D6.2: Current Agricultural Practices/Policies and Evaluation of the AGRINUPES Tools' Potential for Implementing the EU Legislation

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Abbreviations

AEIs	: Agri-Environment Indicators
BMPs	: Best Management Practices
CAP	: Common Agricultural Policy
EC	: European Commission
EPPO	: European and Mediterranean Plant Protection Organization
EQS	: Environmental Quality Standard
EU	: European Union
FAS	: Farm Advisory System
GAEC	: Good Agricultural and Environmental Condition
IACS	: Integrated Administration and Control System
IPM	: Integrated Pest Management
MS	: Member State
NVZs	: Nitrate Vulnerable Zones
RDP	: Rural Development Program
SMR	: Statutory Management Requirement
GES	: Good Environmental Status
N	: Nitrogen
P	: Phosphorus
K	: Potassium
WB	: World Bank
WFD	: Water Framework Directive

1. Introduction

Consumption patterns are evolving as world population increases and lifestyles are changing. This change results in an increase in the demand and allocation of food, and this drives the transformation in agricultural systems. The global food demand is estimated to increase by 70% to 110% in 2050 (FAO and IWMI, 2018). Although there are several measures that can play role to cover the growing demand, such as cutting off food waste taking place on field and through distribution chains, as well as fair-allocation issues. The growing demand has been met by the expansion of agricultural lands and through the intensive use of inputs (pesticides and chemical fertilizers). Irrigation plays a vital role in improving productivity and rural livelihoods, yet this may also lead to discharge of excess nutrients, pesticides and other pollutants from agricultural areas to water bodies.

Agriculture is one key global polluter as large quantities of drainage water reaches water bodies with large impacts on aquatic ecosystems, human health and productive activities. Only 44% of the freshwater withdrawn is consumed (3 928 km^3) every year due to evapotranspiration in irrigated agriculture. 56% of the remaining water is released into the environment as agricultural drainage (~ 1 260 km^3) (FAO and IWMI, 2018).

Nitrate from agriculture is the most common chemical contaminant in groundwater aquifers (WWAP, 2013). United Nations World Water Assessment Programme (WWAP) reported that 38% of water bodies are under significant pressure from agricultural pollution in the European Union (WWAP, 2015). The annual costs associated with deterioration of water quality and aquatic ecosystems as well as human health impacts are presumed to exceed billions of euros. A study revealed that the annual cost of pollution by nitrogen is in the range of €35–€230 billion per year in the EU (FAO and IWMI, 2018). Unfortunately, the processes linking agricultural activities to pollutant concentrations are still not clear. Thus, water quality monitoring and data on management practices are essential to understand the causes and effects of water pollution from agriculture and to identify and plan the right responses.

This report provides insight to current agricultural practices in the EU and Turkey. It investigates trends regarding use of nutrients and pesticides in agriculture, best management practices, and related policies including Common Agricultural Policy and incentive mechanisms. The aim of this report is to identify and understand the current practices and policies in order to suggest solutions to enhance the implementation capacity with the employment of NPK-sensors and biosensors.

2. Water Pollution from Agricultural Activities

Water pollution has become a major problem in both developed and developing countries that needs to be addressed across the world. It poses a threat to the economic development of countries, socio-environmental sustainability and health of billions of people worldwide. Although, the main concerns with regards to this issue has been on water quantity, water-use efficiency, and allocation problems; water quality problems caused by poor management of wastewater and agricultural drainage in many countries should not be undervalued (FAO, 2018).

The most significant water pollution concerns related to agriculture are (FAO, 2010):

- eutrophication, hypoxia and algal blooms caused by excess nutrients that accumulate in surface and coastal waters;
- nitrate accumulation in groundwater;
- contamination of groundwater and surface water bodies by pesticides residues

Agriculture accounts for 70% of the world's water consumption. It is also known that agriculture plays a significant role in water pollution. Inefficient irrigation methods are the world's largest producer in volume of wastewater. Over 40 % of the total water abstraction in Europe is used for agriculture. Agriculture is the highest water user (more than two thirds of total abstraction) in southern Europe countries. On the other hand, less water is used in agriculture in the northern Europe countries where irrigation is less frequent but still responsible for more than 30% of water use in some areas (Sordo-Ward et al., 2019).

2.1. Use of Nutrients in European Agriculture

There has been a rapid increase in the use of fertilizers due to the intensive and expansive agricultural production in recent years. Fertilizers are used to enhance soil fertility leading to higher crop yield. There are many forms of agricultural fertilizers which include commercial nitrogen, phosphorus, and potassium, which are the three main macro nutrients. Nitrogen (N) is the main constituent of proteins and the fundamental element for the growth of plants. Indeed, vitality, growth, color, and yield of a plant are mainly conditioned by the nitrogen supply. Phosphorus (P) is vital for sufficient root development and drought resistance. Further, the ripening of seed and fruit necessitates adequate amounts of phosphorus. On the other hand, Potassium (K), which leads to more quality crops and helps them resist lodging, disease, and drought, is essential to the photosynthesis (YARA, 2017).

Table 1. Nitrogen and Phosphorus Fertilised Utilised Agricultural Area (Kg N+P/ha) (Eurostat 2015).

Country	2006	2015
Austria	40.5	61.6
Belgium	109.6	111.3
Bulgaria	36.3	85.2
Croatia	193.4	92.8
Cyprus	91.7	72.3
Czech Republic	93.5	120.9
Denmark	77.5	84.6
Estonia	30.5	41.5
Finland	81.7	77.3
France	80.6	89.4
Germany	115.0	119.5
Greece	94.6	67.4
Hungary	64.0	86.4
Ireland	113.3	103.8
Italy	80.7	53.1
Latvia	35.1	60.7
Lithuania	51.7	64.2
Luxembourg	114.7	103.0
Malta	64.4	62.0
Netherlands	157.7	139.2
Poland	76.9	81.6
Portugal	50.9	66.9
Romania	22.3	32.2
Slovak Republic	56.8	78.4
Slovenia	84.3	78.6
Spain	66.2	74.3
Sweden	59.2	71.9
United Kingdom	86.4	94.2
Turkey	104.57	137.70

Netherlands with 139 kg/ha uses the highest amount of fertilizer per unit area (kilograms per hectare of arable land) among the EU member states. Estonia, on the other hand, is the country that consumes the least fertilizers with 41.5 kg/ha. In 2016, the amount of fertilizer used in Turkey per hectare area was 137.7 kg, which is just about the world average (Table 1).

