PERSEUS

POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

SES land-based runoff and nutrient load data (1980 -2000)

Deliverable Nr. 4.6

Project Full title		Policy-oriented marine Environmental Research in the Southern EUropean Seas	
Project Acronym		PERSEUS	
Grant Agreement No.		287600	
Coordinator		Dr. E. Papathanassiou	
Project start date and duration		1st January 2012, 48 months	
Project website		www.perseus-net.eu	
Deliverable Nr.	6.10	**Deliverable Date**	T24*
Work Package No		WP4	
Work Package Title		SES land-based runoff and nutrient load data (1980 -2000)	
Responsible		Lex Bouwman, UU	
Authors & Institutes Acronyms		Dirk van Apeldoorn, UU Lex Bouwman, UU	
Status:		**Final (F)**	
		Draft (D)	●
		Revised draft (RV)	
Dissemination level:		**Public (PU)**	●
		Restricted to other program participants (PP)	
		Restricted to a group specified by the consortium (RE)	
		Confidential, only for members of the consortium (CO)	

* Deliverable 4.6 was delayed by 5 weeks. This was caused by the need to implement the base year 2010; only very recently FAO data for 2009-2011, necessary to compile a 3-year average for 2010, became available.

SES land-based runoff and nutrient load data (1980 -2000)

Contents

BACKGROUND

Riverine nutrient, pollutant and freshwater fluxes are major drivers for marine ecosystems functioning in the coastal waters of the Southern European Seas (SES). Insight in the amounts and compositions of river loads can help in achieving good environmental status in these waters. The purpose of this deliverable is to produce quantitative data of the river loads in the future from 2010 to 2020 for the entire SES domain. Future projections are made by scenarios, developed by WP6 deliverable 6.2 (Breil et al., 2012). These scenarios, which are based on the Millennium Ecosystems Assessment, where implemented in the integrative assessment model IMAGE (Integrated Model to Assess the Global Environment). This model calculates point and diffuse sources of nitrogen and phosphorus that are used to compute river export of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP).

This deliverable is a supplement to deliverable 4.3, and uses the scenarios presented in WP6 deliverable 6.2. In this deliverable 4.3 an empirical model was made to predict nutrient loads at the river mouth using the land based forcing functions from the integrative assessment model. Using this empirical model and future predictions of the land based forcing functions, predictions are made for nutrient loads at the river mouth.

Figure 1. area of influence of the SES (black outline)

DIFFUSE SOURCES

The Integrated Model for the Assessment of the Global Environment (IMAGE) version 2.4 was used to develop the input datasets for PERSEUS project. Here we use an updated IMAGE (version 2.4) with improved simulation of livestock production systems, land cover, land use and N and P surface balances (Bouwman et al., 2006). Data for crop production and livestock production are taken directly from FAO statistics (FAO, 2012). These data are used as input for the IMAGE model to generate the N and P inputs and outputs in agriculture. Although IMAGE 2.4 is global in application with data and scenarios at the scale of 24 world regions, it performs many of its calculations spatially explicit. For PERSEUS we used a terrestrial 5 by 5 minute resolution (crop yields and crop distribution, land cover, land-use emissions, nutrient surface balances and C cycle). Data from different sources were used to calibrate the energy, climate and land-use variables in IMAGE over the period 1970-2000 (Bouwman et al., 2006).

The annual soil N and P budget includes the N and P inputs and outputs for 5 by 5 minute grid cells for agricultural and natural land. N inputs include biological N_2 fixation (N_{fix}), atmospheric N deposition (N_{dep}), application of synthetic N and P fertiliser (N_{fert}, P_{fert}) and animal manure (N_{man}, P_{man}). Outputs in the soil N budget include ammonia (NH_3) volatilization (N_{vol}), N and P removal from the field through crop harvesting, hay and grass cutting, and grass consumed by grazing animals (N_{withdr}, P_{withdr}). The soil N budget (N_{budget}) was calculated as follows:

$$N_{budget} = N_{fix} + N_{dep} + N_{fert} + N_{man} - N_{withdr} - N_{vol} \quad (1)$$

The soil N budget ignores N accumulation in soil organic matter where there is a positive budget (surplus), and also ignores N supply from soil organic matter decomposition in case of a negative budget (deficit). With no accumulation, N surpluses therefore represent a potential loss (by denitrification, surface runoff and leaching).

Compared with earlier work (Bouwman et al., 2009) we assumed lower biological N_2 fixation rates in natural ecosystems, based on Vitousek et al. (2013), who estimated that N_2 fixation was only 58 Tg yr^{-1} (Tg = teragram; 1 Tg = 10^{12} g) in pre-industrial times. The estimates used to calculate N fixation in natural ecosystems are based on the medium estimate for area coverage of leguminous plants and free-living N fixing bacteria (Cleveland et al., 1999). Here, we used the low estimate for the areal coverage, and this reduces global N fixation for the year 1900 from 143 to 75 Tg N yr^{-1} and for the year 2000 from 101 to 53 Tg N yr^{-1}. For the calculation of the other input and output terms, we refer to the original publications (Bouwman et al., 2013).

