Phosphorus Flows in the Portuguese Livestock and Agriculture Systems: A Roadmap Towards Sustainability

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Phosphorus is an essential element for the support of life on Earth; it forms part of DNA, ATP, teeth, and bones. To maintain the high yields of modern agriculture it is necessary to apply high amounts of mineral fertilizers, which contain phosphorus derived from phosphate rock. As a result of phosphate rock being declared part of the critical raw materials list of the EU, there is growing interest in phosphorus scarcity and food security.

Former studies show that phosphate rock reserves could be depleted within 100 years (Smit et al.,2009; Cordell,2010) and that the peak of phosphorus could take place as early as 2033 (Cordell et al.,2009). Regardless of timelines, it is indisputable that most of phosphate rock reserves are held in only a handful of countries, mainly Morocco, which controls approximately 75% of the world's reserves according to the latest USGS estimates (Jasinki, 2017). The reserves of most producing countries, such as China and USA will be depleted in the coming decades (Cooper et al., 2011). Additionally, increasing demand, lower quality of phosphate rock and the rising of production costs will drive up the future phosphorus price, consequently have a strong repercussion for food costs (Childers, Corman et al. 2011, Metson, Cordell et al. 2016).

Along with being an essential element for life, phosphorus is also a dangerous water pollutant. While at the same time that fertilizers increase agricultural production, they simultaneous increase the load of nutrients in water bodies causing eutrophication: a phenomenon known for causing algae bloom, which depletes the dissolved oxygen in water and can lead to the death of a whole ecosystem. Phosphorus can enter water bodies through point sources (effluents from wastewater treatment plants) and through non-point sources (soil erosion from agriculture or surface runoff due to the application of mineral fertilizers and manure) (Linderholm, Tillman et al. 2012). Based in the Water Framework Directive, the EU demands both the surface and groundwater bodies to reach a 'good chemical and ecological status', which can be achieved by reducing point and diffuse emissions of phosphorus.

Portugal has no phosphate rock reserves and relies entirely on imports of phosphate fertilizers to maintain its required agricultural yields. Consequently, Portuguese agriculture depends on the affordable supply of mineral fertilizers containing phosphorus. For the sake of food security, Portugal should move towards a circular system that would reduce consumption, prevent losses and increase phosphorus-recycling rates (Schroder, Smit et al. 2011, Cordell and White 2013, Abdulai, Kuokkanen et al. 2015).

A crucial starting point for developing a sustainable phosphorus governance system is to compute substance flow analysis (SFA), which determines the flows and stocks of a material-based system. This analysis reports the major processes of the material's life cycle and reveals the main accumulation stocks and losses to the environment (Brunner and Helmut, 2004). Numerous phosphorus SFAs have been carried out on different scales: global scale (Smil 2000, Cordell, Drangert et al. 2009), continental scale focusing on Europe (Ott and Rechberger 2012, van Dijk, Lesschen et al. 2016) and Africa (Cordell et al. 2009), various SFAs at country scale like Australia (Cordell et al., 2009), Spain (Alvarez, Roca et al. 2018), Austria (Lederer, Laner et al. 2014) and Singapore (Pearce and Chertow 2017), and several have focused on the P flows in the agricultural system (Li, van Ittersum et al. 2016, Wironen, Bennett et al. 2018).

The current work aims to study phosphorus (P) flows in the Portuguese agriculture and livestock systems. The study covers a period of five years (2010-2015), uses data gathered from several statistical sources, such as, FAOstat, Eurostat, the Portuguese statistics bureau (INE) and ODCE-stat using the software STAN to model the flows.

The Agro-Livestock system modelled in this work is depicted in figure 1. By analyzing these systems we are able to quantify all the flows (inputs, outputs, and flows within the systems) in relation to the P content. The input flows to the agricultural system are: fertilizers, manure, biosolids, compost and P atmospheric deposition. The output flows of this system are: agricultural production (fruits and vegetables), leaching and runoff. In addition, concerning the livestock system the input flow is animal feed and the output flows are meat-eggs-milk and runoff. Within these systems there are two flows: manure, which flows from livestock to agriculture system, and forage, which flows from agriculture to livestock system.

By analyzing the data for this five-year period we could conclude that the utilized agricultural area (3 668 145 ha) has been maintained at a stable value, although the number of units has decreased, because larger farming units have bought smaller and medium units. The same line of thought can be applied for the livestock system;

the total number of heads has been kept fairly stable, although the number of small and medium units decreased because larger units bought them. The fluctuation in the total number of livestock heads can be explained by the economical crises that hit hard the Portuguese country and due to the implementation of the EU animal well-fare norms (from 2013). Portuguese agricultural yields rely on the use of inorganic fertilizers and for this period of time a P-stock was observed in the Portuguese soils.

The establishment of a sustainable agricultural phosphorus management system can increase resource efficiency use and decrease losses to the environment addressing both issues of phosphorus scarcity and its pollution effects.

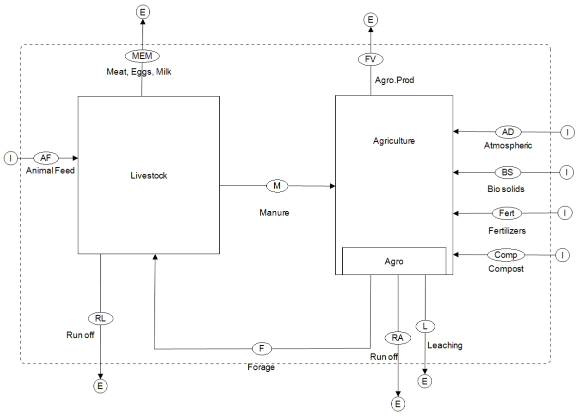

Fig 1: Representation of the Agro-Livestock System under sutudy and main P flows. (I – input flow; E – output flow)

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