ATLAS OF RIVERINE INPUTS TO THE MEDITERRANEAN SEA

UNEP

MAP

40 Years
TOGETHER FOR A SUSTAINABLE MEDITERRANEAN

PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

ATLAS OF RIVERINE INPUTS TO THE MEDITERRANEAN SEA

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Preface

The Mediterranean Sea is one of the most fascinating areas of the world, with peculiar geomorphology and climate; it is a crossroad of cultures and civilizations; it is one of the world's major tourist destinations and an important biodiversity hotspot. The Mediterranean is at the same time under considerable pressure from human activities and climate change.

Regarding freshwater inputs, the Mediterranean watershed has unique characteristics of scientific and policy interest. The river water discharge to the Mediterranean Sea accounts for only one tenth of the total freshwater inputs, but carries most of the nutrients to the coast and sea. In cases of high nutrient loads, increased algal growth or even eutrophication occur in coastal areas.

The UNEP/MAP Barcelona Convention, representing 21 countries bordering the Mediterranean and the EU, has been for many years the main body, at basin level, dealing with the challenges of environmental degradation in the sea and coastal areas and linking sustainable resource management with development, in order to protect the Mediterranean region and contribute to its improved quality of life. The Barcelona Convention and its Land Based Sources Protocol, as well as a considerable number of EU Directives (e.g. the Water Framework Directive), represent crucial legal frameworks to tackle riverine nutrient pollution and its consequences.

PERSEUS, as an EU research project, assesses the dual impact of human activity and natural pressures on the Mediterranean and Black Seas. It merges natural and socio-economic sciences, with the aim to provide evidence-based science as a basis for policymakers to act on the protection of the marine environment.

This Atlas is the result of the successful collaboration between UNEP/MAP and PERSEUS. It gives an overview of the major rivers' runoff as well as four different scenarios for the future, some with a more proactive approach of the societies to environmental problems. The Atlas describes, in a few pages, the riverine input of nutrients and water discharge in the Mediterranean Sea for the period 1980-2010 and aims to enhance access to river management processes in the Mediterranean.

Significant gaps exist regarding nutrient concentration and water discharge data, which hinder effective management of the rivers around the basin, their outflow to the sea and the evaluation of their environmental status. There is therefore a critical need to foster all initiatives for monitoring water discharge data, in particular nutrients, and to standardize monitoring methods and analytical protocols between national networks.

The Atlas is published on the occasion of the 40th anniversary of the UNEP/MAP Barcelona Convention. It also marks the end of the PERSEUS EU project.

All contributors believe that this Atlas signals a strong message of collaboration between policy and science bodies, urging for better monitoring and management, enhancing regional governance, and raising public awareness.

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The main contributors were, in alphabetical order: Faidra Bazigou and Vasiliki Vournazou.

We acknowledge the original work the ATLAS was based on:

- Ludwig, W. and Montreuil, O., (2013), SES land-based runoff and nutrient load data (1980 - 2000). *PERSEUS Project Deliverable no 4.3*. (http://www.perseus-net.eu/site/content.php?artid=675).
- UNEP(DEPI)/MED WG 379.Inf.7, (2013), Report of nutrient riverine inputs.

Introduction

Source	Nitrogen (10^3tN)	Phosphorus (10^3 tP)	Water (km^3)
Atmosphere	1140:1335	65	825:1485
River	1285	126	340:347
Atlantic	-3135:-1080	-242:-38	925 :1578
Black Sea	120:130	2	197:311
Evapotranspiration			2300:2922
Point source	285	74	
Groundwater			50

Table 1 Fluxes of water and nutrients flowing in and out of the Mediterranean Sea.