A number of factors such as level and type of fertilization, the timing and method of fertilizer application, properties of soils (e.g. pH, structure and organic matter content), crop type, the method of cultivation, agronomic practices all affect nutrient leaching. Also, the intensity and quantity of nitrogen leaching can be severely influenced by the weather conditions and the use of catchment areas (Lawniczak et al., 2016). Due to nitrogen especially, nitrate being highly soluble substance, this situation can cause pollution originated from fertilization with the effect of nitrogen quickly dissolved in water. On the other hand, phosphorus, although, is less mobile, it can reach surface water by erosion as it bounds to soil particles. . It is complicated to preserve the quality of water due to these various pathways. Moreover, the elimination of one source may lead to the aggravation of another. Reducing the level of fertilization or one of the elements, for example, may not lead to reduction in the leaching of nutrients because of the unfavorable ratio of nutrients already present in the soil. However, if the nutrient concentration of the soil is monitored regularly through sampling and fertilization is adjusted accordingly, positive results may be achieved in long term. Plants may not absorb adequate amounts of nitrogen even when the level of nitrogen is sufficient, due to inadequacy of phosphorus or potassium. Therefore, loss of nitrogen may occur due to low level of fertilization as a result of insufficiency of potassium and phosphorus. This may, in turn, produce water and soil pollution. Furthermore, potassium deficiency has the potential to affect two-thirds of the entire agricultural land worldwide (Lawniczak et al., 2016).

The question of how to manage nutrient for agricultural activities and the concept of Best Management Practices (BMPs) are tightly linked. BMPs can be defined as a practice or combination of practices that is the most effective, technologically, and economically feasible means of preventing or reducing the amount of pollution caused by nonpoint sources to a level that meets water quality goals (USEPA, 1980). In this regard, pollution-prevention farming methods categorized as BMPs are practical ways aiming to minimize risks to the environment without sacrificing economic productivity.

As a method of pollution-prevention, one of the most important elements is reducing use of potentially harmful substances such as fertilizers, manures and pesticides (Centner and Keeler, 1999). By this means, the environment is less likely to be affected by them. The nutrient management should start with identifying the type and amount of needed nutrient, so the over-use of nutrients can be prevented. Such thoughtful management is needed for ensuring ideal yield and economic benefit through resources optimization (Nutrient Management, 2019). BMPs are a significant tools for mitigating the impacts generated from agricultural activities and protecting water; however, they cannot be expected to solve all water quality problems.

There are also much needed regulations concerning water pollution control and water management to supplement BMPs, not only the state policies in which BMPs work together. The primary framework legislation at EU level concerning the prevention of nutrient pollution is elaborated further through the following paragraphs.

2.2. Water Legislations relevant to Agricultural Practices in European Union and Turkey

Producing more food minimizing input use and environmental impact while maximizing the benefit is the basic principle of efficient agricultural water use. Current EU legislations on water are drafted with this spirit.

The main aim of EU water policy is "to ensure access to good quality water in sufficient quantity for all Europeans, and to ensure the good status of all water bodies across Europe" (EEA, 2017). The following lines compile the EU water legislations relevant to agricultural activity and explain their logic briefly.

The EU Water Framework Directive (2000/60/EC)

The Water Framework Directive (WFD) came into force on 22 December 2000. The aim of the Directive is to protect and restore water bodies in Europe. Water bodies all over Europe should have had a "good status" by 2015. An important step in the course of its implementation involved establishing river basin management plans. These efforts are based on a six year cycle of assessment for the years2015, 2021 or 2027.

WFD requires Member States to establish monitoring programs for the assessment of the status of surface water and of groundwater in order to provide a coherent and comprehensive overview of water status.

74% of the EU groundwater bodies by now have achieved good chemical status, while 89 % of the EU groundwater bodies achieved good quantitative status. The situation is less satisfactory for surface waters: only 38% of monitored surface waters are in good chemical status and around 40% holds good ecological status (EEA, 2018).

The Council Directive Concerning the Protection of Waters Against Pollution Caused By Nitrates From Agricultural Sources (91/676/EEC)

The Nitrates Directive was adopted in 1991. The directive aims to prevent and reduce water pollution caused by nitrates from agricultural sources and to promote the use of good farming practices. All EU Member States are obliged to:

- The designation of Nitrate Vulnerable Zones (NVZs)

- The identification of polluted waters or waters at risk of pollution
- The establishment of Codes of Good Agricultural Practice to be implemented by farmers on a voluntary basis.
- The establishment of action programs to be implemented by farmers within NVZs on a compulsory basis
- National monitoring and reporting

The European Parliament and of The Council Directive on The Protection of Groundwater Against Pollution and Deterioration (2006/118/EC)

The EU adopted in 2006 the Groundwater Directive (2006/118/EC) which complements the WFD and sets groundwater quality standards in terms of nitrates and pesticides (Table 2). The Directive introduces measures to prevent or limit inputs of pollutants into groundwater. It establishes quality criteria that takes into account local characteristics and allows for further improvements to be made based on monitoring data and other relevant knowledge.

The EU Groundwater Directive sets out European-wide groundwater quality standards for the following substances and substance groups:

Table 2. Quality standards of groundwater.

Pollutant	Quality Standards
Nitrates	50 mg/L
Pesticides (= plant protection agents and biocides)	groundwater quality standard for individual substance: 0.1µg/L, Total groundwater quality standard: 0.5µg/L].
(1) ‘Pesticides’ means plant protection products and biocidal products as defined in Article 2 of Directive 91/414/EEC and in Article 2 of Directive 98/8/EC, respectively. (2) ‘Total’ means the sum of all individual pesticides detected and quantified in the monitoring procedure, including their relevant metabolites, degradation and reaction products.	

The Council Directive on the quality of water intended for human consumption (98/83/EC)

Known as the Drinking Water Directive, it came into force on 3 November 1998. The Directive aims to protect human health from the adverse effects of any contamination of water intended for human consumption.

According to 98/83/EC, EU Member States shall set values applicable to water intended for human consumption for the parameters set out in Annex I. As stated in **Erro! Autorreferência de marcador inválida.**, limit values are given for nitrate and nitrite, as 50 mg/L and 0.50 mg/L, respectively.

Table 3. Chemical parameters of water intended for human consumption.

Parameter	Parametric Value	Unit
Nitrate	50	mg/L
Nitrite	0.50	mg/L

Table 4 below shows the nitrate threshold levels applied in project partner countries for environmental quality standards. The EU Directives allow countries to define their own threshold values according to local conditions and needs. In Turkey's and Sweden's cases, countries choses to cluster quality thresholds according to purpose of water use. For instance, the water of very good quality level represents a high potential to be used for drinking, swimming and farming. As the level drops, it indicates that water is suitable merely for industrial use (cooling, process, etc.) and requires advanced treatment before to be used in other areas.

Table 4. Nutrient Threshold Levels.

	The Netherlands	Turkey	Portugal	Sweden
Nitrates (2006/118/EC)		50mg/L	50mg/L	50mg/L
N (EU WFD)	1-4 mg/L			
N (local water authority)	1.8 mg /L			
N (national)	2.8 mg N/L	Total Nitrate 1st class (very good): <3,5 mg/L 2nd class (good): 11,5 mg/L 3rd class (moderate): 25 mg/L 4th class (poor): >25 mg/L	Criteria for a Good ecological status of rivers[2] Nitrates 25 mg/L Ammonia 1mg/L Nitrates[1] VMR- 25 mg/L VMA - 50 mg/L Kjedal Nitrogen[1] - 1 mg/L Ammonia[1] (NH_4) – 0.05 mg/L	Criterias for diffrent levels where the lowest levels are: low : 300µg/L moderate: 300-626 µg/L high: 626-1250 µg/L very high: 1250-5000 µg/L extreme: >5000 µg/L
P (local water authority)	0.3 mg /L	-		-
P (EU WFD)	0.03-0.14 mg/L	-		-
P (national)	0.15 mg P/L	Total P mg/L 1st class (very good): <0,08 2nd class (good): 0,23rd class (moderate): 0,8 4th class (poor): >0,8	Phosphates[1] 0.4 mg/L Criteria for a Good ecological status of rivers[2] P total<=0,10 mg/L	No legislation but criteras for different surface waters and their status exist but they are individual for every surface water.