POINT SOURCES

N and P flows in urban wastewater are based on country-scale data and estimates for the period 1980 to 2010 using a recent update (Morée et al., 2013) of the model originally presented by Van Drecht et al. (2009). In brief, this model uses FAO country estimates on food protein consumption (FAO, 2012) to estimate N and P excretion by humans. The model uses country population data and data on urban and rural populations, as well as WHO estimates on improved sanitation (WHO/UNICEF, 2006). As improved sanitation includes a range of systems (pit latrines up to water closets), country estimates on the number of people with a sewage connection, and the presence of primary, secondary and tertiary wastewater treatment plants. Wastewater discharge to surface water is the sewage effluent after wastewater treatment. We also account for urban inhabitants lacking a sewage connection, for which we assume discharge through open sewers, accounting for ammonia losses during transport. Populations in cities at the sea are assumed to directly discharge to the sea, and the waste from all other populations is transported through rivers.

P in detergent use is also estimated on a country basis from various data listed in the original publication (Van Drecht et al., 2009), assuming this is only relevant for inhabitants with a sewage connection.

SCENARIOS

Five different futures of the SES were calculated based on the Millennium Ecosystem Assessment (MEA) (Alcamo et al., 2006). The storylines proposed for PERSEUS in terms of demographics, economic projections and other assumptions relevant for agriculture and pointsources are based on the same scenarios. By using the existing MEA-scenario and their quantification of population and economic growth, and using assumptions on nutrient management and wastewater management, a conssitent set of scenarios for all countries involved (see Figure 1) of the SES area of influence is obtained. The scenario assumptions are summarized in Table 1 for agriculture and Table 2 for urban wastewater management.

These scenarios are linked to the scenarios presented in deliverable 6.2 (Regional Blue Economy (RBE), Regional expanding block (REB), Blue Archipelago (BA) and Market for All (MFA)). For business as usual (BAU), the settings for Regional expanding block were used, except for the efficiency for nutrient use and wastewater treament, which remain at the level of 2010. The corresponding MEA scenarios are Technogarden (TG)=Regional Blue Economy, Global Orchestration (GO)=Regional expanding block, Adapting Mosaic (AM)=Blue Archipelago and Order from Strength (OS)=Market for All).

The regional scenarios for the use of N and P fertilizers are based on efficiency of N and P in crop production as defined (Table 1). This efficiency is based on the ratio crop dry matter production : N or P inputs (Bouwman et al., 2009). For the year 2030 the regional data from the Agriculture Towards 2030 study (Bruinsma, 2003) are used as a basis. For constructing the regional scenarios we distinguish countries with a current nutrient surplus (e.g. Western European industrialized countries, Egypt), countries with a deficit, i.e. the crop uptake exceeds the inputs leading to degradation of soil fertility, and the Eastern European transition countries. In all scenarios the surplus countries show an increasing efficiency, while for deficit countries we assume an increasing use of fertilizers to restore soil fertility and prevent further land degradation (Table 2). For the Eastern European transition countries we assume that fertilizer levels will gradually increase and efficiencies will converge to western European levels. Manure production is computed from the livestock production, animal numbers and excretion rates, and distributed over different animal manure management systems (Bouwman et al., 2009).

Table 1. Main drivers of agricultural change for the MEA scenarios from *Alcamo et al.* (2006) and our assumptions for the fertilizer use.

IMAGE model parameter	Scenario				
	Business as Usual	Regional Expanding Block	Market for All	Regional Blue Economy	Blue Archipelago
	BAU	REB	MFA	RBE	BA
Per capita food consumption	High, high meat	High, high meat	Low	High, low meat	Low, low meat
Agricultural productivity increase	Same as 2010	High	Low	Medium-high	Medium
Fertilizer use and efficiency	No change in fertilizer use efficiency after 2010	No change in countries with a surplus; rapid increase in N and P fertilizer use in countries with soil nutrient depletion (deficit)	No change in countries with a surplus; slow increase in N and P fertilizer use in countries with soil nutrient depletion (deficit)	Rapid increase in countries with a surplus; rapid increase in N and P fertilizer use in countries with soil nutrient depletion (deficit)	Moderate increase in countries with a surplus; slow increase in N and P fertilizer use in countries with soil nutrient depletion (deficit); better integration of animal manure

For the years 2020, the calculated influents to wastewater treatment systems (if any) are computed from per capita incomes, and stem from human N and P emissions and P-based detergent use. Here we use the country population and GDP data from MEA. The MEA scenario storylines were interpreted to generate scenarios differing in the degree of access to improved sanitation, connection to sewage systems and the nutrient removal in wastewater treatment systems (Van Drecht et al., 2009). Our MEA interpretations assume that sewerage systems are the preferred means for better control on waste water. In RBE and REB the fraction of the population with a sewerage connection is growing faster than in MFA and BA, reflecting faster economic growth and slower population growth in REB and RBE. Full details of the scenario assumptions for sewage are in *Van Drecht et al.* (2009).