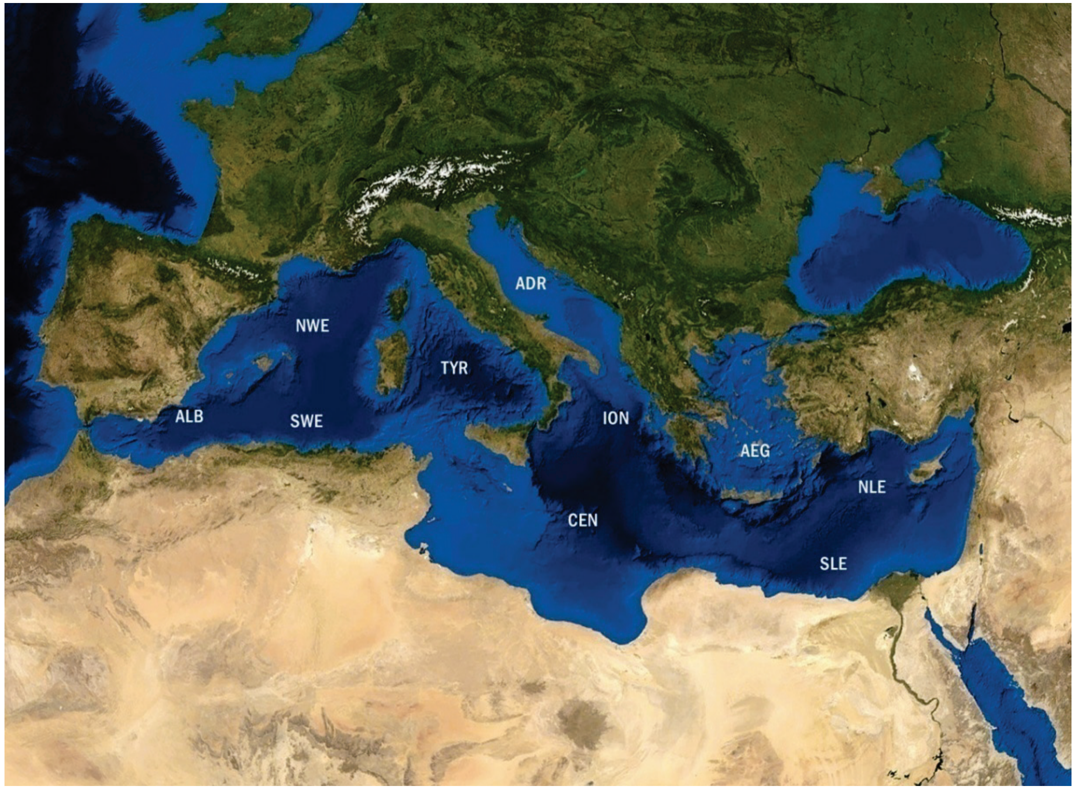


Figure 1 Satellite view of the Mediterranean Sea (source: www.wikipedia.com). The major sub-basins are indicated with white text.*

The **Mediterranean Sea** covers about 2.5x10^6 km^2, with an average water depth of about 1.5 km.

It is a semi-enclosed oligotrophic basin with nutrients decreasing from West to East. As seen in Table 1, rivers are the main contributors for the input of nutrients to the sea **accounting for about 50% for Nitrogen (N) and 75% for Phosphorus (P)**, which together with **Silica (Si)** are crucial elements for maintaining biological productivity in the sea. River basins accumulate the products of various natural and anthropogenic activities (agriculture, urbanisation, wastewaters, industry, etc.) emitted into surface waters, which are transported downstream to the river mouths and eventually to the sea.

Rivers do also feed the Mediterranean sea sub-basins (Figure 1) with freshwater. The water discharge of rivers depends though on climatic factors such as temperature and precipitation but also on water uses such as irrigation and damming.

The different sub-basins are constituted by: the Alboran (ALB**), the North-Western (**NWE**), the South-Western (**SWE**), the Tyrrhenian (**TYR**), the Ionian (**ION**), the Central (**CEN**), the Adriatic (**ADR**), the Aegean (**AEG**), the North-Levantine (**NLE**) and the South-Levantine (**SLE**) sub-basin.*

