The 'circular economy' applied to the agriculture (livestock production) sector – discussion paper

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Agriculture is a critical sector of the EU economy, providing the food, feed, and bioresources that help sustain society. This sector in particular is at the centre of the challenges associated with population growth, food security, climate change and resource scarcity. In the last 50 years, agriculture has become more resource intensive, relying heavily on the availability of fossil inputs in the form of synthetic nitrogen and phosphorus fertilisers, oil derived agrochemicals and fossil fuels. ‘Circular economy’ principles can offer many opportunities for agriculture in general, and livestock production in particular, to become more resource efficient. This paper presents ten key questions that are relevant to understanding the role of the 'circular economy' in livestock production.

The 'Circular' v. 'Linear' Economy: The 'circular economy' is a generic term for an industrial economy that is producing no waste and pollution, and in which material flows are of two types: biological nutrients, designed to re-enter the biosphere safely, and 'technical' nutrients, which are designed to circulate at high quality in the production system without entering the biosphere as well as being restorative and regenerative by design. This is in contrast to a 'linear economy' which is a 'take, make, dispose' model of production.

Q1. How do we define 'circular economy' in the case of livestock production?

Livestock production and agriculture are mainly linear in structure, utilising quite high levels of inputs, a large proportion of which is not converted into edible products but instead results in wasteful and environmentally damaging outputs. The UN FAO estimate that inefficiencies in the global food economy cost between $1-2 trillion per annum (FAO, 2011). Ultimately, when analysing the entire agri-food chain, up to one third of the food produced for human consumption is wasted (FAO, 2011). This waste equates to lost money as well as the resources that were invested in its production.

'Circular economy' in agriculture centres on the production of agricultural commodities using a minimal amount of external inputs, closing nutrient loops and reducing negative discharges to the environment (in the form of wastes and emissions). Examining the entire agri-food system from the ‘circular economy’ perspective can reveal opportunities at all stages, from primary production using precision agriculture techniques, to the recycling and utilisation of agricultural wastes.

Q2. What are the trade-offs between extended ‘linearisation’ and the bioeconomy versus ‘circularisation’?

Resources can be circulated through many pathways, by employing different technologies and creating new value chains. This ‘circular economy’ should perhaps be viewed differently to options that extend the ‘linear chain’ viz. utilising unwanted agricultural resources (considered ‘waste’) but not feeding the resulting product back into agricultural production, such as creating bioplastics. The bioeconomy, defined as those parts of the economy that use renewable biological resources (such as agricultural wastes) to produce food, materials and energy, may not necessarily close resource loops in agricultural production systems. Resources such as crop residues and manures can remain within the agricultural system but may also be valorised to produce energy/chemicals for the wider bioeconomy, thereby not being ‘circularised’. Determining which pathways (closed loop agriculture vs. wider bioeconomy utilisation) are most effective for creating sustainable agricultural systems remains a priority for researchers and policy makers.

Q3. Does precision livestock farming offer any inherent advantage in terms of 'circularisation', i.e. does it have any real role to play in a 'circular economy' (as opposed to sustainable agricultural production)?

In 2014, the EU-28 farmed circa. 1.2 billion livestock (cattle, swine, sheep, goat, poultry), producing 1.6 billion tonnes of manure and requiring millions of tonnes of feed. Resource use per unit energy output in livestock production is typically much higher than agricultural crops due to the inherent inefficiencies of biological feed conversion and to the higher energy demands of sustaining animals. Industrial farming requires between 10 and 60 J fossil energy input per 1 J of protein produced (Pimintel, 2003).

Livestock production can be quite wasteful of resources. The European nitrogen assessment estimates that overall nitrogen use efficiency in animal production for the EU27 is around 15 - 17%, when accounting for the full chain from fertiliser application to N in edible produce (ENA, 2011).

Precision livestock production methods can enable an enhanced level of control over the application of input fertilisers and agrochemicals that reflect geo-spatial variability in soils, microclimate and other relevant husbandry parameters. Precision agriculture utilises the capabilities of information technology systems to optimise the application of agricultural inputs (e.g. fertiliser, agro-chemicals) by delivering 'the right amount, at the right time, in the right place', thereby ensuring that the minimum resources needed are used at the production stage in order to achieve optimum performance with minimal environmental impact. While not directly contributing to 'circularisation', precision livestock farming addresses the use of minimal levels of invested resources that is essential to achieving sustainable agricultural production.