Table 2. Approach for scenario development for the main drivers of sewage N and P emission to surface water in each of the PERSEUS scenarios.

IMAGE model parameter	Business as Usual BAU	Regional Expanding Block REB	Market for All MFA	Regional Blue Economy RBE	Blue Archipelago BA
Population	As in REB	MEA regional scenarios (Alcamo et al., 2006) downscaled to countries based on country UN (2006) projections according to Van Vuuren et al. (2007)			
Per capita GDP	As in REB	MEA regional scenarios from Alcamo (2006) downscaled to countries according to Van Vuuren et al. (2007) based on country data from Worldbank (WorldBank, 2001) and United Nations Statistics Division (UN, 2005). Income growth rates range from 1.3% to 3.0% and increase in sequence of OS, AM, TG, GO. Per capita purchasing power, GDPppp, was calculated under the assumption that the ratio GDPppp/GDPmer is decreasing with GDPmer and converging to 1.			
Urbanization	As in REB	Downscaling to country scale is from Grubler et al. (2006); B1 is used to represent GO (low urbanization rate), A2r is used for OS (rapid urbanization), B1 for TG (low urbanization rate) and B2 for AM (medium rate).			
S_u, fraction of population with access to improved sanitation	Constant S_u (2010)	Increase 2030: reduce 50% of the gap between S_u(2000) and 100% improved sanitation; 2050: reduce 50% of the gap between S_u(2030) and 100% improved sanitation.	Constant S_u (2010)	As in Regional expanding block	Constant S_u (2010)
D, fraction of population connected to public sewerage	The share of sewerage connection in the population with access to improved sanitation				
	Constant c (2010)	Increase 50% of the gap between c(2000) and c=1 is closed in the period 2000-2030 and constant afterwards, except for countries with c(2000)>1 where c remains constant	Constant c (2010)	Increase As in Regional Expanding Block	Constant c (2010)
Detergent use	Laundry detergent use (E_{Ldet}) and fraction of P-free laundry detergents ($f_{\mathrm{Ldet}}^{\mathrm{Pfree}}$) and automatic dishwasher detergent use (E_{Ddet}) and fraction P-free dishwasher detergents ($f_{\mathrm{Ddet}}^{\mathrm{Pfree}}$) are entirely based on GDP				As in REB
R^N and R^P, removal of N and P through	Constant after 2010	Removal of N and P through wastewater treatment plants will increase by a gradual shift to a higher technological treatment classes. The removal efficiency per class remains constant			

wastewater treatment plants					
	No change	50% of each treatment class shifts toward the next in line[a] in the period 2005-2030 and another 50% in 2030-2050	25% of each treatment class shifts toward the next in line[a] in the period 2005-2030 and another 25% in 2030-2050	50% of each treatment class shifts toward the next in line[a] in the period 2005-2030 and another 50% in 2030-2050	25% of each treatment class shifts toward the next in line[a] in the period 2005-2030 and another 25% in 2030-2050

Table 3. Total nitrogen load to the agricultural area of the SES basins and emissions of point sources from 1970 to 2010 and the 4 scenarios.

Year	N fertilizer (Tg yr^{-1})	N Manure (Tg yr^{-1})	N fixation (Tg yr^{-1})	N uptake (Tg yr^{-1})	Soil N balance of diffuse sources (Tg yr^{-1})	N emission from sewage (Tg yr^{-1})
1970	9.69	15.31	2.57	11.88	12.81	0.87
1980	16.61	17.94	2.55	13.41	17.27	0.97
1990	17.17	17.47	2.91	13.76	17.39	1.03
1995	11.01	16.26	2.66	13.46	12.66	0.98
2000	12.01	15.35	2.56	12.85	13.11	0.96
2005	12.75	15.70	2.60	13.49	13.10	1.03
2010	13.41	16.96	2.61	14.66	12.88	1.09
BAU 2015	13.14	18.04	2.69	15.07	13.13	1.14
BAU 2020	12.86	19.12	2.77	15.48	13.39	1.19
BAU 2030	12.31	21.28	2.93	16.30	13.92	1.28
REB 2015	13.39	18.04	2.69	15.07	13.25	1.11
REB 2020	13.37	19.12	2.77	15.48	13.62	1.16
REB 2030	13.33	21.28	2.93	16.29	14.38	1.16
MFA 2015	13.17	17.60	2.70	14.91	13.02	1.16
MFA 2020	12.94	18.24	2.79	15.16	13.16	1.22
MFA 2030	12.47	19.53	2.97	15.65	13.47	1.22
RBE 2015	13.23	17.57	2.68	14.97	12.86	1.13
RBE 2020	13.06	18.19	2.76	15.29	12.84	1.19
RBE 2030	12.71	19.42	2.92	15.91	12.86	1.19
BA 2015	12.94	17.09	2.68	14.71	12.74	1.15
BA 2020	12.47	17.21	2.76	14.75	12.60	1.22
BA 2030	11.53	17.47	2.92	14.84	12.37	1.22