Spatial variation of river water discharge

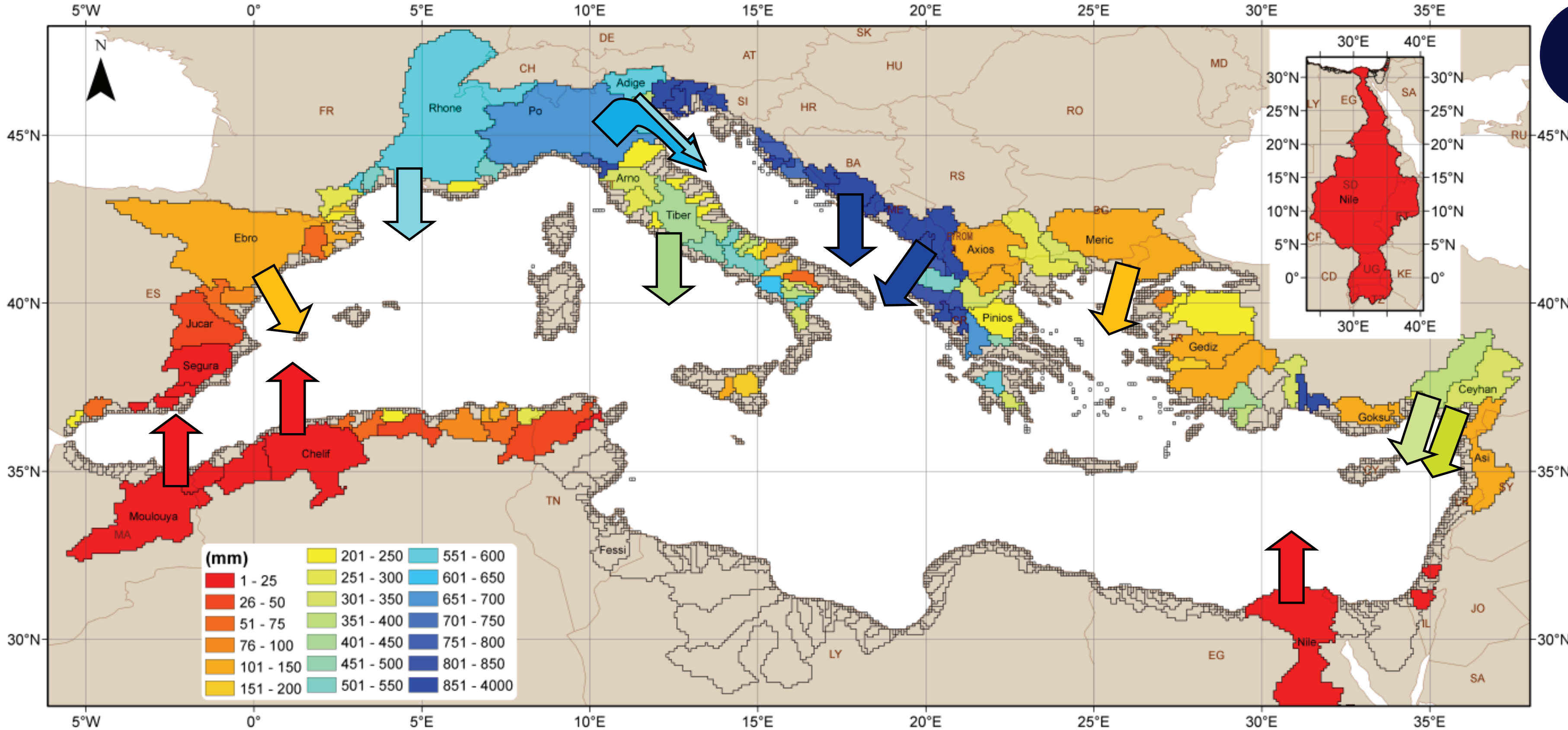
Available discharge data cover about 85% of the Mediterranean drainage basin, while most of lacking data concern the Southern part of the Mediterranean, where runoff is assumed to be close to zero (lacking data could be estimated via the Pike formulation).

The largest freshwater discharge is provided by the Rhone to the Northwestern Mediterranean Sea, while the second largest freshwater discharge is provided by the Po to the Adriatic (Figure 2). Both rivers of the Northern Mediterranean Sea provide about **25%** of the total continental freshwater discharge.

A relatively high water discharge is also provided by Buna-Drini and the Nile, whilst among the rivers with higher discharge rates, six have their mouth along the Adriatic Sea (Po, Buna-Drini, Adige, Soca, Neretva and Vjosa).

A strong heterogeneity of freshwater discharge between rivers irrespective of the drainage area is observed. Expressed per unit of area, the river runoff roughly decreases from Northern to Southern Mediterranean Sea.

Figure 2 Inter-annual average of annual river runoff computed with discharge data series from GRDC, EWA, national and regional databases and completed with inter-annual values from scientific references. The arrows indicate the course followed by the water masses, ending up in the sea (Data adapted from GRID-Arendal, 2013).



Climate as a driver of spatial change in riverine runoff

A major peculiarity of Mediterranean rivers is attributed to climatic factors. Probably the most important criterion in defining the Mediterranean climate type is related to the strong seasonal rainfall contrast between the summer and winter (autumn) seasons.

While difference in drainage area explains a large part of the spatial variation in freshwater discharge, precipitation and temperature (Figures 3 & 4) are the main drivers of spatial variation in runoff. The physical characteristics of river basins, such as soil characteristics, available water capacity, drainage class and depth, have an important effect on the relationships between climatic factors and the water discharge and quality of rivers.