[1]stands for Law by Decree 236/98, of 1 of August – on the quality of surface waters used to withdrawal water for human consumption; VMA – maximum acceptable levels; VMR- maximum recommended values.

[2]stands for Criteria for the classification of surface water masses – Ministry of the Environment for the application of the WFD

All EU countries including Turkey have to adapt to the EU directives. Last decade, Turkey has issued several laws and Regulations to align with EU legislations. The main water legislations relevant to agricultural practices in Turkey are summarized below:

- **The Regulation on Water Pollution Control**

  It came into effect in 2004. The Regulation aims at conserving the quality of water resources and water-dependent ecosystems, and protecting and improving water quality to meet human demands. It establishes discharge standards which define the maximum allowable discharge of pollutants into receiving natural and artificial water bodies.

- **The Regulation on Surface Water Quality Management**

  The Regulation entered in force after being published in the Official Gazette No. 28483 dated on November 30, 2012. It was adopted to conform to the EU Water Framework Directive.

  It was prepared with the objective to designate the procedures and principles on; determining and classifying biological, chemical, physicochemical and hydro-morphological qualities of surface waters, coastal waters and transitional waters, monitoring water quality and quantity, determining utilization purposes for these waters in accordance with sustainable development aims by considering the balance between utilization and protection, protecting these waters and taking measures to improve the quality of waters to a level of good water.

- **The Regulation on the Protection of Groundwater against Pollution and Deterioration**

  The Regulation was first issued in 2012 (Official Gazette 28257, 07.04.2012) and revised in 2015 (Official Gazette 29363, 22.05.2015). It aims to preserve the status of groundwater that is classified as being of good status; and to protect and improve the status of the groundwater against pollution and deterioration.

- **The Regulation on the Protection of Waters from Agricultural Nitrate Pollution**

  The Regulation was published in Official Gazette number 29779 on 23 July 2016, came into force on the same date. It aims to reduce nitrate and nitrate-based components originating from agricultural practices that pollute groundwater, surface water, and soil.

- **The Regulation on the Waters Intended for Human Consumption**

  The Regulation was adopted on February 17, 2005. It aims to provide technical and hygienic conditions and quality standards of the water intended for human consumption establishing principles and procedures regarding the production, packaging, labeling, marketing and auditing of the spring waters and drinking waters.

- **The Regulation on Protecting Water Basins and Preparing Management Plan:**
  The regulation came into force on October 17, 2012. The aim of the regulation is to set procedures and principles of planning for and the protection of surface and groundwater quantity and quality (physical, chemical and ecological) with an integrated approach and preparing water basin management plans.

- **The Regulation on Monitoring Surface Waters and Groundwaters**
  The Regulation took effect after being published in the Official Gazette No. 28910 dated 11.02.2014 within the process of harmonizing Turkish legislation with Water Framework Directive. By means of this Regulation, provisions of Article 8 and Annex-5 of Water Framework Directive have been integrated into Turkey's national legislation.

Table 5. Turkish Regulations in Harmony with relevant EU Directives.

EU Directive	**Turkish Regulation in Harmony**
Water Framework Directive (2000/60/EC)	Regulation on Protecting Water Basins and Preparing Management Plan Regulation on Monitoring Surface Waters and Groundwater Regulation on Surface Water Quality Management Regulation on Water Pollution Control
Marine Strategy Framework Directive (2008/56/EC)	---
Nitrates Directive (91/676/EEC)	Regulation on the Protection of Waters from Agricultural Nitrate Pollution
Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater	Regulation on the Protection of Groundwater Against Pollution and Deterioration
Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption	Regulation on water intended for human consumption

3. Pesticide Pollution Control in Europe

3.1. Use of Plant Protection Products (Pesticides) in Agriculture

Pesticides are chemical substances used in agriculture to protect plants from pests, weeds and diseases. The use of pesticides has led to increased farm productivity and is often necessary to deter pests that could destroy the crops, thus increasing both the quantity and quality of food production. However, they require great care and control due to the risk of polluting the environment and harming human health (Guler et al., 2010). All pesticides by their nature are mildly, moderately, or highly toxic and thus may create health hazards for humans, animals, and the environment through consumption, exposure, and agricultural activities (He et al., 2018). There is an increasing concern about the impact of pesticides to both the environment, particularly water pollution and the impact on bee health, as well as a risk to consumers. Many studies have shown that pesticides can be attributed to carcinogenesis, reproductive dysfunction, immunotoxicity, neurotoxicity, behavioural impairment, skin conditions, endocrine disruption, developmental diseases, and respiratory illnesses such as asthma (Solomon et al., 2000).

Pesticides can be classified according to target organism; insecticides, herbicides, fungicides, bactericides, rodenticides, acaricides; or they can be grouped according to their chemical structure; organochlorine insecticides, organophosphate pesticides, carbamate pesticides, pyrethroid pesticides and neonicotinoids (FAO and IWMI, 2018).

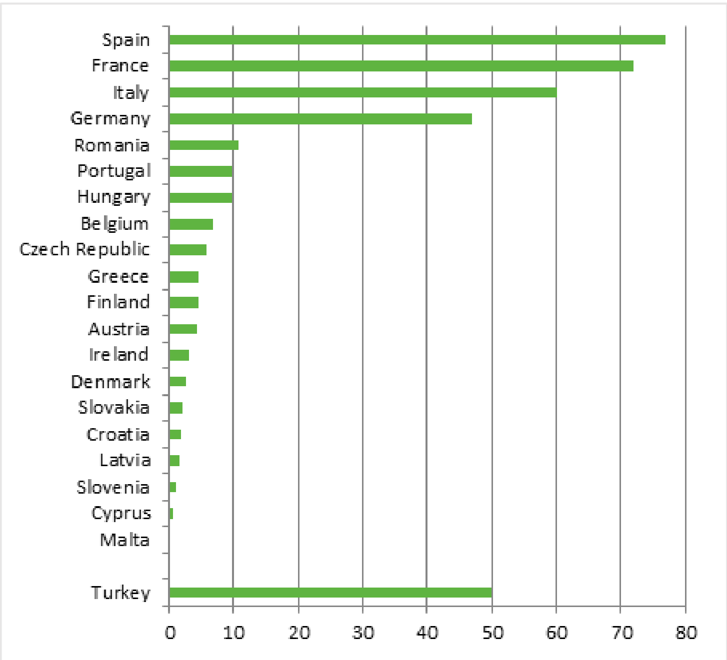

Figure 1. Pesticide sales in 2016 – millions of kilograms (Eurostat, 2018).

