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Anthropogenic Material Flow Analysis of Phosphorus in the European Union

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"Master of Science"

supervised by
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Affidavit

I, **LIVIA FÄRBER**, hereby declare

1. that I am the sole author of the present Master's Thesis, "ANTHROPOGENIC MATERIAL FLOW ANALYSIS OF PHOSPHORUS IN THE EUROPEAN UNION", 54 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

The European Union is nearly entirely dependent on imports of phosphorus for its food production, yet there are high losses and wastes in the food commodity chain. There is currently no direct P Regulation or Directive at EU level that would make EU countries liable to its application. This results in unsustainable P practices in the EU leading to environmental and resource related challenges.

Based on previous Phosphorus Flow Analysis, the management of the European Union's phosphorus flows; processes and stocks will be investigated (Phosphorus import into EU; soil, waste management and hydrosphere). The European phosphorus balance will be analysed and presented by STAN, to quantify the losses of phosphorus in the EU15 P cycle.

The main goal and novel part of this thesis is the analysis of current P policies at EU level and the introduction of EU policy recommendations for future EU P policy. Current and potential future European policies addressing the flow "P imports" and the three processes "hydrosphere", "soil" and "waste management" will be analysed, determining how effective current P policy is in tackling challenges regarding environmental protection and resource availability in the EU. According to the analysis of the EU P Balance, the over application of P on EU soils pose the greatest environmental challenges. In order to overcome the current unsustainable use of P, the EU must firstly implement agricultural policy directed at the use of P at farm level, based on contemporary farming technologies. Subsequently, the application of agricultural policy, as estimated in **Figure 1,** will have the greatest effect on the hydrosphere and import of P. The recommended policies for the flow "import" and the three processes "soil", "waste management" and "hydrosphere" are estimated to reduce 45% of excess P import to the EU.

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‘‘We may be able to substitute nuclear power for coal, and plastics for wood, and yeast for meat, and friendliness for isolation—but for phosphorus there is neither substitute nor replacement’’ (Asimov, 1974).

1. Introduction

1.1. Background and Problem Definition

P is an indispensable, non-renewable and non-substitutable element. It is fundamental for plant growth and crucial for every known living organism.

It is needed for nerve functions, muscle contractions and to build bones and teeth. Furthermore, phosphorus is a component of each cell's genetic material and adenosine triphosphate, which is essential for protein synthesis and energy metabolism

The EU currently faces three main challenges regarding P. Firstly it completely depends on P imports, as there is only a small P mine in Finland. In 2008 92% of EU P was imported (Council Regulation (EEC), 1992). The EU also has a high demand of P due to the high-density population and food production. Due to intense agricultural farming, the EU also faces various environmental challenges such as eutrophication. (Withers et al., 2015) P that is currently economically feasible to extract, is most commonly found in four countries in the world (Morocco, Algeria, Israel and Russia). The instability in various regions in some of these countries coupled with future availability of high grade P, leads to various geopolitical implications in the future. The risk to Europe's security of phosphate supply is therefore a serious matter, which however has rarely sparked intense political fervour in the past.

Phosphorus is a critical resource in the EU and it has been argued that currently economically extractable P will be depleted by 2050-2070. Although this is a subject open to much debate, there is an overall consensus that there is a critical need to develop methods that will encourage the sustainable use of P in the future to ensure food security in the EU.

As well as being a critical element for food security, the lack of appropriate management of P leads to numerous environmental challenges. Excess P that is transported into surface waters due to erosion; exceptionally on agricultural land that has been treated with P fertiliser and manure, lead to eutrophication and a very high accumulation of P in EU soils (Bomans et al., 2005) Soluble P can be transported with runoff water during rainfall, and can also enter groundwater by leaching; causing further detrimental effects such as death of biodiversity and pollution of potable water.

The use of Phosphorus is inefficient. According to Brunner and Baccini merely 10 per cent of P applied in agriculture is contained in the food and large losses occur to the soil and hydrosphere. (Baccini & Brunner, 1991)

Currently there is no regulation regarding the sustainable use of P at EU level, which poses further serious implications on the environment and on resource availability in the near future. Furthermore, P was only included in the list of critical raw materials in the EU in 2013.

There is a linear flow of P along the anthropogenic P chain, which causes most of the detrimental environmental and food security challenges. This is a result of inefficient nutrient management along the process, where at end of the chain it is landfilled or disposed of into the hydrosphere. Furthermore, almost 100% of the phosphorus consumed in food is directly excreted, but until now only a very small amount of the human excreta is actually treated for reuse and either ends up discharged to water as effluent or non-agricultural land as landfill. (Schröder et al, 2010)

The lack of recycling and reuse of P in further food production needs to be dealt with to reduce further unwanted impacts.

The EU is lacking in efficient policies aiming at forming a cycle for P where it can be recovered and reused in order to reduce P losses and therefore also reduce environmental impact. There is a general lack of policies that are aimed at diffuse sources such as agriculture and there is also no EU legislation aiming directly at the sustainable us of P. Most EU countries have no regulations regarding P use. At EU level there are only general water Directives in existence that have a minimal **indirect** effects for the use of P in the EU.

The EU needs to implement stringent regulations directly aimed at P recycling technologies in order to become less dependent on P imports, for its food security in the future. As there is no EU level policy on P apart from directives, each member state is left to meet stated objectives. Furthermore these are subject to very little monitoring and therefore don’t result in a positive outcome.

In order to reduce existing environmental challenges posed by the lack of P management in the EU, EU policy must focus on the agricultural sector as it causes the biggest leakages. Even though the EU has implemented various agricultural programs that are directed at P inputs in agriculture there is still no coherent and efficient recycling policy implemented at EU level.

Europe is affected by environmental as well as economic aspects of the P challenge. In 2007-2008 prices for phosphate rose 700%-800% and China introduced an export duty of 110-120% on Phosphate rock (Minemakers Limited, 2008)

In order to prevent environmental, economic and resource scarcity challenges in the future, it is imperative that policy makers focus on agricultural policy (the main culprit for P leaching) and the recycling and recovering of P policy at EU level to overcome these challenges.

Only a couple EU member states have signed multinational environmental agreements that relate directly to policy considering nutrient flows. Most of them aim at the protection of aquatic resources and incorporate nutrient management in the aquatic environment. The European member states currently have some legislation on P but strict policies are only being exercised at state level not on the EU level.

The persisting application of new imported P and applied in form of fertiliser causes an end of pipe loss throughout food production and consumption. Present market mechanisms overall encourage over application rather than cautious application and effective reuse such as the utilisation of various P recycling technologies to improve nutrient recycling. This problematic issue is exacerbated because most of the effort is set to combat the leaching of Nitrogen, little effort is put into recycling technologies regarding P and most of the environmental and agricultural existing instruments are based on the definition that nutrient over application is considered a pollution challenge instead of looking at it from a resource management and recycling perspective.

Overall, there is a lack in European legislative frameworks concerning P recycling. Existing approaches to improve the management of P at EU level are based on action plans and optional strategies farmers may use, however there is little emphasis regarding P recycling at policy level which is a critical aspect.

1.2. Research Questions and aims of the Thesis

The main aim of this thesis is to **1.** analyse the role of **EU policy** in P management of the flow “Import”, and processes, “Hydrosphere”, “Soil”, and “Waste Management” and **2.** Introduce P policies that will substantially improve the following challenges:

EU P dependence in the future

Resource related challenges

Ecological impact

Food security

Firstly, challenges related to inefficient P management in the EU will be examined. This will be represented by a Material flow analysis of the EU P budget.

The policy recommendations will be based on preventative and recycling strategies. In order to step away from the current P management practices that are based on disposal and landfilling methods.

The main goal of this thesis is to demonstrate how policy recommendations will affect the flows and the three processes and will therefore improve the main P challenges stated above.

In order to present the two scenarios of applicable P recommendations, a Material Flow Analysis of P cycle in the EU is used to illustrate the current anthropogenic cycle of P. This system demonstrates the flow “Import” and processes “Soil”, “Hydrosphere” and “Waste Management” in the human induced anthropogenic cycle in the EU and demonstrates where management of P is essential.

The final goal is to close the anthropogenic P loop by changing the linear unsustainable P flow in the system, to a circular economy, by reusing P. This will eventually lead to environmental improvement in soil, hydrosphere, towards food security in the EU and decreased landfilling of P.

2. Methodology

The theoretical section of the research is based on current and past European Union legislation, policy measures, and action plans regarding the direct and indirect effects of Phosphorus use in the European Union.

To provide an adequate plan for limiting the impacts of P over enrichment necessitates an understanding of the sources and transport mechanisms for this nutrient and how human actions impact this nutrient over enrichment. MFA illustrates this precisely in every step in the system.

The Material Flow Analysis for the system EU 15 was illustrated, (Brunner & Rechberger, 2004) based on the data on the EU15 Phosphorus budget (Ott & Rechberger, 2012)

The MFA illustrates the critical processes and flows of P in the European Union. Moreover, it identified where efficient management of P in the anthropogenic metabolism is needed and where policy measures need to be applied in order to overcome current environmental and resource efficiency challenges.

The study demonstrated that critical loops could be identified with the MFA through the analysis of the EU metabolism.

In this research, MFA serves to illustrate and estimate the flow “Import” and the three processes “Hydrosphere”, “Waste Management” and “Soil” in order to make an estimation of how the application of new EU policy may improve the current P situation in the EU.

2.2. Phosphorus

Every living organism relies on Phosphorus to carry out its basic functions. It is a key player in fundamental biochemical reactions, involving genetic material (DNA, RNA) and energy transfer (ATP) and in structural support of organisms provided by membranes and bone. (Ruttenberg, 2003) Mineral phosphorus in rock phosphate was formed ten to fifteen million years ago, (White J., 2000) and comprises 0.08%-0.13% by weight of the earth crust (Buecker, 2000) making it the 11^{th} most abundant element in the earth crust and also the 6^{th} most common element found in the human body.

Phosphorus as well as Potassium and Nitrogen are a central component of fertilisers in the modern era and it is impossible to produce current food supplies without the help of phosphorus fertilisers.

Approximately 17.5 Mt of P is mined in Phosphate rock each year. The largest amount is for food production 82%, feed 5%, and detergents 10% therefore approximately 14.9 Mt per year is processed into phosphate products (European Commission, 2015) However, only a minor percentage of P exists in high enough concentrations to be utilised by humans for producing fertilizers (Smil, 2002)

The declining accessibility of high quality rock phosphate in addition with a predicted population rise of 9 billion in 2050 due to the consumption habits, especially the increasing intensive farming of animals, poses an alarming food security threat in the future.

The natural global phosphorus cycle has four main stages. *Tectonic uplift and exposure of Phosphorus bearing rocks to the forces of weathering, physical erosion and chemical weathering of rocks producing soils and providing dissolved and particulate phosphorus to rivers, riverine transport of phosphorus to flood plains, lakes and oceans and sedimentation of phosphorus associated with organic and mineral matter and burial sediments* (Ruttenberg, 2003)

Human beings have severely altered the natural phosphorus cycle. Currently there is a severe conflict between social development and the ecological environment, stemming from the anthropogenic interference in material flows.

It has been disputed that the intervention of man-made material flows in the present day is far more intense than that of the natural cycle.