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Q4. Should 'circularising' animal manures to reuse nutrients be prioritised over merely reducing their environmental impact?

The utilisation of animal manure and food residues along the agri-food supply chain as nutrient sources should reduce the amount of fossil mineral fertilisers required to produce food. For example, the low cost Irish grass-based rotational-grazing system for milk, and to a lesser extent beef production, requires 'circularisation' of animal manure in order to be cost effective and is readily controlled because the cycle occurs usually within a single farm holding i.e. the scale of animal manure production matches the land resource available. In contrast, it can be more difficult to manage 'confinement production systems' (such as intensive pig or poultry production) in a 'circular' manner

Creating demands for perceived 'wastes' creates a trade of waste. The UK Refit scheme for AD, for example, has made it economically profitable to transport agri-food wastes large distances from the Republic of Ireland to Northern Ireland in order for it to become feedstock for AD plants. This example highlight the potential trade-off between environmental and economic benefits created by policy-based 'circularisation' strategies that use economics as an implementation 'driver'.

Q5. What is the impact of 'virtual water' and 'nutrient trading' due to livestock production and is this compatible with a 'circular economy'?

Q6. Are we giving proper thought to the implication of 'circularisation' through space and time, i.e. are solutions for Europe creating problems elsewhere?

There are at least three components of feed, livestock, the food produced and the 'waste' produced that need to be considered: protein, nutrients and water. There is a tendency to consider systems in terms of their energy flows, but 'circularisation' requires consideration of protein, nutrient and water. This is of particular importance if the early stages of a value chain are in regions with a scarcity of one or more of these resources, yet the 'valorisation' of the 'waste' occurs in a region of plenty (i.e. the system is not 'circular'). For example, creating and transporting meat and milk products from areas high on the water scarcity index to locations low on the water scarcity index, without addressing the 'circularisation' of water will only exacerbate scarcity issues at the point of production. The 'circular economy' needs to address the scale of loops, in order to prevent the exploitation of resources in one area to satisfy demand in another.

To achieve optimum meat and milk production, imported feeds are usually required in order to meet the energy demand of the herd and to fine-tune the quality of the food product. This means that there is a virtual trade in both nutrients and water which requires further attention. International trade of agricultural commodities implies an international flow of 'virtual' water and nutrients. The global volumes of international 'virtual' water flows mean that about 20% of the global water used in agriculture is aimed at producing products for export (Chapagain and Hoekstra, 2003). Virtual nutrient trade is also a relevant issue to the 'circular economy'. The global trade in phosphorus has made the EU reliant on imported 'virtual' phosphorus (P). The contribution of 'virtual' P flows to the total P 'footprint' of the EU has increased by 40% from 1995 to 2009. Imported agricultural products require fertiliser to be used in foreign countries to grow crops that will ultimately feed European people and livestock. As such, these imports represent a displacement of European P demand, possibly allowing Europe to decrease its apparent P 'footprint' by moving P use to locations outside the EU (Nesme et al., 2016).

The impacts of global livestock production can be widespread and when a country substitutes imported for domestically produced meat, the environmental burdens are effectively shifted abroad, affecting distant countries where the commodities are produced. Japan, for example, greatly benefits from importing grain for meat producing animals because Brazil, which provides the land, water and nutrients to raise the grain, suffers the true environmental cost that is incurred. Japan would have to devote 50 percent of its total arable land to raise the equivalent of their chicken and pig imports (Galloway et al., 2007)

In the horticulture sector, for example, flowers produced in Kenya are 15 times less carbon intensive than the equivalent Dutch production, as the Kenyan flowers are largely grown outside using the abundant solar energy as opposed to Dutch ones grown in fossil fuel heated greenhouses (Williams, 2007). However, the low carbon flowers extract significant amounts of water from an area of high water scarcity causing a virtual trade of water from Kenya to Europe (Leipold and Morgante, 2013). ‘Circularising’ activities in Europe can help close resource loops where resources are consumed but may not, as in our example, return critical resources (i.e. water) back to the point of production – Kenya. The circular economy must address this virtual trade of resources which is closely linked to the impacts of ‘circularisation’ through space and time.

Q7. Does the terminology we use (‘waste’, ‘resource’, ‘circular’, ‘bioeconomy’) help or hinder our progress towards properly understanding the system?

