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Scenario analysis of pollutants loads to European regional seas for the year 2020

Part I: Policy options and alternative measures to mitigate land based emission of nutrients

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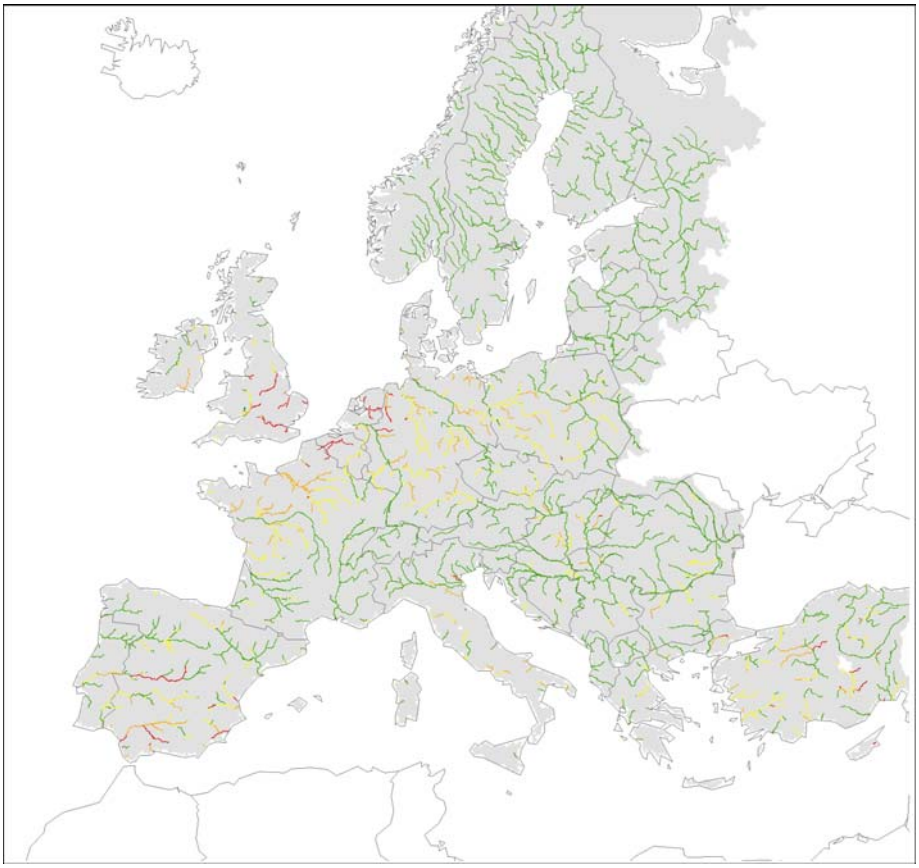

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Executive Summary

In order to support the implementation of the Marine Strategy Framework Directive, DG Environment and the Joint Research Centre of the European Commissionjoined to carry out a study on the expected cumulative impact of existing EU environmental legislation on the quality of the marine environment, with specific reference to the case of aquatic discharges to European seas. The assessment, considering regional seas as final receiving water bodies, focused mainly on trends and options for reduction of inland-based emissions of nutrients and chemicals. Therefore, the results of this study are useful not only for the implementation of the Marine Strategy Framework Directive, but also to other policies developed by the EU to control emissions to water bodies from a variety of sources (e.g. the Water Framework Directive, the Nitrates Directive, the Urban Waste Water Treatment Directive).

The results of some scenario analyses affecting emissions to the European regional seas up to the year 2020 are presented for convenience in two separate EU reports. The present one deals with the assessment of loads of Nitrogen and Phosphorus, and the other focuses on three chemicals taken as pilot substances - Lindane, Trifluralin and Perfluorooctane sulfonate (Marinov et al., 2011). The scenarios were agreed with stakeholders at DG Environment following some preparatory meetings. They do not intend be exhaustive, but examples of what can be further achieved by making use of the modelling tools and databases developed during the different phases of the project.

Part I: Policy options and alternative measures to mitigate land based emission of nutrients (Nitrogen and Phosphorus)

The study on nutrient loads was divided in three phases. The first one was focusing on data collection and model development. The second phase dealt with the retrospective assessment for the years 1985-2005, including the collection of all relevant data and a trend analysis for nutrient loads to pave the way for the scenario development and evaluation that was the focus of the third part of the study. The results of the previous two phases are reported elsewhere (Bouraoui et al., 2009 and 2011). The present report summarizes the results of the third phase. First, a Business as Usual (BAU) scenario was defined and then three types of mitigation scenarios were developed and tested by addressing:

i) the collection and treatment of point sources (UWWD and PFREE scenarios),

ii) a change in European human diet (WHO and WCRF scenarios)

iii) the management of manure application in Europe (MANU scenario).

Scenarios were run with the GREEN model, which uses input from anthropogenic activities (agriculture, industries, wastewater) to calculate the load of nitrogen (N) and phosphorus (P) for the whole Europe on a sub-catchment basis. The dual objective was to assess changes of land based nutrient loads to European regional seas providing at the same time an assessment of impacts of actions affecting inland based nutrient emission.

All mitigation measures were assessed using as reference both the year 2005 and the Business as Usual scenario (BAU) including change in population count and distribution and considering the status-quo in wastewater treatment for 2020. It also includes prospects for food production and prediction for crop requirements.

The Results on the mitigation of nutrients emitted as point sources combined several parameters as the changes in population density, the increase of connection rate to the sewage network, the upgrading of wastewater treatment plants. The gap between EU-15 and new Members States is clearly evident.

For EU 15, the implementation of the Directive 91/271/EEC (UWWD scenario) mostly results in the upgrading of existing treatment plants with basic treatment to more stringent treatment of nitrogen and phosphorus, leading to a significant decrease of point sources emission for nitrogen (from -7% for the Netherland up to -50% in Ireland). Results for phosphorus are also very significant (with a decrease up to 63% in Belgium) when combined with a ban of phosphates and other phosphorus compounds in household laundry detergents (PFREE scenario), as suggested by the Commission proposal COM (2010) 597 amending Regulation (EC) No 648/2004.

For the new Member States, the full implementation of the UWW-Directive leads to an important transfer of nutrient sources from non-collected emission (scattered dwelling) to point-sources emission (connected to sewers). This transfer tends to limit the impact of the UWWD scenario and leads to a significant increase of point source, as for example for Romania (+54% N; +34% P) or for Slovenia (+73% N; +51% P) where a complete reduction (>90%) of scatter dwelling emissions is simulated. It is important to note in this context that scattered dwellings are a major source of groundwater contamination.

Options to mitigate nutrient emissions as diffuse sources include the change in European human diet (WHO and WCRF scenarios) and the management of manure application in Europe (MANU scenario). The WHO and WCRF scenarios, considering progressive decrease of beef and pork meat consumption and an increase of vegetal proteins in human diet, have a low impact on nitrogen and phosphorus diffuse sources. This is partially explained by the storylines of these two scenarios, which, according to the agri-economic prevision of the CAPRI (Common Agricultural Policy Regional Impact) model, consider a significant decrease in meat consumption in Europe, but at the same time an important increase of meat export outside Europe necessary for farms to be economically sustainable. In the more stringent WCRF scenario, the sum of anthropogenic diffuse emissions is decreased by 4 % for nitrogen and 3% for phosphorus at the scale of EU-27. This clearly highlights the necessity to consider simultaneously human meat intake and meat production in order to achieve significant decrease of nutrient emissions from animal breeding.

While previous environmental assessments put emphasis on a change in food *consumption* as an efficient way to reduce nitrogen input to the environment in Europe, this report suggests that a more realistic scenario analysis should consider both agricultural *production* and *trade*. Indeed, it is shown that the *production* of meat in Europe will be essentially preserved even in the presence of a drastic decrease in European *consumption* of meat due to a large increase of meat export towards other countries.

The third type of mitigation scenario tested in this study concerned an optimized distribution of animal manure. The MANU scenario leads to a further decrease of nitrogen diffuse sources, with even a shift in the nitrogen source apportionment for several basins in Europe. This scenario also emphasizes a significant decrease in the application of mineral nitrogen, with evident benefits also due to the continuously increasing price of nitrogen fertilisers.

The assessment of nutrient loads to European seas made use of the GREEN model, which was previously shown to be appropriate for the estimation of nutrient fluxes based on a simplified representation of the processes involved in transport and retention. The following table summarizes the results of the scenarios implementation for each European sea for the year 2020 (see next page):

Nitrogen loads	Baltic	North Sea	Atlantic	Black Sea	Mediterranean
(1000 tons of N/yr, min and max simulated)					
REF	475 - 687	872 - 1420	707 - 1190	434 - 635	697 - 982
BAU	488 - 714	902 - 1469	733 - 1244	458 - 671	731 - 1011
UWWD	483 - 709	836 - 1403	691 - 1202	446 - 659	693 - 972
WHO	486 - 712	893 - 1454	729 - 1236	457 - 670	730 - 1008
WCRF	481 - 701	873 - 1419	717 - 1208	455 - 665	721 - 993
MANU	394 - 540	692 - 1059	591 - 932	400 - 554	616 - 805

Phosphorus loads	Baltic	North Sea	Atlantic	Black Sea	Mediterranean
(1000 tons of P/yr, min and max simulated)					
REF	27 - 35	46 - 64	37 - 48	31 - 38	61 - 83
BAU	27 - 35	47 - 66	38 - 50	33 - 40	64 - 86
UWWD	26 - 34	35 - 53	31 - 43	29 - 36	54 - 75
PFREE	22 - 30	28 - 47	27 - 39	25 - 33	49 - 70
WHO	27 - 35	47 - 65	38 - 49	33 - 40	64 - 85
WCRF	27 - 35	47 - 65	38 - 49	33 - 40	64 - 85
MANU	27 - 37	48 - 69	38 - 51	34 - 49	63 - 81

(Nitrogen and phosphorus loads have been calculated for a range of 21 years hydrological conditions. Results are provided with a Min-Max loads simulated over the 21 years simulation period)

In the horizon 2020, the BAU scenario simulated an increase of both nitrogen and phosphorus loads exported to European seas. This increase is more significant for nitrogen especially when combined with high hydrological conditions (high flow).

When comparing the mitigation of nutrient inputs with the concomitant change in nutrient loads, it is clearly demonstrated that point source mitigation measures are the most effective option. Indeed, a change in point source emissions could be directly linked to a change in nutrients exported to European seas once aquatic retention is taken into account, while mitigation of diffuse nutrient inputs is submitted to both the terrestrial and aquatic attenuation. Beyond this first result, scenarios efficiency has to be considered with respect to the source apportionment of each nutrients (N and P), in order to estimate its capacity for mitigating nutrient emissions. Scenarios results differ for Nitrogen and Phosphorus.

For phosphorus, the rate of removal in WWTPs has considerably improved during the last decades with about 90 % of P removal now achieved for the most advanced WWTPs. Considering that human emissions of phosphorus are now stabilized to a value close to physiological releases, additional mitigation could only come from a complete ban of phosphorus in laundry detergents (PFREE scenario), which will result in the most significant reduction of phosphorus export to European seas.

In the case of nitrogen, the source apportionment indicates that nitrogen flowing to European seas is widely dominated by agricultural (diffuse) sources. Consequently, while scenarios targeting nitrogen point-sources are more efficient they enable only a low reduction of the overall amount nitrogen loads. The most important decrease of nitrogen output is related to the optimization of animal manure application.

The mitigation options to be selected might lead to very different effects on respectively nitrogen and phosphorus loads to European seas. The study showed the importance of a simultaneous assessment of both nitrogen and phosphorus emissions and exports.

Part II: The assessment of priority chemicals - example of three pilot substances

The scenario results of a European-scale assessment of chemical loads to regional seas are reported in Marinov et al. (2011). For chemicals, a major difficulty comes from the limited availability of data on the location of sources and the extent of emissions. In this study, we have used statistical information from EUROSTAT plus data available from the European Monitoring and Evaluation Programme (EMEP) and a number of literature studies. However, the sources of information are in general limited, which represents the main obstacle for the evaluation of pollutant loads originating from the European continent.

Due to the extraordinarily high number of chemical products on the market, which potentially could be discharged to the sea after being used or released to the environment during manufacturing, the assessment was not intended to be exhaustive, but rather to develop a methodology for the identification of hot-spots in Europe and its capability for the estimation of chemical loads to European coastal waters under different scenarios.

In order to perform prospective scenarios for Europe, the concentrations and loads of three test-case chemicals were evaluated firstly for the following baseline years: 1995 and 2005 for the insecticide Lindane; 2003 for the herbicide Trifluralin; and 2007 for the industrial pollutant Perfluorooctane Sulfonate (PFOS). Then, a set of different scenarios was defined and the assessments made using either a “direct” or an “inverse” modelling approach.

The “direct” method is based on a priori available information about chemical emissions and answers the question “Where do chemicals go after being emitted?”. In this study, the “direct” version of the spatially resolved Multimedia Assessment of Pollutant Pathways in the

Environment (MAPPE) screening model was applied in the scenario case-studies of Lindane and Trifluralin, additionally supplemented by a simple non-spatial box model application.

The "inverse" approach tries to answer the question "Where do pollutants come from?". Inverse models can support large scale assessments of source apportionment by estimating emission factors at regional, river basin or continental scale in relation to the population density or other proxies. This approach was employed in the backward tracking of PFOS emissions from pan-European riverine measurements. Then, on the basis of the estimated average emission factor for Europe, the spatial GIS analyses made possible to evaluate the scenarios for the annual load of PFOS to European seas.

The scenarios for the three pilot chemicals considered are formulated to the time horizon of year 2020 assuming different types of legislative measures (for example business as usual, ban, phase out, etc.) or aiming at specific targets (as per total and disaggregated load to European seas or possible "cleaning-up" of soil in Europe). Details about the scenarios are provided separately for each test case.

The summary of the results for the scenarios developed in the study is given below. When considering the output of the scenario analyses, it is important to take into account that the project aimed at testing the applicability of the modelling platform. Moreover, since limited data on emissions are available certain assumptions had to be made, thus restricting the use of the present scenario results only for screening purposes.

1. Lindane (γ-HCH)

Lindane is a relatively well known insecticide officially banned in the European Union since 1995. Some Lindane emissions, however, are still occurring due to releases from stockpiles or other sources, which are difficult to quantify. Lindane was selected as a pilot substance in this study because of the availability of data about past emissions and measured environmental concentrations.

Air emissions of post-ban use of γ–HCH are quite difficult to be estimated although these sources may significantly affect the current environmental concentrations (Breivik et al., 2004). A European inventory of Prevedouros et al., (2004) suggests that ca. 135000 tons were applied over the period 1970–1996 with the major contributions originating from France, Spain and the Netherlands. Besides, other authors estimated that approximately 650 tons were emitted in 1998 and the contribution of each European country was calculated (Breivik et al., 2004). However, at present the only comprehensive and reliable source of emission data at European scale is the European Monitoring and Evaluation Programme (EMEP), providing official data on atmospheric emissions by country (CEIP, 2009).

The current study relies on Lindane air emissions estimated by EMEP (www.emep.int). Accordingly, the air emissions of γ-HCH in the Northern hemisphere were estimated to be 432 tons in 2005 including 71 t in North America, 68 t in Central America, 200 t in Southeast Asia and 92 t in Europe. In addition, the European continent received an extra deposition of ca. 2% of emissions coming from sources originated in North America and China (Gusev et al., 2006).

Then, based on the officially reported information for the amount and spatial pattern of the air emissions in Europe and trans-continental long range transport, the following atmospheric scenarios for Lindane were analyzed:

- **BAU** – (Business as Usual) no change of air emissions; keeping 2005 level of emissions up to the time horizon of 2020 (about 92 tons are supposed to be emitted in 2005);
- **trend** – a scenario continuing the emissions decline observed in the period 2000-2005, as a result of the regulation process started in 1995; accordingly, the emissions in 2020 equal to 45.6 t/y (49.6% of 2005 level);
- **linear** – a generic scenario which respects the regulations and assumes a gradual linear reduction of emissions starting in 2005 and ending in 2011 with 23 t/y (25% of the 2005 level of emissions); the choices of 2011 as an end year of measures and the percentage of emission reduction were provisional; no change of emissions after 2011;
- **ban** – a scenario consistent with the regulation acts considering a fast exponential reduction of the European emissions in the period 2005-2011; emissions in 2011 are supposed to be equal to 5.4 t/y (the quantity arriving in Europe by the Long Range Atmospheric Transport according to 2005 data); as for the linear scenario, the selection of 2011 as an end year of measures is provisional; from 2011 to 2020 no European emissions, but the scenario accounts 5.4 t/y intercontinental atmospheric transport from North America and Southeast Asia using 2005 data as a background level (the last available data from EMEP (Gusev et al., 2006).

After the description of possible scenarios for air emissions, the next step was to specify the corresponding emissions to the other environmental media. According to UNEP (Breivik and Wania, 2002), about 59% of the total amount of Lindane is used for soil treatment, while seed treatment, which presumably yields lower emissions to air, accounts for 34%. Furthermore, Lindane is generally applied in liquid formulations (mostly wettable powders) and only a minor fraction is used in the solid state (dusts, powders, and granules). On this basis, a mode of division of total Lindane emissions of 17.5% to the atmosphere, 80% to the agricultural soil, and 2.5% to freshwater is assumed by Breivik and Wania, (2002) and Vizcaino and Pistocchi, (2010). Practically, the equivalent approach was used in the EMEP modeling applications for Lindane (www.emep.int). Therefore, the same fractioning of Lindane emissions was adopted up to the year 1999 and only atmospheric emissions from 2000 onwards since the ban of Lindane in EU for agriculture use.

The results of the present scenario study on Lindane for EU27 plus Norway, Switzerland, Croatia, Serbia, the western Balkan countries and Turkey allowed us to conclude following:

- The comparison with the OSPAR data (OSPAR Commission, 2011) or with data used to force a 3D model of North Sea (Ilyina et al., 2008) showed that MAPPE model produced consistent results for the riverine load of gamma-HCH to European seas which eventually could differ from the other estimates by not more than a factor of two;
- The model assessed European sea loads of 745 tons for 1995 (based on the official emission data provided by EMEP) appears to be reduced by 98.3% in 2005, ten years after the start of the EU regulations for γ-HCH;
- In 2020, under the BAU scenario, a Lindane sea load of ca.12.5 tons per year would be expected;
- The trend and ban scenarios support a reduction of the load to the European seas in 2020 by 74% and 95%, respectively, when compared to the BAU estimate;
- The discharge of Lindane under BAU scenario is affecting mainly the European coast of the Atlantic Ocean (49 % of the total for Europe), Mediterranean (27 %) and Black seas (19 %), while in the case of the ban scenario the Black sea (43 %) is the main recipient, followed by Mediterranean (19 %) and Baltic (17%) seas and Atlantic Ocean (16%).

2. Trifluralin

Trifluralin (a priority substance under the Water Framework Directive) is an herbicide banned in EU countries since 2008. Presently, very little information on Trifluralin emissions is available at pan-European scale, and the only comprehensive dataset for the 25 EU Member States is provided by EUROSTAT with reference to the year 2003. Besides, this study assumed that the contribution of the long-range atmospheric transport and of UWWTP effluents is a negligible source of Trifluralin pollution. Thus, the scenario study of Trifluralin sea load focuses only on the emissions to European soil. In order to assess the soil emissions of Trifluralin, the method of Pistocchi et al. (2009) was applied using EUROSTAT data (although this approach tends to overestimate the use of plant protection products). This method assumes that when a certain class of pesticides is applied, then likely only a single substance from that class is used everywhere across Europe as a representative for this pesticide class. Accordingly, the **BAU** scenario considers as input for Trifluralin the data on the entire class of dinitroaniline herbicides (8 substances including Trifluralin) for which EUROSTAT reported 6174 tons applied to arable crop land in Europe during 2003 (average use of 1.56 kg/km^2/y with a regional variability ranging from 0.01 to more than 20).

Furthermore, the study investigated the potential impact of the complete ban of Trifluralin applications. In the **ban** scenario the emissions were assumed to drop, in the period 2004-2010, from the typical BAU application for 2003 to an amount of 0.005 kg/km^2/y, taken as an approximation towards zero emissions from 2011 onwards for each of the EU25 countries.

In addition, despite of the uncertainty of the data about Trifluralin applied to the soil, a specific **partial effectiveness** scenario was analysed aiming to assess how much the soil emissions should be reduced in order to ensure that the annual sea load remains lower than a given limit taken here as one third of the BAU estimate.

The modelled scenario results for Trifluralin indicated that:

- According to the BAU scenario based on EUROSTAT usage data, in 2020, the sea load of Trifluralin, considered as representative for the entire group of dinitroaniline herbicides, is estimated to be ca. 61.7 tons, the same as for the reference year 2003;
- The complete ban scenario forecasts ca. 0.07 t/y sea load and in practice eliminates the concern about the discharge of Trifluralin to the European seas in a time-frame of one year due to degradation in soil;
- Under the available data used in BAU scenario, the European coastal areas of the Atlantic ocean and North sea receive the higher fractions of the European sea load, 29.5% and 22%., respectively, followed by the Baltic (19%) and Mediterranean (17.5%) seas. However, it is worth stressing again that these estimates are built on incomplete emission inventory considering only EU25 countries.

- In the partial effectiveness scenario the total sea load of Trifluralin is expected not to exceed one third of the BAU load when the application of dinitroaniline herbicides to soil is reduced at least by 66% for the EU25 countries across Europe.

3. Perfluorooctane sulfonate - PFOS

Perfluorinated compounds, including Perfluorooctane Sulfonate (PFOS), are chemicals produced for their non-stick and water repellent properties. They have been used during the last 50 years both in industry and as components of consumer products in the manufacture of coatings for cookware and clothing, stain resistant carpets, food packaging, fire-fighting foams, paints, and adhesives, with additional uses in the photo-, electronics-, and aerospace industries.

Unlike Lindane and Trifluralin, which are multimedia chemicals, PFOS can be regarded as a single-medium molecule primarily related to the water compartment. Actually, PFOS's high solubility and its persistence make it a virtually conservative and instantly a water-transported substance. Since PFOS is environmentally persistent, bioaccumulative and potentially harmful, it was listed as chemical for regulation within the Stockholm Convention and was banned in the European Union in 2007.

The study employed the approach of a backward tracking of PFOS emissions from riverine measurements as described by Loos et al. (2009) and Pistocchi and Loos (2009) who consider the atmospheric deposition of PFOS as a negligible diffuse source that could be disregarded. Accordingly, it was found that PFOS emissions correlate rather well with river basin population. Thus, for PFOS an average European emission factor of 27.4 µg/day per capita was estimated. The latter is fairly consistent with previously found estimates of 40 µg/day/inhabitant in Bayreuth (Germany) and 57 µg/day/person for Switzerland. Then, the average emission factor for Europe was used as a basis of a GIS model able to calculate European maps of PFOS river water concentrations and load to seas.

In the study, the **BAU** scenario for PFOS is referring to 2007 as baseline year. Additionally, the sea load of PFOS was assessed by considering a **scenario of 50% reduction** of emissions and also answering the question by what percentage the emissions should be decreased in order to guarantee that the total sea load stays below a given threshold, "a **scenario targeting a sea load of 1 ton per year"**.

The scenario results allow concluding that:

- Based on the average emission factor of 27.4 µg/inhabitant/day and the map of population density in Europe, when BAU scenario was supposed the concentrations of PFOS in surface water vary from less than 0.001 to more than 10000 ng/L with a mean equals to 7.1 ng/L for Europe;
- Under BAU scenario conditions the total sea load of PFOS from Europe is estimated to be, on average, 5.8 tons per year. Practically, the model foresees a half of this amount if a cut of emissions is assumed to take place as from the scenario of 50% reduction;
- The highest load of PFOS to marine coastal waters according to BAU scenario comes from the Danube river (followed by the Rhine) exporting annually more than 1 ton. Accordingly, Black Sea receives ca. 27.4% from the total load of PFOS to European seas;
- The spatial analyses anticipate that the total annual load of PFOS to European seas will decrease below the target value of 1 t/y only when the current emissions across to European countries are diminished at least by 84%.

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Part I: Policy options and alternative measures to mitigate land based emission of nutrients (Nitrogen and Phosphorus)

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1. Introduction

In order to support the implementation of the Marine Strategy Framework Directive (2008/56/EC), DG Environment and the Joint Research Centre joined to develop a study on the expected cumulative impact of existing EU environmental legislation on the quality of the marine environment, with specific reference to the case of aquatic discharges from inland-based sources. The study is divided in three phases.