At the planetary scale, the additional amounts of Phosphorus activated by humans is so large that it significantly perturbs the global cycle of this critical element (Carpenter & Bennet 2011)
Furthermore, the root and footpath of the processing of flows by humans is very complex. Currently, our natural ecosystems cannot sustain the growth and the pace of economic growth and development.

In order to solve the conflict between human economic development and protection of the natural ecosystems it is impertinent to methodically reflect on human mechanisms of material flows thus integrating the economy with the sustainable treatment of the natural environment.
The constant growth of the agricultural sector, land and its intensification has led to the soils depletion of important nutrients, which has augmented the need for synthetic fertilizers. This has caused the natural cycle of phosphorus to break up and a surplus in stocks of phosphorus globally that end up in the hydrosphere, causing detrimental effects due to eutrophication.
The global use of P is uneven and so the environmental impacts are also uneven, different types of ecosystems have a distinct level of vulnerability towards excess P and therefore it is impertinent to reflect on this and integrate sustainable methods accordingly.

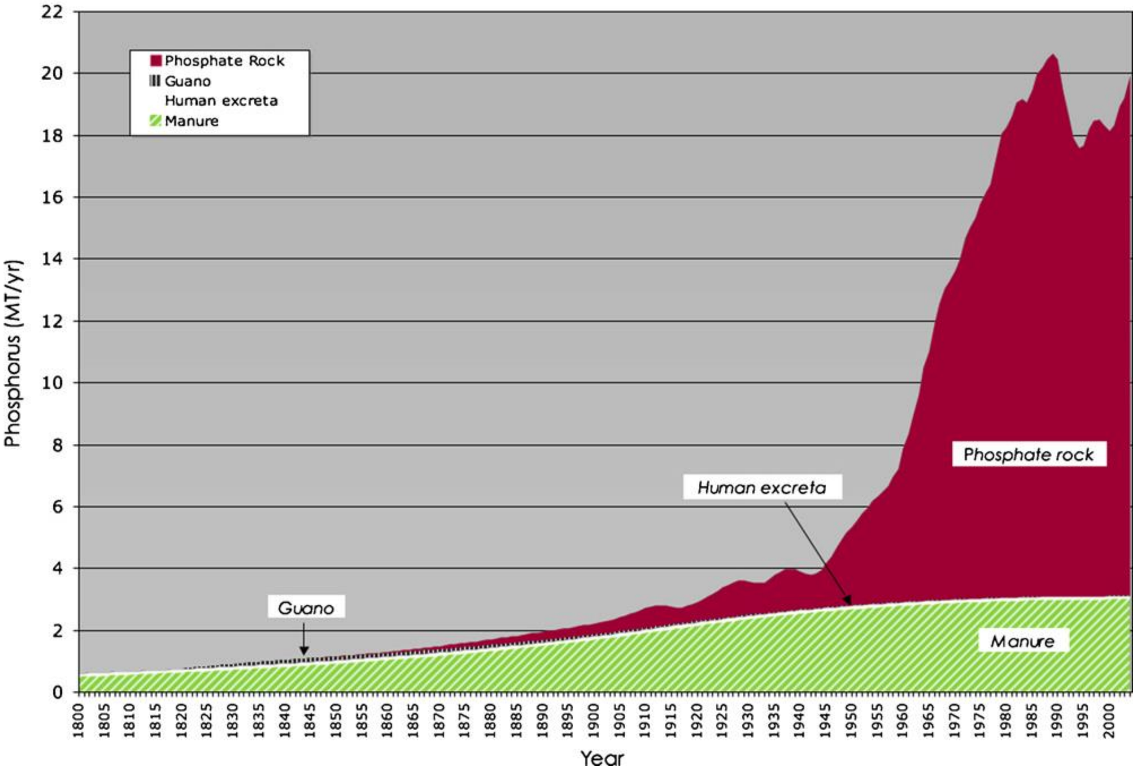

Figure: 1 Historical sources of phosphorus for use as fertilizers, including manure, human excreta, guano and phosphate rock (1800–2000) (Reliability of data sources vary, hence calculations based on data in (Brink, 1977)**,** (Buckingham & Jasinski, 2007)**,** (IFA, 2006)**.**

Approximately 90% of mined Phosphorus is used for fertilizer, to grow food for human consumption or to produce fodder (Rosmarin, 2004). The trend in the diagram above demonstrates how P has been extracted mainly from sedimentary rock. In the beginning of industrialization in 1950 the extraction of Phosphate rose extremely due to high population growth, rising from 2.5 billion and reaching 7 billion respectably, substituting guano and human excreta.

Phosphate rock resources are presently found as sedimentary marine phosphates. The biggest sedimentary deposits are obtained in Northern Africa, China, Middle East and the US.

According to the US geological survey, the production of Phosphate rock capacity was expected to rise from 225 MT in 2014 to 258 MT in 2018. Consumption of $P_2 O_5$ present in fertilizers was estimated to rise from 42.2 MT in 2014 to 45.9 MT in 2018.

The greatest increase in P extraction is predicted to be as a result of the expansion of mines in Morocco and mining in Saudi Arabia. (U.S. Geological Survey, 2014) .

When the whole world depends on mostly four countries for its P supply, the geo-political implications that arise become a great concern. Also, the decrease of quality phosphorus, which is economically feasible to extract, (without large amounts of indirect pollution) is another issue that will have to be faced with in the near future. The current known supply of inexpensive high quality P is gradually becoming scarcer while demand is constantly rising due to population growth.

According to the US geological survey there are 70 billion tons of high quality and easily extracted phosphorus in Morocco and Western Sahara. Further on, estimates of new potential mines are being investigated, however the quality of these necessitates additional assessment. If the concentration of P in the rock decreases and there is an increase supply of P to acquire a given amount then costs for production will increase. Such fluctuations might possibly lead to more energy use and further production of waste. This can lead to many negative effects hence to produce one ton of phosphoric acid, four and one half tons of the byproduct phosphogypsum is produced. This also increases the price of P fertilizers, restricting their availability to a lot of farmers and also causing adverse effects on yields. (United States Environmental Protection Agency, 2011) Peak phosphorus is expected to reach at an estimated population growth reaching 9 billion in 2050. There is a general consensus that there will be a much higher demand of phosphorus in the future due to population growth with decreasing quality phosphorus and with more indirect environmental implications.

The EU is P dependent and most of the imported P rock is transformed to fertilizer, and used on agricultural fields, which the EU depends on to produce crops and economically viable yields.

It is applied as a mineral fertiliser in agriculture in the EU, as natural rock Phosphate, NPK mixtures, super phosphates and organic fertilisers such as manure, compost and sludge. (Bomans et al., 2005) Carbon, Phosphorus, Nitrogen and in some circumstances Silicon are nutrients that cause eutrophication, but because P is the limiting nutrient in the fresh water environment, it draws the most concern.

Elevated amounts of P, the limiting nutrient for algal growth, in most inland surface waters are exceptionally challenging. Although there has been a decrease in P leaching in industry and wastewater treatment plants due to improved P removal technology, agriculture is now mainly the main contributor to P leaching into surface waters in the EU (European Environment Agency, 2005)

An increased concern for the aquatic environment has risen in the EU due to the growing concentration of nutrients causing detrimental changes in the freshwater environment.

In the last half century, P stocks in the hydrosphere and terrestrial systems have augmented by at least 75% while the approximate estimate flow of P to the ocean from the total land area has increased to 22 million tons per year (Bennett et al, 2001) This total is greater than the worlds annual consumption of P estimated at 18 million tonnes in 2007 (FAO, 2014). While much of the phosphorus accumulated in terrestrial systems would finally be available for plants, there is no way to recover P that has been lost to the aquatic systems. In the hydrosphere, a surplus of P causing eutrophication, contributes to excessive algal and aquatic plant growth along with negative impacts on biodiversity, water quality, fish and the recreational value of the environment. Algal blooms can include species that allow toxins that are dangerous to humans and animals be released, while decomposition of algae, can reduce dissolved oxygen levels causing mortality among aquatic species (Carpenter, 2005).

Human generated nutrient over enrichment pushes aquatic ecosystems outside the limit of the natural threshold, causing abrupt shifts in ecosystem structure and functioning (Rockström, 2009).

According to experts quantifying global P flows in the food production and consumption system, estimate that the flow of P prior to increased human agricultural and industrial activity was approximately 8 Tg p/y $^{-1}$ and has increased to 22 Tg p/y $^{-1}$. Current human activities therefore cause an extra 14 Tg p/y $^{-1}$ flow into the ocean sediment sink each year (National Academy of Sciences, 2000).

Furthermore, FAO predicts that the world demand for fertilisers will keep rising with population growth. It specified that fertiliser use demand would increase from 43.8 million t/a in 2015 and to 52.9 million t/a in 2030 (Tenkorang, 2008).

Indirect implications regarding mining and processing will also have future implications, as high quality P is becoming scarcer and the P in Morocco high in cadmium and other known pollutants. This will lead to high costs for

2.3. European Union and the Anthropogenic Metabolism

Historically, nutrient flows in the food commodity chain had completely different implications. Food that was produced, relied on the natural level of soil phosphorus, and on the locally available animal manure and human excreta (Cordell, 2008)

Human excreta was applied on crops in Japan as early as the 12 century and also the Chinese used human excreta as a fertilizer from the early beginning of their civilization (Matsui, 1997). Food was grown, eaten and discarded in a close proximity of each other and what was left over was brought back to the soil and therefore recycled.

Due to the rapid population growth in the 20th century reaching seven billion, guano and also Phosphorus was then used in agriculture to produce sufficient food.

In our modern era the physical separation of the production, processing and consumption of food has produced a liner flow of nutrients from field to fork. The ongoing application of phosphorus through imported phosphorus as fertilizer creates an end of pipe loss both during the production and consumption of food.

The famines that occurred in Europe in the 17th and 19th century led to the increased need of supplementary fertilizers to produce enough food for humans. By the increase of better agricultural techniques and the use of additional fertilizers European agricultural quickly recovered and became very productive.

The mineral theory by Liebig, a scientific explanation of how nutrients such as phosphorus were elements that circulated between dead and living material, (Cordell, 2008, S. 20) replaced the former humus theory that plants and animals were given a life in a mysterious way from dead plants and decomposing animals (van der Ploeg et al, 1999) this took place in a time of rapid urbanization in Europe when fertilizer factories were beginning to flourish throughout rising dense cities. Factories manufactured phosphorus fertilizers from locally available organic waste products such as human excreta, industrial organic waste, by products, animal dung, fish, ash, and bones and other slaughterhouse by products (Cordell, 2008, S. 25). It was in the mid ninetieth century that locally available organic waste products were replaced by phosphate rich rock and guano. The use of guano however declined in the late 19th century due to scarcity. The use of phosphorus flourished, due to it being perceived as an unlimited resource. The introduction of the modern flush toilets in the cities in the eighteenth century resulted in human waste ending in water bodies and not carried back to the soil.

In the nineteenth century Phosphorus fertilizer was applied regularly and the amount used grew steadily until the twentieth century, which on the one hand helped restore deficient phosphorus soils. Agricultural output generally improved and increased with the green revolution, which involved the use of phosphorus fertilizers. The use of fertilizers which in turn increased crop yield and therefore food, saved millions from starvation and even though population was rising, there was a decrease in starvation. It would be impossible in our modern society to produce food at the current rate without the use of fertilizer.