Figure 1 displays the sales of pesticides in 2016 among 20 EU Member States and Turkey. As can be seen in the Figure, Spain, France, Italy and Germany are the major consumers accounting for 79%. Yet, these countries are also the main agricultural producers in the EU, collectively corresponding to around 50% of the EU's total utilised agricultural area and 47 % of its total arable land (Eurostat (a)). Globally, over 4 million tonnes of pesticides are consumed every year (Figure 2), and China, USA and Brazil are the largest pesticide users (FAOSTAT, 2019).

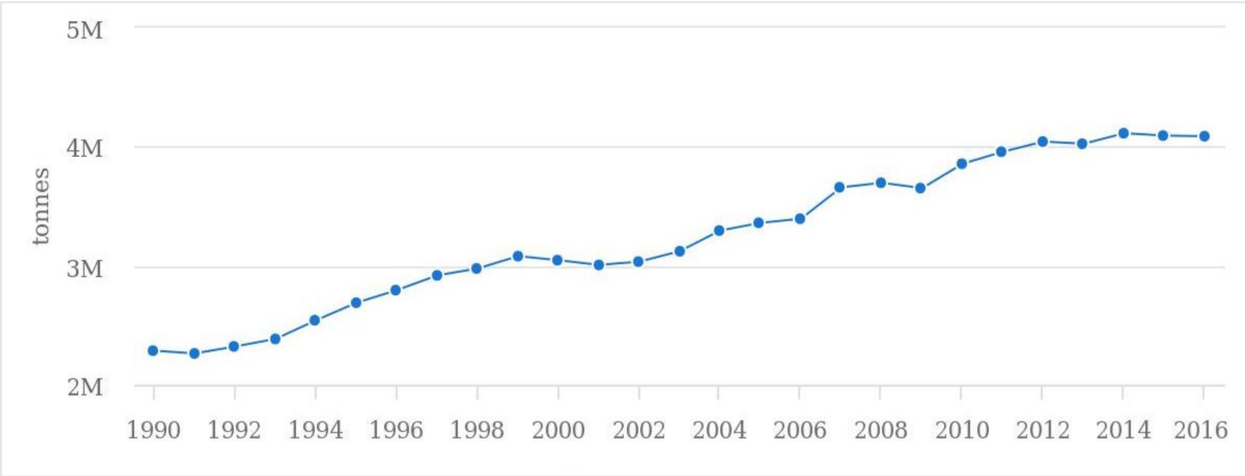

Figure 2. Global Pesticide Use (1990-2016) (FAOSTAT, 2019).

3.2. Fate of Pesticides in the Environment

Pesticides meet a variety of fates once they are applied. If they are not *absorbed by the plants*, they may be *adsorbed to soil particles*, reach surface water bodies through *erosion and runoff*, *leach to groundwater* or carried by spray drift (Figure 3) (FAO and IWMI, 2018; NRC, 1993; Waskom et. al., 2017).

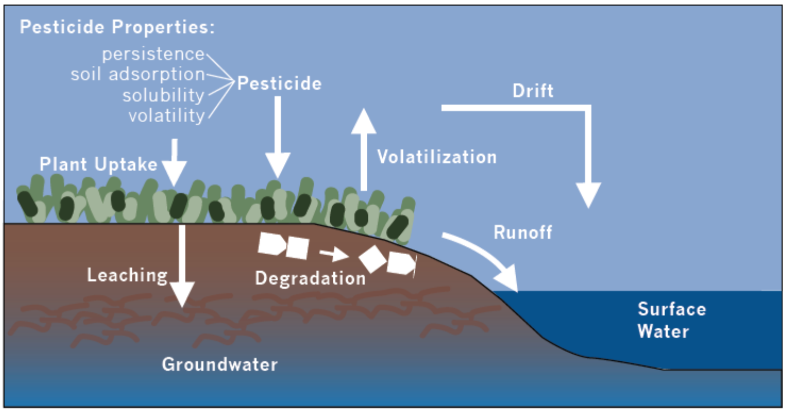

Figure 3. Fate of pesticides in the environment (Waskom et. al., 2017).

Persistence (half-life), soil adsorption, solubility and volatility are important parameters in identifying the fate of pesticides in the environment. After a pesticide is applied to crops, the degradation process begins. The major pathways of pesticide degradation are microbiological breakdown, photolysis, hydrolysis and volatilization (NRC, 1993; Waskom et. al., 2017).

The abovementioned pathways are not only influenced by the chemical structure of the pesticide, but also by soil characteristics; soil texture, structure and macropores, pH, moisture and organic matter content. In addition, distance of the application site to surface and groundwater bodies, topography, climate and irrigation practices can also affect the mobility of pesticides (Waskom et. Al., 2017; NRC, 1993).

There are around 1400 pesticides used globally (He et al., 2018). AGRINUPES will focus on two pesticides in particular, which are used in all countries from the partners: imidacloprid which is a neonicotinoid, and pirimicarb, a carbamate.

3.2.1. Pirimicarb

Pirimicarb is a selective carbamate acaricide-insecticide and is a derivative of carbamic acid. There are more than 50 compounds classified as carbamates found in insecticides, fungicides, nematicides, herbicides, and sprout inhibitors used in agriculture, biocides for industrial applications, and in household products for controlling household pests.

Carbamate insecticides kill insects similarly to organophosphate insecticides by inhibiting a cholinesterase enzyme, preventing the breakdown of acetylcholinesterase, which is needed for a healthy functioning nervous system. Some carbamate insecticides are transferred throughout the plant, making it an effective treatment. Pirimicarb is used for the control of aphids on ornamental plants, vegetables, grains, and orchard crops around the world and used in the United States for pasture and hay crops. There are 23 pirimicarb based insecticides registered globally and the World Health Organization classified it as a Moderately Hazardous Material in 2009 (Natale et al., 2018; WHO, 2009). Carbamates are highly soluble and traces of pirimicarb are traceable in the surface waters nearby farms

Pirimicarb can pose a threat to human health due to its varying degrees of severity of toxic effects and is a suspected carcinogenic agent and mutagen (He et al., 2018; Natale et al., 2018). It is slightly toxic to amphibians and fish, moderately toxic to mammals, and has had adverse effects on microbial communities in freshwater sediments and insects (Natale et al., 2018; Vera-Candioti et al., 2015).

Pirimicarb has been detected frequently in water sources, leading to many researchers studying ways to efficiently remove its presence (Wu et al., 2016).

3.2.2. Imidacloprid

Neonicotinoids are active substances used in insecticides to protect plants from harmful insects. They were created from nicotine compounds after seeing a need for more selective insecticides in the 1990s. Neonicotinoids are a class of neuroactive compounds, including imidacloprid, thiamethoxam, thiacloprid, acetamiprid, clothianidin, and dinotefuran. Unlike contact pesticides, neonicotinoids are water soluble systemic pesticides, thereby easily absorbed by the plant and transported to the leaves, flowers, roots, stems, pollen, and nectar. By value, about 30% of global insecticides used for agriculture are neonicotinoids, particularly for pollinated crops (Cicero et al., 2017). Imidacloprid is the second most widely used agrochemical in the world and is commonly used as a seed dressing to protect crops from insect pests (Feltham et al., 2014). It is approved as an active substance in the European Union, although the European Commission restricted the use of imidacloprid, thiamethoxam, and clothianidin to protect honeybees in 2013. The measure was based on a risk assessment of the European Food Safety Authority (EFSA) in 2012. It prohibits the use of these three neonicotinoids in bee-attractive crops (including maize, oilseed rape and sunflower) except for the use in greenhouse, some crops after flowering and winter cereals (EC, 2018). Turkey banned the use of imidacloprid on certain crops (e.g. okra, apple, tomato, citrus, cucumber, etc.) by the end of 2018, yet its use in greenhouses will proceed (Greenpeace, 2018).