Table 4. Total phosphate load to the agricultural area of the SES basins and emissions of point sources from 1970 to 2010 and the 4 scenarios.

Year	P_2O_5 fertilizer (Tg yr^{-1})	P_2O_5 Manure (Tg yr^{-1})	P_2O_5 uptake (Tg yr^{-1})	Soil P_2O_5 balance of diffuse sources (Tg yr^{-1})	P_2O_5 emission from sewage (Tg yr^{-1})
1970	6.27	6.41	4.68	2.72	0.32
1980	10.28	7.60	5.43	5.28	0.34
1990	9.64	7.37	5.54	4.80	0.33
1995	4.57	6.79	5.39	1.46	0.31
2000	4.16	6.41	5.11	1.35	0.30
2005	4.29	6.56	5.37	1.29	0.31
2010	4.62	7.10	5.88	1.59	0.33
BAU 2015	4.74	7.54	6.08	1.59	0.34
BAU 2020	4.86	7.97	6.28	1.66	0.36
BAU 2030	5.11	8.84	6.67	1.86	0.38
REB 2015	5.07	7.54	6.08	1.68	0.33
REB 2020	5.53	7.97	6.28	1.85	0.34
REB 2030	6.43	8.84	6.67	2.29	0.34
MFA 2015	4.94	7.36	6.00	1.62	0.35
MFA 2020	5.26	7.62	6.11	1.72	0.36
MFA 2030	5.91	8.14	6.34	2.01	0.36
RBE 2015	5.08	7.34	6.01	1.63	0.34
RBE 2020	5.54	7.58	6.13	1.73	0.35
RBE 2030	6.45	8.07	6.38	1.99	0.35
BA 2015	4.82	7.15	5.89	1.54	0.35
BA 2020	5.02	7.19	5.90	1.55	0.36
BA 2030	5.42	7.28	5.91	1.66	0.36

RESULTS AND DISCUSSION

We calculated possible future nutrient fluxes for the years 2015-2020-2030. Tables 3 and 4 list respectively the N and P load over the whole area of SES influence, including the scenario outcomes for manure, fertilizer, biological nitrogen fixation, crop uptake, the soil budget (inputs minus crop uptake). Atmospheric N deposition (not shown, but data is available) is calculated for the agricultural area, natural area and total area.

The changes in nutrient budgets and wastewater differ from river to river and from country to country, as shown in Figure 2 for nitrogen fertilizer use. During the past decades there have been major changes in nutrient cycles in Southern Europe, with peaking agricultural nutrient budget surpluses around 1980, and a rapid decline of fertilizer use and animal manure production in the early 1990's in Eastern Europe (see Figure 2). In more recent years, agricultural surpluses are declining, with even deficits in a number of Southern European countries.

The scenarios show a differentiated picture, with generally more efficient agriculture in Regional Blue Economy and Blue Archipelago than in the Business as usual, Regional Expanding Block and Market for All scenarios. However, depending on the development of domestic agricultural production, budgets may in some countries increase, despite increasing efficiency.