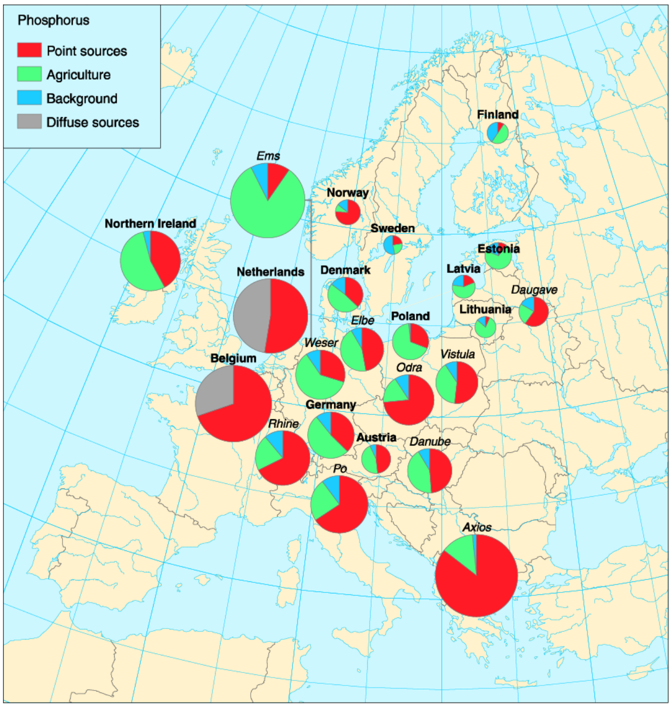

Figure 2: Phosphorus loading in EU (FAO, 2014, S. 5).

2.4. Phosphorus Policy Imports

Each EU state has a different agenda regarding P imports, which generally depend on particular local factors and drivers. Imports in the EU as an integrated entity however are largely predominated by concentrated products for the fertiliser industry.

It is predicted that in the near future the EU will be faced with geopolitical turmoil in supplier regions, with a transition of an international sphere with more prominent state capitalist tendencies, hence leading to more access restrictions, trade barriers, and export quotas as result of protectionism and “resource nationalism”. For a long time in non-democratic countries, the government was in control of the resource sector; however this has now become more predominant in liberal states too, generating a probable future decrease in phosphate rock exports into the EU. The EU mostly relies on its P imports of Phosphate rock from Morocco, Russia, Jordan and Algeria.

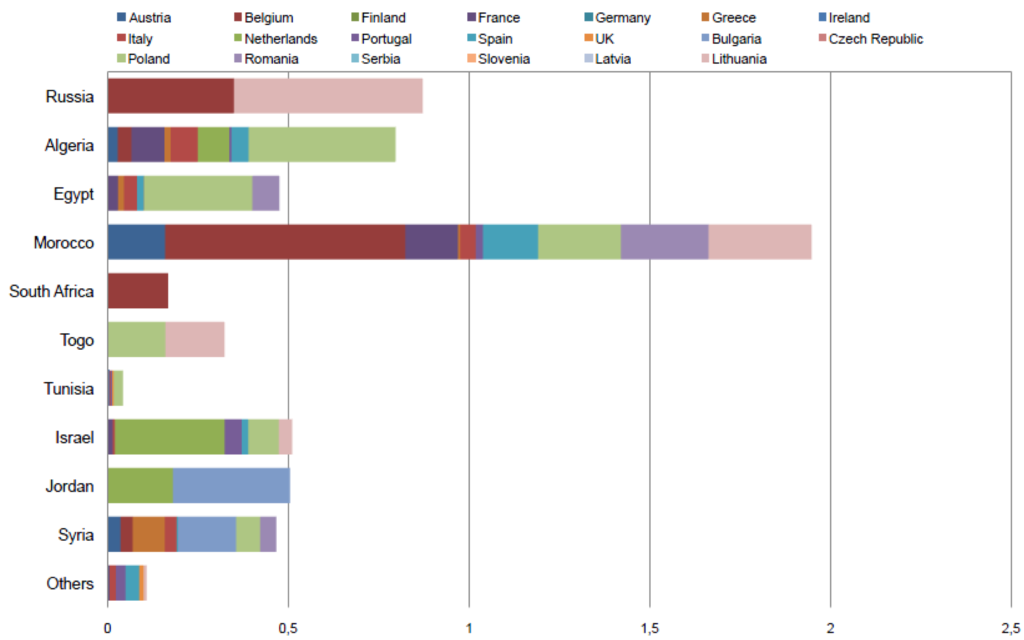

Figure 3: Imports of Phosphorus into the EU

The future availability of P will depend on the size and availability of phosphate rock reserves and on the newly uncovered reserves.

The demand of P and its scarcity has turned large producers into buyers. China and the United States have large reserves of P and in the past have been exporters of phosphate rock globally. Due to the rise in the demand of P domestically, it has turned them into net importers. The United States and China are developing policies to protect their domestic reserves in the future and the fact that they are becoming net importers, suggests that there will be much less competition on the supply side and much more on the demand side, hence for the EU. (A changing Global Phosphate Market-Trends and Developments) Therefore, it is quite clear that Phosphate rock is no longer a resource regulated by the market and free trade, it is continuously subject to new policy strategies, government control and state owned firms. In order to protect its domestic phosphate rock reserves, as a result of widespread alarm with future food security, Chinas ministry of commerce has emphasised that Phosphorus is “Chinas third most important strategic resource”. Furthermore China reduced its Phosphate rock exports by 60,000 tonnes from 102,346 tonnes in 2005 to 39,665 in 2010 (china economic review). Furthermore, as a result that china decided to carry through with its halt on Phosphate exports, against the rulings by the WTO, (and also carried on to impose another export quota in 2012), implies that China will continue to limit its exports of Phosphate in the future, which further on implies that prices on P imports into the EU will continue rising in the near future.

The growing result of state intervention will also lead to the increasing power of only a couple suppliers control over the complete Phosphate rock industry. This can be seen from a shift from many small producers control over Phosphate mines to only a couple owners, encouraging the formation of oligopolies. In case of OCP (the state owned Moroccan firm which already is the biggest exporter of Phosphate worldwide), in the future possibly controlling 80-90% of the total Phosphate exports could set unstable market prices increasing price volatility. Significant changes and progress in the Middle East and North Africa, which the EU depends on for its supply of Phosphate, will be extremely significant.

Furthermore, the process of mining relies on huge amount of water throughout all the process, therefore water scarcity will have enormous future effects on the price of P, as many Phosphate producing regions are subject to water scarcity. The predicted population growth according to UNEP will cause one thousand eight hundred million people living in regions with total water scarcity. The competition for water therefore will develop new technologies such as desalination techniques, which will be extremely costly due to energy use and will therefore also have a future effect on EU imports of Phosphate.

2.5. European Union and the Common Agricultural Policy

Agricultural policy relies on EU policy framework. The treaty of Rome (1957) set up the common agriculture policy's framework, however environmental sustainability was not mentioned due to the fact that the main interest of the European Union was to increase agricultural productivity and increase farmer's income. The Single European Act (1987) founded for the first time a legal requirement to include environmental sustainability and protection into certain policy areas. It was only in 1992 when a common agricultural reform took place, also known as the Mac Sharry reform when the environment was taken into consideration as a major objective for the European Union. The Maastricht treaty coming into force in 1987, made these environmental objectives and requirements more effective, in further integrating them whilst representing the new concept of "sustainability".

The fifth environmental action program a notable political force, adopted by the European commission in 1992, in which the protection of the environment was identified as an essential constituent in the process of developing the European Union. The program covered the time between 1993-2000 in which agriculture is one of the five target sectors. This program sets the foundation and objectives of retaining the most fundamental and basic natural processes essential for a sustainable agricultural sector, through the conservation of water, soil and genetic resources. The program also sets specific targets to control chemical inputs, to achieve a balance between nutrient inputs and the absorption capacity of the soil and plants, to encourage rural environmental management practices, to conserve biodiversity and natural habitats and to minimize natural risks (Brouwer & Lowe, 2000)

The European Fertilizer Manufactures Association stated that even though it does not explicitly state that the reuse of human excreta could be a possible future option for an agricultural fertilizer, instead of Phosphorus fertilizer, it states that the two main opportunities for increasing the life expectancy of the world's phosphorus resources, are dependent on recycling by recovery from municipal and other waste products and in the efficient use in agriculture of both phosphatic mineral fertilizer and animal manure (Johnston & Steen, 2000, S. 5)

Phosphate rock and fertilizer demand boomed and exceeded supply in 2007-2008 which lead to the price increase of phosphate rock and fertilizer by 700%. (Minemakers Limited, 2008, S. 23) The main factors responsible for this are the increased demand in meat and dairy based diets and the biofuel industry.

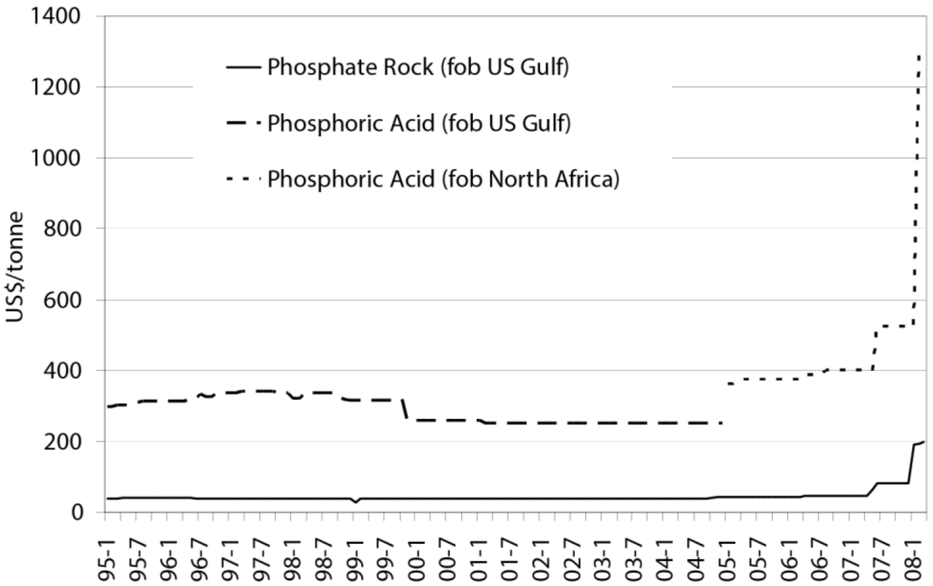

Figure 4: Phosphate Price Development (von Horn & Sartorius, 2012)

The price of P is determined by the supply and demand. The current P reserves that are used for P fertilizers are decreasing in quality and quantity. The mining of deeper soil layers leads to higher production costs and phosphate rock is increasingly contaminated with heavy metals such as cadmium and uranium. It is becoming less economic to mine P at current prices and therefore the price of P can be seen as continuously rising. (von Horn & Sartorius, Impact of Supply and Demand on the price development of phosphate, 2009). The environmental challenges that P extraction causes, further explains the reason why P prices are increasing rapidly. "Since 2007 the supply situation is tight due to production capacity shortages" (von Horn & Sartorius, 2012, S. 3) However, the main reason for the increasing price of P is the rising population and the need to produce more food every year, with an increase of population in 2030 estimated to be 9 billion. The rise in the price of oil also has a strong influence on the price of P, as well as the increase costs for transport. The processing step is becoming more complex as P mined is becoming more contaminated and also, the production of P requires ammonia, which is greatly influenced by the rising energy costs. The contamination of phosphate also causes future challenges, as decontamination processes are costly. The continuous mining will inevitably increase the heavy metal content. Future fertilizer demand mainly depends on population growth. It is estimated that population in 2030 will rise to 9 billion this amounts to a 20% increase and demand of P fertilizer. The nutrition is also predicted to change due to the growth of the average income in developing countries. The increasing future consumption of milk products and meat will further increase the demand of fertilizer.