Imidacloprid has been found in soils years after its application, and its general persistence in water has led many countries to study its presence and longevity in water (Johnson and Pettis, 2014). Generally, imidacloprid is not easily biodegradable (Van Djik et al., 2013). Its hydrolysis half-life ranges from 33-44 days (at pH 7.0 and 25°C), while its aqueous photolysis half-life is less than three hours. In soil, its photolysis half-life is 39 days at the soil surface and 26.5-229 days when incorporated into the soil (Fossen, 2006). While many reports say imidacloprid does not have a high risk of groundwater contamination if used correctly, there are consistent reports of detections of imidacloprid above maximum allowable risk (MTR) level at which the ecosystem's species are safe from effects of the substance. Equilibrium partitioning over soil and water has been estimated to give a soil to water ratio of 1:3 (log P= 0.57), thus indicating that imidacloprid could easily end up in water, proven in studies in the Netherlands and America. In the Netherlands, 50% of surface water samples taken from 2004-2013 were above the MTR of 0.013 µg/L (Van Dijk et al., 2013). Imidacloprid has also been found in very high concentrations in surface waters especially nearby greenhouse production in Sweden. It is the substances are that are most often found over the acceptable levels in surface waters close to greenhouses (Kreuger et al., 2019).

Both imidacloprid and pirimicarb have high solubility (at 20 °C) of 610 mg/L and 3100 mg/L, respectively (NPIC, 2010; UH, 2018). Pirimicarb is reported to be moderately persistent with a soil degradation rate (aerobic) of 86 days (DT50), while imidacloprid is highly persistent in soils (Liu et. al., 2006; PPDB, 2019).

3.3. Monitoring and Management of Pesticides

The main issues concerning pesticides' application worldwide are their overuse on a variety of crops (e.g. cotton, vegetables and rice) and improper regulation in some countries, resulting in illegal pesticide use, and ineffective implementation of pesticide residue standards (FAO and IWMI, 2018).

Pesticides are not only regularly found in surface waters receiving agricultural runoff (usually after heavy rainfall or surface irrigation), but increasing numbers of pesticides are also being detected in groundwater bodies in Europe and North America (Morris et. al., 2003; Waskom et. al., 2017). The EC reports that several countries in Europe have concentrations of pesticides in groundwater exceeding the quality standards, and about 7 % of the groundwater stations reported excessive levels for one or more pesticides (Eurostat (b)). Pesticide concentrations in water bodies that are close to agricultural fields have been reported to reach tens of milligrams per litre. The levels of pesticide water pollution can be ranked from highest to lowest concentration as: cropland water > field ditch water > runoff > pond water > groundwater > river water > deep groundwater > sea water (FAO and IWMI, 2018).

Information is limited on pesticide contamination, even though groundwater and surface water are used as a drinking water resource, because monitoring of pesticides is a challenging task due to the high number of registered pesticides, cost of analyses and the need for sampling to be performed during periods of application and use. Key pesticides are regularly monitored by most developed countries, yet high costs for sampling and analysis mean many datasets are not extensive. According to a recent meta-analysis, monitoring data is lacking for approximately 90 % of global cropland (Eurostat (b); Stehle and Schulz, 2015). Thus, one of the objectives of AGRINUPES project is to develop biosensors for on-site monitoring which will, in return, catalyse monitoring of pesticides by shortening the analysis time and reducing associated costs.

Pesticides in surface water and groundwater are addressed by several directives in the EU:

- Pesticides Framework Directive (Directive 2009/128/EC)
- Water Framework Directive (WFD) (2000/60/EC)

- Environmental Quality Standards Directive (Directive 2008/105/EC)
- Drinking Water Directive (Directive 98/83/EC)
- Groundwater Directive (Directive 2006/118/EC)

In both the Drinking Water Directive (98/83/EC) and the Groundwater Directive (2006/118/EC), concentrations of pesticides in drinking water may not exceed 0.1 µg/l for a single pesticide and 0.5 µg/l for total pesticides. In addition, each Member State is obliged to establish monitoring programmes to check that water intended for human consumption meets the requirements of this Directive.

Pesticides Framework Directive (2009/128/EC), on the other hand, aims to achieve "sustainable use of pesticides in the EU by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of **Integrated Pest Management (IPM)** and of alternative approaches or techniques". EU countries, therefore, have drawn up **National Action Plans (NAPs)** to implement the range of actions set out in the Directive, and include indicators to monitor the use of pesticides containing active substances of particular concern. The Directive also imposes Member States to take measures to inform the general public and to promote and facilitate information and awareness raising programs on pesticides.

The Directive asks Member States to take necessary measures regarding information and awareness raising (Article 7), pesticide application equipment (Article 8), aerial spraying (Article 9), aquatic environment and drinking water (Article 11), reduction of pesticide use in specific areas (Article 12), handling and storage of pesticides (Article 13). Additionally, Article 14 requires Member States to describe in their NAPs how the general principles of Integrated Pest Management (IPM) are going to be implemented, and to establish risk indicators in order to measure the progress achieved in the reduction of risks and adverse impacts from pesticide use for human health and the environment.

So far, all 28 Member States developed the first round of NAPs by 2013 and were obliged to revise their NAPs by the end of 2018. According to the EC Overview Report on Sustainable Use of Pesticides (2017), Member States have taken different approaches as there is a huge diversity in agriculture and land use patterns. Also, NAPs had different starting points as some Member States had previously adopted plans.

21 Member States provided targets for pesticide risk reduction, while 9 Member States included targets for pesticide use reduction in NAPs. Only five Member States set measurable targets, of which four aim at risk reduction and one at use reduction. It has been reported that Denmark and Sweden have changed focus from use reduction to risk reduction based on their past experiences. EC Report from the Commission to the European Parliament and the Council (2017) remarks good examples of

risk reduction **targets** can be found in Germany, The Netherlands, Finland and Denmark which developed risk reduction indicators based on pesticide hazard classification. Nevertheless, in around 80% of the cases, action plans do not specify how the achievement of targets or objectives will be measured. Thus, it is difficult to assess the progress in implementation and to identify areas where further actions are needed. In addition, all the NAPs include some measures on the promotion of IPM, in particular to encourage availability of IPM guidelines, and the provision of training or demonstration farms. Nevertheless, the plans do not specify how the application of IPM by farmers can be measured, do not set targets or indicate how implementation will be ensured. The report states that there are significant gaps with regards to aerial spraying, information to the public, the gathering of information regarding poisoning cases and measures to protect the aquatic environment as well as IPM, because most of the Member States have not yet set clear targets and ensured their implementation (EC, 2017).