The first phase focused on data collection, database development and modelling-based assessment for the year 2000.

The second phase (conducted in 2009) concerned the retrospective assessment for the years 1985-2005, including the collection of all relevant data and a trend analysis for nutrient loads. The second report has demonstrated over the period 1985-2005 that the Urban Waste Water Directive has been successful in decreasing nitrogen and phosphorus emissions in most EU27 countries (Table 1).

Table 1: Change in nutrient anthropogenic pressure for EU 27 (with the exception of Malta) between 1990 and 2005 (in 1000 tons).

	Point source N		Manure N		Mineral N		Point source P		Manure P		Mineral P	
	1990	2005	1990	2005	1990	2005	1990	2005	1990	2005	1990	2005
AT	21	10	148	174	141	119	3	1	47	40	29	20
BE	9	32	215	241	158	147	1	4	60	66	28	18
BG	29	21	172	106	419	156	4	3	40	25	57	5
CY	0	0	13	19	14	10	0	0	0	5	4	3
CZ	36	15	239	160	460	352	6	2	57	38	107	29
DE	191	114	1356	1371	1814	1778	22	9	345	310	283	149
DK	16	7	260	344	374	224	3	1	53	57	36	15
EE	6	2	54	18	55	20	1	0	15	5	13	2
ES	99	221	754	1207	937	1190	17	30	167	444	202	266
FI	4	4	55	54	195	172	0	0	24	31	46	16
FR	164	131	1259	1444	2482	2271	32	18	369	350	548	305
GR	24	28	262	214	580	263	5	5	63	62	106	43
HU	22	21	230	181	391	365	4	3	57	38	61	29
IE	12	15	462	424	388	346	2	2	84	81	68	42
IT	229	218	636	758	748	748	30	26	156	178	235	148
LT	14	7	168	80	136	132	2	1	43	20	13	16
LU	1	2	11	10	14	10	0	0	4	3	2	1
LV	4	3	93	37	88	38	0	0	24	8	7	3
NL	55	23	453	476	387	282	6	2	124	96	33	22
PL	53	48	550	574	864	848	9	8	146	146	177	132
PT	26	26	140	146	143	89	5	4	44	41	32	19
RO	49	45	370	342	639	274	7	7	86	77	125	35
SE	10	10	141	160	214	201	1	1	35	33	25	18
SI	1	5	63	44	75	33	0	1	24	10	21	7
SK	11	9	96	54	124	84	1	1	20	9	42	8
UK	183	207	1169	1031	1528	1104	40	34	222	179	159	113

The anthropogenic input of nitrogen and phosphorus from agricultural sources shows great spatial variability. Most countries have seen a sharp drop in the amount of mineral fertilizer used. Most of the countries having the largest share of manure production in Europe have increased the produced amout (except for the UK).

It was estimated that between 1985 and 2005 the total nitrogen load entering the European seas varied between 3700 ktN/yr and 5300 ktN/yr with fluctuations following the water discharge. Agriculture represents the major source followed by point sources. Similarly, we estimated that during the period 1985- 2005 the total phosphorus load into the European seas ranged between 215 kt P and 328 kt P with point sources contributing the most and agriculture and background losses accounting for the rest. Comparing the estimates for 2005 with those of 1990, at European scale the total nitrogen export has decreased by 9%, while the total phosphorus load has decreased by around 15%, mainly due to a decrease in point sources emission. The concentration of total nitrogen and total phosphorus for all European seas is displayed in Figure 1. From 1990 to 2005 the predicted concentration of total phosphorus decreased from 0.2 to 0.15 mg/l a drop of 25% while the concentration of nitrogen dropped by less than 7% (from 3.2 to 2.96 mg/l).

The second report *(Bouraoui et al., 2011)* has demonstrated that over the period 1985-2005, the Urban Waste Water Treatment Directive has been successful in decreasing nitrogen and phosphorus emissions. On the other hand the effectiveness of the Nitrates Directive is more limited, due in part to the delayed response of soils and aquifers to the implementation of mitigation measures. In continental Europe, including countries of EU15, there are still areas where nitrate concentrations in surface waters are still increasing despite stringent regulation aiming at controlling nitrate losses. A detailed analysis on the Elbe and Loire river basins performed by Bouraoui and Grizzetti (2011) has shown the importance to consider the impact of lag time when analyzing water quality time series. This is necessary in order to understand what type of measures are the most effective in controlling nitrate and phosphorus losses and the lag before the effects of these measures can be detected.

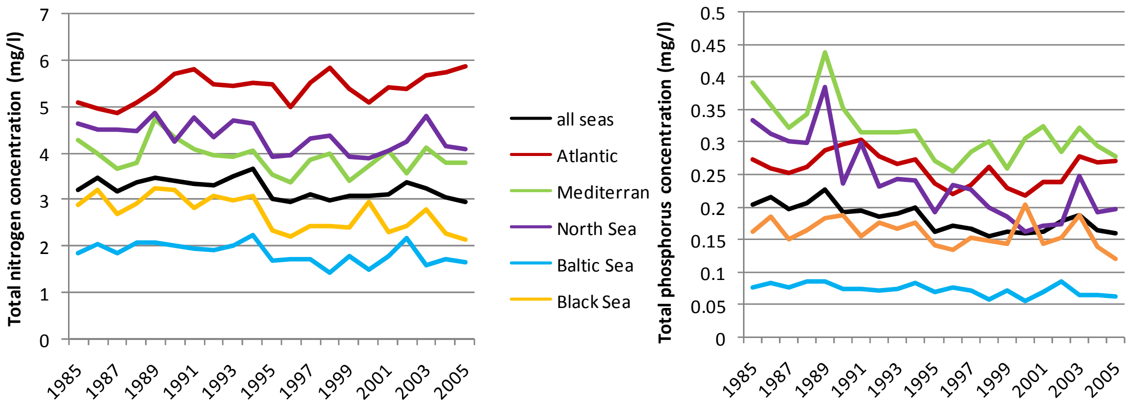


Figure 1: Change in nitrogen and phosphorus concentrations (freshwater) entering European seas from 1985 to 2005.

The third phase of the FATE project aims at testing various scenarios related to the application of existing EU legislations, already adopted by Members states or with ongoing implementation.

Scenario development represents a powerful tool to help stakeholders and policymakers managing the various, highly complex and uncertain predictions of how future environment will evolve. By essence, it integrates multiple assumptions (storylines) to explore potential consequences of different plausible or unrealistic futures.

Consequently, the first part of this report introduces the relevance of the FATE-approach as a support to European policy and formulates the storylines of the proposed scenarios.

The second part is devoted to scenarios building. Indeed, the construction of scenarios is intimately related to the nature of the information collected and structured with respect to the formalism of the chosen modelling approach. While the two first phases of the FATE project have provided material and methods to implement the GREEN model at the EU-scale using existing data, the third part of the study focused on the changes and adjustments to be performed for implementing the selected set of scenarios with a sufficient accuracy.

Finally, the last part of the report details the results which are organized with respect to the distinction between “point sources” and “non-point (diffuse)-sources” of nutrients. Efficiencies of scenarios implemented are discussed in terms of capacities to mitigate land based emissions of nutrients, and also according to their impacts on the loads of nutrients exported to European coastal areas based on the simulations provided by the GREEN model.

2. Story line of scenarios to be implemented

The development of a consistent set of scenarios raises the issue of the scale of the analysis. Worldwide dynamics controlling economic and demographic trends call for global scale assessments, although they are not able to represent regional processes and are not relevant to support national or European policies. On the contrary, local scale analyses are generally more reliable, but are unable to take into account regional dynamics and cannot be transposed to a broader regional context.

The first two phases of the study have provided a consistent overview (estimation) of nutrient loads into European seas. This uniform modelling approach is based on wide harmonized databases, precise enough to support the assessment of the impact of implementation of EU environmental legislation, starting from the specificities of each Member State (MS) and associated administrative regions and sub-watersheds to a pan-European implementation. The area covered by the FATE project includes EU-27 and other regions which territory drains totally or partially into one of the major European Seas (Mediterranean, North, Baltic, Black Seas and Atlantic Ocean). These additional regions include Albania, Bosnia Herzegovina, Serbia, Montenegro, Croatia, Norway, FYROM, and Turkey. The overall area will be referred to as either "study area" or "continental Europe" across this report.

2.1 List of scenarios

An overview of all scenarios implemented is listed in Table 4. The PAST scenario uses 1985 as the early starting point simulated. The current level of anthropogenic pressure is set by the REF scenario and refers to the year 2004-2005.Assessments of prospective changes in nutrient emission systematically refer to the BAU scenario that forms the baseline situation at the horizon 2020. UWWD and PFREE scenarios mimic the full implementation of ongoing legislation on point sources emission. It was assumed that the scenario PFREE will represent a step further in the mitigation of phosphorus point source. For this reason it will be consider as an addition to the UWWD scenario.

Three scenarios WCRF, WHO and MANU deal with the mitigation of nutrient diffuse sources of agricultural origin.

Table 4: List of scenarios to be implemented

Acronym	Main feature	Time line	Assumption
PAST	Past reference	1985	Past reconstruction
REF	Current level of anthropogenic pressure	2005	Current state
BAU	Business as usual	2020	No nutrient mitigation measure
UWWD	Urban Waste Water Directive 91/271/EEC	2020	Full implementation of the directive
PFREE	UWWD + Regulation on detergent 648/2004/EEC	2020	UWWD + P-free laundry detergent
WCRF	WCRF recommendation	2020	Diet with less meat intake
WHO	WHO recommendation	2020	Healthy Diet
MANU	Optimised Use of Available Manure	2020	Adjustment to nutrient crop demand

2.2 Reference situations

*Past situation: 1985 reference (**PAST** scenario)* - Long term evaluation of scenario effectiveness needs to be drawn in parallel with past trajectories, and trends obtained for the last twenty years (1985-2005) will be highly relevant to understand the prospective simulations performed for the next twenty years. It also worth mentioning that the OSPAR Convention (2005) refers directly to such an earlier state, with an objective of a 50% reduction of N and P sources compared to the level of 1985.

*Current state: 2005 reference (**REF** scenario)* - Current statue has been described up to the year 2005 by the second phase of the FATE-Project. This specific year was selected as representative of present conditions as it is the year for which the most complete input data was available. It characterized the most current level of pressures and was thus considered as a starting point for scenario building. This reference is used for comparative assessments as it represents the most recent situation reported for Europe.

All prospective scenarios were built for the timeline 2020, and they integrate intrinsically a common progression of anthropogenic pressures from 2005 to 2020 described in the BAU scenario (next paragraph). **When the assessment of nutrient mitigation measures refers to *REF scenario*, it has to be kept in mind that the predicted impact is a combined response to implementing mitigation measures and compensation or side effects resulting from the basic changes assumed to take place from 2005 to 2020 and** integrated in the BAU scenario.

*Future baseline: Business As Usual reference (**BAU** scenario)* - This reference is built as a generic scenario. It aims at propagating the current trend of anthropogenic pressures but considers the status-quo in the mitigation of land based nutrient emissions. It includes changes in population count and distribution, prospects for food production and consumption and associated change in land distribution. Such long term prospective (2020) is required for a realistic implementation of the scenarios. This is especially true for non-point source scenarios, as they incorporate some inertia (e.g. delayed response of groundwater) and might required several decades to enable a full assessment of their impact. **The BAU reference is used to assess i) how future nutrient pressure will evolve if nothing is undertaken and ii) the efficiency of various nutrient mitigation measures at the horizon 2020.**

2.3 Ongoing legislation on point sources emissions

It has been demonstrated that the mitigation of point sources is an efficient way to reduce the amount of nutrients transferred to the aquatic system, especially for phosphorus (Bouraoui et al. 2009). And despite their recent improvement, European wastewater treatment plants do no fully comply with European requirements. Consequently, two scenarios are considered with respect to the Directive 91/271/EEC and the Regulation 648/2004/EEC.

Urban Waste Water Directive - The first scenario mimics the full implementation of the 91/271/EEC Directive concerning urban wastewater treatment, dealing with impacts of urban wastewater emissions on surface and ground-water quality. This directive requires all Member States to implement efficient wastewater treatment infrastructures. It defines a set of conditions and contingencies, including the size of municipalities and the sensitivity of receiving area (Fig. 2), and requires wastewater discharged to undergo appropriate treatments (Table 2).

Phosphate free detergent - The second scenario is based on the Commission proposal COM (2010) 597 amending Regulation (EC) No 648/2004 concerning the use of phosphates and other phosphorus compounds in household laundry detergents (PFREE scenario). The scenario simulates the ban of phosphates and others phosphorus compounds in household laundry detergent to reduce the contribution of phosphates from detergents to eutrophication in EU waters and to reduce the cost of phosphorus removal in wastewater treatment plants. Per capita P emission has been estimated in the 2nd FATE report (Bouraoui et al, 2009) and the annual P emission used in laundry represents on average 24 % of the total per capita emission (Fig. 3).

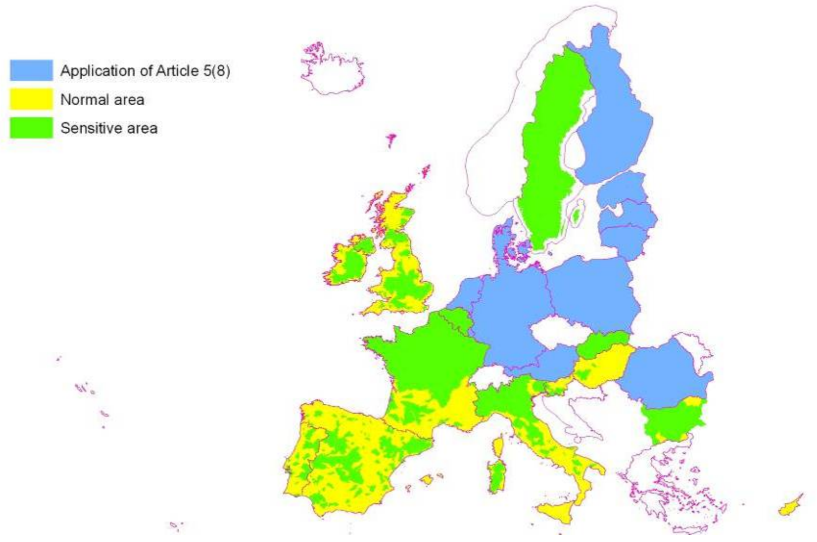


Figure 2: Sensitivity of receiving area reported in Europe for the year 2004, following the Urban Waste Water legislation, Directive 91/271/EEC

Table 2: Summary of requirements and deadlines for implementation of articles 3, 4, 5 and 7 of the Directive 91/271/EEC.

(p.e)	0 -2000	2000-10,000	10,000-15,000	15,000-150,000	>150,000
Sensitive area	If collection, 31.12.2005		If collection, 31.12.1998		
	appropriate treatment	secondary treatment	more advanced treatment	more advanced treatment	more advanced treatment
Normal area	If collection, 31.12.2005			If collection, 31.12.2000	
	appropriate treatment	secondary treatment	secondary treatment	secondary treatment	Secondary treatment
Less sensitive areas	If collection, 31.12.2005			If collection, 31.12.2000	
	appropriate treatment	appropriate treatment	primary or secondary treatment	primary or secondary treatment	primary or secondary treatment

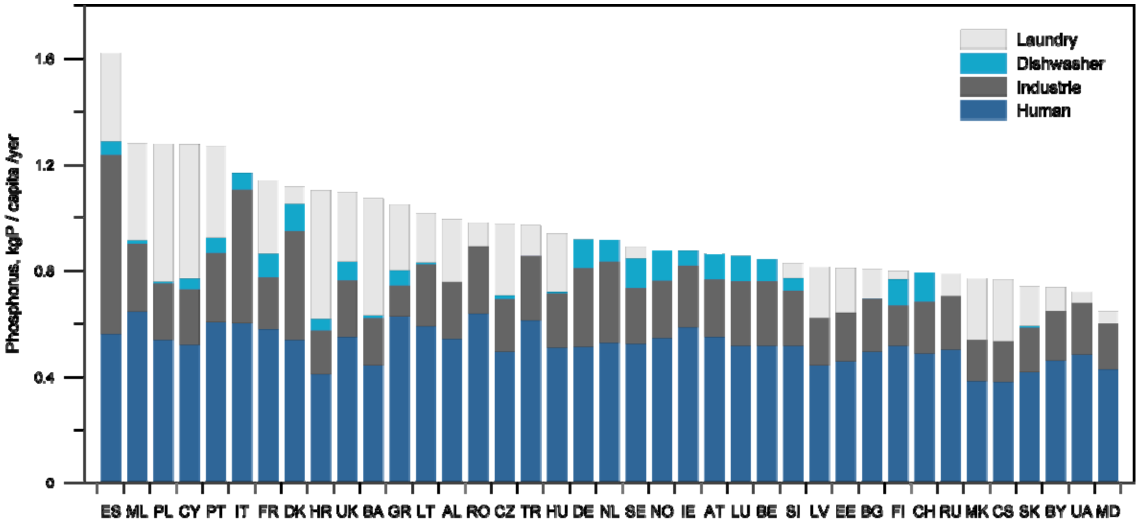


Figure 3: Per capita emission of phosphorus (in kgP/capita/year) for regions included in the study area according to Bouraoui (2011)

2.4 Environmental friendly diets

It is now accepted that meat products, in particular beef and pork have to be consumed in low quantity in order to prevent diseases as diabetes, obesity. The World Health Organization clearly states the importance to integrate fruit, vegetables and high carbohydrate in human daily diet (WHO, 2003). Transcribing such a change in the population lifestyle raises the issue of the adaption of agricultural production and the respective change in land use. The third group of scenario includes prospective changes in human food consumption following the recommendations made by international organisations for a healthier diet. They go beyond the strict framework of the ongoing changes planned by European policy, and offer an outlook on the potential effect of worldwide health recommendation, their impact in terms of agricultural production and change in land use. These two scenarios are summarized in Table 3.

Recommendations of the Word Health Organization – This scenario considers adaptation of agricultural land to support a human diet with slightly less meat, more fruit and vegetables. It basically integrates WHO dietary recommendation for an optimal diet from a nutritional perspective.

Recommendation of the World Cancer Research Fund – This scenario goes a step further with a stronger reduction of meat intake (*World Cancer Research Fund*, 2007).

Table 3: Consumption changes simulated per food commodity (% change to 2020 baseline diets in Europe). (The main objective of the project CAPRI (Common Agricultural Policy Regional Impact) was the development of an EU-wide economic modelling system able to analyse the regional impacts of the Common Agricultural Policy) (see Britz, 2004 for more detail)

Food category (as in CAPRI)	Diet WHO	Diet WRCF
Wheat	-1.4%	-12.5%
Rye and meslim	-1.6%	-13.4%
Barley	-2.3%	-16.0%
Oats	-2.5%	-16.9%
Maize	-2.3%	-16.2%
Other cereals	-2.5%	-16.9%
Rapeseed	3.9%	2.7%
Sunflower seed	3.9%	2.7%
Soya	3.9%	2.7%
Rapeseed oil	14.4%	16.0%
Sunflower oil	14.4%	16.0%
Soy oil	14.4%	16.0%
Olive oil	14.4%	16.0%
Rapeseed cakes	5.0%	5.0%
Sunflower cakes	5.0%	5.0%
Soy cakes	2.7%	0.0%
Pulses	-1.6%	-5.6%
Potatoes	-1.5%	-5.4%
Tomatoes	13.0%	12.7%
Other vegetables	13.0%	12.7%
Apples	10.3%	9.9%
Table grapes	10.3%	9.9%
Citrus fruits	10.3%	9.9%
Other fruits	10.3%	9.9%
Table olives	-1.0%	83.5%
Table wine	0.0%	0.0%
Beef	-6.8%	-42.1%
Pork meat	-5.6%	-43.0%
Sheep and goat meat	3.9%	-26.8%
Poultry meat	-0.2%	13.5%
Eggs	-0.2%	13.5%
Butter	-1.1%	-1.5%
Skimmed milk powder	-1.1%	-1.5%
Cheese	-1.1%	-1.5%
Fresh milk products	-1.1%	-1.5%
Cream	-1.1%	-1.5%
Concentrated milk	-1.1%	-1.5%
Whole milk powder	-1.1%	-1.5%
Rice	1.5%	-1.1%
Sugar	-3.6%	-4.1%

2.5 Optimized reuse of animal manure

By putting emphasis on limiting the amount of nitrogen applied as manure, the Nitrates Directive leaves flexibility in the amount of applied mineral fertilizer (Bouraoui et al 2011). By doing so the total combined application may result in an agronomical imbalance with a clear excess of nutrient supply. While mineral application can be adjusted according to crop demand for both nitrogen and phosphorus, animal manure is used with a determined N:P ratio, directly related to the type of breeding activities. However, there is a general imbalance between the manure nutrient supply and the crop nutrient demand in many regions of Europe. In terms of quality, the excess of phosphorus present in animal manure might result in a systematic over fertilisation if applications attempt to cover the demand for nitrogen (Fig. 4) (Eghball an Power 1999).

Thus, this scenario intends to improve nutrient supply in Europe based on an optimal reuse of organic manure and the adjustment of minimized mineral inputs. It emphasizes the possibility of redistributing the manure locally produced, according to the demand for both N and P in surrounding areas.

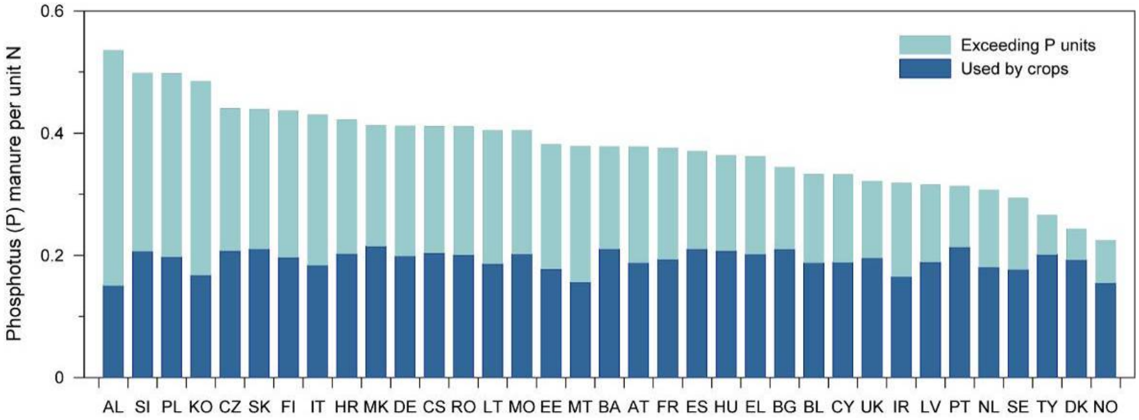


Figure 4: Phosphorus units brought by one unit of nitrogen manure (*P:N ratio*) for all regions included in the study area. Light blue indicated the exceeding phosphorus units (over fertilisation)

2.6 GREEN model description

The quantification of nitrogen and phosphorus fluxes is hampered by many constraining factors including the availability of detailed water quality and quantity measurement in Europe, and the lack of high resolution nutrient pressure from anthropogenic activities. Indeed these limitations seriously limited the possibility to use detailed physically based model within the time frame of the FATE scenarios project. Statistical tools have shown to be robust (Grizzetti et al., 2008, 2005) to perform large continental scale nutrient pressure assessment with limited data requirements. Such statistical approaches are not only valid as screening tools, but also can provide detailed analysis that could be readily used by local, regional and national authorities (Grizzetti et al., 2011) for developing appropriate management strategies.

The GREEN model is a statistical model developed to estimate nutrient fluxes to surface water in large river basins GREEN contains a simplified representation of the processes of nutrient transport and retention in the river basin and a spatial representation of the various nutrient sources and physical characteristics that influence the nutrient transformations and losses. To apply the model, an area on interest is divided into a number of sub-basins that are connected according to the river network structure. GREEN considers diffuse sources that include mineral fertilizers, manure applications, atmospheric deposition (only for nitrogen), crop fixation (only for nitrogen), and scattered dwellings, and point sources that consist of industrial and wastewater treatment discharges. For each sub-basin the model considers the input of nutrient diffuse sources, point sources and loads coming from upstream and estimates the nutrient fraction retained during the transport from land to surface water (Basin Retention) for the diffuse sources and the nutrient fraction retained in the river segment (River Retention) for the point sources and the fraction of diffuse sources reaching the river. In the model the nutrient retention is computed on annual basis and includes permanent and temporal removal.