Another factor contributing to the future demand of P is the increase production of agro fuels. The EU stated that its goal is to increase the amount of agro fuels used in transportation by 10% by 2020. It is therefore questionable if the use of future agro fuels is environmentally sustainable taking to account GHG emissions, land use change and water demand. If EU policy remains to consider the increase use of agro-fuels in the future this will have a very high impact on the future demand of P and therefore on the price.

Agro fuels are expected to supply 20% transportation fuels by 2020. Because of this, it is estimated that agro fuel production will amount to 300 million tons in 2030. This expected prediction would result in the demand of 21 million tons of fertilizer. This according to FAO will result in total of 13% of the entire fertilizer demand of 166 million tons in 2030.

Phosphate is not traded globally. Fertilizer companies commonly have a long lasting contract with P mines.

The price of P rock has continued to be the same at 30$/t throughout 1990. However in 2006 it rose by 4.6$/t and finally it increased immensely to 200%/t in 2008. The reason for the increase in demand for P can be generally attributed to the demand for phosphate fertilizer. It is the absence of the potential to produce more P that leads to the increase in price in the long term. Recently, the price for P has risen steadily due to the rise in price of oil. The increase in price of oil indirectly has an effect on the price of P due to transportation costs. The predicted increase in price for transportation will have an inevitable effect on the price of P in the future. It is predicted that it will increase up to 20% for P rock import in the EU. Whether there will be an increase in price as a result of P availability and reserves is subject to much debate as it is also argued that existing reserves do not currently pose a danger of P availability, and it will therefore not lead to any notable changes in price for the next seventy years.

The predicted price of P fertilizer is expected to rise by 1% annually, however if the use of agro fuel will increase as predicted then this in return will increase the price of P by 2% as agro fuels will result in 20% of the entire agricultural production.

2.6. EU Policy on Soil

Fertiliser related legislature in EU member states differs greatly from region to region. Only a couple member states have strict limitations on P application on agricultural land whereas most countries have no legislative protection at all and rely on voluntary measures that are part of the Common Agricultural Policy, on the limits of manure use, the Nitrates Directive, or Water Framework Directive, and in this way indirectly limit the use of P on soils.

Only Flanders, (Belgium), Sweden and Netherlands have strict legal national restrictions on P application. Legislation considering application of fertilisers exists as a means to comply with the Good Agricultural Practices that are part of the Nitrates Directive, the codes of usual Good Farming Practices, or with the Cross Reference Practices.

Overall, very few member states have detailed legislation on the protection of soil and the EU has no direct legislation on P use. Soil has not been a question and issue faced with a comprehensive and coherent set of policy strategies in the EU. Currently existing policies in the EU that focus on water, waste, chemicals and agriculture contribute indirectly to the protection of soil thus P policies are integrated mainly in agro-environmental policies such as policies addressing mitigation strategies of soil erosion and reduced fertiliser use. However, since these policies have other aims and goals, they are not appropriate to ensure an acceptable and satisfactory level of soil P management in the European Union.

P is perceived as a pollutant rather than a nutrient that should be recycled.

“Initiatives that are directly focused on P efficiency, and recovery remain scattered and are rarely considered in policy development” (European Commission, 2013)

An exception to this is Sweden, where a temporary target was to recycle 60% of the P present in wastewater by 2015 and apply it on productive and arable land. Also, in the Netherlands various stakeholders have agreed to make efforts to reuse P in their manufacturing processes. Germany also announced that it would make efforts to introduce policy measures on reducing the waste of P by 2015.

However, generally there is a lack of regulatory framework and more effort has to be invested into setting policies concerning the reuse and recycling of P in the EU in order to attempt to close the P anthropogenic cycle.

The main focus firstly will be to analyse and focus on soil **directives**, as there are no currently existing EU **regulations** on Phosphorus. **Regulations** have a general application and are legally binding in its entirety. Directives also play a significant role as they have a legally binding effect but as oppose to **regulations,** the manner of implementation is left to the national member state, meaning that the EU member state may apply any method to achieve the results required. Secondly, the various action plans that consider P management will be analysed.

Also it has to be taken into account that the quality of soil has a direct impact on the hydrosphere therefore correct policy application towards the sustainable management of soil indirectly impacts the well-being of the hydrosphere. It also has to be noted that policy on water management and soil management combined with recycling strategies will have an effect on imports of P as a reduction is likely to happen. Therefore policy measures applied for P cannot be looked as single measures to combat environmental impacts of P but have to be seen as measures with a chain of effects that impact the whole anthropogenic P cycle.

In 2002 the 6th Environmental Action Programme introduced the Seven Thematic Strategies in the EU, of which one thematic strategy was dedicated to soil. It was the first time that the commission introduced a proposal for a directive on soil in the EU, which consisted of goals tackling the various challenges and dangers concerning soil, while creating a common EU framework.

It was only in 2006 that the commission adopted the Soil Thematic Strategy, with the goal of integrating a sustainable programme in order to protect the soils in the EU.

The primary goals of the Soil Thematic Strategy was firstly to attempt to stop and reverse the process of soil degradation and ensure that the soils in Europe will be healthy for the next generations and continue being proficient in supporting the ecosystems.

The second significant goal was to increase the public's understanding about soil sustainability, integrating soil protection into national and EU policies and lastly, setting up a legislative framework to protect soil. This legislative framework (**Soil Framework Directive)**, would have been a legally binding, enforcing document, making all the EU member states liable to its application and therefore allowing EU members to implement procedures adapted to their local needs and delivering measures to identify challenges, inhibit soil degradation and remediate contaminated or degraded soil. However, the Soil Frame work Directive was blocked by a minority and therefore failed to enter into force as will be discussed further on.

The third document of the **Soil Framework Directive** would have played a crucial role in the creation of a sustainable soil plan for the EU regarding P and N as it consisted of an obligatory Impact Assessment SEC (2006) for every legislative proposal, making every EU member responsible in reporting the benefits of the sustainable treatment of soil and the cost of non-compliance. The impact assessment would have been the first step in providing soil related scientific evidence and translating it into policy-making strategies. The legal aspect of the Directive making all EU countries liable of its application could have potentially been a leading step towards improving the status of soil regarding P in the EU.

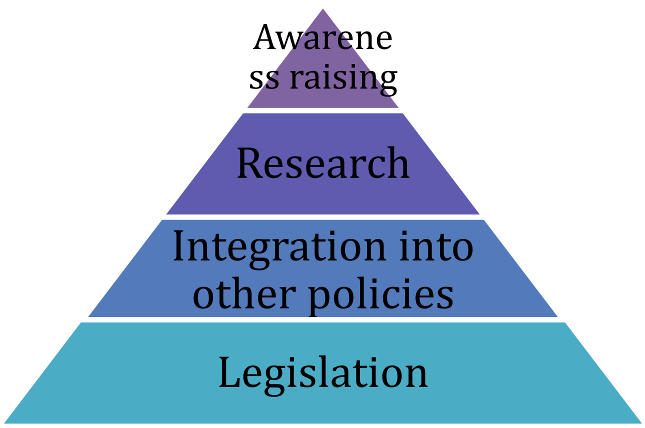

Figure 5: Four Pillars of the Soil Thematic Strategy

2.6.1. Legislation

The basis of the framework consisted of introducing and adopting EU soil framework legislation, the **Soil Directive**, (which failed to enter into force). The Soil Directive consisted of underlining the importance of public awareness concerning soil sustainability, by farmers and also the overall public. It emphasised the need to increase the knowledge among all parties in the agricultural sphere about the benefits of sustainable soil and nutrient management, together with dangers that are associated with decreased soil organic matter content. Also, its goal was to increase the awareness of daily farm practices that concern the principles of farming strategies that could be taken to decrease nutrient and soil organic matter at farm level. Thirdly it gave an instrument to farmers that would reinforce sustainable nutrient management, to improve the effective implementation of sustainable soil and nutrient management in daily farm habits.

The goals of the Soil directive, in the light of P management objectives, could be outlined indirectly in two consecutive strategic plans. Firstly in informing farmers about the sustainable farming practices, that consider nutrient and soil organic matter management and secondly, by informing farmers about sustainable farming, to consider that the management of sustainable nutrients (such as P) and soil organic matter management not only depend on the correct use of fertilisers but it consists of the management of every process happening at the farm level (Crop rotation and tillage practices). Farmers would then be informed about sustainable farming practices that they could apply at their farms.

2.6.2. Integration into other policies

The second pillar consisted of systematically integrating soil protection criteria into other soil relevant areas such as the Common Agricultural Policy (which covers 40% of EU budget).

One of the most significant aspects of this pillar was the EU compliance scheme procedure of possible sanctions by cutting farmers subsidies if the correct farming practices were not applied.

2.6.3. Research

This pillar focuses on the importance of improving research activities on the functioning of soil, at EU level, especially in areas where more information and research is needed, in particular in soil ecology and soil biodiversity.

It emphasises the need of investment in this important sector and introduces future possible needs in investment in soil related projects. It also emphasises the need of positive cooperation between states regarding research on soil, and the integration of P sustainability by all stakeholders in the P cycle.

2.6.4. Awareness Raising

Awareness raising addresses the fundamental lack of awareness of EU citizens, including EU policy makers, about soil degradation in the EU.

This pillar emphasises the importance of wide spread awareness about soil to non-experts, as it stresses that without this, it will be impossible to succeed in improving and supporting soil sustainable management and protection in the long term. The lack of awareness of EU citizens about soil protection was observed by the outcome of the EU wide public consultation online survey that was introduced in 2005, to improve the commissions understanding of EU citizen's perception about soil protection. It was introduced before the Soil Thematic Strategy came into existence, to understand EU public thoughts on the most crucial aspects of soil management. According to the survey, soil contamination was seen as the first problematic area on the agenda, however there was a general lack of knowledge in the recycling of nutrients and nutrient management in general. The survey pointed out to a lack of awareness of non-experts and a general lack of public knowledge about the importance of recycling of P to reduce environmental impact.

In 2013 the commission made a statement declaring that the directive has been pending during eight years, during in which no effective actions were ensued. The proposal was repeatedly examined but continually ran into a blocking minority and in 2014 the commission therefore withdrew the proposal. The Directive failed to enter into force and could not be implemented.

However the Commission stated that it was committed to the goal of the proposal of taking further actions towards the sustainable use of soil and it is impertinent to reconsider adopting a new strategy.

The failure to implement the directive had many consequences relating to the sustainable management of P. One of the main objectives of the Directive encompassed compulsory identification by EU members of erosion endangered areas, salination and landslides, compaction and organic matter decline which would have a major effect on anthropogenic P cycling.