Turkey has recently revised and aligned the regulations related to water and agriculture as part of the alignment with the EU acquis in the EU accession process. The Turkish Regulation on Surface Water Quality (29797/ 2016) sets environmental quality standards for specific pollutants in surface water resources, including imidacloprid and pirimicarb. Table 6 displays the designated EQSs for each partner of the AGRINUPES project.

Table 6. Environmental Quality Standards for Surface Water Resources.

EQSs (yearly ave.)	**The Netherlands**	**Turkey**	**Portugal**	**Sweden**
Pesticides (total)		0.1 µg/L (per substance) 0.5 µg/L (total)	VMA* – 1.0 µg/L (surface water) 0.1 µg/L (per substance) 0.5µg/L (total) (groundwater**)	0.1 µg/L (per substance) 0.5µg/L (total) (groundwater**)
Imidacloprid	0.0083 µg/L	0.14 µg/L	Not available	0.005 µg/L
Pirimicarb	0.09 µg/L	3.3 µg/L	Not available	0.09 µg/L

* stands for Law by Decree 236/98, of 1 of August – on the quality of surface waters used to withdrawal water for human consumption; VMA – maximum acceptable levels

** Directive 2006/118/EC on the protection of groundwater against pollution and deterioration

Similar to the EU case, Turkey is experiencing difficulties in pesticide use and risk reduction as control mechanisms, penalties, and effective implementation of policies fail to fulfil the needs. Thus, improvements are needed both in the application and use of pesticides and surveillance on the impacts of pesticides in water bodies.

4. Common Agricultural Policy and Incentive Mechanisms: What Can AGRINUPES do to Increase Implementation Capacity?

4.1. Introduction

The incentives system in the EU is a strong pillar of 'Common Agricultural Policy' (CAP) that makes farming business attractive for farmers, while maintaining food security and market stability across the continent. Incentives and other support mechanisms are structured to prescribe farmers' agricultural activity in a standardized way and maintain well-being of ecosystems. There are certain indicators that farmers must fulfil in order to obtain access to incentive mechanisms. The task of keeping pesticide and nutrient concentration levels below nationally determined thresholds in water bodies and soil is referred in several criteria for proof of environmental compliance.

Verification of compliance is a challenging task for field inspectors, who are charged with controlling and affirming farmers' compliance level. The main challenge is to monitor the compliance level accurately on a timely and affordable way with enough human capacity. AGRINUPES NPK sensors and pesticide biosensors proves high potential as tools to assist farmers with optimum input use and to assist field inspectors to verify compliance with environmental standards accurately and affordably at ease of use. In this context, the following paragraphs investigate the incentives mechanism in the CAP structure associated with environmental conservation -particularly water quality management- and propose potential areas of use for AGRINUPES tools.

4.2. The Process of Integration of Environmental Concerns into the Common Agricultural Policy

The incentive schemes investigated in the following paragraphs are designed and regulated under the Common Agricultural Policy; the single most ambitious component of EU's free-market economy that represents approximately 40% of the EU budget. The CAP interacts with a chain of economic sectors including food, water, chemicals, health, transportation and storage among other sub-sectors. In the context of this report, the significance of the CAP lies in its capacity to melt EU's policies of water and agriculture in a common pot. The CAP's method of bridging these two domains is evolved through decades and incentive mechanisms have their role in this evolution. To put it briefly, beneficiaries of the CAP's incentive payments need to comply with requirements of EU's water related framework legislations as adapted by Member States.

Although the EC's current agricultural incentives system is built upon ecological guidelines, it was not the case until the end of 1990's. One major step forward was taken in 1999, with the European Council enacting a “Council Strategy” that integrates environmental and sustainability concerns into Common Agricultural Policy, which is known as Agenda 2000 (European Council, 2000). Until then, the primary focus of Common Agricultural Policy was to improve living standards of farmers while maintaining market stability and availability of supplies. The last stroke for good came in 2013, with reformation of CAP for the period of 2014-2020. Currently, preparations for the post 2020 CAP reform are ongoing at the EU level (European Parliament, 2019).

The evolution of CAP shifted the backbone of incentives system from “price support” to “direct payments” gradually. Basically, the former system used to encourage farmers to produce more with no environmental measures taken, whereas the current formula enables access to direct payments for farmers who must comply with environmental standards. Furthermore, with the integration of environment into the CAP and good agricultural practices concept, certain methods of agriculture including low-input farming as promoted by AGRINUPES sensors, are formulated to remunerate farmers voluntary efforts. For instance, the Council Strategy explicitly calls for reducing nutrients use in line with crop needs and applying PPPs in accordance with the principles of **Good Plant Protection Practices** as described by **European and Mediterranean Plant Protection Organization (EPPO**). In the principles section of the Council Strategy document, the general orientation is formulated in a way that attributes farmers the responsibility to “observe the reference level of good agricultural practices”(European Council 2019) and puts farmers on the driving seat to be accountable for their actions.

Another concrete development that signifies integration of environmental aspects into the CAP has been the development of **Agri-Environment Indicators (AEIs)**. Launched in 2002 as the outcome of **The IRENA operation** (Indicator Reporting on the Integration of Environmental Concerns into Agriculture Policy), AEIs are designed to track the integration of environmental concerns into the CAP according to reference values in 28 indicators (EUROSTAT, 2019) (Table 7). The reference level values regarding water quality are described in numerous legislations including, but not limited to the Drinking Water Directive (98/83/EC), the Groundwater Directive (2006/118/EC) and in the Environmental Quality Standards Directive (2008/105/EC).

More specifically, AEIs are designed for compiling relevant environmental data that shows the current state of environment and exposing the pressures and impact agriculture imposes over environment. So that, environmental policies within the CAP can be evaluated and modified based on interpretation of indicators. Despite the good reasoning behind the formation of AEIs, there are several limitations remaining that damage the indicators’ use value such as harmonization deficiencies in the data sets, data availability and indicators' lack of conceptual clarity. The question is how AGRINUPES sensors can contribute to overcome listed limitations?

It can be observed at a glance, among all 28 indicators (Table 7), four of them –namely, gross nitrogen balance , risk of pollution by phosphorus , pesticide risk , water quality-nitrate and pesticide pollution - are suitable for utilizing AGRINUPES tools to increase data gathering capacity. More specifically, NPK sensors can help nitrogen balancing and mitigating phosphorus pollution risk, while pesticide biosensors can be utilized to mitigate risks associated with PPPs.

Table 7. List of Agri-Environmental Indicators.