3. Scenarios building

3.1 Population count and distribution

Many databases are able to provide a geospatially explicit population data. For example, future population projections are provided by IIASA (International Institute for Applied Systems Analysis) with the GPW (Gridded Population in the World, CIESIN, 2005) or the LandScan database developed by Oak Ridge National Laboratory. Among them, the HYDE (History Database of the Global Environment, Klein et al 2006) database offers a useful resource at 5' resolution that separates urban and rural fraction at the time line 2020. The HYDE database also includes global historical population and has supported the retrospective population estimates performed in the second phase of the FATE project. The HYDE database was also used to estimate population count and distribution change for the time frame of 2020.

From 1985 to 2020 HYDE predicts an overall increase of population densities in Europe, with a progressive decline of rural population and a concomitant increase of urban densities. When looking in more details (Fig. 5), from 2005 to 2020 the population of EU15 (except Germany) follows this trend with an increase of urban population by 11% (on average) and a rapid decrease of rural population (-20% on average). The relatively low contribution of rural population to the total population (less than 28% in mean) leads to an overall increase of EU15 population (+5% on average). Countries with a slower increase of urban population experience a slight decrease of their total population. This is the case of Romania (-7%), Hungary (-5%), Germany (-1.5%), Czech Republic (-1%) and Slovak Republic (-0.5%).
Both urban and rural populations decrease in Estonia (-13%), Bulgaria (-11%), Latvia (-8%), Lithuania (-7%), Poland (-3%) and Slovenia (-1%), while they impressively increase in Cyprus (31%) and Luxembourg (16%).

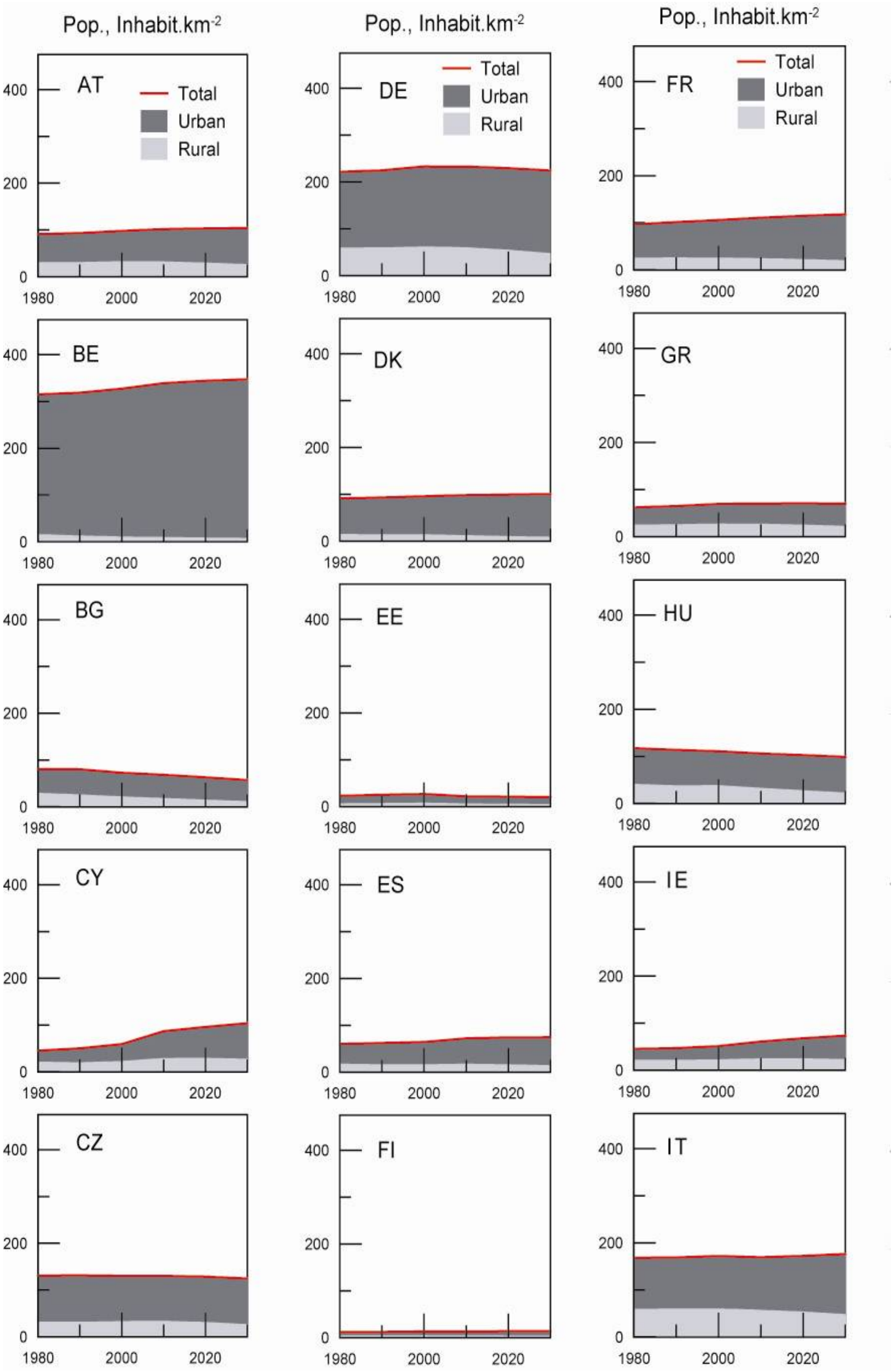


Figure 5: Change in rural (light grey) and urban (dark grey) populations densities as simulated by the HYDE model (Klein Goldewijk and Van Drecht, 2006) from 1980 to 2030

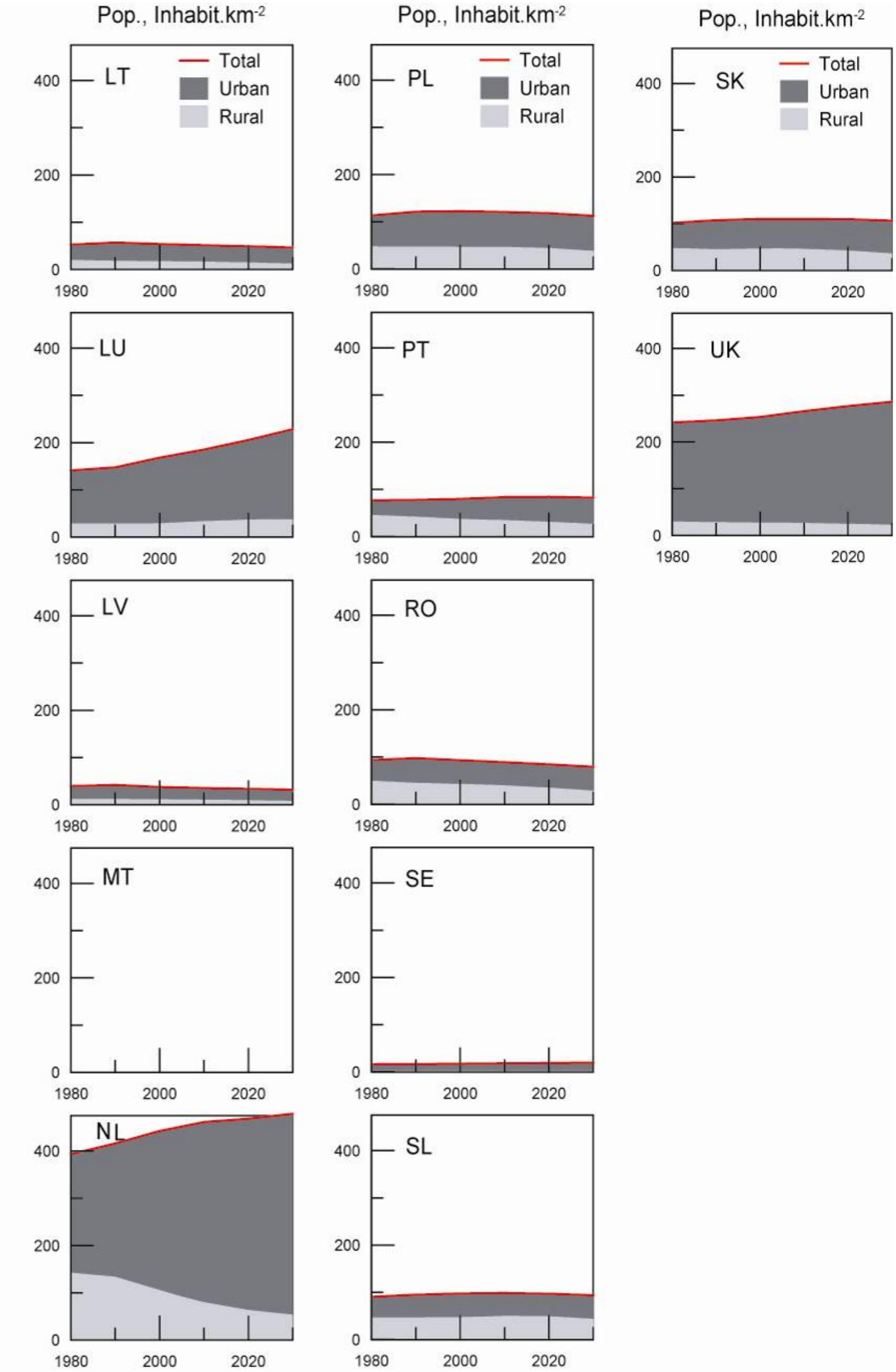


Figure 5 (continued): Change in rural (light grey) and urban (dark grey) populations densities as simulated by the HYDE model (Klein Goldewijk and Van Drecht, 2006) from 1980 to 2030

3.2 Wastewater collection and treatment

Point source emissions are estimated starting from the collection of household and industrial effluents. In the two previous phases of the FATE project, the percentage of population connected to sewerage system was defined at the country scale, preventing a detailed assessment of the Urban Waste Water Directive implementation.

For this reason, the analysis has been refined at the basin scale and integrates now for all agglomerations a detailed and spatially explicit census of wastewater collection, connection to sewers and treatment as reported by most of the EU-27 Member States (Waterbase, EEA 2010). The overall formula to calculate the net nutrient emission discharging to surface water is as follows:

$$PS_{N,P} = POP_{urb,\,rur}\ E_{N,P}\ C_{sewage}\ (1 - R_{N,P})$$

where $PS_{N,P}$ are the point source emissions of nitrogen (N) or phosphorus (P). $POP_{urb,\,rur}$ is the population density (either urban or rural inhabitant) retrieved from the HYDE database (see previous section), C_{sewage} is the faction of the population connected to sewage network, $R_{N,,P}$ is nitrogen or phosphorus removed after collection of wastewater effluent and $E_{N,P}$ is the per capita emission of nutrient.

C_{sewage} values are first processed using the information available for all individual agglomerations (EEA 2010) and then aggregated as a single average value calculated at the basin scale. C_{sewage} distinguishes between urban and rural population, by confronting the HYDE population values with the reported cumulated loads for each basin. Then a simple allocation rule has been used to prioritize the connection of urban population.

$R_{N,,P}$ is calculated by basin according to the identification of wastewater treatment plants for all releases and the corresponding N and P removal faction defined according to previous work of Van Drecht et al (2009).

$E_{N,P}$ is calculated independently at the Member State level for both nitrogen and phosphorus:

$$E_N = E_{N\text{-}Hum} + E_{N\text{-}Indus},$$
$$\text{with}\quad E_{N\text{-}Hum} = 0.11\ TFP_{intake} \text{ and } E_{N\text{-}Indus} = E_{N\text{-}Hum}\ f_{Indus}$$

$$E_P = E_{P\text{-}Hum} + E_{P\text{-}Laudry} + E_{P\text{-}Dishwash} + E_{P\text{-}Indus}$$
$$\text{with}\quad E_{P\text{-}Hum} = 0.01\ (TFP_{intake} VGP_{intake}) \text{ and } E_{P\text{-}Indus} = E_{P\text{-}Hum}\ f_{Indus}$$

where $E_{N\text{-}Hum}$ and $E_{P\text{-}Hum}$ are the raw daily emissions from human excretions, calculated according to Jonsson and Vinneras (2004), using total food (TFP_{intake}) and vegetable (VGP_{intake}) proteins intakes (in g/yr/person) retrieved from FAO database (2009). $E_{P\text{-Laudry}}$ and $E_{P\text{-Det}}$ are the per capita emission from P-based detergents used for laundry and dishwasher, respectively.

$E_{N\text{-}Indus}$ and $E_{P\text{-}Indus}$ are indirect industrial emissions connected to sewage system basically included in the wastewater loads as reported by the Waterbase (EEA 2010). For the areas not covered by the Waterbase, a census of all agglomerations larger the 2,000 inhabitants (Geoname database) was used, assuming an additional mean contribution of industrial releases (f_{Indus}) (see Table 4). Information related to the raw per capita emissions of nutrient (E_N, E_P) is calculated at the country level, and then downscaled to the basin scale.

The fraction of households emission collected through septic tank or other individual collecting systems not connected to sewage network ($1 - C_{sewage}$) is considered as a scattered dwelling source and is calculated similarly, assuming non industrial emission ($E_{N\text{-Indus}} = 0$ and $E_{P\text{-Indus}} = 0$) and an average 50% of retention ($R_N = R_P = 0.5$) before reaching surface water.

With respect to the Commission proposal COM (2010)597 on the use of phosphates and other phosphorus compounds in household, laundry detergents $E_{P\text{-}Laudry}$ is set to zero in the scenario PFREE. Other types of detergents such as dishwasher detergents ($E_{Pdishwash}$) were not considered as no technically and economically viable alternatives have been found yet.

Table 5 provides an estimation of yearly per capita emission of N and P in EU-27, and contribution of industrial releases (F_{Indus}), and average rate of wastewater collected through sewage network.

Table 5: Estimation of N and P per-capita emissions in EU-27. Contribution of industrial releases (F_{Indus}) and average rate of wastewater collected to sewage network. (Csewage* includes collection with or without treatment)

	$E_{N\text{-}Hum}$	$E_{P\text{-}Hum}$	$E_{P\text{-}Laudry}$	$E_{P\text{-}Dishwash}$	f_{Indus}	C_{sewage}*
	kgN/cap/yr	kgP/cap/yr	kgP/cap/yr	kgP/cap/yr	%	Avg %
AT	4.42	0.55	>0.01	0.09	40.00	98.75
BE	4.18	0.51	>0.01	0.08	40.00	97.45
BG	3.61	0.49	0.12	>0.01	40.00	92.48
CY	4.18	0.51	0.51	0.04	40.00	70.41
CZ	3.77	0.49	0.27	0.01	40.00	79.00
DE	4.02	0.51	>0.01	0.11	39.00	98.66
DK	4.34	0.54	0.07	0.10	46.00	100.00
EE	3.53	0.46	0.17	>0.01	40.00	88.80
ES	4.54	0.56	0.33	0.05	60.00	98.65
FI	4.10	0.51	0.03	0.10	27.00	98.97
FR	4.70	0.58	0.28	0.09	40.00	100.00
GR	4.70	0.62	0.25	0.06	25.00	68.00
HU	3.81	0.51	0.22	0.01	40.00	79.79
IE	4.70	0.58	>0.01	0.06	40.00	100.00
IT	4.54	0.60	>0.01	0.06	51.00	91.73
LT	4.46	0.59	0.18	0.01	40.00	92.75
LU	4.18	0.51	>0.01	0.09	33.00	97.78
LV	3.33	0.44	0.20	>0.01	40.00	100.00
MT	4.86	0.64	0.37	0.01	40.00	100.00
NL	4.18	0.53	>0.01	0.08	38.00	100.00
PL	3.97	0.54	0.52	0.01	40.00	81.93
PT	4.70	0.60	0.35	0.06	43.00	95.49
RO	4.50	0.60	0.09	>0.01	40.00	79.93
SE	4.34	0.52	0.04	0.11	40.00	100.00
SI	4.02	0.51	0.06	0.05	40.00	76.56
SK	3.05	0.42	0.15	0.01	40.00	79.48
UK	4.22	0.55	0.25	0.06	40.00	99.18

3.3 Land use development

The land coverage and the use of agricultural land for specific purpose like cropping and breeding activities are central for the estimation of nutrient diffuse sources. The regionalized economic model for agriculture CAPRI (Britz, 2004) was used to obtain information on the crop share per NUTS2 administrative regions in EU27. The downscaling of agricultural statistic was realized according to the methodology proposed by Bouraoui et al. (2009) combining several global databases including the HYDE 3 database (Goldewijk and Van Drecht, 2006) and the GLC (Global Land Cover: Bartholomé and Belward, 2005). Although the spatially explicit downscaling of the crop share has been developed with a conservative methodology it also includes a random assignation of specific crop type shares within general crop classes regionalized at a finer scale. Consequently, the regionalization to 1 km grid cell of cropland and grassland within the 10 km grid-cell defined by the combined HYDE and GLC databases is preserved across the different scenarios. Only the distribution of crops types and pastures (CAPRI classes) is affected during scenario building.

The REF Land use – is based on CAPRI results for the base year 2004. A weighted average over the calendar years 2003-2005 has been considered to smooth out effects of weather impacts on crop yields

The BAU scenario Land use – represents the base line 2020 which was built on a medium term outlook published in 2009 from AGLINK and FAPRI (Food and Agriculture Policy Research Institute). The baseline incorporates moderate yield increases for crops in Europe and some input technical saving progress, so that fertilizer application at unchanged yields would drop. Table 6 indicates CAPRI estimates for Land use changes between 2004 and 2020. In the 2020 base line scenario (BAU) both extensive and intensive grassland decrease (-5% in area), while industrial crop (+43%) or soya (+116%) greatly increase. It captures the impact of the recent CAP reform steps, the end of obligatory set-aside (-100%) to the favor of voluntary set-aside (+30%).

The WHO and WRCF Land use – Total area devoted either to cropland or grassland is not greatly impacted by a hypothetical change in diet. Thus, it strengthens the assumption made to build these Land use layers (preserving the current regionalization of cropland and pasture). These two scenarios assume a lower per capita consumption of meat and a higher consumption of proteins and fats through vegetable oils (+3.5%) and to a lesser extent fruits (+2%) and vegetables (+4.5%). Also, extensification of grassland is more obvious in the WRCF scenario where 12% of pastures are concerned while only 3% of them are turned from intensive to extensive in the WHO scenario. A more extensive use of grassland also leads to a decrease of fodder crops (- 3% to -7.5%) production (Table 6). It is important to note here that large part of the animal production is now exported outside Europe, as the internal consumption has dropped. There is no direct relationship thus between the decrease of consumption and the decrease of production. This is done in CAPRI to preserve some income for agricultural holdings with livestock (4.8 million holdings in 2005 for EU27 according to EUROSTAT)

Table 6: change in Land use across REF scenario (2005), and BAU, WHO, WCRF scenarios (2020)

	REF	BAU	WHO	WCRF	BAU	WHO	WCRF
General classes	1000 ha	Changes expressed as a % of REF			1000 ha	Changes expressed as a % of BAU	
Cropland	125635	-4.6	-4.6	-5.2	119809	0.03	-0.60
Grassland	65786	-5.0	-5.3	-5.6	62516	-0.33	-0.70
Utilised Agricultural Area	191422	-4.8	-4.8	-5.4	182325	-0.10	-0.63
Detailed classes							
Apples Pears and Peaches	1010	-13.1	-12.6	-12.7	878	0.54	0.49
Barley	13883	-1.5	-1.8	-2.4	13670	-0.23	-0.85
Citrus Fruits	576	11.0	11.8	11.6	639	0.65	0.54
Durum wheat	3887	-8.7	-9.4	-9.5	3548	-0.72	-0.83
Fallow land	8649	7.7	7.8	11.7	9319	0.08	3.66
Flowers	88	12.6	12.6	12.6	99	0.00	0.00
Gras and grazings extensive	32210	-2.6	0.2	8.2	31367	2.94	11.12
Gras and grazings intensive	33576	-7.2	-10.6	-18.9	31149	-3.62	-12.60
Set-aside obligatory, used as grass land	44	-100.0	-100.0	-100.0	0		
Set-aside obligatory, idling	2354	-100.0	-100.0	-100.0	0		
Fodder maize	4934	-12.3	-12.4	-12.6	4326	-0.09	-0.27
Grain Maize	9351	3.9	3.4	0.7	9713	-0.49	-3.00
Nurseries	104	8.1	8.1	8.1	113	0.00	0.00
Oats	4481	-7.7	-7.8	-6.7	4138	-0.12	0.99
Other cereals	2787	-17.9	-17.7	-16.3	2288	0.27	1.91
Other crops	1288	42.1	42.1	42.1	1831	0.00	0.00
Fodder other on arable land	13839	-19.4	-20.1	-22.3	11161	-0.88	-3.61
Other Fruits	2102	-4.8	-3.9	-3.8	2001	0.98	1.02
Other industrial crops	286	43.3	43.3	43.3	410	0.00	0.00
Olives for oil	4519	15.7	19.6	20.0	5229	3.37	3.69
Other oils	378	-3.8	-3.8	-3.8	364	0.00	0.00
Other Vegetables	2140	-9.0	-5.3	-5.5	1948	4.01	3.88
Paddy rice	448	-25.6	-25.5	-25.3	333	0.11	0.36
Potatoes	2411	-35.2	-35.6	-36.8	1563	-0.67	-2.47
Pulses	1958	-15.3	-14.7	-16.2	1658	0.73	-1.03
Rape	4484	52.9	53.3	54.4	6856	0.29	1.00
Fodder root crops	293	-65.8	-66.7	-68.2	100	-2.48	-7.10
Rye and Meslin	2705	-8.4	-8.3	-7.6	2479	0.09	0.88
Soya	413	116.6	115.4	113.9	894	-0.51	-1.24
Sugar Beet	2256	-32.1	-32.5	-32.0	1532	-0.61	0.14
Sunflower	3766	3.9	4.7	3.7	3912	0.75	-0.15
Soft wheat	22086	-7.7	-8.1	-10.9	20386	-0.48	-3.43
Table Olives	312	0.1	0.3	10.4	313	0.16	10.29
Table Grapes	205	-26.8	-26.3	-26.4	150	0.75	0.62
Flax and hemp	599	6.3	6.3	6.4	636	0.00	0.09
Tobacco	184	-20.2	-20.2	-20.1	147	0.01	0.03
Tomatoes	331	-2.1	-1.5	-1.5	324	0.64	0.61
Set-aside obligatory, tree cover	94	-100.0	-100.0	-100.0	0		
Wine	3561	-11.4	-11.4	-11.4	3156	0.00	0.02
Set-aside voluntary	2829	30.7	30.8	32.8	3697	0.12	1.61

3.4 Animal breeding activities

Despite a significant decrease of beef (-6.8% to -42.1%) and pork (-5.6% to -43.0%) consumption in human diet assumed in the WHO and WCRF scenarios (Table 3), the overall European production is not as much impacted (see Table 7). Indeed, these two scenarios are affecting European diet while European production of meat supports international trades, and changes in meat production according to WHO and WCRF are less significant (respectively -7.6% and -21.5% for beef and pork).

Table 7: Change in beef (suckler cows + adult cattle for fattening) and pork production in the WHO and WCRF scenario compared to the REF 2005 and BAU 2020 baselines.

	REF	BAU	WHO	WCRF	BAU	WHO	WCRF
	[1000 hd]	Changes expressed as a % of REF			[1000 hd]	Changes expressed as a % of BAU	
beef herd							
EU15	26833	9.2	10.6	16.2	24360	-1.5	-7.7
10 New MS	1662	19.1	20.8	28.6	1345	-2.1	-11.7
EU27	29578	9.5	10.8	16.3	26776	-1.5	-7.6
Pigs							
EU15	195460	-7.2	-3.6	16.2	209476	-3.3	-21.8
10 New MS	37280	2.0	5.2	22.0	36525	-3.2	-20.4
EU27	239641	-4.4	-0.9	18.1	250067	-3.3	-21.5

Detail information on the WHO and WCRF scenarios regarding changes in market balances per EU Member State, or income and supply details for major product are given in annex 1. It clearly indicates that a decrease of the European demand for beef and pork meats is not followed by a similar decrease of production at the EU-scale. Indeed, a high degree of realism is required and in order to ensure the economical sustainability of agricultural activities in WHO and WCRF scenarios, the decrease in the demand for meat product is concomitant with an increase in meat export over Europe. As a consequence, the net trade for European beef products is increased from -276 10^3 tons in BAU to +51 10^3tons of beef in WHO scenario and up to 2050 10^3 tons in the WRCF scenario (see annexe 1). It means that the global market balance of EU Member States is reverse and Europe will be considered as a net exporter of beef in WHO and WCRF. For pigs, EU27 has already a positive balance (2203 10^3tons) but this latter increased to 2468 10^3 tons in WHO and 5252 10^3tons in WCRF (see annex 1).