EU member states would then have been obliged to set objectives and adopt management strategies to diminish these risks and to report its effects. Member States would also have needed to take measures to control soil sealing and diminish its effects. The proposal for the directive also stipulated EU members taking the correct actions to stop overall soil contamination. The directive stated that MS would then be obliged to draw a list of sites polluted by dangerous substances when concentration levels present a substantial risk to human health and the environment and off sites were particular activities have been carried out such as landfills, airports and military sites. In the case that these sites were sold and the transaction made, the proprietor or possible purchaser would then be obliged to present a report to the competent national authorities on the state of the soil. EU member states would then be responsible to remediate the polluted sites. If it would not be manageable for the member state to remediate the site according to the national strategy, or to sustain the cost of remediating the location, the EU member states concerned would have had to make provisions for the financing.

The next discussion on a European plan towards sustainable soil use took place during the environmental council meeting under Greek presidency in 2014. The discussion pointed towards a common objective between states, to protect the soil despite the failure to implement the Soil Directive. However, there is still no legal EU framework on the sustainable use of soil.

While the proposal for the Soil directive was withdrawn in 2014, the 7th Environmental Action Programme, entering into force in 2014, established that soil degradation is a severe challenge.

7th Environmental Action Programme to 2020

titled as "living well, within the limits of our planet", states that – the Union has set itself the objective of becoming a smart, sustainable and inclusive economy by 2020 with a set of policies and actions aimed at making it a resource efficient economy. (European Parliament, 2003). The goal of the 7th environmental action programme therefore stated that by 2020 land is managed sustainably, the soil is sufficiently protected and that rigorous management programs designed for contaminated sites should be carried out. It also commits the European Union to intensify efforts to decrease soil erosion and increase soil organic matter which indirectly will have effects on the sustainable use of P (Specific criteria on P use in the 7th Environmental Action plan will be discussed further on).

Phosphorus is explicitly mentioned in the annex thematic priority objectives To protect, conserve and enhance the unions natural capital (26) stating that even though there has been a reduced level of P in the system in the EU, excessive nutrient releases carry on to affect the quality of water and have a negative impact on the natural ecosystem causing significant threats for human health. It also states that further attempts to control the nutrient cycle is needed in a more cost effective, sustainable and resource friendly way, to increase the effective use of fertilizers at farm level. It states that attempts to do so require investment in research and progress in the effective implementation of EU legislation at member state level. It also states the importance of increasing the standard levels of current existing policy and taking the nutrient cycle into account.

Hence one of the main goals of the 7th Environmental Action Plan is:
"Taking further steps to reduce emissions of nitrogen and phosphorus, including those from urban and industrial wastewater and from fertilizer use, inter alia, through better source control, and the recovery of waste phosphorus" (European Parliament, 2003) A special emphasis is placed on the importance of equipping all stakeholders that are involved in the anthropogenic P cycle.

OSCAR

Goal is to improve subsidiary crop application in rotations. It is a joint research project in agronomy supported by the European Commission. It is a very valuable proposal as it assesses the ecological and economic impacts of new impacts of the new cropping systems in agriculture.

One of its main goals is to reduce fertilisers used by increasing the duration of soil coverage. (OSCAR, 2012)

2.7. EU Policy Hydrosphere

2.7.1. Water Framework Directive

The Water Framework Directive (2000/60/EG) is a European Union Directive that commits EU member states to attain good qualitative and quantitative status of all water bodies including marine waters up to 50 kilometres from shore. (European Communities, 2003). The fundamental goal of the water directive was to create a "good status" for all water bodies by the year 2015. A good status is delineated through three aspects- chemistry, morphology and biology (Daly & Mills, 2000). (Environmental RTDI Program 2000-2006)

To attain this goal, an integrative method was proposed. The directive switches the emphasis to whole ecosystems through focusing on water catchments.
It stipulates the forming of a community framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater, in order to prevent and reduce pollution, promote sustainable water use, protect the aquatic environment, improve the status of aquatic ecosystems and mitigate the effects of flooding and drought. (European Union, 2011). It promotes an integrated approach of water management encouraging member states to work together to reach mutual goals. It was the first introduced cross border EU integrated approach.

The Water Framework Directive has had certain significant indirect implications on the national policies regarding P. Although P limits are not exquisitely mentioned in the Water Framework Directive, it has raised awareness in countries with extremely high P levels in water bodies, leading to the conclusion that P causes the main reason for the failure to achieve legislative goals regarding the Water Framework Directive. For instance P Standards to reinforce high ecological statues in rivers were established as a measure part of the first round of environmental standard development in the UK in order to comply with the good ecological status of the Water Framework Directive. (UK Technical Advisory Group on the Water Framework Directive, 2008)

As already stated, there's a fundamental connection between the environmental system of soil and the hydrosphere. Undesirable impacts on the soil have implications on the hydrosphere and vice versa. The Water Framework Directive as a policy therefore has an indirect effect on the sustainable use of soil and therefore indirect implications on the use of nutrients.

Before the Water Framework Directive was introduced, existing legislation only focused on single pollutants such as nitrate. (Nitrates Directive)

The overall objectives as set in **article 1** of the Water Directive, which is to

Protect and enhance the status of aquatic ecosystems and ground water, including terrestrial ecosystems, which depend directly on water.

Before the Directive was implemented, member states were responsible to examine and detect problems in their own river system as if it were an isolated body. However, it became quite clear that it's impossible to carry on with such a system that consists of solely individual approaches, when the Danube River flows through 10 EU countries. Because of the indirect environmental influences that affect all neighbouring countries, there is a need to focus on implementing a cross boarder approach when discussing river basins.

The Elba flood and other unforeseeable floods that occurred in Europe causing cross boarder nutrient flows in the past few years, demonstrated how crucial it was, to have a cross boarder approach where information is easily accessible and transparent.

The directive therefore gives obligations for river basin districts, to decrease the input of nutrients that could potentially have cross boarder effects.

The directive was implemented to improve the current water management, abolishing some of the old provisions with emphasis on a new strategic way.

The surface Water Directive, and the Drinking Water Directive, substituted by Directive in 1998, established the criterion for the standard of water, for drinking water, with the maximum limit of pesticides and N.

Further Directives that are connected to the water Directive, such as the

Directive on Pollution by dangerous substances had the goal controlling and setting a maximum limit on the chemicals being produced in the EU and therefore also limiting the indirect negative effects of P.

2.7.2. The Groundwater Directive

specified that European members states have to take the right moves to avoid the affluences in "list one" to enter the groundwater and decrease the ones in "list two" to hinder the contamination on those in the groundwater. P is included in the second list and is therefore stated as an element that is potentially dangerous.

2.7.3. The Freshwater Fish Directive

Specifies that industries that use chemicals affecting water, are advised to reduce harmful substances entering fresh water that affect fish. However it is quite clear that there is a profound need to clarify the dangers of leaching P in the groundwater and introduce stringent policies that regulate P at farm level, for instance monitoring the runoff of livestock processes.

2.7.4. Water Framework Directive

Establishes ecological goals for the status of water centred on ecological and chemical parameters, assisting and evaluating strategies and setting up a specialised agenda for each River basin district to attain the ecological goals for different water bodies.

The central procedures are based on the application of community legislation, to integrate, implement and enforce strategies in order to prevent leaching into the hydrosphere. Other actions taken are monitoring the retrieving of water and controlling agricultural pollution.

For these agendas, MS are responsible to take a joint approach regarding agricultural pollution and industrial water. Stringent actions have to be taken on agricultural pollution as waste management has been improved. A good ecological standard of water is present when the named pollutants in the directive are not passing their limit. This therefore indirectly applies to P that is included in the WFD legislative document that contributes to eutrophication. The WFD obliges member states to report specific data that includes current water challenges therefore reports about agricultural pollution of P is indirectly included although again the application of this is relative and overall the measures taken to reduce nutrient emissions, are linked to the **Best Environmental Practices.**

2.7.5. Nitrates Directive

As discussed, at the present moment there is no direct EU legislation on P application and only a few member states have clearly defined legislature that has defined general legal ceilings on P application. Limits on Nitrate application introduced by the **Nitrate Directive**, have foreseeable but differing effects on P use, which depends mostly on the type of manure. Nevertheless, its limit on use of manure have indirect implications on the use of P, therefore this policy has a possibly strong indirect effect on P use.

Codes of good farming practice portray minimum standards for farmers to obtain compensatory allowances and therefore dedicate many units to decrease directly or indirectly the danger of P pollution but are frequently on a voluntary basis.

Sewage Sludge use on Agriculture is controlled by the Sewage Sludge Directive, limits usually relate to the heavy metal substance and in some countries, on P content too. Denmark taxes P in mineral Fertilisers.

As mentioned before, Flanders, the Netherlands and Sweden have a legislative restriction on P production. This happens through the restrictions to the livestock density. In Flanders and Netherlands, the amount of livestock units is represented in terms of P production furthermore, farmers have a P quota. In Sweden livestock concentration is restricted to 22kg of P per hectare. In Denmark, even though there are no restrictions for P production, there is a tax on P in the feed, which should encourage farmers to choose feed with less P content and produce less. The cost of not fulfilling the P limits is nine euros per kilogram in the Netherlands, and one euro per kilogram in Flanders.

Techniques practices to reduce P in manure at farm level are used in Austria, Denmark the Netherlands, Flanders and Sweden. This consists of using feed with low P, and using phytase in raising animals and eggs.

Nutrient balances at farm level are only compulsory in Flanders and the Netherlands. In this case farmers have to annually state how P enters and leaves the system.

2.7.6. Waste management

The main legislative procedures in the EU regarding waste management are the EU landfill Directive, the Packaging and Packaging waste Directive and the Landfill Directive.

In 2014, the European Commission adopted a legislative proposal and annex to review new waste targets in the EU considering Phosphorus.

The Environmental action programme sets the main objectives for environmental policies in the European Union and contains a part on waste. This part has been agreed by all EU member states in 2013. However how this will be dealt with in practice is another complex issue.

2.7.7. The consultative communication on the sustainable use of Phosphorus

Issued by the European commission in 2013 was a document, clearly stating that P is as a critical resource in the EU that has to be managed sustainably. It states that losses in every process in the anthropogenic metabolism, contributes to concerns of detrimental effects for the hydrosphere, soil and to its future supplies.

It states that with the efficient use of management, which includes recycling, the correct application on soils and minimisation of wastes of P, will lead the correct pathway for the whole world, leading to the sustainable use of Phosphorus and thus its availability for future generations. (Schröder et al, 2010). The intention of the consultative communication was to emphasise the need for sustainable use of P and commence a wide reaching discussion on the current use of P promoting a future plan to confront these challenges in the EU. Again, this is not a directive therefore not a legally binding document for member states, but a part of the **Roadmap to an efficient Europe and waste management** and acknowledges as a general goal to improve resource management in the EU.

The consultative communication emphasises the need to monitor P in the anthropogenic cycle as it poses a food security threat for the EU in the future. It clearly emphasises the EU is nearly completely dependent on P imports and therefore affected by the possible future price fluctuations, such as the 700% price increase of P in 2008. (Kronenburg & van der Vlist, 2009). A very big emphasis is laid on the importance of P recycling and the fact that it will have not only various positive effects on the future food security for Europe but also highlights the benefits for the environment, if P were to be used more efficiently and recycled in the future.

Many challenges associated with p build-up in soils from manure, due to intensive farming are innate and the physical distance between the waste and sewage from arable land where it can be recycled back into the system is so big that it creates a further loss of P in the chain. The document stresses that there are several practical approaches that can be taken to hinder such losses of P in the system. However, most policies, as already mentioned are directed at tackling general problems related to the hydrosphere and not specifically on recycling P.