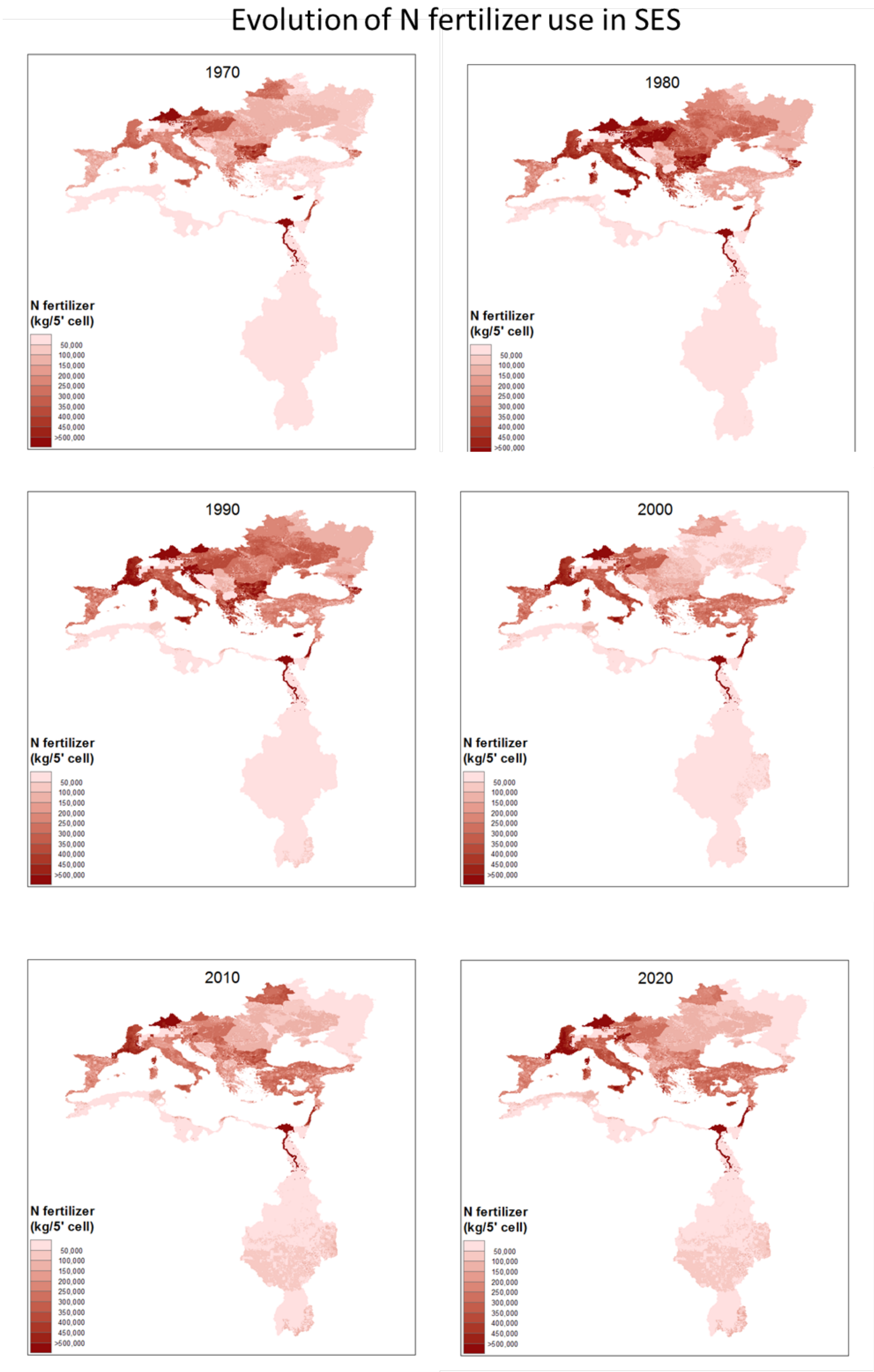

Figure 2. Maps showing the N fertilizer use in the period 1980-2020 for the BAU scenario in kg per 5 by 5 minute grid cell for all rivers draining into the Mediterranean Sea and Black Sea.

An important aspect of fertilizer use is the increasing molar N:P ratio in nearly all countries surrounding the Black Sea and Mediterranean Sea (Appendix, Figure A1 and A2.. In many countries, especially Southern Europe and Central Europe, P fertilizer use has been excessive, leading to a build up of residual soil P, and therefore an increasing availability of plant-available phosphate (Sattari et al., 2012). With this increasing availability of P, fertilizer P application rates have dropped, causing and increasing N:P ratio.

While sewage treatment has started to be important in the 1970s in Northern Europe, in other parts of Europe this development was later, and in North Africa the degree of connection to sewage systems and wastewater treatment is still low. All these changes, together with the changes in hydrology, and construction of dams, have major consequences for the nutrient stoichiometry in river water.

Table 5 lists the data files that were used to compute the N and P river load following the approach outlined in deliverable 4.3. The results indicate that the changes in dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus export to coastal marine ecosystems have been rapid over the period 1980-2020 for the BAU scenario (Figure 2a-c). However, in the period 2010-2020 river export indicates an increase, although the year to year variability is large.

In the Regional Blue Economy and Regional Expanding Block scenarios, major improvements are assumed in both fertilizer use efficiency and wastewater treatment removal. Hence this will lead to a less pronounced increase or even a decrease in river DIN and DIP export.

While the changes in agriculture are only slow, difference between the BAU and Regional Blue Economy scenarios show that major reductions can be achieved by reducing nutrients in wastewater discharged to surface water.

Table 5 Description of maps used for the calculation of the nutrient river load.