3.5 Nutrient input to agricultural land

Fertilizers application – they were obtained from CAPRI (Britz, 2004) for both references (REF) and prospective scenarios (BAU, WHO and WCRF). For the whole Europe, manure application decreases progressively from REF to BAU (-2%) in agreement with the lower consumption of meet assumed from 2005 to 2020 (Table 8). A further decrease is simulated from BAU to WHO (-1%) and WCRF (-7%) under a stringent change human diet (Table 8). Mineral applications of N continue to increase (+4.7%), while they slightly decrease for phosphorus (-5.2%) from REF to BAU. Change in diet leads to a decrease of application by 3% for nitrogen and 1% for phosphorus under the scenario WCRF (Table 8).

Biological N2 fixation – fixation by Pulses and Soya crops is based on agricultural yield provided by CAPRI, and assuming an average N content of 35 gN/kg. The corresponding amount of N in harvest products is multiplied by two to account for N residue below ground plant parts (Moisier et al. 1998). For paddy rice 25 kgN/ha is assumed for biological N2 fixation (Bouwman et al 2009). Fixation for non-leguminous crops and grassland is then deduced with respect to the value provide at the NUTS2 level (3.6 kgN/ha in average) by the CAPRI model.

Downscaling of atmospheric deposition – Deposition values provided by CAPRI are downscaled following the spatial distribution of EMEP (EMEP, 2001) deposition data for 2005 overlaid with Land use allocation. For phosphorus, no fixation-deposition were calculated.

Nutrient balance – Nutrient supply and balance are provided in table 8. From REF to BAU nitrogen surplus at the soil level decreases by 4 % while for phosphorus an impressive decrease of 21% is simulated by the CAPRI model. The more stringent scenario (WCRF) adds a further decrease of 5.4% and 6% for nitrogen and phosphorus surplus, respectively. For the spatial distribution of nutrient balances, maps of nitrogen and phosphorus surplus are produced in annexe 2 of this report.

Table 8: Changes in nutrient supply and balance as calculated by CAPRI model from 2005 to 2020 scenarios.

	REF	BAU	who	wcrf	BAU	who	wcrf
Nitrogen	1000t N	changes expressed as a % of REF			1000t N	changes expressed as a % of BAU	
Atmospheric deposition	2222	1.5	1.6	2.1	2189	0.1	0.7
Biological fixation	1079	-0.6	0.2	3.1	1085	0.7	3.7
Gaseous loss	3937	0.2	1.4	6.7	3928	1.2	6.5
Import by crop residues	5553	-13.5	-12.6	-9.9	6301	0.8	3.2
Import by manure	9501	2.9	4.0	9.6	9226	1.1	6.9
Import by mineral fertilizer	10963	-4.7	-3.9	-1.6	11480	0.8	3.0
Nutrient retention by crops	17634	-8.1	-7.3	-4.5	19063	0.7	3.3
Surplus total	**11684**	**4.0**	**5.0**	**9.1**	**11219**	**1.1**	**5.4**
Phosphorus	1000t P	changes expressed as a % of REF			1000t P	changes expressed as a % of BAU	
Import by crop residues	1140	-13.5	-12.7	-10.2	1294	0.7	2.9
Import by manure	2144	1.7	2.7	7.5	2108	1.0	5.9
Import by mineral fertilizer	1435	5.2	5.5	6.0	1360	0.3	0.9
Nutrient retention by crops	3433	-9.4	-8.7	-6.1	3756	0.6	3.0
Surplus total	**1285**	**21.8**	**22.5**	**26.5**	**1006**	**1.0**	**6.0**

3.6 Optimization of manure application in Europe

MANU Scenario- In this scenario, an optimization of the amount of animal manure locally produced is considered. In this optimization procedure, the available amount of manure is first applied on grassland area and the remaining part is then used as crop fertilizer. In both case, supplies of phosphorus manure (P_{org}) and nitrogen manure (N_{org}) cannot exceed the net demand of the plant (either grass or crop).

This net demand is calculated according to the crop export, after substituting the inputs corresponding to nitrogen deposition, fixation and nitrogen crop residues. The net demand has to be covered by a suitable application of organic fertilizer (manure application after gaseous losses and with a certain N:P ratio) and complemented by mineral input adjusted according to the remaining plant demand for both nitrogen and/or phosphorus.

Example of N-deficient manure – If $N:P_{manure} < N:P_{plant\ demand}$ manure is considered as *N-deficient*. In this case the P supply is first calculated based on the available phosphorus manure (P_{man}) with the constraint that P demand could not be run over. In case of a shortage of manure, this application is adjusted with adequate mineral input (P_{min}). As $N:P_{manure} < N:P_{plant\ demand}$, the nitrogen demand could not be covered by the amount of manure supplied. For this reason, a mineral nitrogen supply (N_{min}) is calculated to satisfy the crop and grass needs (calculated in turns).

Inversely, if $N:P_{manure} > N:P_{plant}$ then the priority is given to the satisfaction of the N demand first, and a mineral P adjustment is systematically calculated.

Management of residual manure – MANU scenario will result in a null nutrient balance as nutrient supply is optimized according to the demand of both N and P. However, in some case, a residual amount of manure - that could not be applied without exceeding the demand for N or P - is calculated. This latter is not locally applied and might be considered as an exportable supply able to support deficient area. The *sub-basin* was selected as an elementary unit to optimize the application of locally produced manure, and the *basin* as a further unit to redistribute the excess of manure as detailed below:

- Manure application is optimized within all EU sub basins following the procedure detailed above.
- Residual (not applied) manure is cumulated at the basin scale (with an average quality $N:P_{manure}$), and redistributed to sub-basin candidates according to their residual demand for both nitrogen and phosphorus ($N:P_{plant\ demand}$). By doing so, residual manure application prioritizes sub-basins with a need similar to quality of manure potentially exportable at the basin scale.

- In case all manure could not be redistributed (without exceeding the crop and grass demand for N and/or P), the cumulated residual manure is proportionally distributed to all sub basins according to their size, and weighted with respect to their initial excess of manure.
- Mineral application is finally calculated to cover the residual demand for N and/or P for each individual sub basin.

The total amount of manure applied at the scale of European river basins is preserved across BAU and MANU scenarios, only its distribution at the sub-basin scale is affected. However, the impact on mineral supply is important. For phosphorus, increase or decrease in mineral application is simulated across Europe. Localization of these changes (either increase or decrease) integrates the heterogeneity of agricultural practices within a river basin and the concomitant possibility for the manure locally produced to be redistributed to other sub basin. An increase in mineral input may be observed in regions holding a negative surplus (see Annexe 2), but it may also include areas with a positive surplus resulting from cumulated non-distributed manure at the basin scale. For nitrogen, as mineral applications are widely exceeding the plant demand a general decrease is observed under an optimized manure management scenario (Fig. 6).

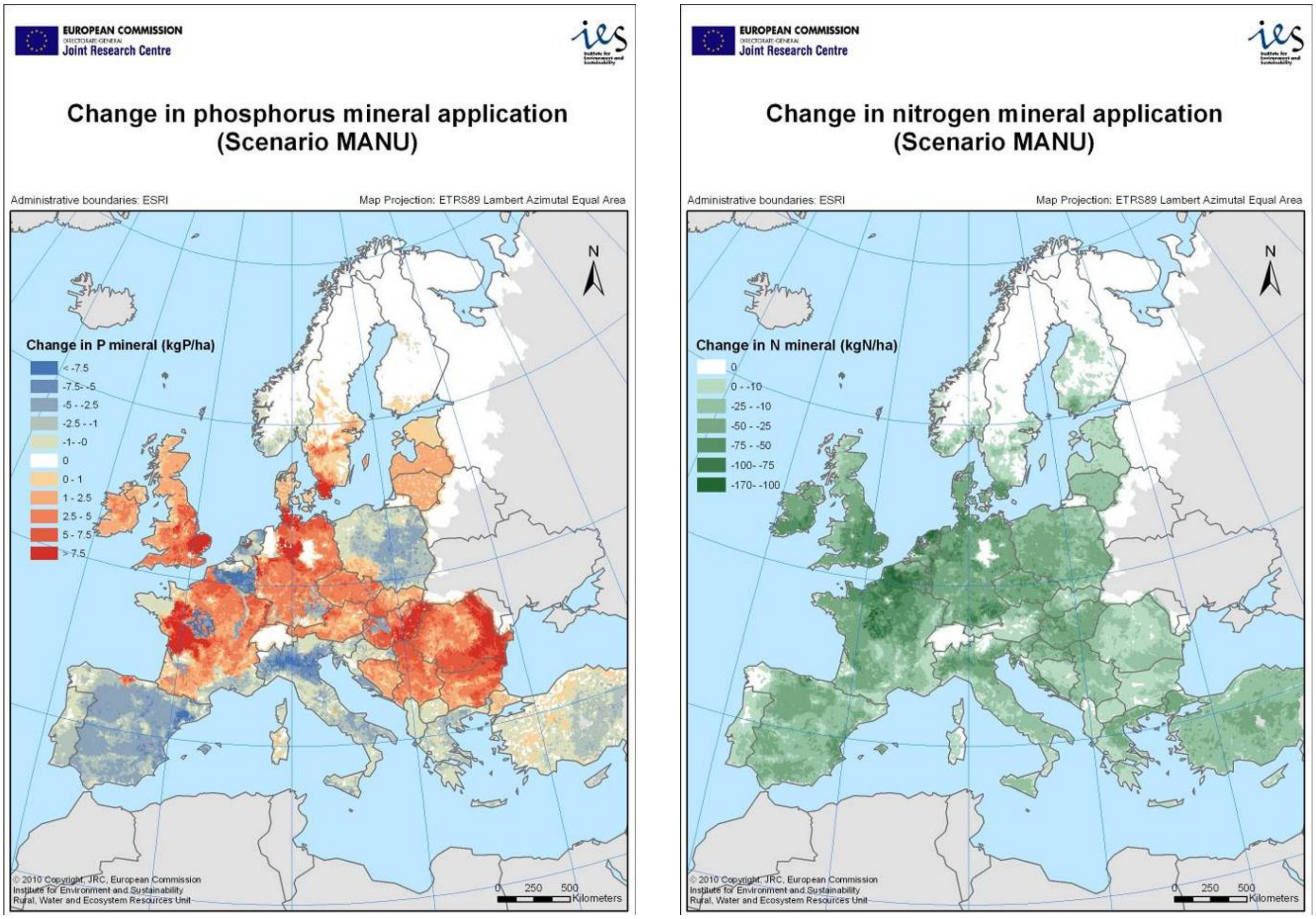


Figure 6: Change in mineral application of phosphorus (left) and nitrogen (right) under the MANU scenario.

3.7 Hydrological conditions

In these scenarios, future changes in hydrological conditions are not taken into account. Indeed 2020 is considered too short term for including possible climate change. In order thus to avoid the introduction of additional source of variability, no potential climate change was used to perturb the actual hydrology. Impact of hydrological condition greatly impacts the contribution of diffuse sources of nutrient. For this reason, it has been decided to run our simulations for a wide range of hydrological conditions. By doing so, our simulations integrate the variability of climatic conditions. The time series 1985-2005 has been used as a common hydrological dataset to run all scenarios, and the calculation of nutrient fluxes are systematically computed as an average of all the simulation performed over these 21 years.

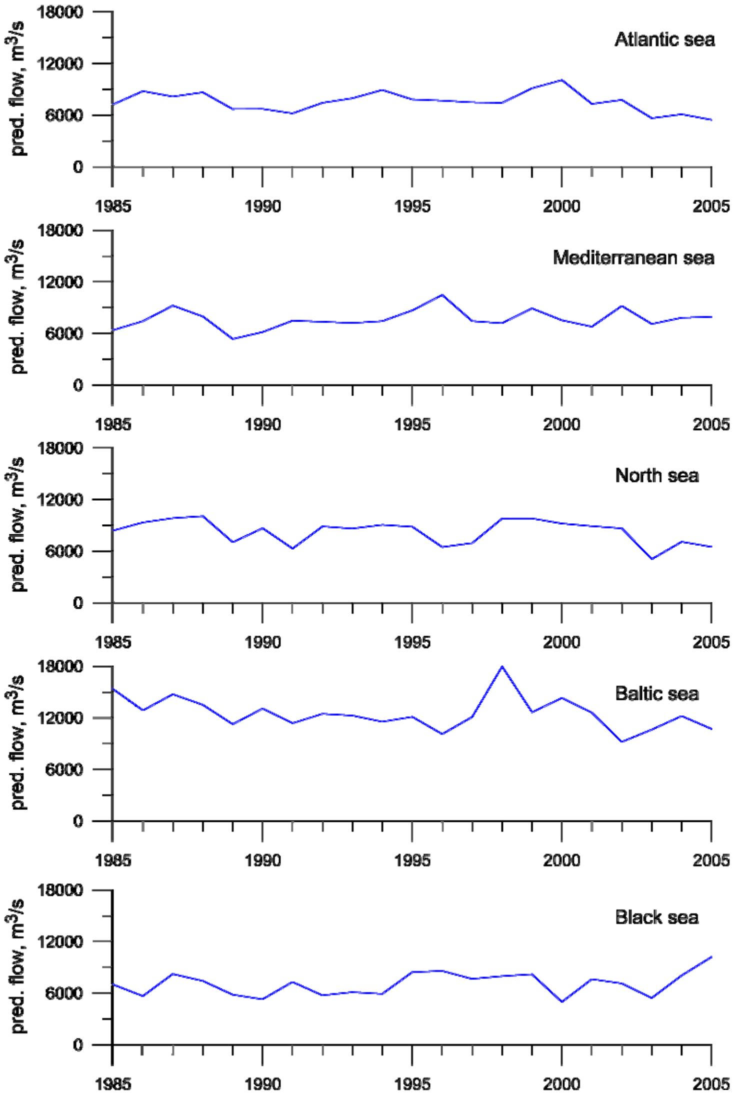


Figure 7: Modelled water discharge entering European seas from 1985 to 2005

4. Results and discussion

Sections 4.1 and 4.2 describe the impact of the selected scenarios on the land base emissions of point and diffuse nutrients sources. First, the changes assumed from 2005 and 2020 are provided as the basis for the comparison of all other scenarios simulated for the timeline 2020. Indeed, each scenario (UWWD, PFREE, WHO, WCRF and MANU) is considered as the combination of the BAU and a specific nutrient mitigation measure. Part 4.3 details the GREEN model results and the assessment of scenarios impact on nutrients loads to European seas.

4.1 Impact on nutrients emitted as point sources

It can be seen that a full implementation of the Directive 91/271 will result in significant differences between EU-15 and new Member's State. In the former, collection and basic (primary and secondary) treatments are already in place for both N and P. Most of the changes are due to the upgrading of wastewater treatment plant from secondary to tertiary treatments (65% of upgraded Inhabitant Equivalent I.E.). For new Members state (EU 10+2), only a small percentage is upgraded from secondary to tertiary treatment (10% of upgraded I.E.). However the proportion of uncollected or untreated release was much more important in 2005 (REF scenario) with 5% of total I.E. for EU-15, and 45% for new Member States. For these latter, a full implementation of the UWWD basically results in an increase of point-source emissions (resulting from the transfer of scattered dwelling emissions to point sources). Figure 7 shows the emissions of N and P point sources and scattered dwelling emissions resulting from the implementation of the Directive 91/271/EEC (scenario UWWD) and the Regulation 648/2004/EEC (scenario PFREE).

From 2005 (REF) to 2020 (BAU) changes in point source and scattered dwelling are intimately related to the changes in population count and distribution described in section 3.1. In Europe-27, scattered dwelling emissions evolved similarly for both N and P with a generalised decrease supported by the progressive change in population structure (the proportion of rural population in EU is decreasing from 2005 to 2020). The concomitant increase of inhabitant connected to sewage network and wastewater treatment plants (increase of the urban fraction of the population) leads to a slight increase of point-sources emissions. This latter is particularly important for Cyprus (+39% of N and +41% of P); Ireland (+17% of N and +16% of P) and the Luxembourg (+16% of N and + +16% of P) at the horizon 2020.

In 2020, the implementation of the UWW-Directive leads to an increasing rate of connection to sewer, combined with an upgrading of waste treatment plants. Consequently, important decreases of point source (from BAU to UWWD) are calculated in Belgium (-47% N; -64%P); Bulgaria (-35% N; -50%P); Spain (-31% N; -35%P); France (-29% N; -42%P); Ireland (-50% N; -61%P); Italy (-12%N; -32%P), Portugal (-23%N; -27%P) and United-Kingdoms (-26% N; -24%P).

The decrease of point source emissions is less significant for Luxembourg (-5%N; -9%P); Latvia (-6%N; -13%P); Netherland (-7%N; -17%P) and Sweden (-35%N; -2%P) where a significant difference between N and P treatments was observed.

For other Member States, point sources slightly increase, as in Germany (+4%N; -9%P) or Finland (+3%N; +7%P) reflecting an increase of population with an already high connection rate and treatment level. However drastic increases are simulated for Romania (+54%N; +35%P); Slovenia (+74%N; +51%P); Slovakia (+49%N; +30%P) accompanied with complete reduction (>90%) of scatter dwelling emissions (from BAU to UWWD).

For phosphorus, the PFREE scenario adds a further reduction of both point-source and scattered dwelling emissions (-20% in average compared to the single implementation of the UWWD). For countries with a large proportion of P- laundry emissions (see Figure 3) the impact of the PFREE scenario is particularly important, including Cyprus (-48% of P-point sources compared to UWWD), Poland (-46%), Portugal (-35%) and Estonia (-35%).

Maps of point sources emissions are given for nitrogen (Fig. 8) and phosphorus (Fig. 9) according to the four scenarios: REF, BAU, UWWD and PFREE

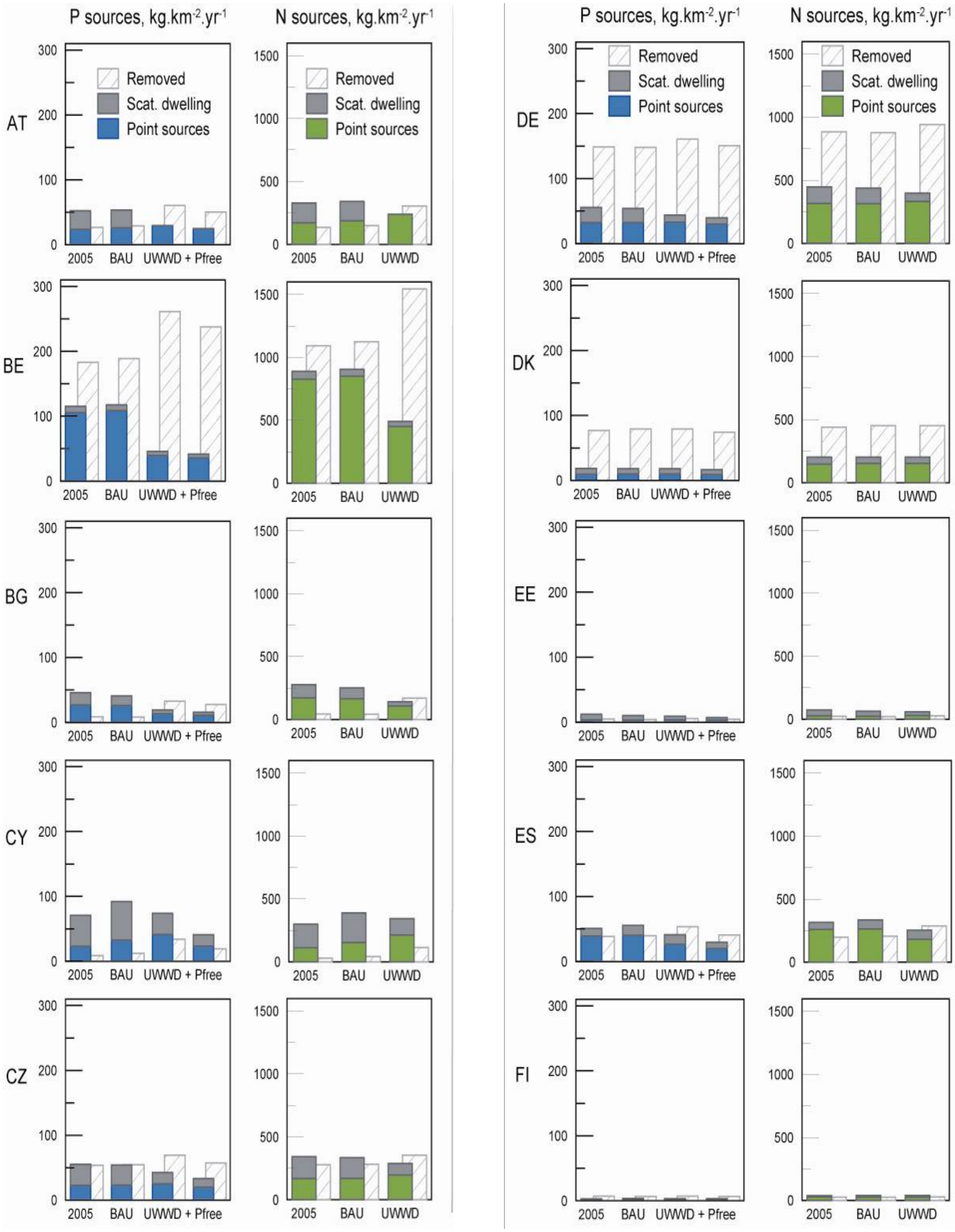


Figure 7: mitigation of N and P point sources and scatter dwelling emissions by the Directive 91/271/EEC (scenario UWWD) and the Regulation 648/2004/EEC (scenario PFREE)

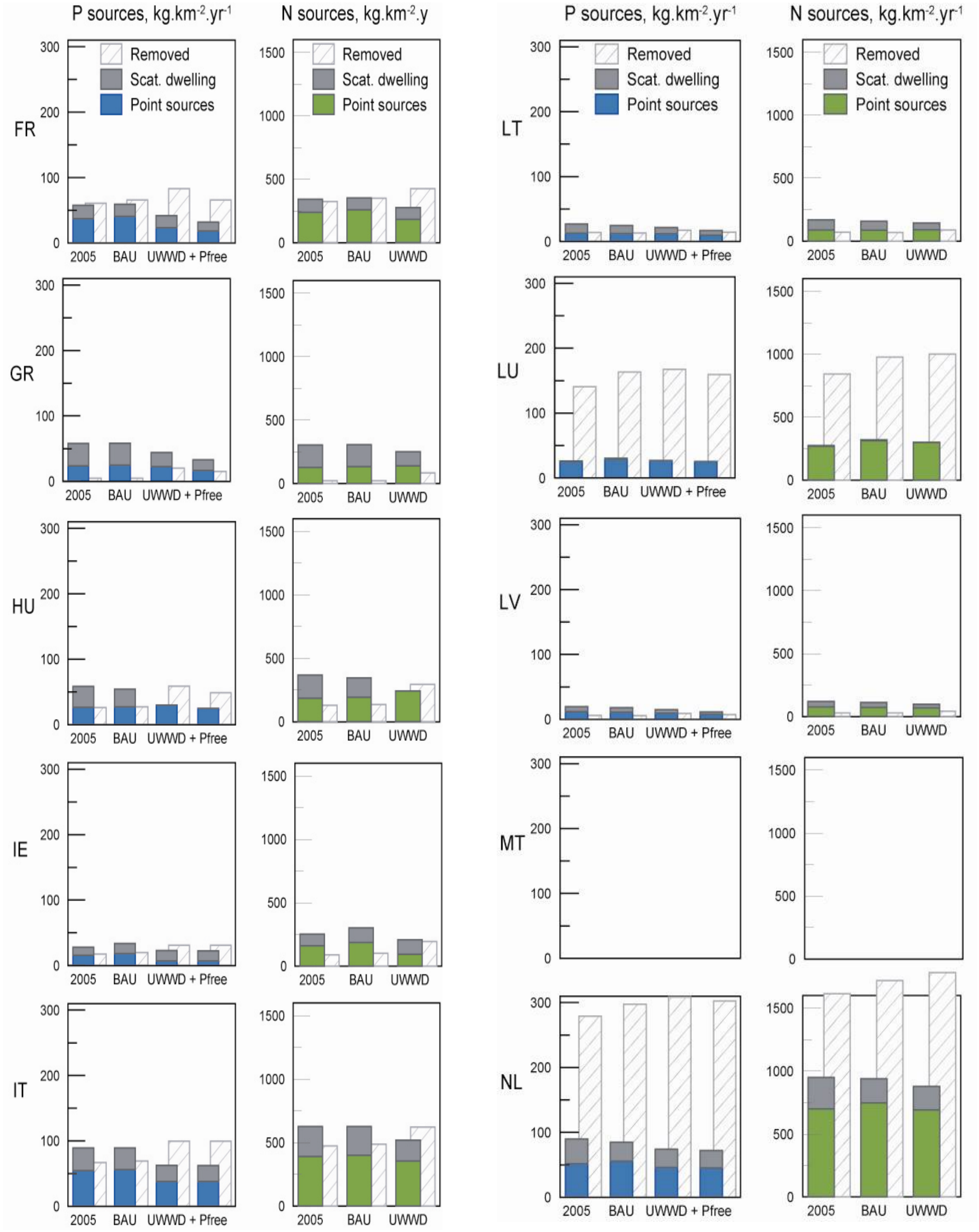


Figure 7(continued): mitigation of N and P point sources and scatter dwelling emissions by the Directive 91/271/EEC (scenario UWWD) and the Regulation 648/2004/EEC (scenario PFREE)