After the first European Conference on sustainable P was introduced, for the first time a European Phosphorus platform was set that aims at setting a European recycled phosphorus market.

However, the document states that the absolute replacement of phosphate mined in the EU by recycled P is either possible or necessary. Nevertheless it encourages recycling a part of the P in the foreseeable future, to impede water contamination and soil degradation. This is encouraged to “close the P cycle in the long term” and when the scarcity on P will play a significant role. The near future will demonstrate how successful the first European Platform for sustainable use of P will be in its recycling methods.

There are several important questions raised in this document that apply to the future sustainable use of P. A significant question raised is related to the future technologies with the potential to increase the sustainable use of P, lowering the costs and increasing the benefits. Another important issue raised was the question regarding the promoting the EU P challenge as a means to further make research and innovation of the sustainable use of P (European Commission, 2013, S. 14) Further on it is evident that the efficient use of P should start at the mine when P is extracted and being processed. It is estimated that one third of the rock is lost to mining and processing and beneficiation processes (EUR-Lex, 2013) Also, another 10% is lost through transportation. It is stated that a very big emphasis is currently set on the improvement and innovations in the mines to impede such great losses of P. As a result the EU commission states that future cooperation with P producing countries is vital. The rising prices of P and resource scarcity will be the primary triggers to enforce that such innovations take place but the health and safety obligations in the EU regarding expensive decontamination may also play a huge role. This could point to future cooperation between import and export countries on internal policy measures regarding P. Furthermore an overview of the positive steps and efforts towards a future sustainable EU regarding the sustainable P process is highlighted, such as the reduction of P in various products for instance in detergents, in the revised **Detergent Regulation**.

Another important sector mentioned is agriculture. Although emphasis is set on the various measures that have already been taken to improve the status of soil through existing legislation, for instance the Nitrates Directive and various others, it is highlighted that there is still a very big loop in the anthropogenic phosphorus cycle that has to be closed. This could begin at the farm level, by adopting environmental friendly farming practice that is based on the right amount of application of manure, using inorganic phosphate and trying to reduce erosion and leaching.

The most significant Directive for waste management in the EU is the Waste Framework Directive. It is a legislation that makes member states liable to ensure that "waste is recovered or disposed of without endangering human health and without using processes and methods that would harm the environment" The Directive emphasises the importance for states to achieve self-sufficiency in waste disposal, and also stresses that member states should take the right actions to form integrated and an adequate network of disposal installation. It encourages environmental protection through the "waste Hierarchy"

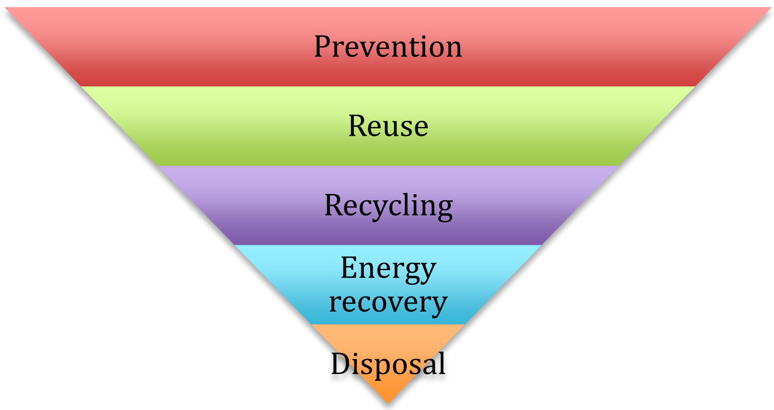

Figure 6: Full implementation of EU waste legislation based on waste hierarchy

This establishes the goal of prioritising prevention before waste is recycled or disposed of. The definition of Waste Management in the directive is the collection, transport recovery and disposal of waste including the supervision of such operations and after-care of disposal sites (European Parliamant, 2008). The Directive therefore promotes an improved resource use and reusing waste for beneficial purposes therefore applying methods of recovery. Recovery strategies aim at waste being utilised rather than discarded of and in this way protect natural resources. Whereas disposal measures are linked with discarding waste in a safe manner, and with the goal to get rid of waste, the Directive clearly states that all waste operations have to be in line with the health and safety precautions, with not using methods that would cause environmental challenges and without risk to animals, plants, soil, air and water.

2.7.8. The European landfill Directive

Is the most dominant Directive relating to Waste Management regulations. Its basic goal is part of the Waste Framework Directive to prevent or reduce as far as possible the negative effects of landfilling on the environment as well as any resultant risk to human health. (European Commission, 2015) It tried to attain this goal through introducing technical standards and specify requirements for monitoring landfills. The definition of the Landfill Directive waste disposal site for the deposit of waste onto or into land implies that the Directive is only concerns the disposal side of Waste Management and not recovery activities.

Phasing out landfilling (limited to non-recycling and non recoverable waste)

The landfill Directive: Because big amounts of P are lost in landfills the directive obliges member states by 2016 towards decreasing the landfilling of municipal biodegradable waste by 35% of the whole waste generated in 1995. This has a caused a considerable rise in the recycling of bio-waste to produce biogas and

The main challenges related to these goals are firstly the successful implementation of EU waste legislation and enforcement and support in EU member states. This in the past has posed major problems as it is a very complex process to monitor each country to test if legislation is being implemented correctly.

This requires better enforcement and implementation strategies by the authorities (EUR-Lex, 2013)

2.7.9. Environmental Action Programme to 2020

which is titled as “living well, within the limits of our planet”. In the first paragraph the programme states that – the Union has set itself the objective of becoming a smart, sustainable and inclusive economy by 2020 with a set of policies and actions aimed at making it a low carbon and resource efficient economy. (European Parliament, 2003)

2.7.10. Nitrates Directive

The Nitrates Directive goal is to protect water quality in the EU by hindering nitrates from agricultural sources polluting ground and surface water and by encouraging the use of good farming practices, such as crop rotations and soil and winter cover.

The Framework Directive for the sustainable use of pesticides Directive states that it is crucial to promote a rational and precise pesticide use as well as appropriate crop and soil management practices. (European Parliament, 2006) The Rural development programmes and CAP supports the preventative and mitigating measures of soil degradation processes especially agricultural environmental measures that enhance the build-up soil organic matter and reduction of soil erosion. Furthermore, the provisions of cross compliance with according to the obligation to maintaining agricultural land in good agricultural and environmental condition, can play a crucial role for soil protection. The Conservation of Soil is not clearly expressed in either the Birds Directive or the Habitat Directive nevertheless agricultural soil protection can be regarded an implied a required condition for the protection of habitats. As mentioned before, there is not current policy framework addressing EU soil.

3. Results

As discussed in previous analysis, policy regarding P recycling in the EU is not fully developed yet, although the conservation of P and its careful use has become a global concern.

Phosphate in agriculture, sewage treatment and industrial side streams is a problem in the EU resulting in various challenges. The EU is lacking coherent policies that will have a direct effect on the sustainable use of P in the EU. To reduce the wasting of P in landfills and to reduce the depletion of natural phosphate sources, the EU must explore new technologies and integrate them into the EU policy.

The inefficient management of P across the chain in the EU causes a linear flow of P. There are losses in the production and on the other hand there is a lack of recycling. There is no legislation addressing phosphorus directly and therefore it is imperative to make policies that will have a direct liable effect in the EU integrating EU Directives at national level.

As humans carry on altering the natural cycle of the environment with an unsustainable lifestyle, it further increases the adverse effects and the losses of P. Since a real global governmental structure that secures the equal distribution P is missing, policy makers should focus on measures that seek to **recycle** P to reduce dependence on imports and ensure food security in the future. The focus needs to be placed on reusing raw materials and developing technological innovations that will enable the EU to sustain economic survival with the natural environment. In order for this to come to fruition, the resource must be used in a sustainable way before it is released back into the biosphere. The introduction of policies aiming at recycling will improve the consumption chain and not discard the materials after use, but recycle them and maintain them in the system as long as possible. Since the greatest challenge related to the P problem takes place within the agricultural sector, policy must be aimed at providing adequate agricultural management as a means to improve the overall efficiency of P use in the EU.

In order to understand the anthropogenic P flow in a given system it is fundamental to understand its substance flows. SFA illustrates the system as a whole and depicts the losses occurring along the production and consumption chain from mining to food consumption. Mankind's usage of P is rather non circular and dissipative (Baccini &

Brunner, 1991). This applies to the EU anthropogenic P flow and is represented in Figure 1 (highlighting P losses in the flow "Soil" and the processes**, "Hydrosphere", "Soil"** and "**Waste Management".**

The following Diagram of the EU P balance by Rechberger represents the flows and stocks that pose current P challenges in regards to environmental protection and resource conservation. The recommended P policies are based on the following challenges posed by the physical separation of the production, consumption and processing in out modern society resulting in a linear flow of nutrients from field to fork.

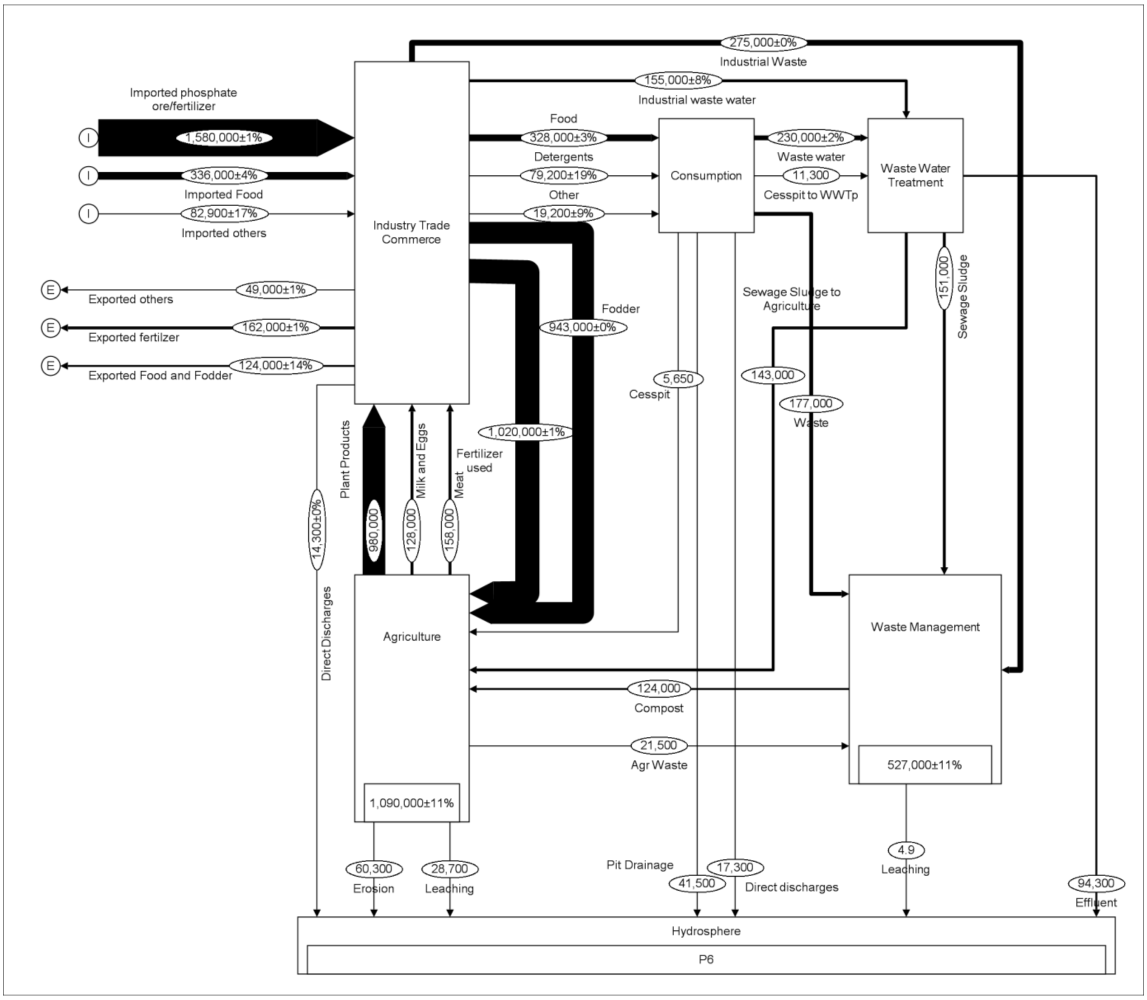

Figure 7: **The European Phosphorus Balance reconciled data (T P/A) Rechberger** (Ott & Rechberger, 2012)

The EU is a net importer of **2 MT** p/a (This is calculation is based on the European P balance by C. Ott and H Rechberger taken that there is an import of 4.1± % 5 kg cap/a, and EU15 citizens of 377 million.

