its nutrient availability and content, and thereby increases the agricultural value of the waste when used as fertilisers, while contributing to a more bio-based, 'circular' economy. It is therefore important to guide future policies on waste management and on the development of industries related to processing of organic wastes from agriculture, industry and households. However, there is a lack of understanding of the decision-making processes underlying the use of processed and unprocessed organic waste-based fertilisers by farmers. We conducted a survey asking farmers in Denmark about their current use of organic fertiliser, their interest in using alternative types in the future, and their perception of most important barriers or advantages to using organic fertilisers.

A representative sample of farmers with >10 ha of land were sent a questionnaire; in total 452 responses (28% response rate) were received. Almost three quarters of respondents (72%) used organic fertiliser, and half of the arable/horticultural farms (without livestock) used unprocessed manures, suggesting significant manure exchange from animal production farms to arable farms in Denmark.

Looking forward three years from the time of the survey, respondents did not expect to increase the amount of organic fertiliser they used. However, future interest in using processed manures (PRO) and urban waste-derived fertiliser (URB) was greater than their use at the time of the survey (66% interest vs 19% current use of PRO and 32% vs 9% current use of URB). Anaerobically-digested slurry, acidified slurry, and composted/thermally-dried manure or slurry were products of particular interest. A large percentage (40%) of farmers did not have access to processed forms of organic fertiliser, particularly PRO (35% of respondents). Farm and farmer characteristics such as farming activity, farmer age, farm size, and conventional/organic farming influenced the likelihood of future interest in alternative organic fertilisers.

The most important barriers to the use of organic fertiliser identified among respondents were: unpleasant odour for neighbours, uncertainty in nutrient content, and difficulty in planning and use. Improved soil structure was clearly chosen as the most important advantage or reason to use organic fertiliser, followed by low cost to buy or produce, and ease of availability.

Danish government policies aim to increase in manure processing (e.g. increasing anaerobic digestion for bioenergy recovery). A mix of industry and government-led measures could potentially increase availability and farmer-use to meet these targets.

1. Introduction

To prevent pollution and make better use of limited resources, there is an increasing need to retain and recycle waste in the European Union (European Commission, 2015). An important waste stream is animal and urban waste sources that can be used as fertilisers in agriculture (European Commission, 2016; Foged et al., 2011). Organic wastes intended for use in agriculture as fertilisers can be broadly classified into three categories: animal-based organic wastes such as manure, green manures and composts based on plant sources, and urban wastes such as sewage sludge and organic household waste (Kirchmann et al., 2005; Oelofse et al., 2013).

Each year approximately 1400 Mt of manure is produced in the EU (Buckwell and Nadeu, 2016). Over 90% of manures are currently applied directly to land without further processing, which are responsible for over half of the P and a third of the N applied to agricultural soils

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(Buckwell and Nadeu, 2016; Sutton et al., 2011; van Dijk et al., 2016). In 2013, 42% of the approximate 10 Mt of sewage sludge produced in the EU was applied to agricultural land; however, this value varied widely between countries (Buckwell and Nadeu, 2016).

Organic waste-based fertilisers can be processed in a number of ways to retain greater amounts of nutrients (e.g. nitrogen, N, or phosphorous, P) and increase their suitability for agricultural use while minimising climate change impact (Dalgaard et al., 2011; Rigby et al., 2016; Roy et al., 2011; Sommer et al., 2013). By increasing organic waste processing, there is scope to increase the fertilisation via recycled nutrients in the EU (Buckwell and Nadeu, 2016). Organic waste processing can be performed to separate components, e.g. manure separation technology to improve handling and optimise nutrient content (Burton, 2007), recover energy e.g. through anaerobic digestion (Möller and Müller, 2012) or incineration, remove unwanted substances such as pathogens (Bicudo and Goyal, 2003; Dumontet et al., 1999), or retain nutrients (e.g. N or P) and therefore abate nutrient emissions (Fangueiro et al., 2015). Depending on the technology used, processing may improve the product in terms of manageability, fertiliser value, soil amelioration value, and hence enhance its economic and environmental value.

According to Foged et al. (2011) approximately 7.8% of total manure production was processed in the EU in 2011. In total, 6.4% was anaerobically-digested, 3.1% is separated, and 0.5% was processed (organic waste may be subject to multiple processing techniques) with additives or other pre-treatments (e.g. acidification). Sludge is processed in sewage treatment works to reduce water content, increase stability, and remove pathogens. Common stabilisation techniques include AD, aerobic stabilisation, lime stabilisation, composting, and drying (Bennamoun et al., 2013; Buckwell and Nadeu, 2016; Chen et al., 2002). A number of technical and economic issues need to be considered before undertaking organic waste processing (Flotats et al., 2009; Sunding and Zilberman, 2001). To increase the adoption of organic waste processing technologies and produce new types of organic fertiliser on a large scale, a good understanding of the fertiliser market is required, as well as an understanding of technology adoption by farmers and other stakeholders in relation to agricultural innovations.