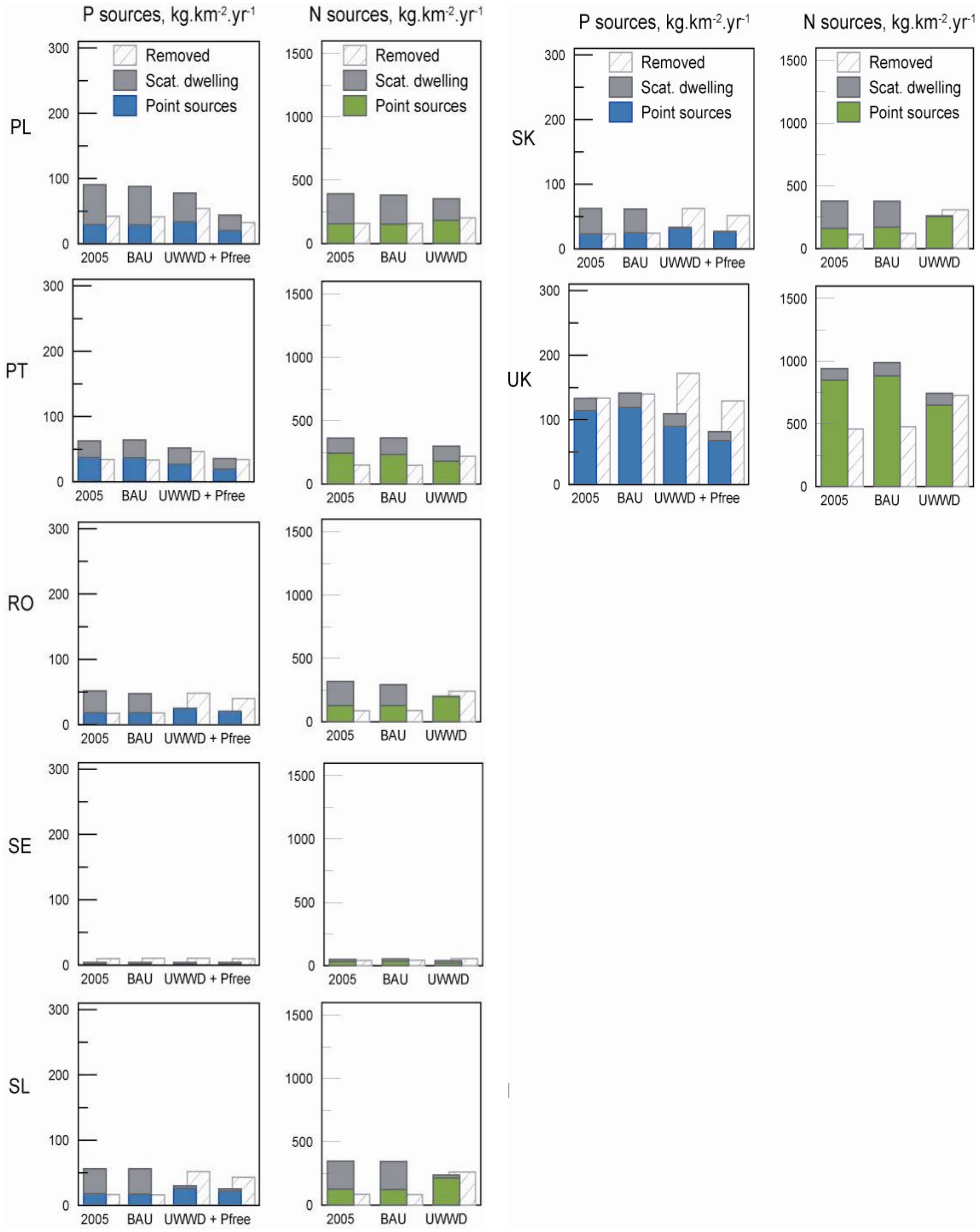
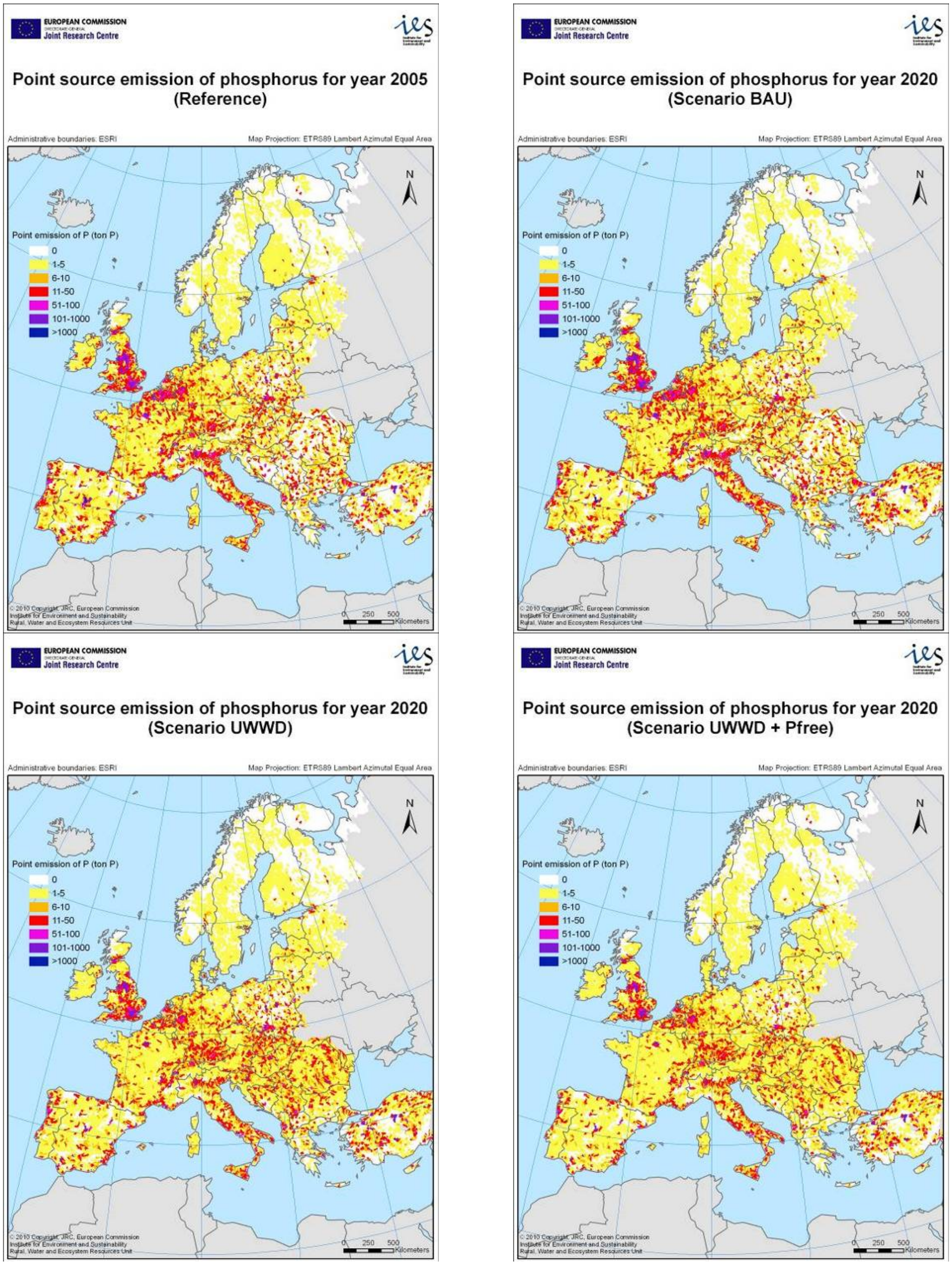


Figure 7(continued): mitigation of N and P point sources and scatter dwelling emissions by the Directive 91/271/EEC (scenario UWWD) and the Regulation 648/2004/EEC (scenario PFREE)



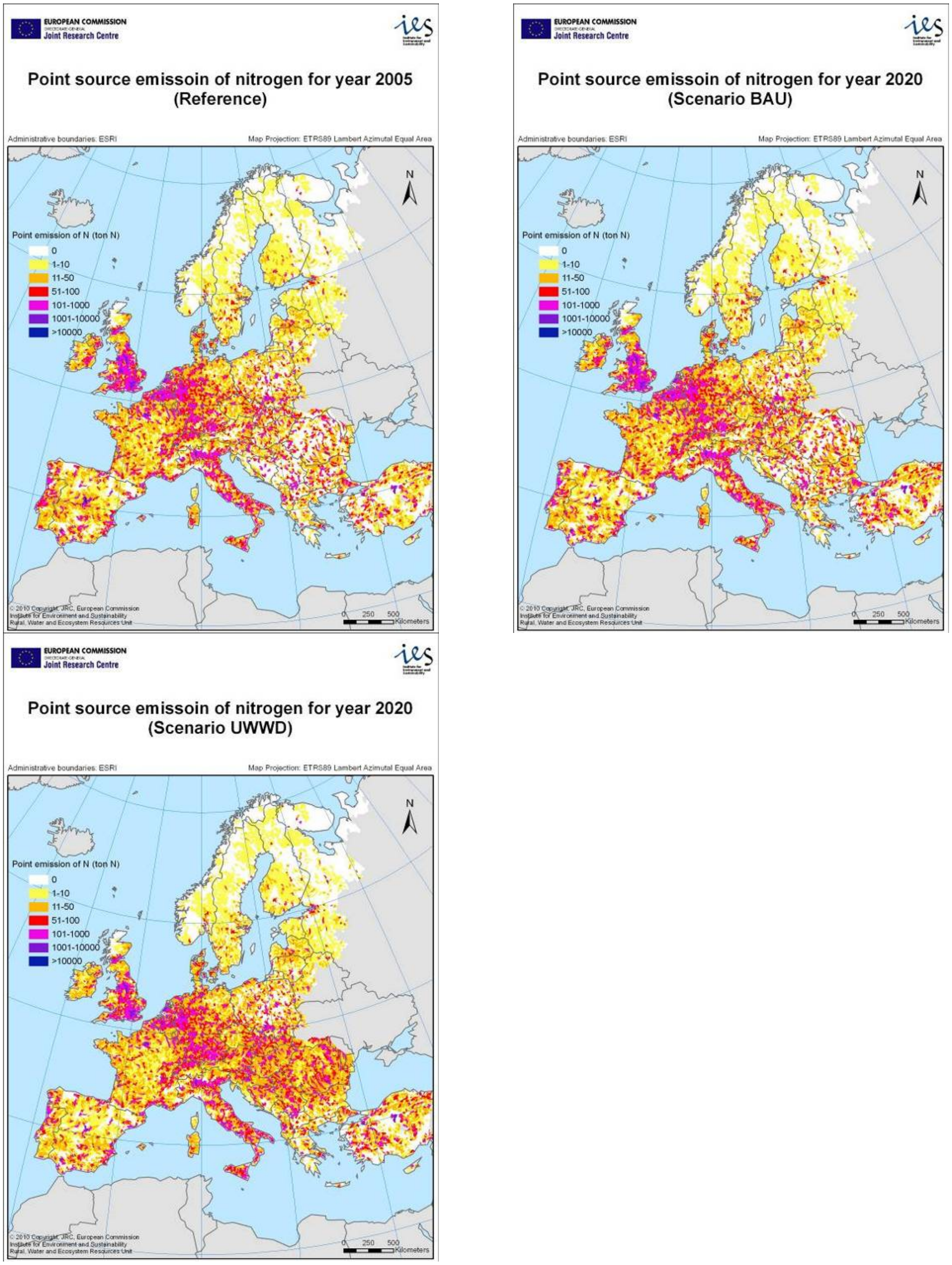
Point source emission of phosphorus for year 2005 (Reference)

Point source emission of phosphorus for year 2020 (Scenario BAU)

Point source emission of phosphorus for year 2020 (Scenario UWWD)

Point source emission of phosphorus for year 2020 (Scenario UWWD + Pfree)

Figure 8: Map of point source emission of phosphorus (ton P) per sub-basin for REF, BAU, UWWD and PFREE scenarios



Point source emissoin of nitrogen for year 2005 (Reference)

Point source emissoin of nitrogen for year 2020 (Scenario BAU)

Point source emissoin of nitrogen for year 2020 (Scenario UWWD)

Figure 9: Map of point source emission of nitrogen (ton N) per sub-basin for REF, BAU and UWWD scenarios

4.2 Impact on nutrients emitted as diffuse sources

From 2005 to 2020, the BAU scenario indicates that nitrogen diffuse inputs may decrease significantly in Greece (-22%); Bulgaria (-17%); Portugal (-13%); Denmark (-10%); the Netherlands (-9%); the United Kingdom (-7%) and Cyprus (-4%) due to a decrease in mineral inputs. For other Member States diffuse sources of nitrogen continue to increase despite the decrease of organic inputs c (Czech Republic; Serbia; Estonia; Latvia, Lithuania, Luxembourg and Slovakia).

A change in human diet (WHO and WCRF) appears as a low efficient option at the horizon 2020, while redistribution of manure (MANU) leads to a significant decrease of total nitrogen diffuse sources (Fig. 10). Reduction of nitrogen by the WHO scenario does not exceed 1% but can reach 8% according to the WCRF scenario. In this latter both mineral and organic nitrogen inputs are decreased, but most of the change is driven by a reduction in manure application, with the exception of United Kingdom where an important decrease in mineral nitrogen fertilizers is also simulated (-18%). It is important again to remember that there is a drastic decrease in human in human consumption of meat but with much less marked decrease of beef and pork production. Annexe 3 provides a detailed summary of diffuse emissions values (for both N and P) by countries (the MANU scenario is not included as it provides results at the basin scale). The impact of the MANU scenario on mineral application of nitrogen is shown in Figure 6.

For phosphorus the BAU scenario simulates from 2005 to 2020 a significant decrease in Ireland (-14%); United Kingdom (-8%); Czech Republic (-9%) and Greece (-12%). However Figure 11 indicates that such changes are highly regionalized according to the intensity of breeding within each country (e.g. Brittany; Western France, Eastern Spain, southern parts of Ireland and England). There is also a significant increase simulated in Estonia (+39%); Hungary (+20%); Spain (+20%); Lithuania (+13%) and Belgium (+11%).

There is no major impact of a change in human diet on phosphorus diffuse emission and a maximum reduction of 6% is simulated following the recommendations of WRCF. In this scenario phosphorus manure (and nitrogen manure) decreases, and despite a significant increase in P-mineral application in Denmark and the Netherlands, the overall phosphorus supply decreases for all European countries.

The MANU scenario does not consider a change in the amount of manure applied at the basin scale, and changes in diffuse sources are directly related to the mineral supply calculated to meet the crop requirement in each sub-basin (Fig. 6). These changes in P-diffuse sources are explained by i) the balance of P surplus at the sub-basin scale (see Annexe 2) and ii) the inadequacy between the quality of the manure locally produced and the nature of the crop demand at the basin scale. Furthermore, in our approach we do not allow crops to be subject to a phosphorus (or nitrogen) deficit as it is the case in many areas in Europe.

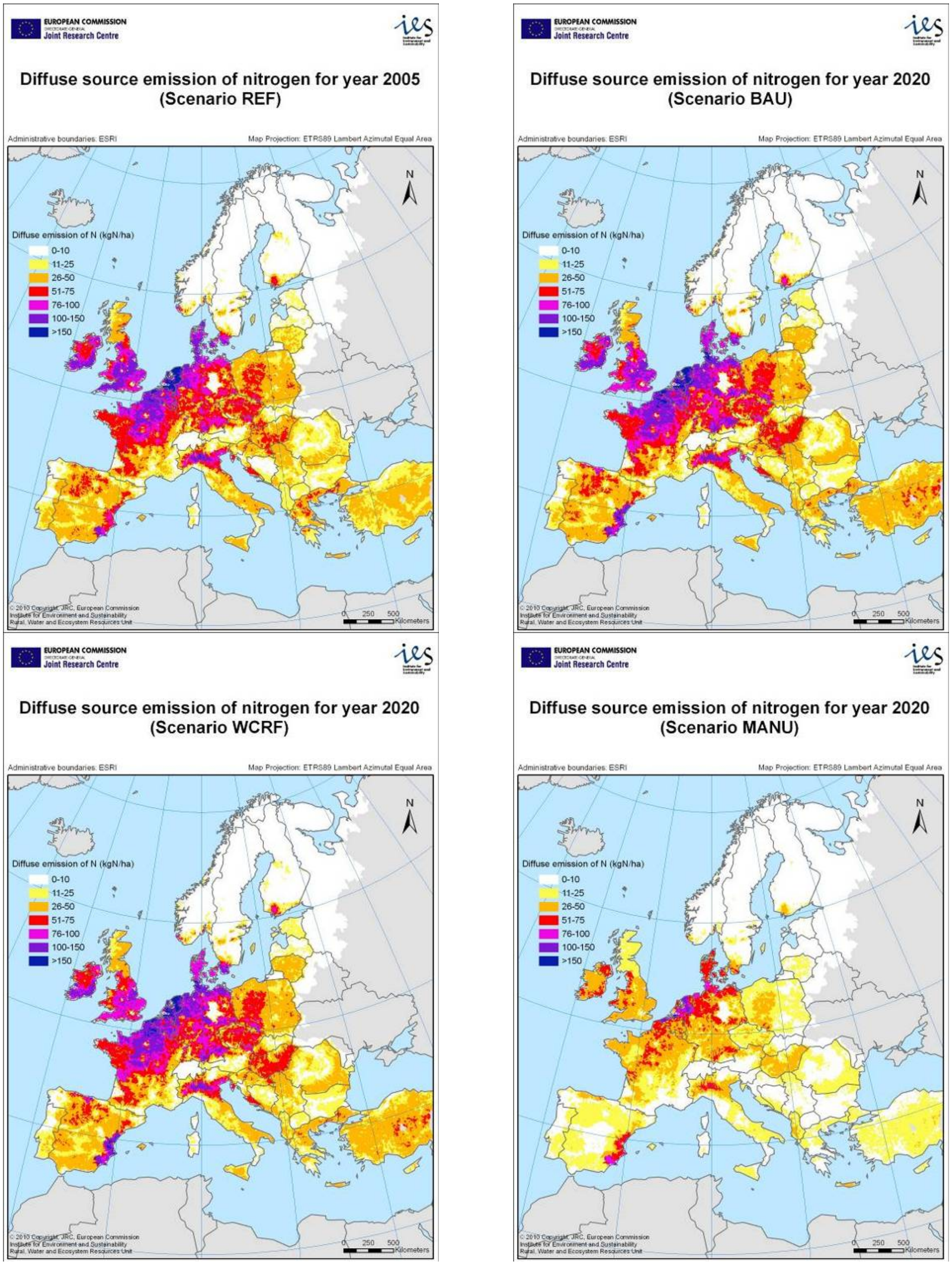


Figure 10: Map of diffuse source of nitrogen (ton N) per sub-basin for REF, BAU, WCRF and MANU scenarios

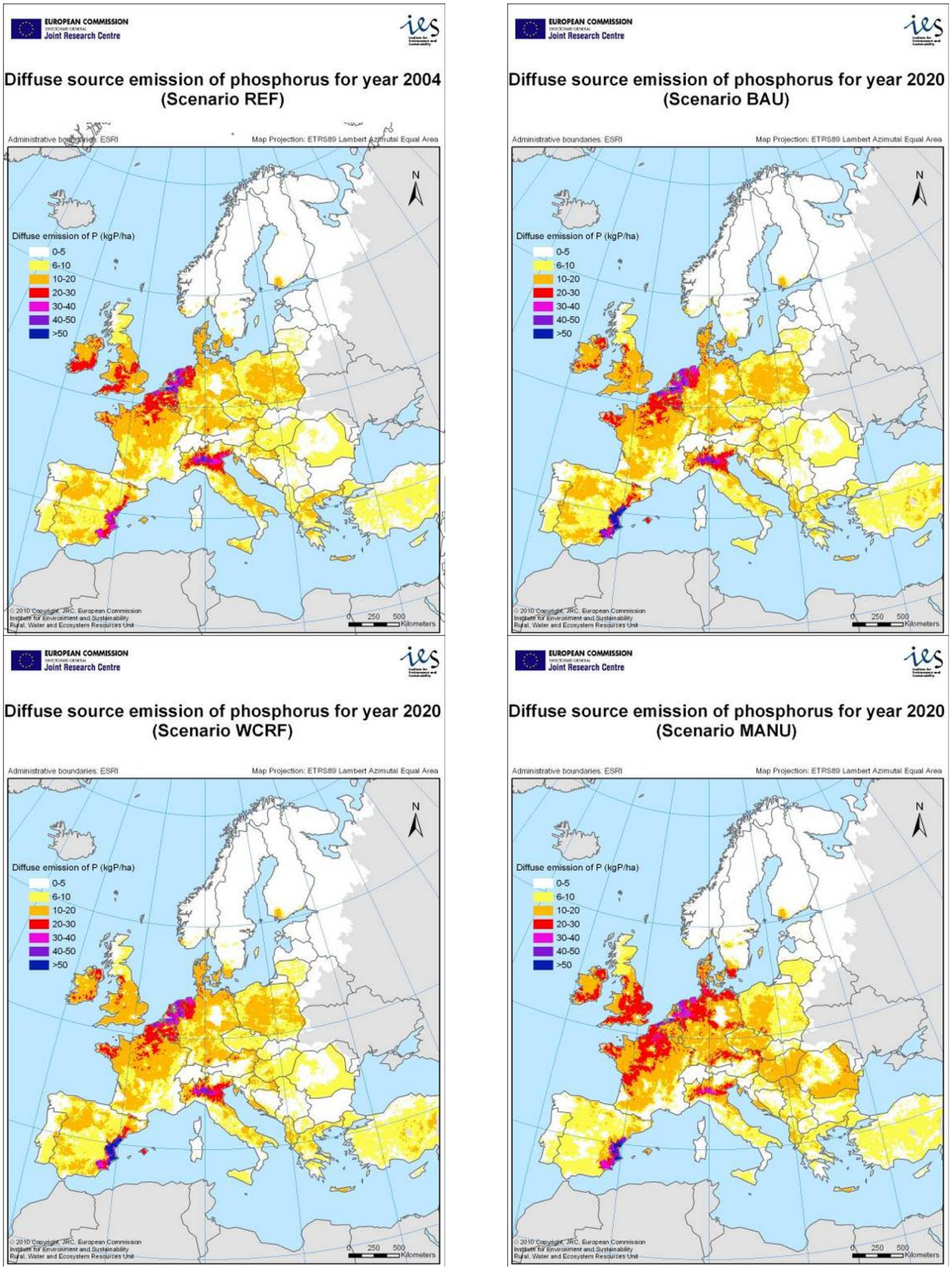


Figure 11: Map of diffuse source of phosphorus (ton P) per sub-basin for REF, BAU, WCRF and MANU scenarios

4.3 Impact on modelled nutrients export to sea

4.3.1 Nutrients sources apportionment

The GREEN model was used to quantify the load of nutrients exported to European Seas and to assess the contribution of diffuse and point sources to the total load exported to the sea.