- From the P imported, 17% is then exported as food and fodder, fertilizer and others.
- The input in the "Consumption" subsystem (only 25% of the total import of P) is dominated by food 76%, detergents 18% and others 4%
- 15% of the total P imported is exported directly into the hydrosphere as waste products and other, leaving the system and lost. It cannot be recycled causing eutrophication and other unwanted environmental effects.
- 97% of P imported is used in agriculture as fodder and fertilizer used.
- 66% of the total import of P is accumulated in agricultural soils while 5% is lost to leaching and erosion. Soil erosion can carry significant amount of soil bound P into surface water. Runoff from applied fertilizer or manure can contribute further to water pollution. The application of excess amounts of P on soils will not impair crop growth but affects plant biodiversity in natural ecosystems. Also, the dispersion of P to the surrounding water bodies also affects the overall biological balance.

  Agricultural emissions of P to fresh water exceed 0.1 kg of P per hectare per year across the EU but reach levels of excess of 1.0 kg per hectare per year in hotspots. As a consequence, several marine and coastal waters across the EU have a high concentration of P (SOER, 2010).

  The results of the assessment of river basin management plans highlight that 82% of river basins agriculture is causing very high P pressure on water bodies. (European Commission, 2013) Losses of P and other nutrients through these flows create excess growth of plants and algae, which creates eutrophication. This causes an imbalance between the processes of plant algal production and consumption, which have a very negative effect on species diversity, and the sustainability of water for human use. (European Commission, 2013)
- Soil that is available for food production per person is limited. Soil degradation processes for instance erosion and soil contamination and the decline in soil biodiversity can lead to the inability of the soil to carry out its main activities.

- Only 63% of the total 98% P import entering the subsystem “Agriculture ”is processed into plant products, milk and eggs and meat. The rest is accumulated in soils and only 25% of the total import of P enters the “consumption” subsystem. Due to lack of resource availability, the food system in the EU is highly dependant on exported P as discussed previously. However, as presented by the MFA, from the imported P only 25% reaches the consumer. This is a result of a highly inefficient system. The remaining P is either accumulated in EU soils, which leads to environmental challenges due to the leakage into water bodies causing eutrophication.
- As already mentioned by OSCAR, conservation agriculture, which aims to preserve soil structure by reducing soil disturbance, maximizing soil cover and using crop rotation is practiced less than 4% in the EU.
- In order reduce 50% of the current leaching and erosion of P from the soil directly into the hydrosphere, correct farming practices could be implemented by applying cover crops (Baresel et al, 2012).
- There are various challenges associated with leaving arable land as bare soil in the wintertime at farm level. Weathering leads to the leaching and erosion of soil P into ground water, streams and rivers. The loss of soil and the nutrients associated with erosion and leaching causes detrimental challenges to the environment, but also poses economic problems for farmers. Adopting cover cropping widely offers many advantages and only requires the farmers to be informed about its general application methods.
- Whereas the P that is not taken up by plants is accumulated in the soil, 14% of total P is used for animal products, milk and meat.
- 32% of the total P import is accumulated in the “Waste Management” subsystem. The environmental challenges that are caused here have led to Directives such as the Waste Water treatment Directive which imposes that all WWTP’s in large populated areas to install nutrient removal plants, where P and Nitrogen is removed. This leads to the production of sludge’s that are high in P or N as a by-product. However the recycling of this P back into the system is not yet optimal as presented in the MFA- 26% of the total import of P remains in the accumulation in the Waste Management sector mainly from industrial waste, which remains untreated. This P then accumulates in landfills causing further

distribution to soil and the hydrosphere. P could potentially extracted and returned into the system, however due to the heavy metal and toxic organic substances that is present in the sludge Phosphates, a decontamination process in needed before it can be applied in agriculture. There have been various technologies recently that have been developed that are ready to be applied at industrial level to produce P fertilizers. THERMPHOS an established industrial process for P production for instance, or ASHDEC a semi industrial scale technology, successful at heavy metal removing technology from incinerated sewage sludge, chicken litter or manure and residues from anaerobic digestion using a thermal decontamination. However, the lack of investments in these technologies has lead to the insolvency of several of these technologies including ASHDEC.

- On the output side it is noted that the food eventually produced in the system contains relatively low amounts of P. 98% of total input flows to the subsystem "Agriculture" and only 25% is present in the final product, milk and eggs, meat and plant products to be consumed. There is a loss of 35% through leaching, erosion and accumulation in the soil.
- Only 24% of the total P imported is processed in the "Waste water treatment subsystem" This amount is imported mainly from "Industry, Trade Commerce" subsystem and the "Consumption" subsystem.
- 36% of this amount returns to agriculture, 38% results in the "Waste Management" subsystem where it is landfilled, and 24% leaves as effluent. **This means that there is a possibility of recycling 62% of the total P entering the water treatment plant, which equals to 20% of the total import of P.**
- This accumulation occurs in a form, which cannot be reused in agriculture. The sewage sludge is used as input for cement industry or in landfills or deposits of ashes from incinerators.
- Only 36% of P in the "Waste management" sector is recycled into the soil while 24% is lost to leaching, landfilling and effluent to the hydrosphere.
- In total, the losses are 58% of the total P entering the "Waste" subsystem"
- Outside of agriculture, phosphate is often wasted in a number of different ways hence many phosphate rich products are treated as waste

- Only approximately 36% of the total sewage sludge within EU15 is reused in agriculture.
- If all the dry sludge would have been recycled it could have resulted in 23% of the P fertilizer used on soils.

From the total P import into the EU15, 16% is directly lost into the hydrosphere. This P cannot be recycled and causes detrimental changes in the fresh water environment. Furthermore only 24% of the total P import is treated. Only 25% of the total imported P is used for human consumption and **only 13**% of the total P is recycled back into the subsystem agriculture.

As the MFA balance **in Figure 1** illustrates, there are clear losses in various processes in the anthropogenic system.

As humans carry on altering the natural cycle of the environment with an unsustainable lifestyle, it further increases the adverse effects and the losses of P. Since a real global governmental structure that secures the equal distribution of P is missing, policy makers should focus on measures that seek to **recycle** P to reduce dependence on imports and ensure food security in the future. The focus needs to be placed on reusing raw materials and developing technological innovations that will enable the EU to sustain economic survival with the natural environment. In order for this to come to fruition, the resource must be used in a sustainable way before it is released back into the biosphere. The introduction of policies aiming at recycling will improve the consumption chain and not discard the materials after use, but recycle them and maintain them in the system as long as possible. Most importantly policy makers should focus on strategies that will enable to reduce the import of P in the future. For this to be able to occur, there are various policy measures that have to be looked at. Generally it would not be optimal to introduce a policy that reduces imports, as this would be inefficient as the whole system and anthropogenic P have to be studied simultaneously. Therefore, it is crucial that policy makers focus on integrating scientific evidence within the system as a whole, integrating it in various policy measures in each step in the chain. Only if there is a reduction and improved P management in each step can there be a chance of reducing P imports in the EU, leading to improvement in the current P challenges that the EU is faced with today.

3.1. EU Policy Recommendations in relation to challenges posed by P Flows and Stocks in the EU

3.1.1. Import

Due to the exportation taxes changing drastically, it is becoming less affordable to import P in the future. The global P spike in 2008 suggests that the unequal dispersion of P reserves globally will potentially create monopolies (Elser & Bennett, 2011).

It is therefore essential to improve the information on P flows in the food production and consumption sectors in order to understand better the losses in the P chain in the EU. There is enough agricultural data, however there is not enough information on the precise amount of P entering the system in the food chain and waste system together with the import of detergents and other (Ott & Rechberger, 2012). It is also essential to understand that there is currently a large degree of uncertainty associated with some estimates especially in the degree of P recycled and how much is lost to water bodies. (Withers et al., 2015) This is due to the complexity associated with monitoring these flows.

The first step for policy makers would therefore be to focus on measures that will improve the monitoring of P imports. Introducing reporting requirements could do so. This policy could be integrated into the European sustainable P conference. Policy makers could focus on introducing regulations that would require EU states to improve the transparency and monitoring of the P flows entering each member state, as there are currently no legislation or policy regarding the import of P.

EU policy makers should focus on setting policies where the quantification of P is clear. Due to P being an un-renewable resource, also listed in the EU- critical raw materials list, the reporting of P imports should become an obligation on EU level.

3.1.2. Hydrosphere

The importance of the application of EU Directives (making each country liable to its application) regarding P is based on the fact that the challenges created by the inefficient management, influences all neighbouring EU countries. The leakage of P into the Baltic Sea in one EU country will inevitably affect the other EU bordering countries simultaneously; therefore it is clear that the P challenge in Europe is not one that can be associated with exclusive sovereign state regulations. It is therefore crucial to integrate and harmonise national P regulations with regulations at EU level. If policy at EU level would be implemented, EU countries with no national policy regarding P would then have to integrate P regulations into their national policy accordingly. Only this way current ecological and resource related challenges could be tackled.

The ecological condition of surface waters has improved during the last ten years however it is still lacking a high standard in many European lakes and waterways (Zou & Christensen, 2012). The use of excessive P fertilisers, the limiting factors for algal growth, poses a serious threat to the hydrosphere and contributes greatly to eutrophication. Although there has been a reduction in point sources regarding the use of P, Agriculture and effluent from waste management is frequently the main contributor to the current challenges.

As presented in the MFA, 15% of total import of P is directly lost to the hydrosphere. The main contributor of P leakage is the wastewater treatment plant and the agricultural sector, which are both represented as a “process” in the MFA. This results in the leaching of P from the soil into the hydrosphere. This is mostly due to P fertilisers applied on soil and animal manure. Therefore, as discussed earlier, the ecological state of the hydrosphere is linked closely to soil management and therefore it is essential to focus on policy regarding soil when discussing the future status of the hydrosphere.