Many agricultural wastes are ideal raw materials for biological processes to create new products or existing products by new processes, providing a major innovation opportunity for European industry. There are many agricultural material

http://www.agrocycle.eu [an €8 million Sino-EU H2020 project addressing the application of the ‘circular economy’ across the agri-food industry] flows that are perceived as waste in the subjective opinion of the relevant observer, but may be valuable resources in the agricultural system. To overcome this ambiguity, it has become important to categorise agricultural wastes that are generated each year. Many agricultural wastes are unavoidable materials arising from food production systems, typically described as by-products, co-products or residues (e.g. manures, crop residues, leaves, peels). The classification of material streams as 'wastes' or 'resources' has influenced how they are treated, with the term 'resource' highlighting a potential value (in comparison to waste which currently implies it has little or no value and an incurred cost). Livestock manure may be viewed by some as a 'waste', but is a valuable fertiliser for agricultural land due to its value as a nutrient source and soil conditioner. Farmers have also utilised crop residues such as straw to maintain soil organic matter levels and improve soil structure. These examples highlight that classifying what once was considered 'wastes' as 'resources' through recognising and valuing their characteristics, such as incorporating manures into nutrient management planning provides a template for policy to change how the EU recognises and valorises agricultural waste in a circular economy.

Q8. Should we prioritise reduction, valorisation or circularisation and are there situations when these priorities are complementary or antagonistic?

Q9. Are we using the right tools in the right way to assess scenarios and to help develop policy?

It is also necessary to consider whether we can extract more value from the unwanted resource streams (e.g. extracting water, protein and energy) and whether doing this will interfere with nutrient and carbon cycles. Technologies that facilitate valorisation of agricultural organic wastes include composting, anaerobic digestion,

http://www.agrocycle.eu [an €8 million Sino-EU H2020 project addressing the application of the 'circular economy' across the agri-food industry] open-pond bioreactors, pyrolysis, chemical extraction or a hybrid of aforementioned technologies. These technologies have their benefits and drawbacks, such as energy production, carbon sequestration, return of organic matter, nutrient recycling but may also cause environmental damage.

In order to understand which technology pathway should be prioritised for a given agricultural waste or for a specific scenario, a number of tools exist, the most prominent being life cycle assessment (LCA). LCA tools have been used extensively for assessing waste management and are being used now to evaluate the implications of waste valorisation within a 'circular economy'. For the latter use, some of the assumptions appropriate to managing waste perhaps do not apply (e.g. the 'zero burden' assumption). These tools are also open to questioning because of market assumptions (consequential LCA), geographical specificity (available data) and value judgements for interpretation.

LCA has been predominantly used to assess the environmental impacts of a system, but social LCA and life cycle costing are becoming established methods that allow for a holistic analysis of the potential implications of policy. Their integration into life cycle sustainability assessment is as yet under developed. There is also the question of whether or not these tools help us understand critical thresholds, e.g. how much of something we should produce (as opposed to looking at impact per unit production).

Q10. Are we sure that circular economy always uses less resources, or is it just different ones;
does it create more jobs and financial flows within the economy, or just displace established ones, perhaps with less;
are businesses founded on ‘circularising’ agricultural waste long-term secure if the source of that waste is inefficient and will eventually have to be reduced?

The upstream investment in fossil inputs (e.g. fuel, phosphorus, soil) and natural capital impacts (e.g. land use, soil degradation) make reduction, where feasible, a priority to create a sustainable, secure agri-food supply system. However, this is not necessarily compatible with creating a ‘circular economy’ because, with a ‘cradle-to-cradle’ approach, waste in a system can be perceived as a good thing if it creates an economic opportunity. The ‘circular economy’ will benefit by acknowledging that system efficiency is important, and due diligence will require a risk assessment of raw material and resource supplies rather than assuming that if a waste is ‘used’ then the system is in some way more sustainable. A ‘circular efficiency’ approach may be more suitable, whereby upstream inputs are minimised (using precision agriculture) and downstream residues/by-products (manures/crop residues) are ‘circulated’, perhaps where possible via technological pathways to maximise use of hard won protein, nutrients and water.

It is generally assumed that the ‘circular economy’ transition for agricultural materials offers clear benefits to EU industries from an economic, social and environmental perspective. This assumption needs careful thought because it is quite possible that ‘circularisation’ could cause economic and social stress unless properly analysed before implementation.

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