Description:	Name	Unit
Uptake by crops and	[Scenario]_[Year]_Uptake_[Nutrient].asc	kg/5`
N and P balance for	[Scenario]_[Year]_Balance_[Nutrient].asc	kg/5`
N balance for terrestrial	[Scenario]_[Year]_Balance_N-NH3.asc	kg/5`
N fixation in for natural	[Scenario]_[Year]_N_fixation_nat.asc	kg/5`
N fixation for agricultural	[Scenario]_[Year]_N_fixation.asc	kg/5`
N and P2O5 from manure	[Scenario]_[Year]_manure_total_[Nutrient].asc	kg/5`
N and P2O5 from fertilizer	[Scenario]_[Year]_fertilizer_[Nutrient].asc	kg/5`
N output for point sources	[Scenario]_[Year]_Gemnsw.asc	kg/5`
P output point sources	[Scenario]_[Year]_Gempsw.asc	kg/5`

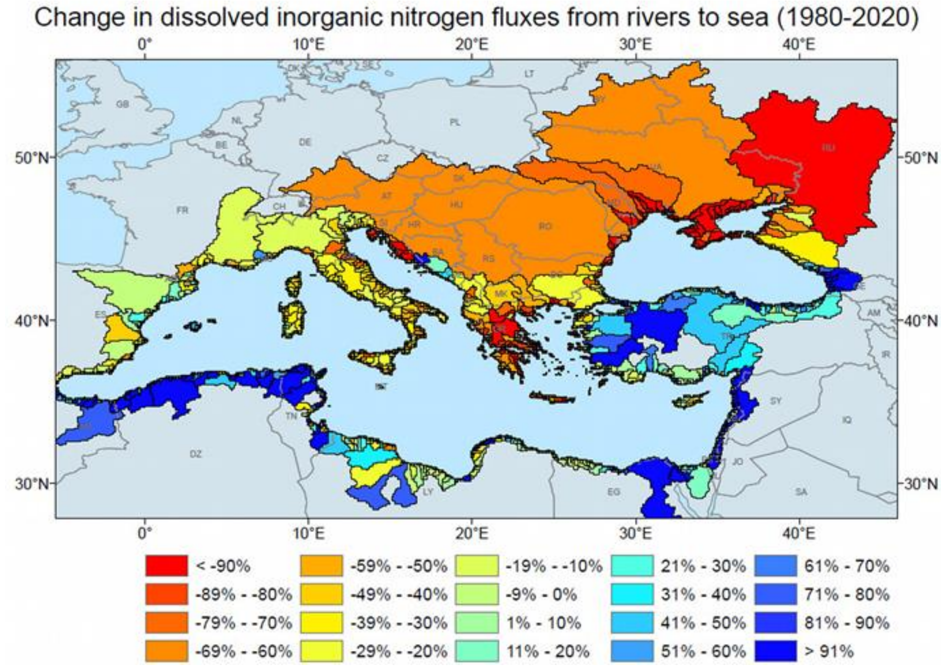

Figure 2a. Changes (%) in DIN export by rivers draining into the Mediterranean Sea and Black Sea for the period 1980-2020.

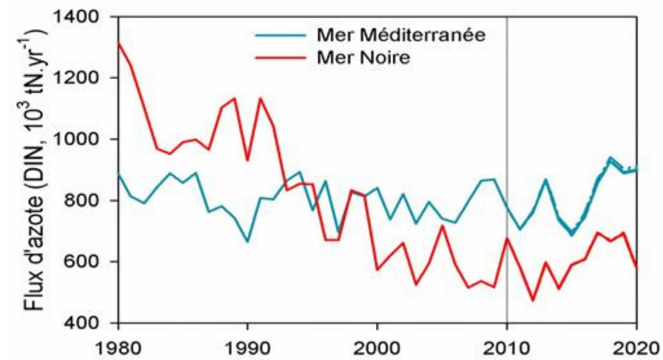

Figure 2b. DIN export to the Mediterranean Sea and Black Sea for the period 1980-2020.

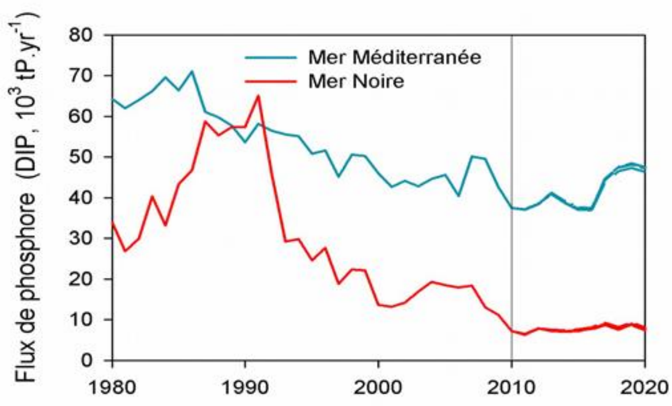

Figure 2c. **DIP export to the Mediterranean Sea and Black Sea for the period 1980-2020.**

Figure 3. Detail of N sewage map of BAU 2020 (top) and difference with Regional Blue Economy scenario (bottom). Please note that difference will grow in later years (see Table 2).