In the case of nitrogen, the highest losses tend to occur in agricultural areas where river basins supporting intensive agricultural activities have a major contribution of diffuse emissions. On the opposite, river basins holding a high population density have their exports of nitrogen dominated by point sources emissions (see Fig. 12). This is typically the case of small coastal watersheds where an important part of the European population is concentrated.

For phosphorus the source apportionment does not allow such a clear distinction. The contribution of point sources emission to the total phosphorus loads entering European Seas is clearly significant. The contribution of diffuse sources is lower for phosphorus than nitrogen (Fig. 13). Areas with important contribution of point sources for nitrogen are similar with those having the highest point sources contribution for phosphorus. This indicates the consistency of wastewater treatment level for both nitrogen and phosphorus whatever the rate of connection to sewage.

Improvement of wastewater collection and treatment in areas presenting a lack of connection to sewage network results in an increase of point sources contribution, due essentially to a transfer of scattered dwelling emission (considered as diffuse sources) to point sources emissions. In countries already having the major part of their population connected to sewage, the implementation of the Urban Waste Water Directive (UWWD) greatly reduces the contribution of point sources for both nitrogen and phosphorus, and the substitution of phosphorus in laundry detergent (PFREE) adds a further reduction. However, for river basins where water treatment was already at a high level, the combined UWWD + PFREE scenarios have no significant impact, as in the case of the Rhine river basin.

Scenarios impacting agricultural activities (WHO, WCRF, MANU) result systematically in a decrease of diffuse sources contribution for nitrogen. Except for some specific river basins (in Spain, Turkey and United Kingdom, see Fig. 12) agricultural practices remain the dominant sources contributing to nitrogen flowing to European Seas. Concerning phosphorus the impacts of WCRF and MANU scenarios on phosphorus diffuse emissions are mixed. T he sources apportionment (Fig. 13) is consistent with the map of the diffuse P sources for these respective scenarios (Fig. 11).

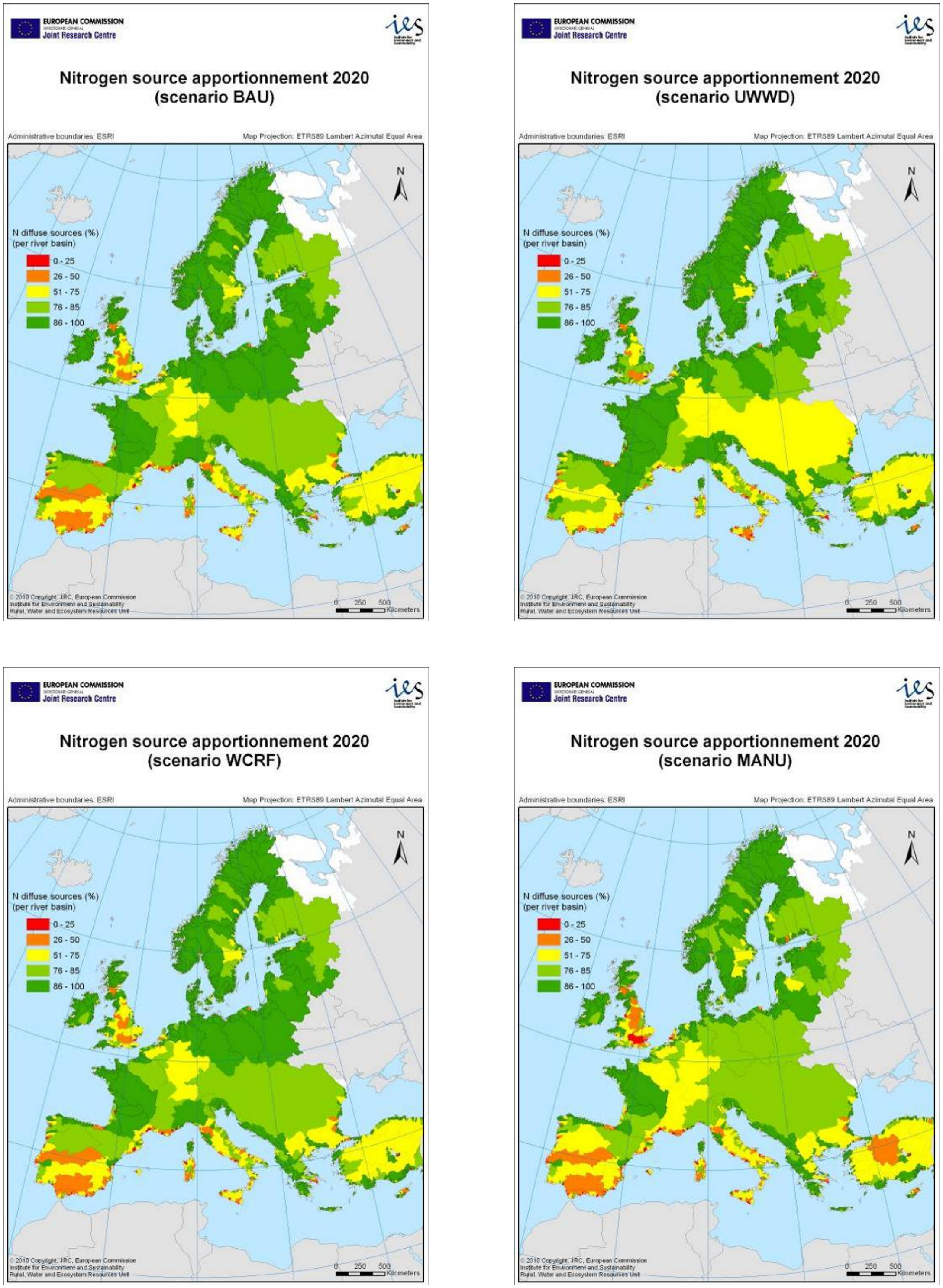


Figure 12: Contribution of diffuse sources to total nitrogen load into the sea per basin. The green colour indicates a predominance of diffuse sources (agricultural sources), while the red colour signifies a higher contribution from point sources (wastewater discharges)

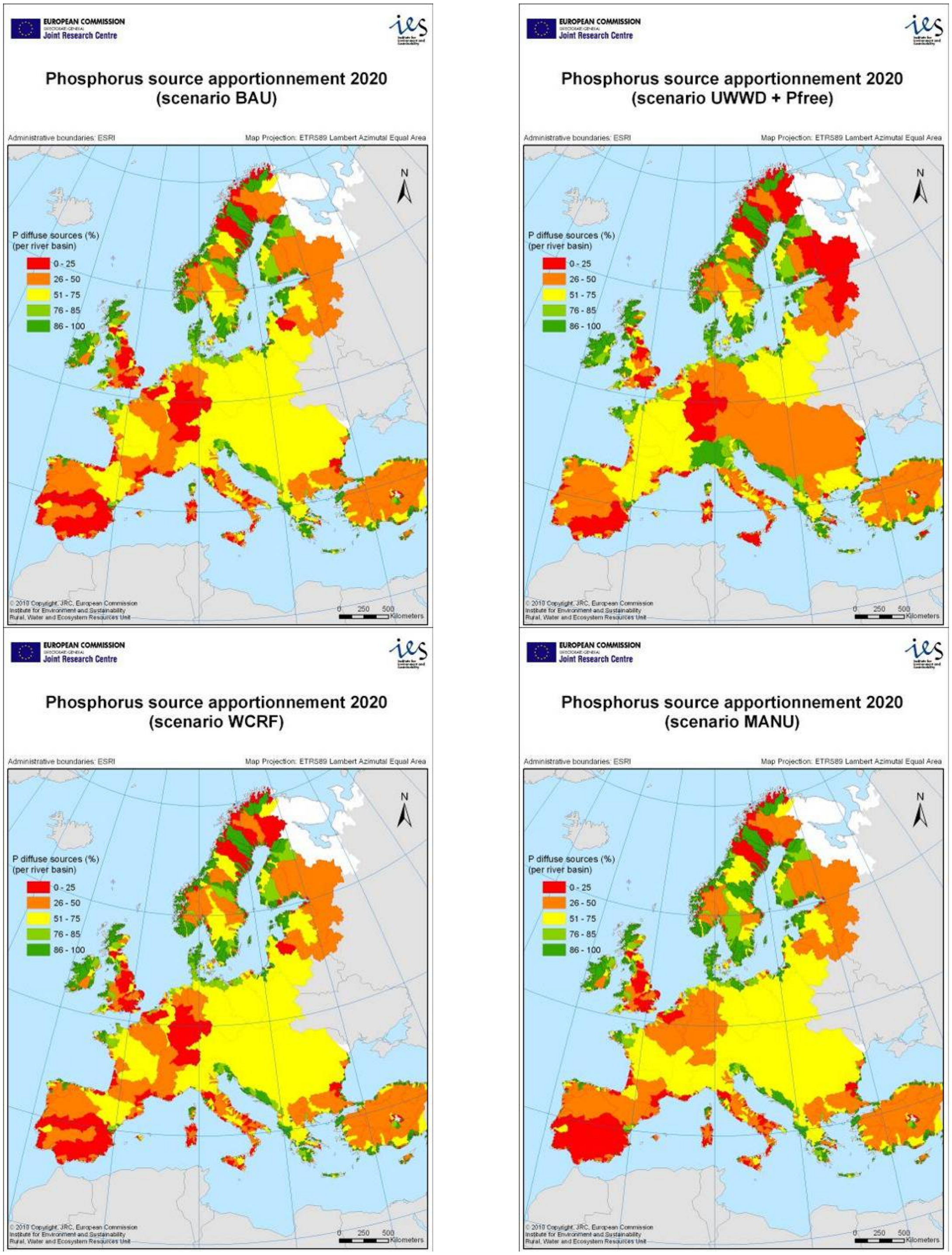


Figure 13: Contribution of diffuse sources to total phosphorus load into the sea per basin. The green colour indicates a predominance of diffuse sources (agricultural sources), while the red colour signifies a higher contribution from point sources (wastewater discharges)

4.3.2 Nutrients loads to European sea

According to the BAU storyline, both nitrogen and phosphorus loads to European sea will increase in a similar way from 2005 (REF) to 2020 (BAU): Baltic Sea +1.6%; the North Sea +3.0%; Atlantic Sea +3.1%; Black Sea +5.8% and the Mediterranean Sea +3.6%.

Impact of the UWWD on point sources loads (fraction of the loads entering the sea and originating from households and industrial emissions) is very significant for the North Sea with a 33% reduction for nitrogen and 40% for phosphorus (Fig. 16). In the Mediterranean and Atlantic Seas, the decrease of nitrogen point source is around 15 %, and up to 25% for phosphorus from point source (Fig. 14 and Fig. 15). Implementation of the UWW-Directive increases (mostly due to the new Member States) both N and P point sources contribution by +4.5% for N and +9.5 % for P for the Baltic and +25% N and +10 % P for the Black Sea (Fig. 17 and Fig. 18). The contribution of scattered dwelling emissions decreases for all seas, but this decrease is highly significant for the Baltic Sea and the Black sea (-20% N and -40 %P). This concomitant increase in point source and decrease in scattered dwelling emission is obvious for regions having an initial low connection rate to sewers and wastewater treatment plants.

The effect of adding phosphorus prohibition in detergents, leads to an additional decrease of point source (from -7 to -57 %P) and scattered dwelling emissions (from -13 to -46 %P).

In the case of nitrogen, point sources represent a minor contribution (Fig. 12), and the overall impact of the UWWD is less significant when the reduction of point sources loads is reported to the total nitrogen loads to the sea. The corresponding nitrogen reduction are of 0.8% for the Baltic sea, 2.1% for the Black sea, , 4.2% for the Atlantic sea, 4.6% for the Mediterranean sea and 5.6% for the North sea.

The impact of a change in diet needs to be considered with respect to the WCRF scenario, as impact of the World Health Organization (scenario WHO) does not significantly affect the nitrogen and phosphorus entering European seas (<1% for N and P). When comparing WCRF to the BAU situation for 2020, nitrogen diffuse emissions (diffuse sources exported to the sea) are reduced by 2.1% for Black sea (Fig. 18), 3% for Mediterranean Sea (Fig. 15), 3.1% for the Baltic Sea (Fig. 17), 4.4% for Atlantic Sea (Fig. 14) and 5% for the North Sea (Fig. 16).

Impact on diffuse emissions of phosphorus (diffuse sources exported to the sea) is in the same range: Black sea -1.4%, Mediterranean Sea -2.8%, the Baltic Sea -2.4%, Atlantic sea -4.5% and North Sea -3.2%.

The MANU scenario greatly impacts nitrogen export to European seas with reductions ranging from 36% to 41%. However, because of the assumptions made in the MANU scenario (accumulation of P in European soils is not taken into account) there is a substantial increase in diffuse emissions of P in Atlantic sea (8%), the Baltic sea (11%) and the North Sea (12%). For the Mediterranean Sea diffuse sources of P are reduced by 11 %. Figure 6 allows a better understanding of the regional differences and changes in mineral application under the MANU scenario.

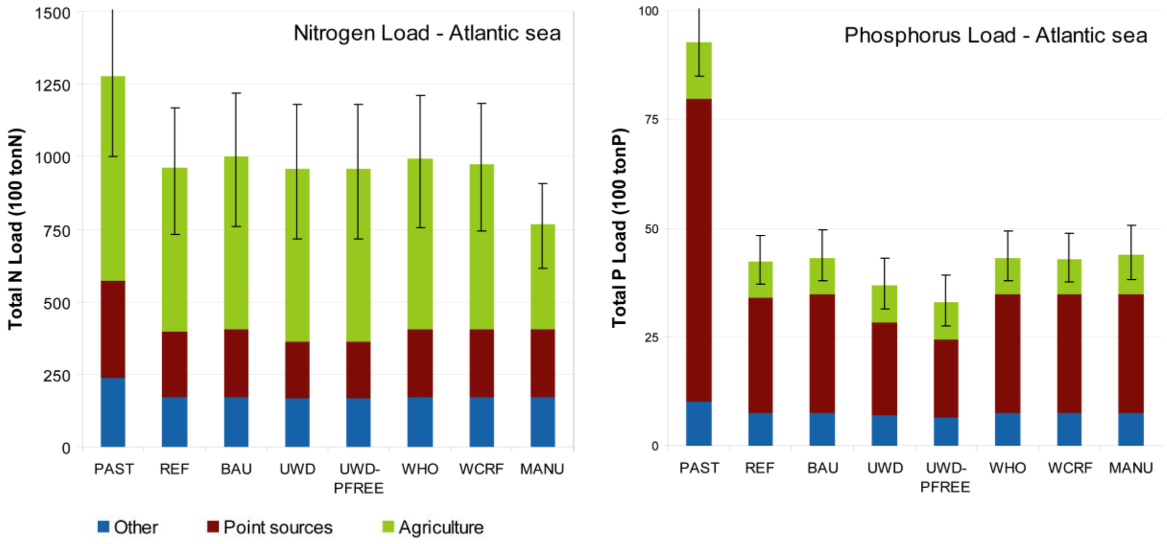


Figure 14: Estimated yearly mean total nitrogen (left) and phosphorus (right) per source entering the Atlantic sea. Error bars indicate the change in diffuse sources contribution (minimum and maximum) according to range of hydrological conditions from 1985 to 2005.

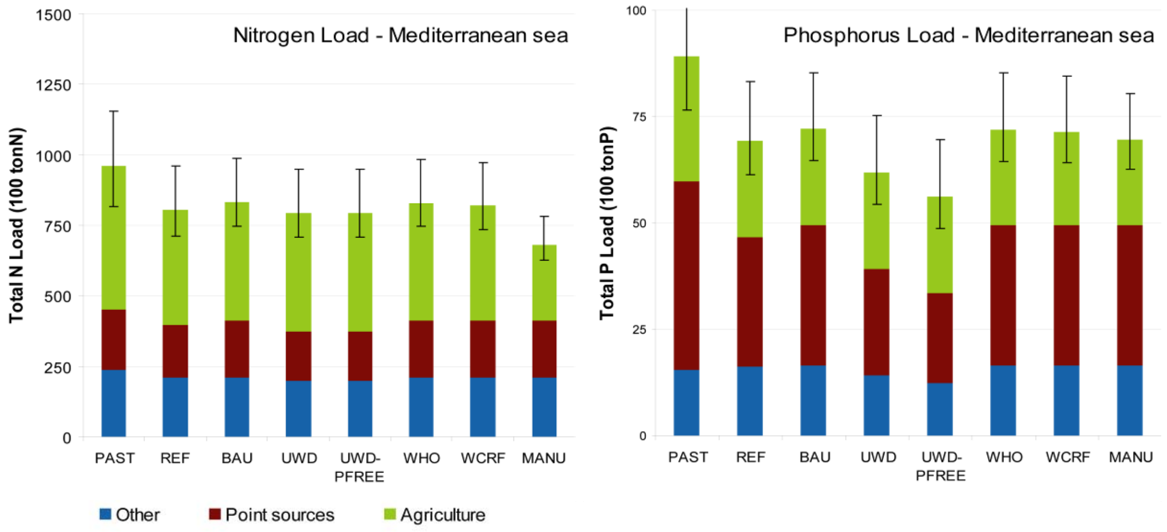


Figure 15: Estimated yearly mean total nitrogen (left) and phosphorus (right) per source entering the Mediterranean sea. Error bars indicate the change in diffuse sources contribution (minimum and maximum) according to range of hydrological conditions from 1985 to 2005.

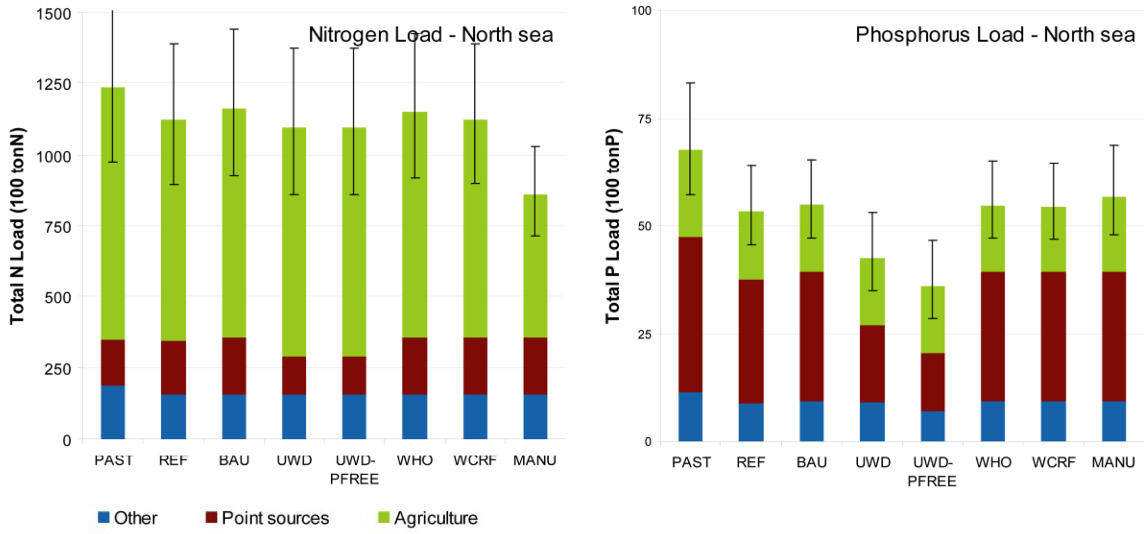


Figure 16: Estimated yearly mean total nitrogen (left) and phosphorus (right) per source entering the North Sea. Error bars indicate the change in diffuse sources contribution (minimum and maximum) according to range of hydrological conditions from 1985 to 2005.

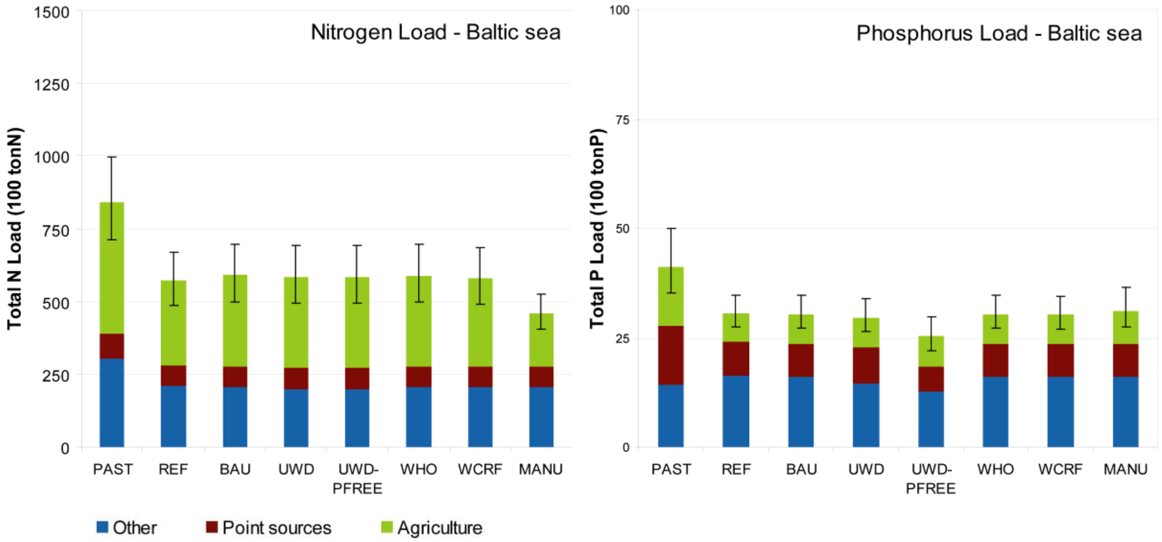


Figure 17: Estimated yearly mean total nitrogen (left) and phosphorus (right) per source entering the Baltic Sea. Error bars indicate the change in diffuse sources contribution (minimum and maximum) according to range of hydrological conditions from 1985 to 2005.

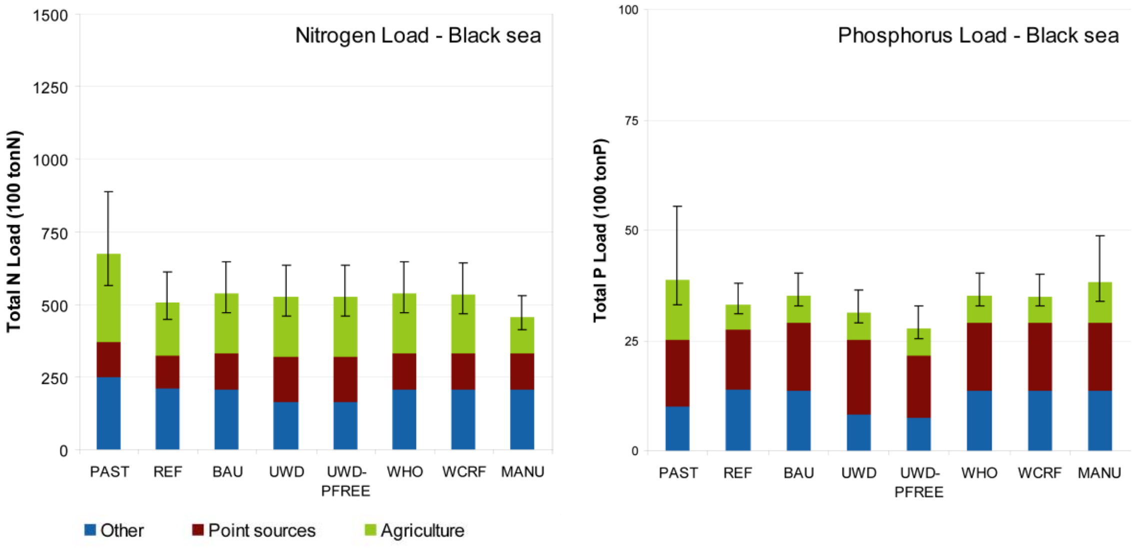


Figure 18: Estimated yearly mean total nitrogen (left) and phosphorus (right) per source entering the Black Sea. Error bars indicate the change in diffuse sources contribution (minimum and maximum) according to range of hydrological conditions from 1985 to 2005.

4.3.3 Scenarios effectiveness

By considering a set of common nutrients mitigation measures applied for the whole Europe, the underlying aim of the study is to assess the effectiveness of each individual scenario. In this exercise, scenarios need to be compared with a similar timeline (here 2020) in order to avoid any compensation or magnifying effects supported by the assumptions made between 2005 (REF) and 2020 (BAU). Figure 19 illustrates a change in nutrient sources and the corresponding change in nutrient exports between the BAU baseline and different mitigation measures. To ensure the readability of these analysis, only MANU, WCRF and UWWD (+PFree) scenarios are presented (the WHO scenario is not included, as impact of this scenario is relatively low). In this figure, specific fluxes of nutrients normalized by the watershed area have been calculated for both inputs and exports in order to support the comparison between all European basins independently of their size.