The adoption and diffusion of agricultural technology depends on a number of factors, such as the characteristics of the innovation in question, farm or farmer characteristics, farmer attitudes towards the innovation, or wider (e.g. environmental) issues (Pannell et al., 2006; Prokopy et al., 2008; Sunding and Zilberman, 2001). However, the effects of these factors differ between studies, even those considering the same agricultural innovation. Some specific characteristics have been frequently observed to influence adoption of agricultural innovations, such as those relating to capacity (including farmer age, farm size, access to capital/credit), attitudes (e.g. towards risks, the environment, towards the future, towards a specific technology), awareness of environmental or technology-related issues, and farm characteristics (e.g. farming activity, system) (Prokopy et al., 2008). The majority of these are demand-side factors e.g. factors affecting the farmer attitudes towards a product or their capacity to use it. However, supply-side factors such as large physical distance from the innovation and/or lack of transport infrastructure can also be barriers to adoption (Sunding and Zilberman, 2001).

Few studies have specifically considered manure and organic fertiliser adoption or acceptance by farmers (Asai et al., 2014a; Gebrezgabher et al., 2015; Núñez and McCann, 2004). In a survey of 111 Dutch dairy farmers, Gebrezgabher et al. (2015) found that lower age, lower education level, larger farm size, and a positive attitude towards the future of the farm increased interest in adoption of manure separation technologies. Núñez and McCann (2004) found that transportation costs, odour, awareness of others using manure, and low off-farm income were major factors affecting the willingness of arable farmers to accept manure in a study of 138 American crop farmers. Battel (2006) surveyed 161 farmers from Michigan, USA, and found that younger farmers (<50 years old) and those with larger land areas (>161 ha) were more concerned with negative effects of manure use such as the spreading of weed seeds and increased soil compaction. Farmers with larger land areas were also more likely to be concerned with manure use interfering with aspects of cropping operations. Younger farmers were more likely to say they would consider accepting manure only if it was provided to them without cost.

The adoption of agricultural innovations is also dependent on the local regulatory and market context, for example the policies and farm industry structure of the country under consideration (Sunding and Zilberman, 2001). As the present survey study was conducted in Denmark, the Danish agricultural sector and the national policies related to organic fertiliser management are briefly presented. In 2014, Denmark had approximately 37,950 agricultural holdings occupying approximately 60% of Danish land area (Statistics Denmark, 2015a). Over 90% of this is arable land (Kronvang et al., 2008). In 2011 approximately 50% of Danish farmers were involved in some sort of manure exchange agreement (Asai et al., 2014a). Nutrient pollution to ecosystems (particularly N and P) has been particularly severe in Denmark (Riemann et al., 2015). Since 1990, the overall use of both mineral and organic fertilisers has decreased in Denmark (Dalgaard et al., 2014; OECD, 2013); a trend primarily attributable to a series of environmental action plans that have reduced crop fertilisation norms and enhanced feeding efficiency in the livestock sector. With these environmental regulations (implementing the European Nitrates and Water Framework directives) Denmark has been most successful in reducing N-surpluses and N-losses to the aquatic environment (a 50% reduction in N and a 56% reduction in P losses from land since 1990; (Riemann et al., 2015). However, N surpluses from agriculture were still among the highest in the EU in 2010 (76 kg N ha^{-1}(OECD, 2014), particularly from livestock farms (Kronvang et al., 2008).

Recently, Denmark introduced legislative incentives and requirements for the processing of organic waste to meet environmental objectives, setting relatively high standards (Edwards et al., 2015; Kronvang et al., 2008; Lipp, 2007). Denmark derived >16% of its primary energy in 2009 from technologies such as biomass and waste incineration (for combined heat and power production) and AD (for biomethane production). With 60 on-farm and 22 centralised AD plants in 2013, Denmark is considered to be one of the leading countries in the use of AD (Edwards et al., 2015). Manure separation technology is used to some extent in Denmark (Jacobsen, 2011). Slurry storage capacity has increased to a minimum of 9 months due to regulations on extended closed periods for land application, and a large proportion of farmers (20% in 2015) have adopted slurry acidification in animal houses, slurry storage or during field application to reduce N loss in the form of ammonia, a technology which is yet almost solely implemented in Denmark (Fangueiro et al., 2015). Also, new or modified pig farms in sensitive natural areas are required to take measures to reduce gaseous N emissions from such facilities and deposition on sensitive natural areas, for example by scrubbing ammonia from the ventilation system, or by acidifying the produced slurry (Petersen et al., 2016).

In Denmark, the vast majority of household and municipal wastewater is processed by large, centralised waste water treatment plants (WWTPs) using mechanical, biological, or chemical processes. These facilities produce an N and especially P-rich sludge, of which a significant proportion (30–50%) is processed by AD for energy recovery. The majority of the sludge is applied to agricultural land after stabilisation or AD. There is furthermore a significant policy interest in increasing the reuse and recycling of waste resources as organic fertiliser (Environmental Protection Agency, 2013; Ministry for Food, Agriculture, and Fisheries, 2013). For example, political targets have been agreed to increase the amount of manure used for energy production (mainly AD) to 50% by 2020 (The Danish Government, 2009), as well increasing recycling of organic household waste fractions, food, and green waste as organic fertiliser (The Danish Environment Ministry, 2014).