The second main area of direct loss of P in the system occurs in the **consumption system.** Here it is essential to introduce policy that relates to recycling.

3.1.3. Recycling P in Domestic and industrial waste

There are various steps in the food chain where P is lost. For instance losses happen from harvested crops during storage due to pests and spillage. During the processing stage losses occur. Bone meal and the removal of grain husks and to products, which are not EU standard, are then discarded. There are also losses that occur via transportation or at the retail stage when supermarkets discard food that has passed its sell-by date but is still edible. France has introduced a new regulation 2015 at state level that makes it illegal for supermarket chains to discard food. The food that is passed its sell date and not purchased is then given to charity or used as compost. Due to the fact that this regulation is very recent the future effect it will have on the overall P use can only be estimated. However, the integration of such policy at EU level can have a potentially large effect on the overall management of P considering that in 2010 there was a 52 kg household food waste kg/capita amounting to 92.2 million tonnes of food waste in the EU. (European Parliamentary Research Service, 2014) Food losses in the chain also happen in the home before the food is consumed. In the UK it is estimated that 60% of the food wasted is edible and could be evaded if there was better planning (White & Cordell, 2011). The use of cover crops and 50% less waste at the domestic level and the application of new recycling technologies in waste management can potentially decrease the discharges of P to the hydrosphere by 50%.

Based on this study, the researchers offer some suggestions for improving the management of phosphorus in the EU. These suggestions include achieving a balance between fertiliser inputs in agriculture, with the phosphorus removed by harvesting; recycling phosphorus in domestic and industrial waste, which would otherwise end up in landfill; ensuring all households have connections to good sewage systems and cesspits; and by upgrading wastewater treatment plants that do not currently treat wastewater for phosphorus content. (Ott & Rechberger, 2012) This last method could recover up to 85% of the phosphorus found in wastewater. It is suggested that EU-15 imports of phosphorus could be reduced by up to 50% through a mixture of technical and management measures such as the implementation of P-recovery technologies from sewage sludge or optimized fertilising practice. (Ott & Rechberger, 2012)

3.1.4. Waste Management

There are a number of current technologies that are based on the removal and recovery of P from wastewater in order to be recycled and returned into the system. These include chemical precipitation, biological phosphorus removal, crystallisation, novel chemical precipitation approaches and a number of wastewater and sludge based methods. (Khan & Irvine, 2012) The treatment of sewage is a natural monopoly. The reason for this is because there are very big cost savings out of having only one plant and sewage infrastructure serving any geographical area just as water supply, the supplying of competing sewage piping systems that cause competing sewage plants for each household would lead to greater costs than for instance having only one system. Therefore the WWTP'S should be subject to public regulation, controlling the end of the cycle of P and treating it accordingly.

EU 15 countries make 5% of the world population. 79% of the population is connected with WWT plants and approximately 70% of the P of the influent is contained in the Sludge, which would provide a 55% extraction of P by WWT in the countries with highest standards of WWT systems (Withers et al., 2015)

To close the balance, only a small amount of the wastes form industries and households appears to be recycled

3.2. Soil

3.2.1. The largest loss of P occurs in agriculture.

In order to reduce the overall inefficient use of P in the EU, this is the first area that requires policy implementation. Soil has until now not been faced with a precise P policy at EU level. Provisions for soil degradation preventative measures are spread across many areas but these particular provisions do not guarantee an adequate level of soil protection as its scope differs widely. A soil regulation is needed that would integrate agricultural P management plan at EU level. It is a well-known fact that environmental challenges regarding soil are local but social and economic aspects of their solution are European. The UK, Germany, France, the Netherlands and Austria have been against the Soil Thematic Strategy forming a blocking minority in 2007. (Davidson, 2014) It is therefore crucial to create a solution between member states coming to an agreement and finding a new solution to the soil problem in the EU. Alternatively, rather than imposing financial obligations on member states as does the Soil Thematic Strategy, a new Soil Directive could be initiated that addresses the key issues regarding funding.

As opposed to Nitrate, there is no European Directive concerning P application on soil or on P that is lost from agricultural land.

The Nitrates Directive mentions the importance of reducing eutrophication and the dangers associated with it, but it does not directly mention P application on Soil. Soil related policy in the EU depends on voluntary soil action plans and regional and national policy. Because of the lacking instrument to implement the Soil Directive the over application of P in the EU is an on-going challenge.

Erosion is a serious challenge in the EU. It is very challenging to quantify the level of soil erosion in the EU as it depends of the soil type. Even though uncertainties remain, there are various possible methods to improve the capacity to increase the ability of soil to hold water and therefore reducing runoff and decrease the use of fertilizer on EU soils. Policy makers shall therefore manage to integrate scientific evidence about soil and integrate policy measures with initiatives to tackle runoff. Introducing an agricultural policy based on the cover crop method could do this.

Generally, market instruments in essence promote overdosing rather than cautious application and effective reuse through technologies to optimise nutrient recycling. Cover cropping is a system practiced since ancient times and performed in different civilizations to increase soil fertility and yield stability. Not only do cover crops minimize runoff and erosion, they also increase organic matter and improve soil structure and its overall physical characteristics fixing atmospheric nitrogen. Farming of cover crops augments the total root volume in the agronomic system and therefore increases the surface area by which nutrients are absorbed and the total volume of exudates potentially released by plant roots (Bünemann et al, 2011)

The balance of nutrients in the soil system is seen as a significant sign of the sustainability of agricultural land use over a period. Nutrients in soils are being continuously depleted as a consequence of intensive farming, through introducing agricultural policy that supports careful farming management this can be reversed and improved and increase soil fertility. Lately, the rising side effects of intensive agriculture reintroduced the cover crop system, however, there are no existing regulations.

As already discussed, P is a fundamental element for plant growth, and is present in soil, in many different chemical forms. Extreme weathering of main minerals together with intensive agricultural production has led to the depletion of organic matter and plant available forms of P. (Hall, 2008) Leaching of nutrients causes eutrophication. The use of cover crops in the past has proved to be an effective method that impacts nutrient cycling and soil organic matter pools.

Erosion and leaching can be reduced by 50% at the farm level with proper agricultural methods such as cover crops. This would reduce 44.000-t/anum directly reaching the hydrosphere which makes cover cropping an important instrument in increasing nutrient conservation in agriculture.

Contemporary farming technology such as precision farming and site specific management can be very effective in reducing the consumption of P in agriculture and allowing a more precise adjustment of fertilizer use to the specific local demand. The use of precision farming can lead to a decrease in use of mineral fertilizer for instance in Germany where there has been an over application of P fertilizer and manure for a long period of time. (von Horn & Sartorius, 2012) “Precision agriculture technologies allow for geo-referencing of measurements such as soil tests, crop yields, scouting counts, and other agronomic observations.” (Mallarino, 2000) precision agriculture entails a broad spectrum of technologies and management practices. Precision farming as the application of technologies and principles to manage spacial and temporal variability associated with all aspects for agricultural production for the purpose of improving crop performance and environmental quality. (Pierce & Nowak, 2002)

After respective cropping seasons the data collected can be employed to issue extensive databases, which lets farmers make decisions accordingly on the soil type. The variable rate P fertilization will notably reduce the total amount of P applied and will also potentially increase yield. The result of introducing an agricultural policy that requires precision farming will have a very positive effect on the efficient distribution of P fertilizer and will also have positive environmental impact in the long run. Integrating a new agricultural policy based on precision farming can substantially reduce 40% of the total fertiliser currently applied in agriculture. This will in turn reduce leaching and erosion, improve the effluent to the hydrosphere, improve the general well being of the soil and also have a very big effect on the future import of P into the EU.

Table 1 Estimated value of changes in processes and Flows

Processes and Flows	t/a ± 11%	Estimated value of changes in processes and Flows
Import	1.700.000	45%
Hydrosphere	256.400	50%
Waste Management	527.000	40%
Soil	1.090.000	40%

4. Discussion

Phosphorus being a critical raw material is clearly an essential component of life that cannot be replaced. Phosphate rock, the principal source of P is a non-renewable resource that cannot be produced synthetically. High quality P is depleting and access becomes laborious and expensive; furthermore the EU is nearly completely dependent on P imports.

Whereas in a natural cycle phosphorus in human and animal excrements would be recycled, in the human induced anthropogenic metabolism this cycle is disrupted. This causes detrimental effects in the natural environment and challenges to the future EU global food security due to the predicted scarcity of high quality P.

P imports are generally larger than its exports at various system levels. This leads to growth of P stocks in soils, in the waste sector and of emissions to the environment. Recycling of P in the system will lead to a reduction of imports and also the surplus. Currently there is no policy regarding imports of P.

If P would be recycled and a sustainable choice of diet and efficient agricultural methods were promoted, it is clear that in the long term the use of P would be more efficient. If the EU adopted a set of policies exclusively directed on the sustainable use of P, the demand for imported P within the EU would be reduced and therefore the dependence on the imports of P would also be reduced. This in turn would not only improve the environmental challenges but could also affect the global price of phosphate rock. Experts continue to agree that P prices will rise and not fall (de Ridder et al, 2012). There are a couple of significant contributors that support this issue- price inelasticity of supply and price inelasticity of demand.

On the supply side there is the risk of high price and the amount of time that is needed to set up a new mine. There is always a certain risk involved and shocks that might inevitably arise due to political instability and environmental issues. On the other hand, on the demand side, P is a vital element to life that cannot be substituted and therefore the demand for P is resistant to price developments.

The main challenge however is the management of P and EU policy makers should focus on agricultural policy as the over application of fertilizers on soils cause the greatest challenges in the EU. .

The intensive use of phosphorus and losses in the anthropogenic metabolism, have caused detrimental challenges in the natural environment, such as eutrophication and soil degradation. This condition takes years to solve as even when the source of pollution has been removed P becomes part of the sediments which are subject to habitual disturbance, causing repeats of the eutrophication process. The predicted future phosphorus scarcity poses a food security threat, as well as critical geopolitical implications due to the location of the largest phosphorus reserves currently available.

In order to have a general picture of the current P flows one needs data from a broad spectrum of Sciences, ranging from geology, mining and chemical engineering, soil and plant sciences and all facets of agricultural and environmental sciences to economics, policy and behavioural and decision science as most flows are affected by human actors (Scholz, 2014) We must identify each stock, process and flows and key actors and key persons concerned and in particular their drivers and the constraints of their behaviour. Most flows are affected by human actors thus this means that we have to link the material flows with human actions and decisions.

Policy makers should focus on regulations that will encourage future transparency about the general state of the soil. As mentioned by the European environmental agency in its previous statues of the environmental report, it is a well-known fact that a pan European assessment of the state of the soil lacks a legal requirement to collect relevant general data on the state of the soils in the EU. While most EU countries have clear reports on the soils on territory that are used for agriculture and forest production, several of these surveys are now outdated. These reports therefore may not contain the information needed to answer specific questions about the state of the soil in the EU and the impact of pollutants on soil micro fauna, the leaching of P due to over fertilization or the state of environmental functions. A couple member states have detailed and soil monitoring networks which measure a few of the parameters regarding soil quality. Nevertheless several of these networks support national priorities and standards making their comparison of results with those of other countries difficult. Most EU countries don’t have provisions for the systematic collection of soil data. As a result, there is a difficulty in introducing a bottom up approach of collating reports from the individual countries to derive a harmonized evaluation for the EU.

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