Mitigation of nutrients point sources by improving wastewater treatment is generally presented as an end-of-pipe option, but it is clearly the most effective way to decrease both nitrogen and phosphorus exported to the sea. For most of European river basins, effectiveness of UWWD scenario ranges between 50-100 % (line 1/1 and line 1/2 Fig. 19). Conceptually the GREEN model considers that nutrient emitted as point sources are only subject to in-stream retention (within the river bed) and the retention coefficients calibrated by the GREEN model are not affected by the implementation of scenarios.

Mitigation of diffuse sources presents a greater variability especially the MANU scenario. In the case of nitrogen, the effectiveness of the MANU scenario remains lower than 50% and most of the river basins are under 25%. This lower effectiveness is explained by the fact that diffuse sources are subject to both terrestrial and in-stream retention processes. The efficiency of the WCRF scenario fluctuates in the same range of values (from 10% to 50%). However, it presents a lower capacity to reduce nutrients sources compared to MANU scenario that is considered as a more drastic option.

In the case of phosphorus, the effectiveness of agricultural scenarios (MANU and WCRF) is very low, less than 10%, due to the high level of terrestrial retention of phosphorus. For some river basins positive values of change in P-inputs can be observed (Fig. 19). Such an increase is particularly significant for the MANU scenario, resulting in an increase of calculated P exports.

These results have to be discussed together with the sources apportionments results. While scenarios on point sources appear as the most effective way to reduce nitrogen sources, they also represent a marginal/minor contribution in the total nitrogen loads exported to the coastal seas. On the other hand, agricultural scenarios (agro-environmental measure), despite their lower effectiveness, offer a greater potential for obviating the problems caused by nitrogen in Europe.

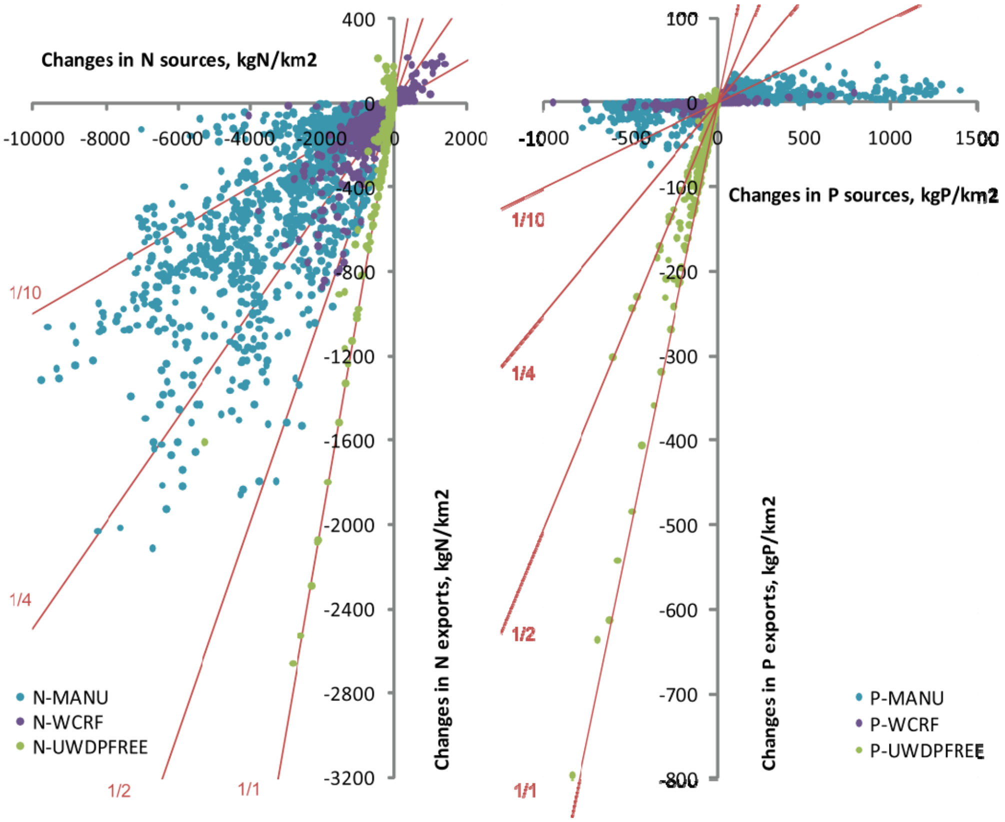


Figure 19: Comparison of changes in nutrients exports by European basin according to changes in nutrients input. Both N and P fluxes are normalized by the total area of the river basin to enable the comparison between all EU-basins. The line 1/1 indicates that for a given change in nitrogen or phosphorus input, a similar increase/decrease in exported fluxe is simulated for the basin.

4.3.4 Nutrients concentrations to European seas

Figures 20 to 25 show the changes of nutrients concentrations calculated for each European sea for the time lines: 1985 (PAST scenario), 2005 (REF scenario) and 2020 (BAU, UWWD, WHO, PFREE, WCRF, MANU scenarios). As each individual scenario has been simulated with a wide range of hydrological conditions (21 years of real hydrology), the extremes (minimum and maximum) and average concentrations are provided to represent the variability of the simulation results.

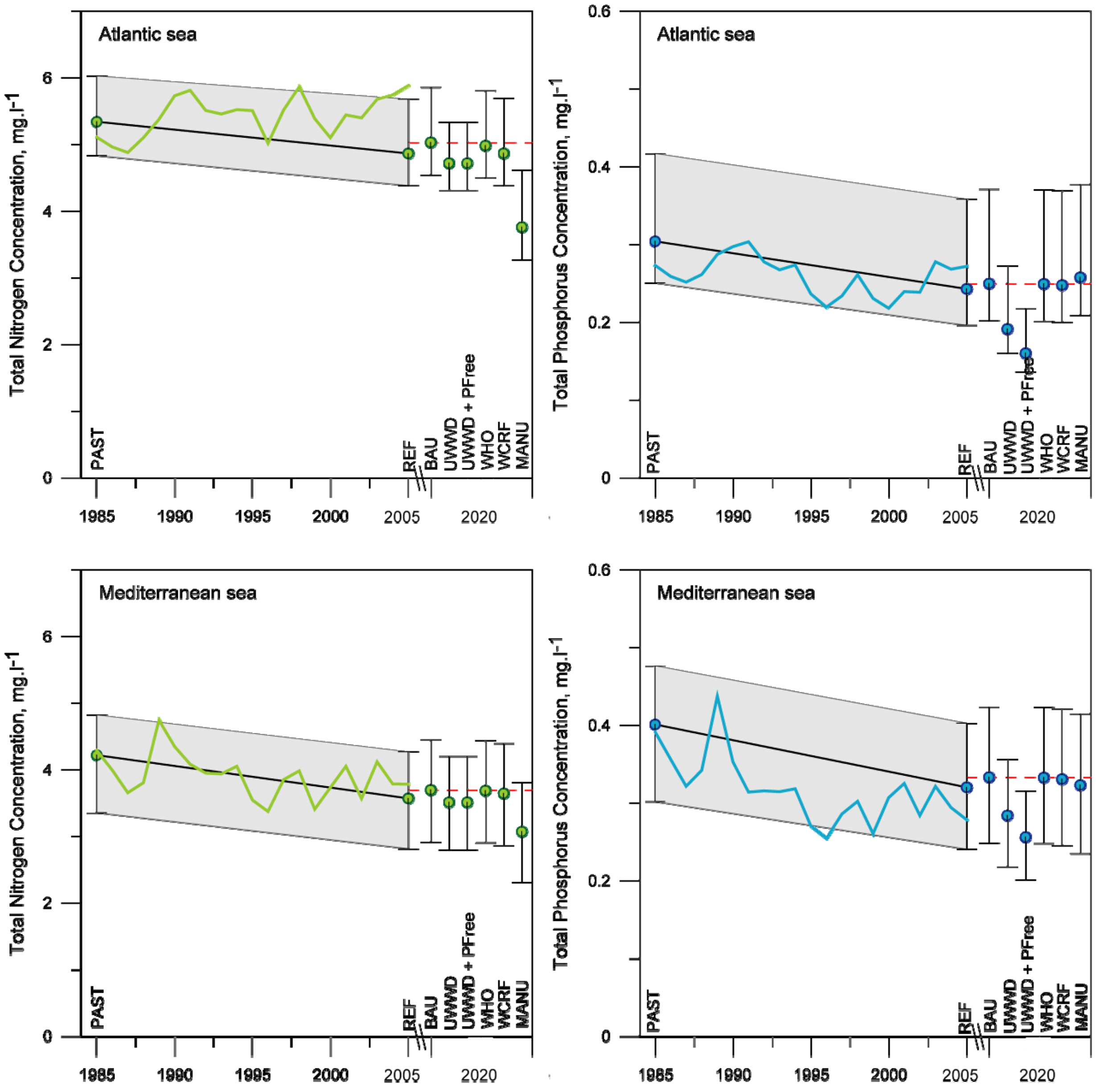
For all European seas the range of in-stream concentrations is clearly increasing from REF to BAU for nitrogen (+ 3.8% to +6.7%) and phosphorus (+ 0.5% to +7.0%). The most important changes over this period are simulated for the Mediterranean and the Black Seas. The Baltic Sea exhibits the less important changes especially for phosphorus concentrations.

Impact of the UWWD is highly significant for phosphorus especially when this latter is combined with a PFREE option. The decrease of nitrogen concentrations from BAU to UWWD allowed to recover the range of concentrations simulated for the REF situation, thus preventing the worsening a nitrogen contamination in 2020.

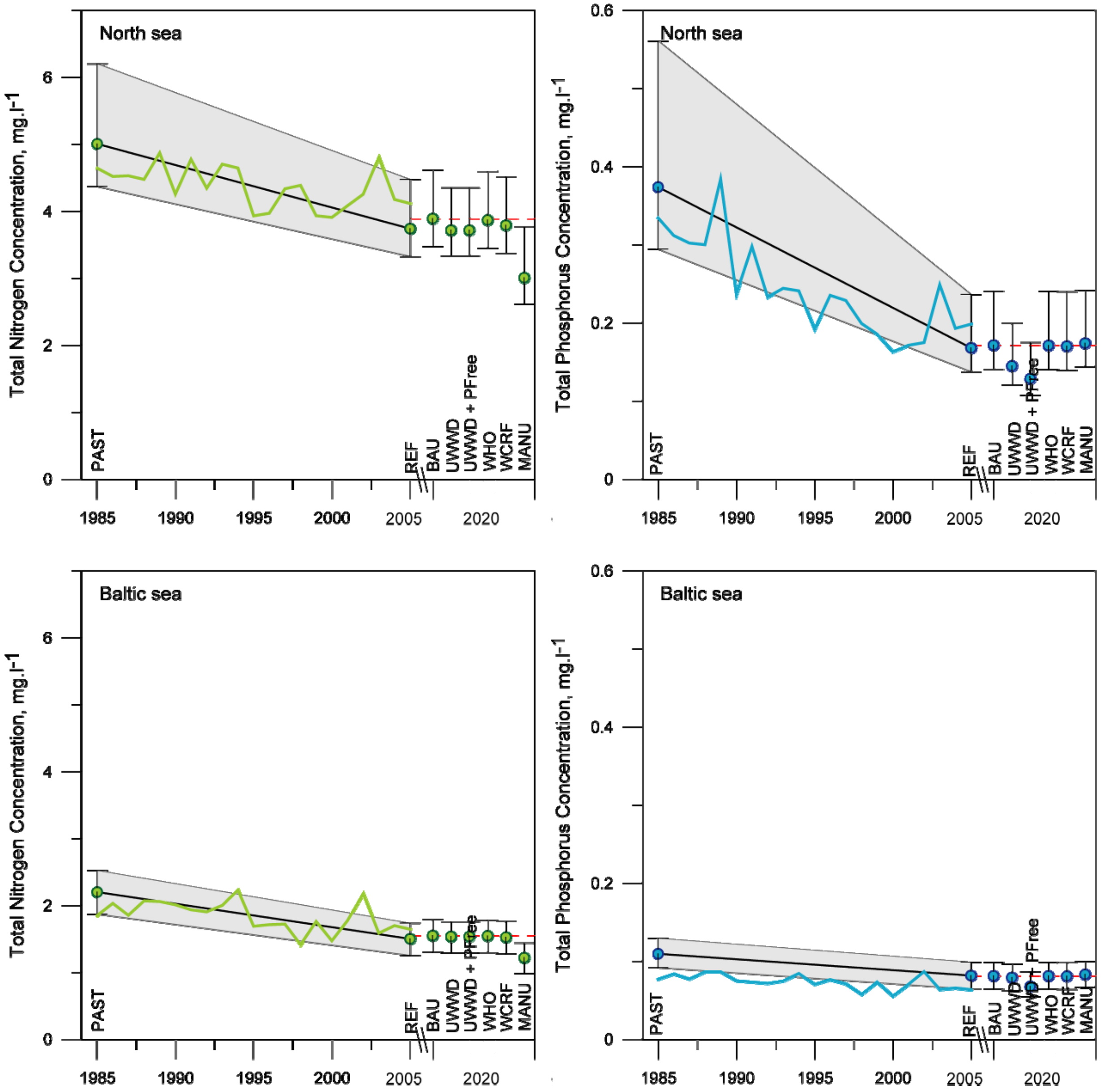
The environmental impact of a change in human diet it rather low, and slight impacts are observed on nitrogen and phosphorus concentrations. The WCRF scenario seems to have the capacity to prevent the increase of nitrogen concentrations simulated under the BAU scenario, but does not offer a significant improvement compared to the present (REF) situation. Again, it is important to remind here that the large decrease of meat consumption was not accompanied for economical reasons by a similar decrease of animal production.

The MANU scenario is the most efficient scenario and allows reducing nitrogen concentrations down to 4mg/l in the river flowing to Atlantic sea (Fig. 20) and down to 3 mg/l for the Mediterranean (Fig. 21) and the North (Figure 22) Seas. This scenario has no significant effect on phosphorus concentrations for the North and the Baltic Seas (Fig. 22 and 23), a negative impact on the Atlantic and Black Seas (Figure 20 and 24) and a positive impact (decrease) on the Mediterranean Sea.

The proposed approach estimated the impact of prospective scenarios considering a time frame analysis of twenty years (from 2005: REF to 2020: BAU). Figures 20 to 25 represent the linear interpolation of the simulation between 1985: PAST and 2005: REF, either 20-year of anthropogenic pressures changes in European watersheds. When overlaying the simulations performed by the GREEN model considering the specific nutrients inputs and hydrological conditions for each of the years between PAST and REF, it clearly appears that a wide range of variations is expected within a time frame of 20 years. Hydrology appears as an important factor controlling the variability of the simulation results, however fast changes in anthropogenic pressures as the rapid improvement of P wastewater treatment in Europe or the progressive saturation of soil need to be considered with a finer time step.



Figures 20 and 21: Change in Nitrogen and Phosphorus concentrations exported to Atlantic sea (top, Fig.20) and Mediterranean sea (bottom, Fig.21). Colour (green and blue) lines indicated the reconstruction of past trends simulated with their respective hydrological conditions from 1985 to 2005. For all scenarios (PAST, REF, BAU, UWWD, Pfree, WHO, WCRF and MANU) simulation results are provided as minimum (lower bar), maximum (upper bar) and average (middle point) concentrations calculated over the hydrological periods1985-2005. An additional red dotted line indicates the average BAU concentrations for 2020



Figures 22 and 23: Change in Nitrogen and Phosphorus concentrations exported to North sea (top, Fig. 22) and Baltic sea (bottom, Fig. 23). Colour (green and blue) lines indicated the reconstruction of past trends simulated with their respective hydrological conditions from 1985 to 2005. For all scenarios (PAST, REF, BAU, UWWD, Pfree, WHO, WCRF and MANU) simulation results are provided as minimum (lower bar), maximum (upper bar) and average (middle point) concentrations calculated over the hydrological periods1985-2005. An additional red dotted line indicates the average BAU concentrations for 2020

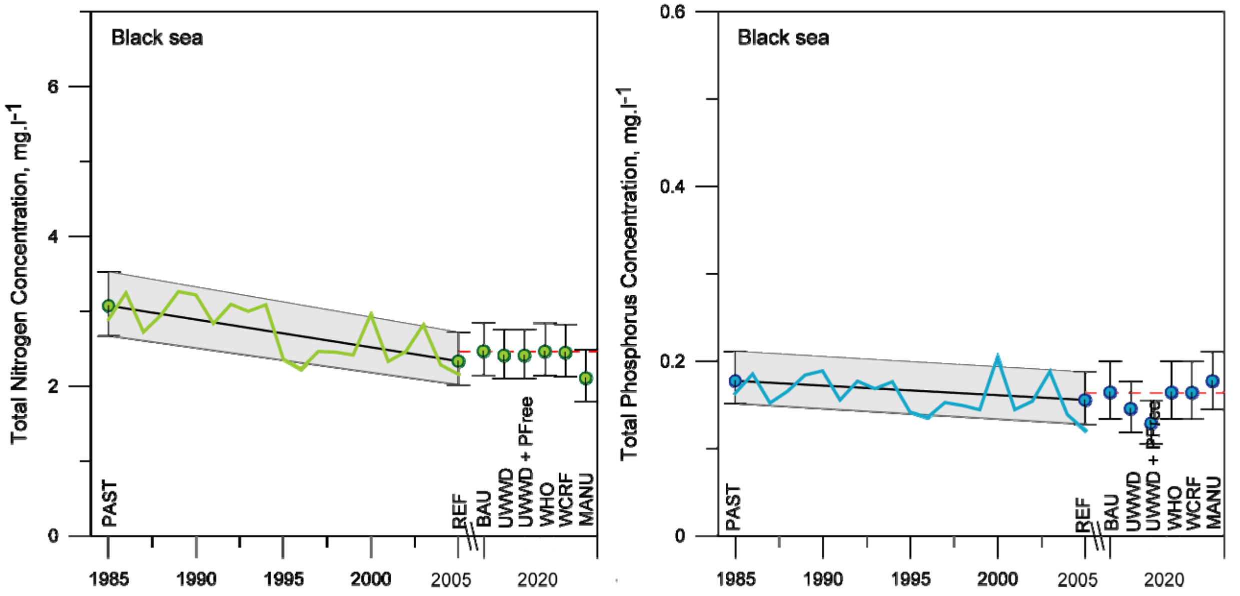


Figure 24: Change in Nitrogen and Phosphorus concentrations exported to Black sea. Colour (green and blue) lines indicated the reconstruction of past trends simulated with their respective hydrological conditions from 1985 to 2005. For all scenarios (PAST, REF, BAU, UWWD, Pfree, WHO, WCRF and MANU) simulation results are provided as minimum (lower bar), maximum (upper bar) and average (middle point) concentrations calculated over the hydrological periods1985-2005. An additional red dotted line indicates the average BAU concentrations for 2020

5. Conclusion and perspectives

In this study, an increase of both nitrogen and phosphorus land based emissions is estimated in 2020 for the whole Europe following a business as usual scenario (see Figures 7 to 9 for point sources and Figures 10-11 for diffuse sources).

For EU27, total nitrogen inputs will increase from 22,900 kt/yr to 24,350 kt/yr, while changes in phosphorus inputs are less important with an increase from 3,500 kt/yr to 3,650 kt/yr for EU27.

Three categories of nutrients mitigation measures were addressed: i) the collection and treatment of point sources (UWWD and PFREE scenarios), ii) a change in European human diet (WHO and WCRF scenarios) and iii) the management of manure application in Europe.

The mitigation of nutrients point sources – This is the most effective option to reduce both nitrogen and phosphorus loads to regional seas. Indeed, it is considered (GREEN model) that point source are only subject aquatic retention, consequently a change in point sources emission is directly followed by a change in nutrients exported to sea. However three characteristics may attenuate the efficiency of this option:

- The location of urban areas in an upstream to downstream gradient. Efficiency of a change in point sources to reduce nutrients is obviously higher when the most important sources are released in the downstream part of the drainage network (as the effect of the measure is not attenuated by the cumulative nutrient retention from the upstream to the downstream parts of the drainage network).
- The importance of scattered dwelling emissions. The benefits of a progressive improvement in WWTPs removal could be compensated by an important transfer of nutrient loads from scatter-dwelling emission (uncollected) to point source (collected). For this reason a full implementation of the UWWD leads to a contrasted assessment in Europe. It is also important to note that the reduction of scattered dwellings greatly reduces the risk of groundwater contamination.
- The technologies already in place to treat wastewater effluents. A clear difference appears between EU15 and new Members States. In EU15, implementation of the UWW Directive mostly results in the upgrading of existing treatment plants with basic treatment to more stringent treatment of N and P. For new Members States, the upgrading of existing plant is comparatively less important, but the increase of connection rate has a greater impact on point sources emissions.

The source apportionment indicates that point sources of nitrogen represent a minor part of the nitrogen exported to sea. Moreover, no additional nitrogen removal processes could be considered as economically sustainable to be generalized (advanced denitrification using ethanol being a very expensive option). In the case of phosphorus, point sources remain the dominant contribution to phosphorus loads exported to sea. Nevertheless, per capita emissions of phosphorus have already been drastically reduced during the last two decades and are now stabilized to a value close to physiological releases. The rate of P removal in WWTP has reached 90 %. Moreover, if a ban of phosphorus used in laundry detergent is clearly expected in Europe for 2020, a similar prohibition or ban is not considered for dishwasher detergent as Sodium tri-Polyphosphate substitutes cannot be used.

The mitigation of point sources of nutrients is the most effective option to reduce nutrients export to European seas. However, feasibility of this latter is relatively low and further reduction of nutrient emitted as point sources will involve important costs.

Change in European human diet – The scenarios WHO and WCRF support similar story lines with a gradient of intensity (a progressive decrease of beef and pork meat consumption and an increase of vegetal proteins in human diet). The lower efficiency of these two scenarios is directly related to their economic realism and their scale of implementation. By limiting the change in diet to European scale, the agri-economic analysis based on the CAPRI model simulated a decrease in meat consumption, but an also an important increase of meat export in order for farms to be economically sustainable. The decrease in the European demand for beef and pork meat is not followed by a similar decrease in meat production in Europe. For this reason, the benefit (assessed with respect to the BAU situation) of implementing such change in human diet appears very low, and the sums of anthropogenic diffuse emissions are only decreased by 4 % for nitrogen and 3% for phosphorus at the scale of EU-27. Following the cascade of nutrient retention in watersheds, the impact on nutrients exported to European seas range from -2.1% to -4.4% for nitrogen and from -1.4% to 4.5% for phosphorus. The potential of a change in human diet for mitigating nitrogen exports is very high considering the importance of diffuse source in the nitrogen source apportionment to all European seas. However, these changes need to be accompanied by a drastic reduction of breeding activities in European watersheds.

A change in European diet can significantly impact nutrients loads to European seas, but there is a need to upscale this analysis and enable a better representation of the link between a decrease in meat consumption (demand) and a decrease in breeding activities at the global scale.

Optimization of manure application in Europe – This scenario represents the ideal option to significantly reduce nitrogen exports to European seas (-36% to -41% of nitrogen loads compared to BAU situation). As it was designed, this scenario preserves agricultural activities and tries to promote the use of nutrient inputs locally produced. It considers the basin scale as a coherent unit to manage manure availability and crop demand for both nitrogen and phosphorus. However, at this stage impact on phosphorus fluxes is not fully satisfactory and might be improved with a better assessment of phosphorus accumulation in European soils. An important decrease of mineral nitrogen fertilizers is estimated in this scenario and might have a significant impact on the economic assessment of the cost associated to this scenario for the whole Europe.

Without forecasting drastic changes in human consumption and agricultural practices, the MANU scenario suggests that a better re-use of manure produced at the basin scale is the most efficient option tested and probably the least costly.

A full implementation of existing policies that aim at mitigating point sources appears efficient, but offers a low feasibility for a further decrease of nutrients loads to European seas (especially for nitrogen). Additional decreases are possible by limiting nutrients losses by diffuse sources. An efficient option is proposed by the redistribution of animal manure. It enables to limit the circulation of nitrogen at the basin scale and the concomitant nutrients losses from terrestrial to aquatic systems. Other options involving a change in life style, e.g. in human diet, have also a significant impact on nutrients loads to regional seas, but such analysis calls for a global assessment to be fully efficient. The use of empirical regression models (such as GREEN) is highly relevant for that purpose, as they enable to integrate the local impact of human activities in watersheds and also the societal and economic drivers acting at a higher scale (from continental to global scales).