LITERATURE

Alcamo, J., Van Vuuren, D., Cramer, W., 2006. Changes in ecosystem services and their drivers across the scenarios. In: Carpenter, S.R., Pingali, P.L., Bennett, E.M., Zurek, M.B. (Eds.), Ecosystems and human well-being: scenarios. Island Press, Washington, D.C., pp. 279-354.

Bouwman, A.F., Beusen, A.H.W., Billen, G., 2009. Human alteration of the global nitrogen and phosphorus soil balances for the period 1970-2050. Global Biogeochemical Cycles, 23, doi:10.1029/2009GB003576.

Bouwman, A.F., Klein Goldewijk, K., Van der Hoek, K.W., Beusen, A.H.W., Van Vuuren, D.P., Willems, W.J., Rufino, M.C., Stehfest, E., 2013. Exploring global changes in nitrogen and phosphorus cycles in agriculture induced by livestock production over the 1900-2050 period. Proceedings of the National Academy of Sciences of the United States of America 110, 20882-20887, doi/20810.21073/pnas.1012878108.

Bouwman, A.F., Kram, T., Klein Goldewijk, K., 2006. Integrated modelling of global environmental change. An overview of IMAGE 2.4. Publication 500110002/2006, Netherlands Environmental Assessment Agency, Bilthoven.

Breil, M., Sanna, S., Sauzade, D., LeTellier, J.P., Diedrich, A., 2012. Preliminary list of issues at risk of nonachievement of the GES and scenarios to be modeled. Deliverable D6.2, Report Workpackage 6, Policy-oriented marine Environmental Research in the Southern EUropean Seas (PERSEUS)

Bruinsma, J.E., 2003. World agriculture: towards 2015/2030. An FAO perspective. Earthscan, London.

ChinaFisheryYearbook, 2007. China Fishery Yearbook Chinese Fishery Yearbook Publishing house.

Cleveland, C.C., Townsend, A.R., Schimel, D.S., Fisher, H., Howarth, R.W., Hedin, L.O., Perakis, S.S., Latty, E.F., Fisher, J.C.V., Elserod, A., Wasson, M.F., 1999. Global patterns of terrestrial biological nitrogen (N2) fixation in natural ecosystems. Global Biogeochemical Cycles 13, 623-645.

FAO, 2012. FAOSTAT database collections (http://faostat.fao.org/default.aspx). Food and Agriculture Organization of the United Nations, Rome.

Grübler, A., O'Neill, B., Riahi, K., Chirkov, V., Goujon, A., Kolp, P., Prommer, I., Scherbov, S., Slentoe, E., 2006. Regional, national, and spatially explicit scenarios of demographic and economic change based on SRES. Environment Science and Technology doi:10.1016/j.techfore.2006.05.023.

Morée, A.L., Beusen, A.H.W., Bouwman, A.F., Willems, W.J., 2013. Exploring global nitrogen and phosphorus flows in urban wastes during the twentieth century. Global Biogeochemical Cycles 27, 1–11, doi:10.1002/gbc.20072.

Sattari, S.Z., Bouwman, A.F., Giller, K.E., van Ittersum, M.K., 2012. Residual soil phosphorus as the missing piece in the global phosphorus crisis puzzle. Proceedings of the National Academy of Sciences 109, 6348-6354.

UN, 2005. UNSTAT National accounts main aggregates database. United Nations Statistics Division (http://unstats.un.org/), New York.

UN, 2006. World population prospects: the 2006 revision. United Nations Department for Economic and Social Affairs (http://esa.un.org/unpp/), New York.

Van Drecht, G., Bouwman, A.F., Harrison, J., Knoop, J.M., 2009. Global nitrogen and phosphate in urban waste water for the period 1970-2050. Global Biogeochemical Cycles 23, GB0A03, doi:10.1029/2009GB003458.

Van Vuuren, D.P., Lucas, P.L., Hilderink, H., 2007. Downscaling drivers of global environmental change scenarios: Enabling use of the IPCC-SRES scenarios at the national and grid level. Global Environmental Change 17, 114-130 (doi:110.1016/j.gloenvcha.2006.1004.1004).

Vitousek, P.M., Menge, D.N.L., Reed, S.C., Cleveland, C.C., 2013. Biological nitrogen fixation: Rates, patterns and ecological controls in terrestrial ecosystems. Philosophical Transactions of the Royal Society B: Biological Sciences 368.

WHO/UNICEF, 2006. Joint monitoring programme for water supply and sanitation. Coverage estimates (update 2006). World Health Organization (WHO) / United Nations Children's Fund (UNICEF), Geneva.

WorldBank, 2001. The 2000 World Bank development indicators. Data on CD-Rom. World Bank.