Number	Agri-Environmental Indicators
1.	Agri-environmental commitments
2.	Agricultural areas under Natura 2000
3.	Farmers' training level and use of environmental farm advisory services
4.	Area under organic farming
5.	Mineral fertilizer consumption
6.	Consumption of pesticides
7.	Irrigation
8.	Energy use
9.	Land use change
10.	Cropping and livestock patterns
11.	Soil cover, tillage practices and manure storage
12.	Intensification/extensification
13.	Specialization
14.	Risk of land abandonment
15.	**Gross nitrogen balance**
16.	**Risk of pollution by phosphorus**
17.	**Pesticide risk**
18.	Ammonia emissions
19.	Greenhouse gasses
20.	Water abstraction
21.	Soil erosion
22.	Genetic diversity
23.	High Nature Value farmland
24.	Renewable energy production
25.	Population trends of farmland birds
26.	Soil quality
27.	**Water quality-nitrate and pesticide pollutions**
28.	Landscape-state and diversity

4.3. The Structure and Functioning of the EU's Incentive Mechanisms

4.3.1. Who Does What?

According to 2013 figures of Eurostat, there were 10.8 million farms across Europe (Eurostat 2013). Considering that most of these farms rely on incentives at varying degrees, it requires a well-functioning, yet simple enough structure to overcome the complexities of bureaucracy. An effective distribution of tasks across **European Commission** and **Member States** is in action to do this. As the grand regulatory, the European Commission regulates the compliance framework for member states. While the Commission is responsible for issuing framework regulations and auditing the performance of Member States, the implementers of the incentive programs are Member States. As the Commission communicates with institutions at state level only, it is Member States' duty to distribute sources by ensuring that farmers have knowledge and capacity to access incentives. There are several institution at state level for that. **National Paying Agencies** commissioned by governments are responsible for distributing incentive sources under the supervision of the Commission. Another important national institution is **Farm Advisory System (FAS).** The FAS advisors are endorsed by governments with duty of providing advice to farmers to increase their compliance capacity (European Commission 2019 (a)). And finally, **Integrated Administration and Control System (IACS)** is responsible at Member State level for management and control of payments (European Commission 2019 (b)). Another important function of IACS is to support farmers in making correct declarations by performing on-the-spot checks to verify that conditions for payment are fulfilled.

4.3.2. How?

The EU's agricultural incentives structure is built upon promoting crop yield without compromising environmental needs as appropriate. It oversees sustainability by decoupling incentives from agricultural yield quantity and prioritizing the quality of activity and its environmental impact above all. The incentives structure under the CAP's agri-environment measures expects farmers to control the impact of their activities in three priority areas; biodiversity preservation, climate change mitigation and adaptation, and water management and use (European Commission 2019 (c)).

The CAP has three primary action measures to safeguard farmers' well-being in particular and EU's food security in general, while maintaining ecosystem's sustainability. **"Market Measures"** are designed to stabilize supply and demand conditions in food market against uncertainties. With the intention of balancing supply and demand in the market, these measures are designed as product-specific to encourage production and marketing of particular crops to eradicate scarcity. Market

Measures have no connotations with environmental concerns, thus it is not a subject for further analysis.

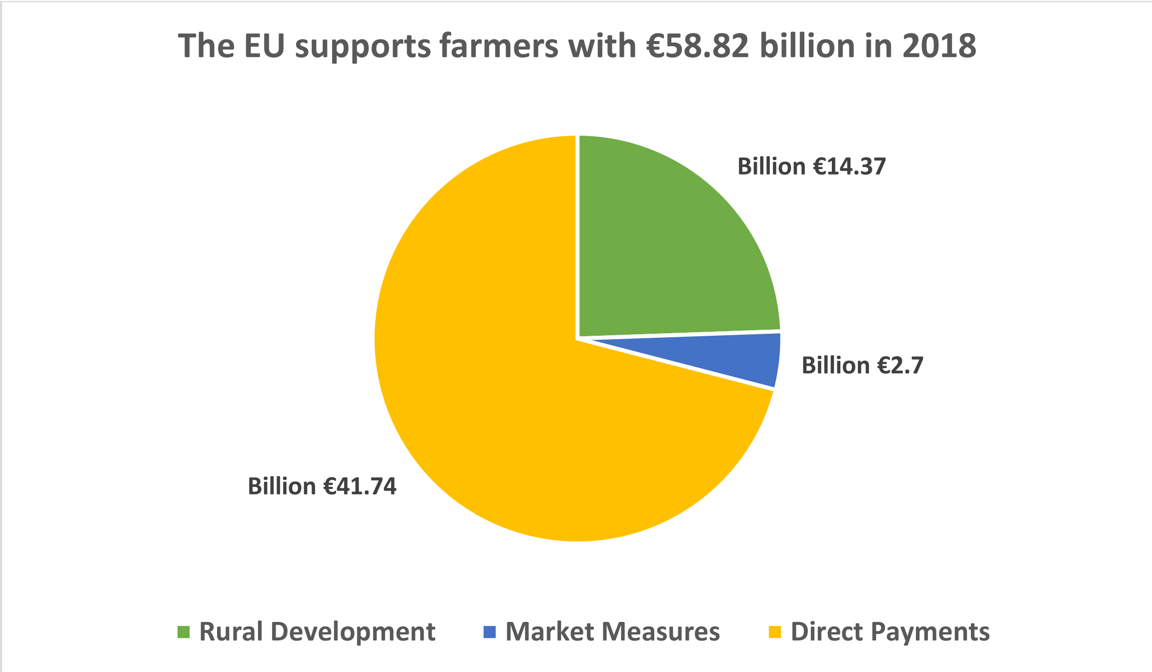

Figure 4. The EU Support to Farmers in 2018 (European Commission 2019 (g)).

"Rural Development Programs" (RDPs), on the other hand, are built for improving farming capacity and competitiveness in rural areas by addressing spatial discrepancies, challenges and needs. For the period of 2014-2020 there are 118 different RDPs operated by Member States (European Commission 2019 (d)). States are responsible for developing agri-environment measures under the RDPs, but it is farmers' voluntary choice to go beyond basic farming practices if they are willing to reach benefits. During the 2007-2013 period, agri-environment measures consisted 22% of EU's expenditure for rural development, which fiscally corresponds to 20 billion Euros (European Commission 2017). During the same time period, Member States allocated 51% or 75 billion Euros of their RDP budgets on investments related to water management. In general, RDP supports are used for new investments and management techniques that oversees quantifiable environmental targets in future. Thus, environmental impact of farmers' current practices do not hinder or enable access to RDP incentives. It is rather about the planned measures' positive impact to environment that determines accessibility of incentives.

The third measure, **"Direct Payments"** intends to sustain income stability for farmers and it composes the largest share of the CAP's dedicated funding scheme, reaching 72% of total financing by 2018. This income support is a means to cover hidden/externalized costs of farmers' expenditure and remunerate them for their environmentally sound farming practices. Current scheme of direct support has evolved for several times since the initiation of AGENDA 2000. Regulation 1307/2013 on rules for direct payments within the framework of CAP now sets up the common rules for operation of direct payments, yet the member states are free to implement their own measures with subsidiarity principle. This flexibility allows room for member states to monitor and incentivize actions with preferred methods, as long as the framework common rules and reference values are supervised. According to the official EC CAP figures, the average direct payments amount to €267 per hectare (European Commission 2019 (e)).

The "Cross-Compliance" system forms the integral part of Direct Payments measure and it ensures that farmers who do not comply with environmental requirements have limited access to incentives. The following paragraphs elaborate the logic of Cross-Compliance system further and provides insight on how AGRINUPES tools can assist in smooth functioning of the system.