However, attention has to be paid to the definition of the scenarios storylines. While current environmental assessments put this emphasis on a change in food *consumption* as an efficient way to reduce nitrogen input to the environment, this report suggests that more effort have to be devoted on re-thinking agricultural *production*. The simulations provided by the economically based CAPRI model (and used in the report) demonstrate that the *production* of meat in Europe will be essentially preserved even if a drastic decrease in European *consumption* of meat is taking place due to a large increase of meat export outside Europe).

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7. Annex 1: CAPRI model inputs for WHO and WCRF scenarios

Table 10: Changes in market balances per EU Member State for beef production in the WHO scenario compared to the 2020 baseline

	Reference year (2020)				Scenario WHO (2020)			
	Beef* herd [1000 hd]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	*Beef* herd [% to REF]*	*Production [% to REF]*	*Demand [% to REF]*	Net trade [Δ to REF]
Austria	532	180	128	53	-2.0%	-1.4%	-6.2%	*5.41*
Belgium-Lux.	690	276	209	67	-2.5%	-1.6%	-6.3%	*8.86*
Denmark	328	110	212	-101	0.8%	0.7%	-5.9%	*13.22*
Finland	228	78	113	-35	-1.0%	-0.8%	-6.4%	*6.68*
France	6346	1696	1667	28	-2.2%	-1.8%	-6.2%	*73.95*
Germany	1603	917	566	351	-1.3%	-0.4%	-6.0%	*30.12*
Greece	325	46	150	-104	-2.2%	-2.1%	-4.3%	*5.54*
Ireland	2599	636	108	527	-1.6%	-1.6%	-5.8%	*-3.73*
Italy	2600	940	1241	-301	-2.5%	-2.2%	-5.9%	*53.45*
Netherlands	62	334	358	-24	-2.4%	-0.9%	-5.5%	*16.76*
Portugal	665	129	216	-86	-1.7%	-2.2%	-5.7%	*9.49*
Spain	4494	741	766	-25	-2.2%	-1.8%	-4.1%	*18.51*
Sweden	354	127	294	-168	-1.6%	-1.2%	-6.2%	*16.65*
United Kingdom	3533	797	1339	-543	1.7%	0.2%	-5.5%	*74.92*
EU15	24360	7007	7369	-361	-1.5%	-1.3%	-5.7%	*329.83*
Cyprus	20	6	9	-4	-3.0%	-2.3%	-6.0%	*0.41*
Czech Republic	116	57	36	21	-2.2%	-1.9%	-2.3%	*-0.28*
Estonia	22	12	4	8	-0.1%	0.5%	0.9%	*0.02*
Hungary	52	33	42	-9	-3.0%	-1.5%	0.8%	*-0.84*
Latvia	69	21	23	-2	1.9%	2.0%	-3.7%	*1.27*
Lithuania	59	31	9	22	-0.4%	1.2%	-5.0%	*0.82*
Malta	3	1	9	-8	-3.6%	-3.1%	-6.1%	*0.53*
Poland	845	357	224	132	-2.3%	-1.8%	-3.7%	*1.96*
Slovac Republic	35	34	38	-4	-4.5%	-2.8%	-0.7%	*-0.68*
Slovenia	123	54	70	-16	-2.5%	-3.0%	-3.6%	*0.84*
10 New MS	1345	605	464	141	-2.1%	-1.6%	-3.0%	*4.05*
Bulgaria	216	61	89	-28	-0.2%	-0.2%	3.2%	*-3.01*
Romania	854	199	226	-28	0.0%	0.0%	1.7%	*-3.87*
Bulgaria/Romania	1071	260	316	-56	-0.1%	-0.1%	2.1%	*-6.88*
EU27	26776	7873	8148	-276	-1.5%	-1.3%	-5.3%	*327.00*

* 'Beef herd' = suckler cows + adult cattle for fattening in this table.

Table 11: Changes in market balances per EU Member State for beef production in the WRCF scenario compared to the 2020 baseline

	Reference year (2020)				Scenario WRCF (2020)			
	Beef* herd [1000 hd]	Production [1000 t]	Demand [1000 t]	Net trade [1000 t]	*Beef* herd [% to REF]*	*Production [% to REF]*	*Demand [% to REF]*	Net trade [Δ to REF]
Austria	532	180	128	53	-9.2%	-6.0%	-38.5%	*38.34*
Belgium-Lux.	690	276	209	67	-11.4%	-6.8%	-40.2%	*65.40*
Denmark	328	110	212	-101	6.6%	5.0%	-37.2%	*84.20*
Finland	228	78	113	-35	-3.8%	-2.7%	-39.9%	*43.01*
France	6346	1696	1667	28	-9.7%	-7.6%	-38.6%	*515.94*
Germany	1603	917	566	351	-5.0%	-1.0%	-39.1%	*212.21*
Greece	325	46	150	-104	-9.9%	-9.1%	-31.3%	*42.70*
Ireland	2599	636	108	527	-6.3%	-6.6%	-37.4%	*-1.25*
Italy	2600	940	1241	-301	-11.4%	-9.4%	-37.5%	*377.16*
Netherlands	62	334	358	-24	-11.0%	-2.8%	-35.9%	*119.02*
Portugal	665	129	216	-86	-7.0%	-9.9%	-36.6%	*66.15*
Spain	4494	741	766	-25	-8.8%	-6.9%	-31.6%	*191.31*
Sweden	354	127	294	-168	-6.7%	-5.0%	-38.4%	*106.66*
United Kingdom	3533	797	1339	-543	-2.9%	-3.9%	-35.0%	*438.27*
EU15	24360	7007	7369	-361	-7.7%	-5.8%	-36.7%	*2299.12*
Cyprus	20	6	9	-4	-15.9%	-12.6%	-36.9%	*2.64*
Czech Republic	116	57	36	21	-11.4%	-9.7%	-18.1%	*0.94*
Estonia	22	12	4	8	2.1%	4.6%	-1.4%	*0.62*
Hungary	52	33	42	-9	-15.2%	-7.4%	0.8%	*-2.78*
Latvia	69	21	23	-2	1.5%	2.7%	-27.0%	*6.85*
Lithuania	59	31	9	22	-0.1%	8.3%	-34.2%	*5.72*
Malta	3	1	9	-8	-20.4%	-14.8%	-37.2%	*3.28*
Poland	845	357	224	132	-12.4%	-9.2%	-27.7%	*29.21*
Slovac Republic	35	34	38	-4	-24.3%	-14.6%	-8.0%	*-1.88*
Slovenia	123	54	70	-16	-16.1%	-17.1%	-23.5%	*7.15*
10 New MS	1345	605	464	141	-11.7%	-8.6%	-22.4%	*51.75*
Bulgaria	216	61	89	-28	-0.3%	-0.4%	9.8%	*-8.96*
Romania	854	199	226	-28	0.6%	0.4%	5.4%	*-11.30*
Bulgaria/Romania	1071	260	316	-56	0.4%	0.2%	6.6%	*-20.26*
EU27	26776	7873	8148	-276	-7.6%	-5.8%	-34.3%	*2330.61*

* 'Beef herd' = suckler cows + adult cattle for fattening in this table.

Table 12: Changes in market balances per EU Member State for pork production in the WHO scenario compared to the 2020 baseline

	Reference year (2020)				Scenario WHO (2020)			
	Pigs [Mio hd]	Production [Mio t]	Demand [1000 t]	Net trade [1000 t]	*Pigs [% to REF]*	*Production [% to REF]*	*Demand [% to REF]*	Net trade [Δ to REF]
Austria	4537	489	477	12	-3.7%	-3.7%	-5.1%	*6.12*
Belgium-Lux.	12030	1224	571	654	-3.2%	-3.2%	-5.4%	*-7.53*
Denmark	24592	1903	249	1654	-3.3%	-3.3%	-5.3%	*-49.55*
Finland	1933	188	198	-10	-3.4%	-3.4%	-5.4%	*4.24*
France	28775	2674	2310	364	-3.3%	-3.3%	-5.3%	*34.32*
Germany	47337	4929	4441	487	-3.3%	-3.3%	-5.2%	*63.97*
Greece	1350	86	368	-282	-3.8%	-3.7%	-5.2%	*15.86*
Ireland	2319	203	212	-9	-3.7%	-3.6%	-5.2%	*3.71*
Italy	13406	1653	2872	-1218	-3.7%	-3.7%	-5.5%	*97.00*
Netherlands	15125	1480	555	925	-3.5%	-3.5%	-5.4%	*-21.46*
Portugal	4762	304	568	-265	-3.2%	-3.2%	-5.1%	*19.40*
Spain	43105	4036	2857	1178	-3.6%	-3.6%	-5.4%	*9.53*
Sweden	2724	274	334	-60	-3.3%	-3.3%	-5.3%	*8.79*
United Kingdom	7481	666	1416	-750	-0.7%	-0.7%	-4.8%	*63.22*
EU15	209476	20110	17429	2681	-3.3%	-3.3%	-5.3%	*247.62*
Cyprus	794	67	84	-16	-3.6%	-3.6%	-4.3%	*1.17*
Czech Republic	3434	410	542	-132	-3.0%	-3.0%	-3.3%	*5.21*
Estonia	469	47	61	-14	-3.4%	-3.3%	-4.5%	*1.22*
Hungary	3774	459	482	-23	-3.4%	-3.3%	-4.7%	*7.36*
Latvia	324	27	34	-7	-1.3%	-0.8%	-4.7%	*1.41*
Lithuania	1284	112	167	-55	-3.5%	-3.5%	-4.9%	*4.18*
Malta	106	9	15	-6	-3.9%	-3.9%	-5.1%	*0.43*
Poland	25113	2501	2180	321	-3.2%	-3.2%	-4.6%	*19.50*
Slovac Republic	960	74	152	-77	-3.8%	-3.8%	-2.0%	*0.18*
Slovenia	266	29	58	-30	-4.0%	-3.8%	-0.5%	*-0.79*
10 New MS	36525	3735	3775	-40	-3.2%	-3.2%	-4.3%	*39.87*
Bulgaria	227	25	75	-50	-2.5%	-2.5%	2.2%	*-2.28*
Romania	3839	405	794	-389	-2.3%	-2.3%	1.3%	*-19.35*
Bulgaria/Romania	4066	431	869	-438	-2.3%	-2.3%	1.4%	*-21.63*
EU27	250067	24275	22073	2203	-3.3%	-3.3%	-4.8%	*265.86*

Table 13: Changes in market balances per EU Member State for pork production in the WRCF scenario compared to the 2020 baseline

	Reference year (2020)				Scenario WRCF (2020)			
	Pigs [Mio hd]	Production [Mio t]	Demand [1000 t]	Net trade [1000 t]	*Pigs [% to REF]*	*Production [% to REF]*	*Demand [% to REF]*	Net trade [Δ to REF]
Austria	4537	489	477	12	-23.6%	-23.5%	-38.9%	*70.36*
Belgium-Lux.	12030	1224	571	654	-19.4%	-19.4%	-42.1%	*2.66*
Denmark	24592	1903	249	1654	-21.1%	-21.1%	-40.5%	*-301.25*
Finland	1933	188	198	-10	-22.2%	-22.2%	-41.5%	*40.42*
France	28775	2674	2310	364	-21.6%	-21.6%	-41.2%	*373.39*
Germany	47337	4929	4441	487	-21.4%	-21.4%	-40.1%	*725.71*
Greece	1350	86	368	-282	-23.9%	-23.6%	-37.5%	*117.67*
Ireland	2319	203	212	-9	-23.5%	-23.5%	-40.7%	*38.49*
Italy	13406	1653	2872	-1218	-23.7%	-23.6%	-41.5%	*802.41*
Netherlands	15125	1480	555	925	-22.4%	-22.4%	-41.4%	*-101.41*
Portugal	4762	304	568	-265	-21.2%	-21.0%	-39.1%	*158.17*
Spain	43105	4036	2857	1178	-22.9%	-22.9%	-40.0%	*216.83*
Sweden	2724	274	334	-60	-20.7%	-20.7%	-40.7%	*79.19*
United Kingdom	7481	666	1416	-750	-18.9%	-18.7%	-38.7%	*423.71*
EU15	209476	20110	17429	2681	-21.8%	-21.8%	-40.4%	*2646.35*
Cyprus	794	67	84	-16	-22.1%	-22.1%	-34.6%	*13.97*
Czech Republic	3434	410	542	-132	-17.7%	-17.9%	-28.5%	*81.12*
Estonia	469	47	61	-14	-19.9%	-19.8%	-36.2%	*12.90*
Hungary	3774	459	482	-23	-19.8%	-19.7%	-37.4%	*89.78*
Latvia	324	27	34	-7	-18.8%	-17.4%	-40.4%	*9.21*
Lithuania	1284	112	167	-55	-21.6%	-21.5%	-38.7%	*40.35*
Malta	106	9	15	-6	-23.8%	-23.5%	-39.6%	*4.00*
Poland	25113	2501	2180	321	-20.6%	-20.6%	-36.5%	*280.62*
Slovac Republic	960	74	152	-77	-22.9%	-22.7%	-20.5%	*14.15*
Slovenia	266	29	58	-30	-25.8%	-24.7%	-14.3%	*1.27*
10 New MS	36525	3735	3775	-40	-20.4%	-20.3%	-34.6%	*547.37*
Bulgaria	227	25	75	-50	-17.6%	-17.4%	15.2%	*-15.82*
Romania	3839	405	794	-389	-15.7%	-15.7%	8.2%	*-128.71*
Bulgaria/Romania	4066	431	869	-438	-15.8%	-15.8%	8.8%	*-144.53*
EU27	250067	24275	22073	2203	-21.5%	-21.5%	-37.5%	*3049.19*

8. Annex 2: Possible changes in nutrient surplus from 2004 to 2020

Figure 16: Map of nitrogen surplus (kg N/ha of total area) per sub-basin for the REF scenario (2004) and the three 2020 scenarios (BAU, WCRF and MANU)

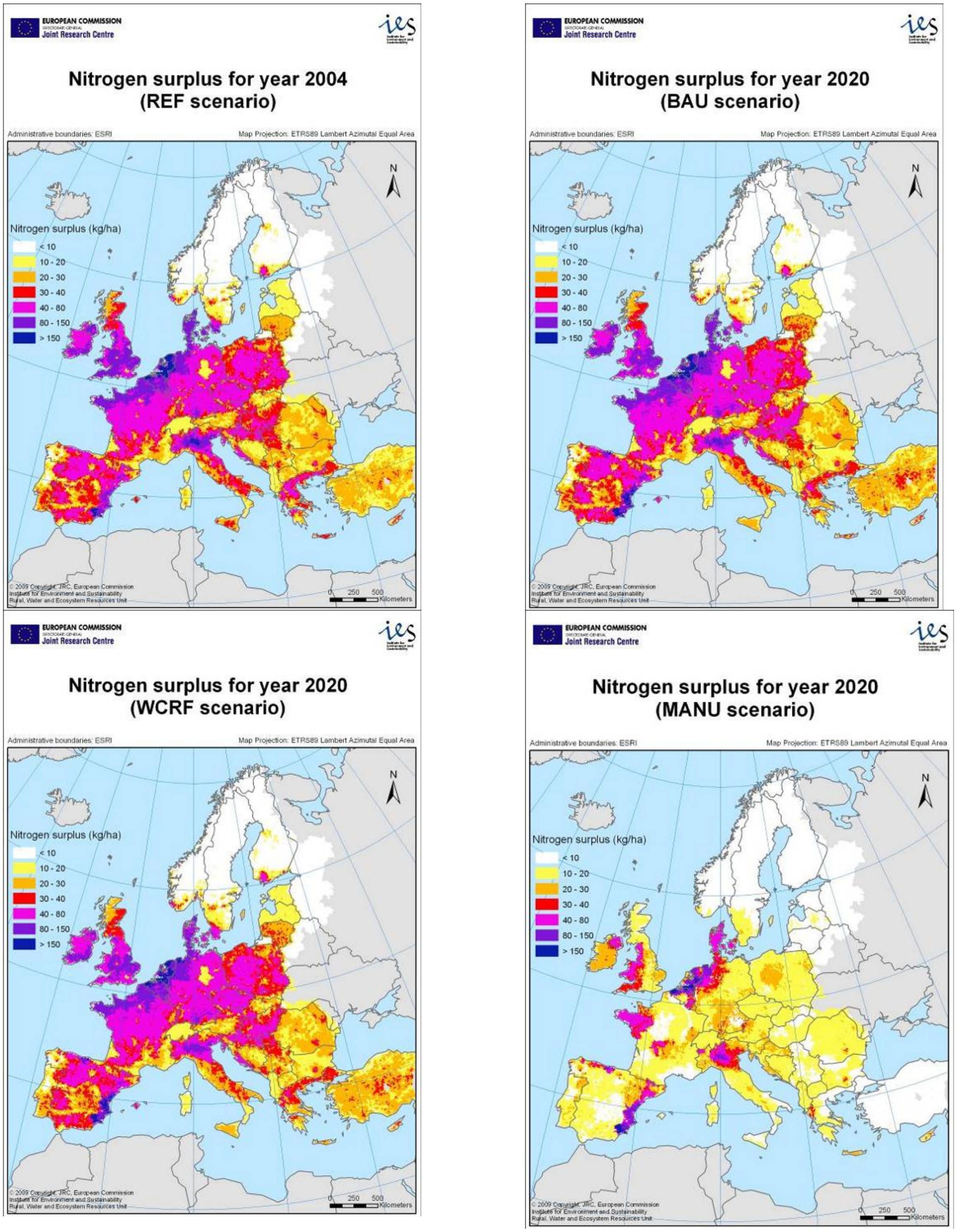
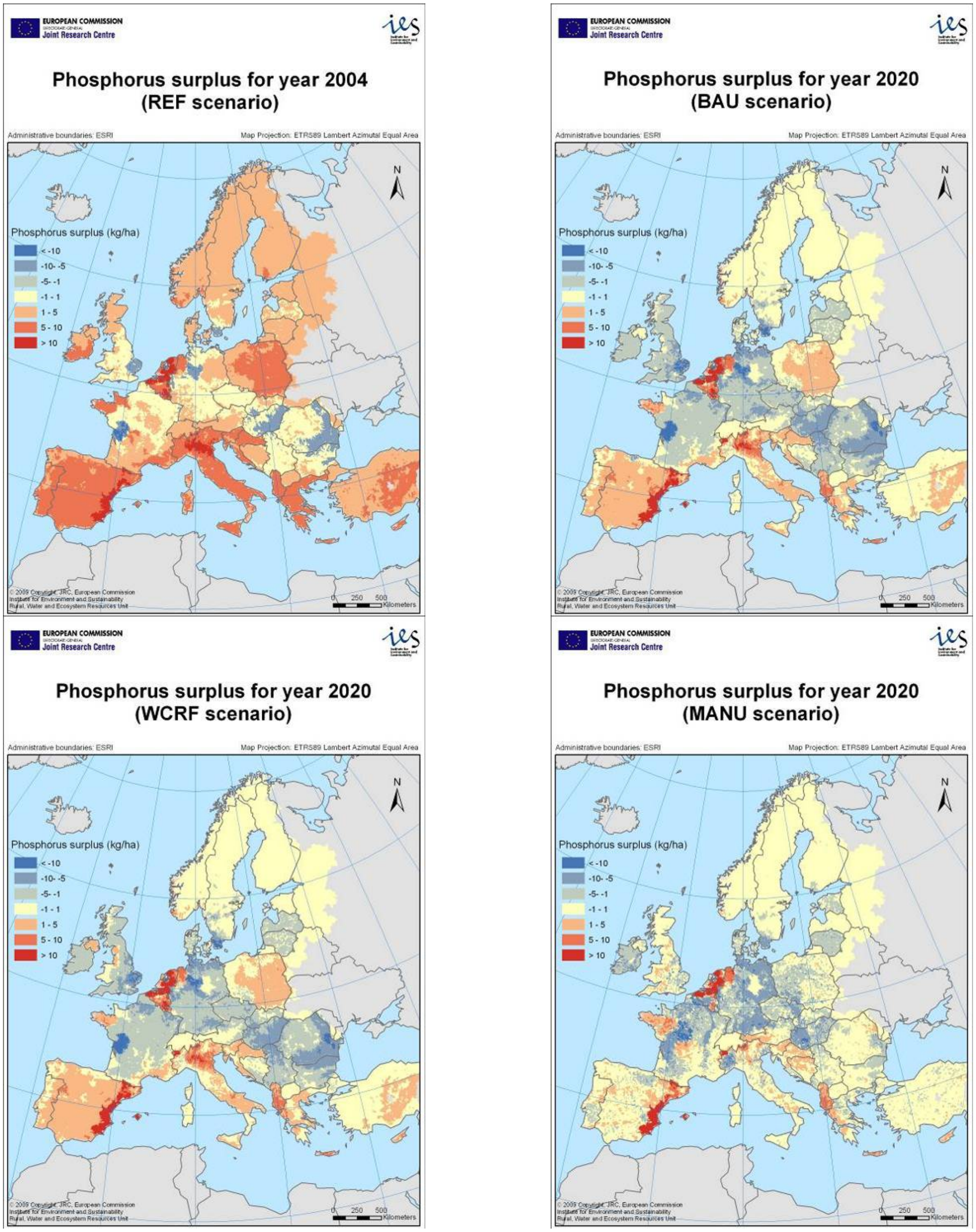


Figure 17: Map of phosphorus surplus (kg P/ha of total area) per sub-basin for the REF scenario (2004) and the three 2020 scenarios (BAU, WCRF and MANU)



Phosphorus surplus for year 2004 (REF scenario)

Phosphorus surplus for year 2020 (BAU scenario)

Phosphorus surplus for year 2020 (WCRF scenario)

Phosphorus surplus for year 2020 (MANU scenario)

9. Annex 3: Nutrient emitted as diffuse sources across the FATE scenario

	N diffuse sources, 1000 tons				P diffuse sources, 1000 tons			
	2000	BAU	WCRF	WHO	2000	BAU	WCRF	WHO
AT	209	219	272	283	55	61	59	61
BE	316	346	423	446	74	83	79	82
BG	181	150	187	189	23	24	23	24
CS	252	274	317	322	44	46	46	46
CY	16	15	20	22	4	4	4	4
CZ	417	439	496	510	60	55	54	55
DE	2241	2755	3210	3307	378	420	409	418
DK	419	378	464	489	67	70	69	70
EE	42	60	67	68	8	12	11	11
ES	1715	1945	2377	2489	500	602	580	599
FI	153	177	185	190	28	28	27	28
FR	3051	3344	3828	3897	603	632	620	628
GR	430	335	374	381	115	101	99	101
HU	400	501	559	577	58	69	67	69
IE	608	631	718	751	124	106	100	105
IT	1099	1020	1355	1398	354	321	311	319
LT	157	192	213	218	30	34	33	34
LU	17	20	23	24	5	5	5	5
LV	59	63	75	78	12	11	11	11
NL	587	532	633	656	119	115	111	114
NO	158	161	160	162	26	25	24	25
PL	1194	1300	1534	1582	293	313	304	312
PT	173	151	197	204	54	50	48	50
RO	432	470	628	635	109	113	114	113
SE	258	268	318	326	42	39	39	39
SI	63	65	76	78	13	12	12	12
SK	107	117	134	136	20	21	21	21
TR	1594	2047	2032	2045	343	391	390	391
UK	1755	1634	1821	1926	322	298	281	292

Table 16: Nitrogen and phosphorpous diffuse sources in 1000 tons for the reference year 2000 and the three (BAU, WCRF and WHO)

European Commission

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Abstract

A spatially explicit statistical approach (GREEN model) applied to continental Europe on a sub-catchment basis, is used to link input from anthropogenic activities and nutrient loads into European Seas (namely nitrogen and phosphorous). Effectiveness of environmental legislation is assessed at the horizon 2020, emphasizing the regional differences between European countries as well as the respective contribution of anthropogenic changes and hydrological fluctuation in nutrient exports. The set of scenarios analyzed includes a business as usual situation, a full implementation of on going policy options, a change in European diet based on a strong reduction of meat intake, and optimized management of agricultural practices. All prospective analyses are implemented for EU-27 and are discussed in terms of capacities to mitigate land based emissions of nutrient, and also according to their impacts on the loads of nutrient exported to European coastal areas.

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