APPENDIX

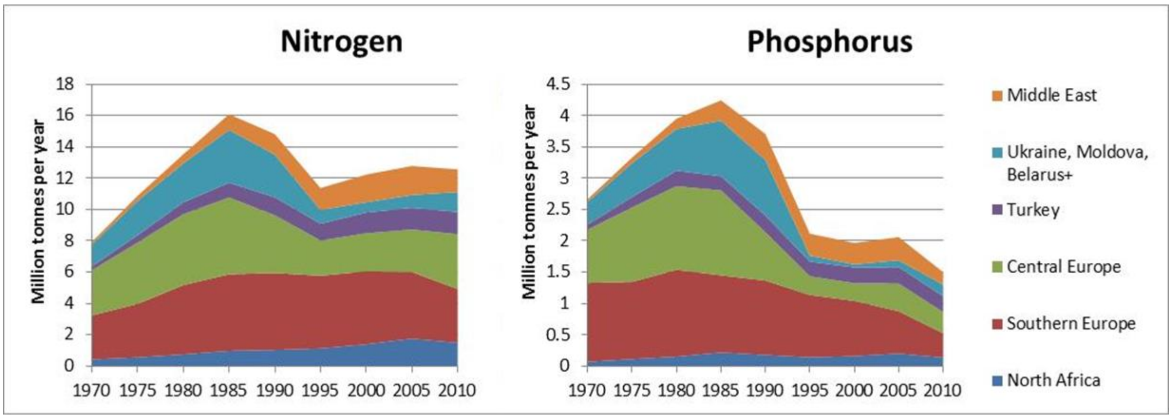

Figure A1. N and P fertilizer use in Middle East, Ukraine, Moldova and Belarus, Turkey, Central Europe, Southern Europe and North Africa.

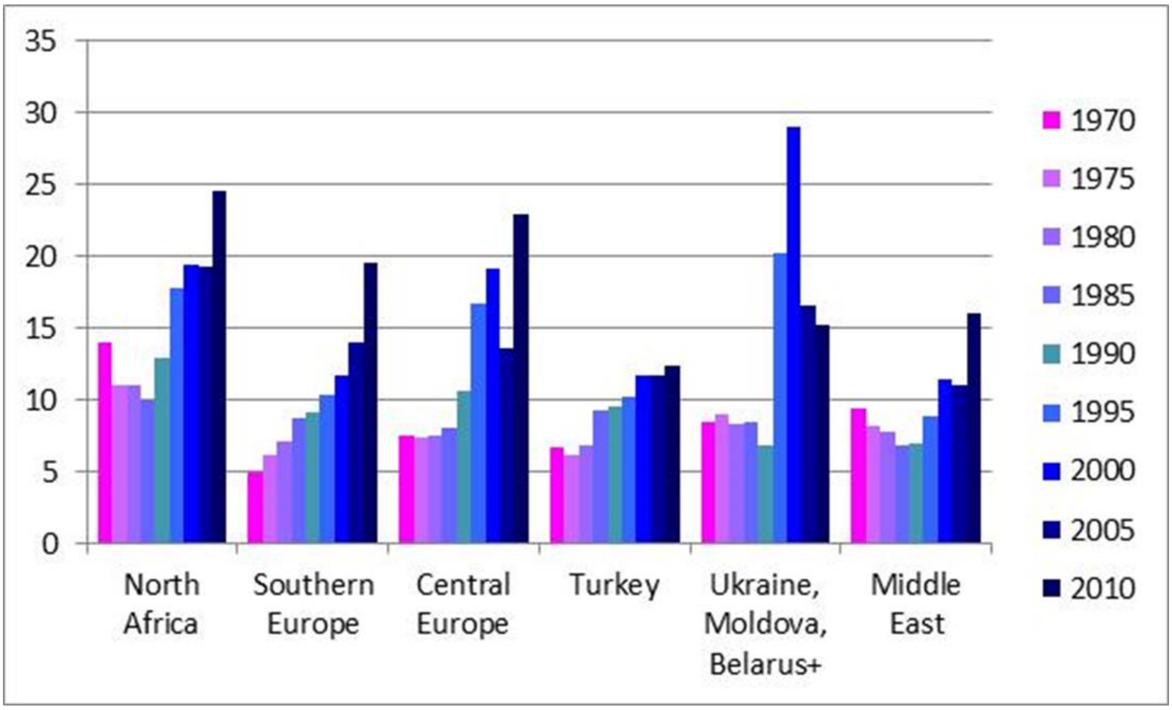

Figure A2. Molar N:P ratio of fertilizers used in Middle East, Ukraine, Moldova and Belarus, Turkey, Central Europe, Southern Europe and North Africa in the period 1970-2010.

PERSEUS

POLICY-ORIENTED MAPINE
ENVIRONMENTAL RESEARCH IN
THE SOUTHERN EUROPEAN SEAS