4.4. Cross-Compliance Further Explained

Thanks to Cross-Compliance, the CAP not only incentivizes good practices, but it also penalizes harms against sustainable farming. Farmers' extra efforts to improve ecological standards are rewarded in line with "provider-gets principle" in cross-compliance structure, whereas in order to avoid penalties shaped around "polluter pays principle", farmers need to ensure that their past and ongoing activities do not contradict with EU law on environment. The potential of AGRINUPES tools shines brightest in this context due to their potential use for verification of farmers' optimum input use and limited impact on water resources; thus increasing their capacity to have access to direct payment opportunities(European Commission 2019 (h)).

Direct payments have one fundamental and several complementary components, the former as known as **basic payments** calculated according to size of farmland and the latter as additional payments, including **green payments** that are granted for farming applications that contribute to environmentally-friendly performance, beyond baseline good agricultural practices. Cross-Compliance is the structure that governs green payments aspect of direct support mechanism. It imposes complementary environmental and public health criteria over beneficiaries of direct support. Farmers who fail to realize these criteria have reduced, or none at all, access to direct support benefits.

Introduced by a Council Regulation in 2003 as a compulsory mechanism for all farmers willing to access direct payments, cross-compliance scheme is based on two-pillars that makes it functional. The first component, **"Statutory Management Requirements" (SMRs)** brings several legislative requirements that relate with environment including water quality (Farm Advisory System Scotland, 2019). In particular, "Regulation on Plant Protection Products" and "Nitrates Directive" are two related regulations contributing to SMRs' water and soil protection aspects. Four out of 13 SMRs proposes measures that have direct impact on water and soil protection, which can be supported by AGRINUPES tools.

Table 8. Statutory Management Requirements.

SMR Cross Compliance Requirement Related to AGRINUPES Tools	Subject
SMR 1	Protection of water against pollution caused by nitrates
SMR 3	Conservation of Natural Habitats and of Wild Flora and Fauna
SMR 4	Food and Feed Hygiene
SMR 10	Plant Protection Products

The other component of cross-compliance requirements known as **"Good Agricultural and Environmental Conditions" (GAECs)** refers to certain standards, primarily related to keeping soil in good condition, but they also contain provisions on water management as well. GAECs, necessitate certain measures to be taken by farmers for receiving the CAP payments such as constructing buffer strips along water courses, formal authorization for using irrigation water and due diligence to prevent groundwater pollution due to agricultural practices.

Table 9. Good Agricultural and Environmental Conditions.

GAECs Cross Compliance Requirement Related to AGRINUPES Tools	Subject
GAEC 1	Establishment of Buffer Strips along Watercourses
GAEC 3	Protection of Ground Water against Pollution
GAEC 6	Maintenance of Soil Organic Matter Levels through appropriate practices

Implementation of cross-compliance system with SMRs and GAECs is ensured by Member States. Member States reach this goal by doing legislative amendments, defining obligations, informing farmers, establishing and running a control system to perform sanctions in the case of non-compliance. Farmers willing to benefit from direct support have to apply for it by declaring the agricultural parcels they possess and proving that they comply with eligibility conditions. To check the eligibility of farmers is the responsibility of field inspectors authorized by IACS.

European Court of Auditors' special case study on integration of EU water policy objectives with the CAP reveals that cross-compliance system has increased farmers' awareness on water and input use (European Court of Auditors, 2014). But, the Court highlights the factors limiting the success as (a) inadequate coverage of water-related issues in cross-compliance structure, (b) partial approach to "polluter-pays principle" since the sanctions under cross-compliance are far from covering the actual costs of impact, and (c) Member States' inability to fully implement the mechanism such as buffer zones. Especially for the first limitation factor (a), the absence of provisions that limits the amount of phosphorus used and prevents excessive pesticide use on lands close to water bodies need to be addressed. During the Court audits, several breaches observed in fulfilment of cross-compliance requirements related to SMRs as well. Nitrate output higher than allowed limits, incomplete fertilizer records and inadequate storage conditions for manure are the most frequently detected failures under SMRs.

Cross-Compliance system is an essential component of direct payments and shapes farmers' behavior for adapting environmentally sound practices. Yet, there is another supplementary set of rules that completes direct payments system, which is known as **"Greening"** component.

4.5. Greening of Direct Payments: How AGRINUPES Tools Can Contribute?

Brought by the 2013 CAP reform, greening mechanism is the gateway for a more sustainable CAP. As a component of direct payments structure, greening payments constitute 30% of direct payments realization (European Commission 2019 (f)). Three sets of activities are defined under greening payments that farmers have to comply with in order to increase their incentive payments:

- Diversifying crop pattern in a given land to increase its resilience,
- Protecting the share of permanent grassland's in total farming area,
- Establishing 'ecological focus areas' to protect habitats within farm zones.

Crop diversification criterion entails farmers who own arable land from 10 to 30 ha of area to grow at least 2 different crops, with the condition that the main crop's coverage does not exceed 75% of the total area. For the arable lands larger than 30 ha, the minimum type of crops should be 3, and the coverage area of two crops should not exceed 95%.

According to **permanent grasslands criterion**, the coverage area of environmentally sensitive permanent grasslands designated according to Natura 2000 shall not be lower than 5% compared to the reference year.

Ecological focus area criterion on preserving ecological areas is the most appropriate field for using AGRINUPES pesticide bio-sensors. Farmers who farm a land exceeding 15 ha and are willing to benefit from greening incentives under this criterion must reserve a minimum of 5% of their land for ecological focus areas. According to Regulation (EU) No 1307/2013 establishing rules for direct payments to farmers, one of the criteria to meet the ecological focus area requirement is not to use any mineral fertilizers and/or plant protection products in the designated area (Art 46.2.g). Biosensors have great potential to be used by IACS's field inspectors to check whether PPP residues are channelled into water bodies.

Table 10. EU Regulations Related to Greening of CAP (European Commission, 2019 ((f)).

Greening is based on the following EU regulations;
• Regulation (EU) No 1307/2013 on direct payments under the CAP (the basic 'horizontal' regulation), in conjunction with
  o Delegated Regulation (EU) No 639/2014 on direct payments under the CAP
  o Implementing Regulation (EU) No 641/2014 on direct payments under the CAP
• Regulation (EU) No 1306/2013 on financing, managing & monitoring the CAP in conjunction with
  o Delegated Regulation (EU) No 640/2014 on the integrated administration & control scheme
  o Implementing Regulation (EU) No 809/2014 on the integrated administration & control system

Although these three criteria are considered as the regular means for validating greening activities, the member states are also free to adapt alternative measures as known as **"equivalent practices",** provided that they are based on national RDPs and certification schemes. For instance, the Annex 9 of Regulation (EU) No 1307/2013 indicates that member states may consider measures for pesticide restrictions and fertilizer regime applications as equivalent to maintenance of permanent grassland. Annex 9 also indicates that "keeping arable peaty under grass without using fertilizers and plant protection products" is an equivalent action for ecological focus area application. Thus it gives flexibility for farmers to choose the most appropriate greening method among a basket of options. This flexibility also indicates that AGRINUPES tools have greater potential –yet to be explored- as means of verification for cross-compliance and greening requirements.

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