The geographic variability of the Mediterranean drainage basin results in an important climatic heterogeneity among the sub-basins areas, which in turn explains the relatively strong spatial variation in runoff.

Figure 3 Inter-annual average of annual precipitation within Mediterranean river basins (1901-2009) calculated from CRU 3.10.1 downscaled at a 5 arc-minutes resolution.

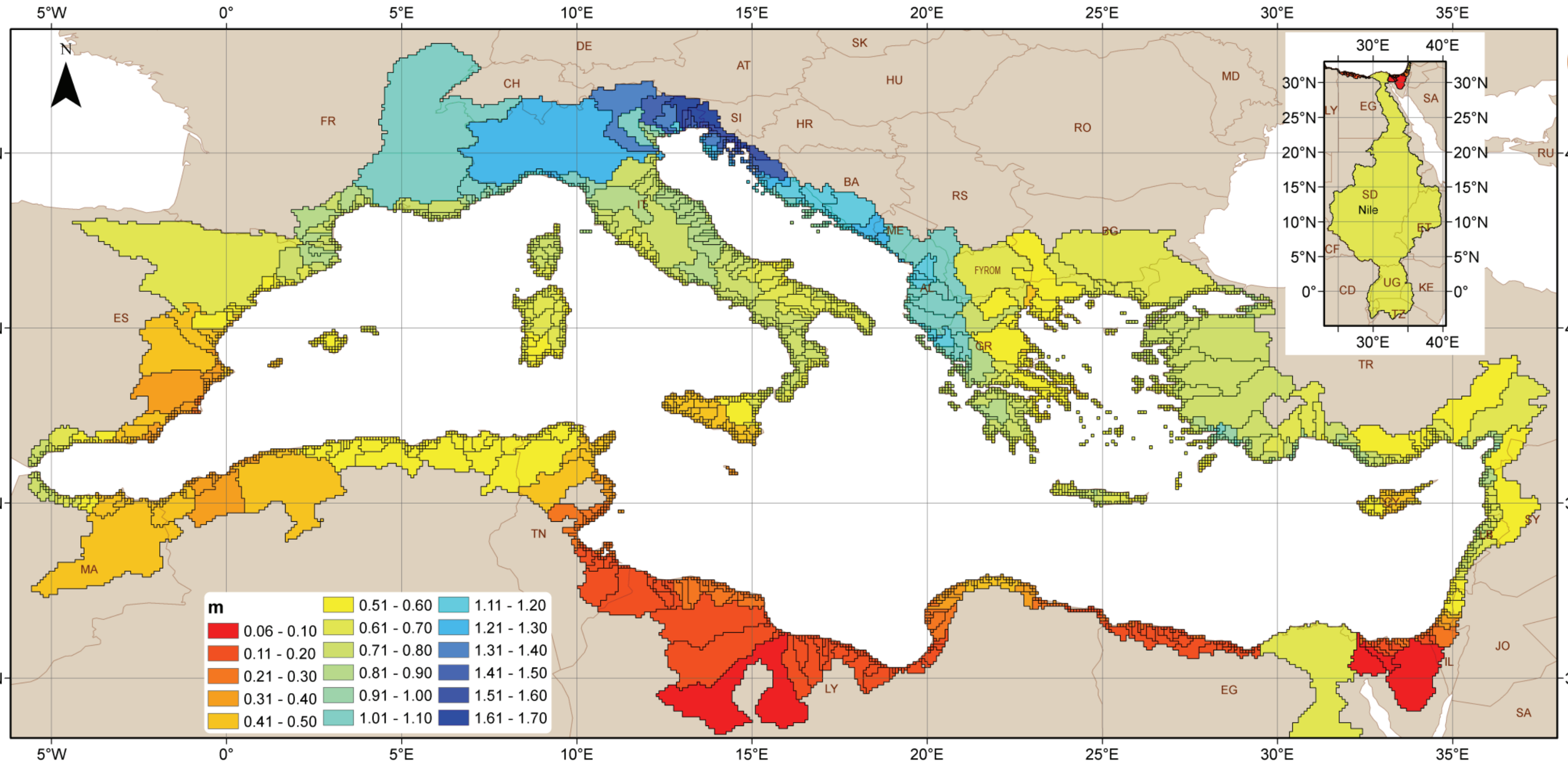
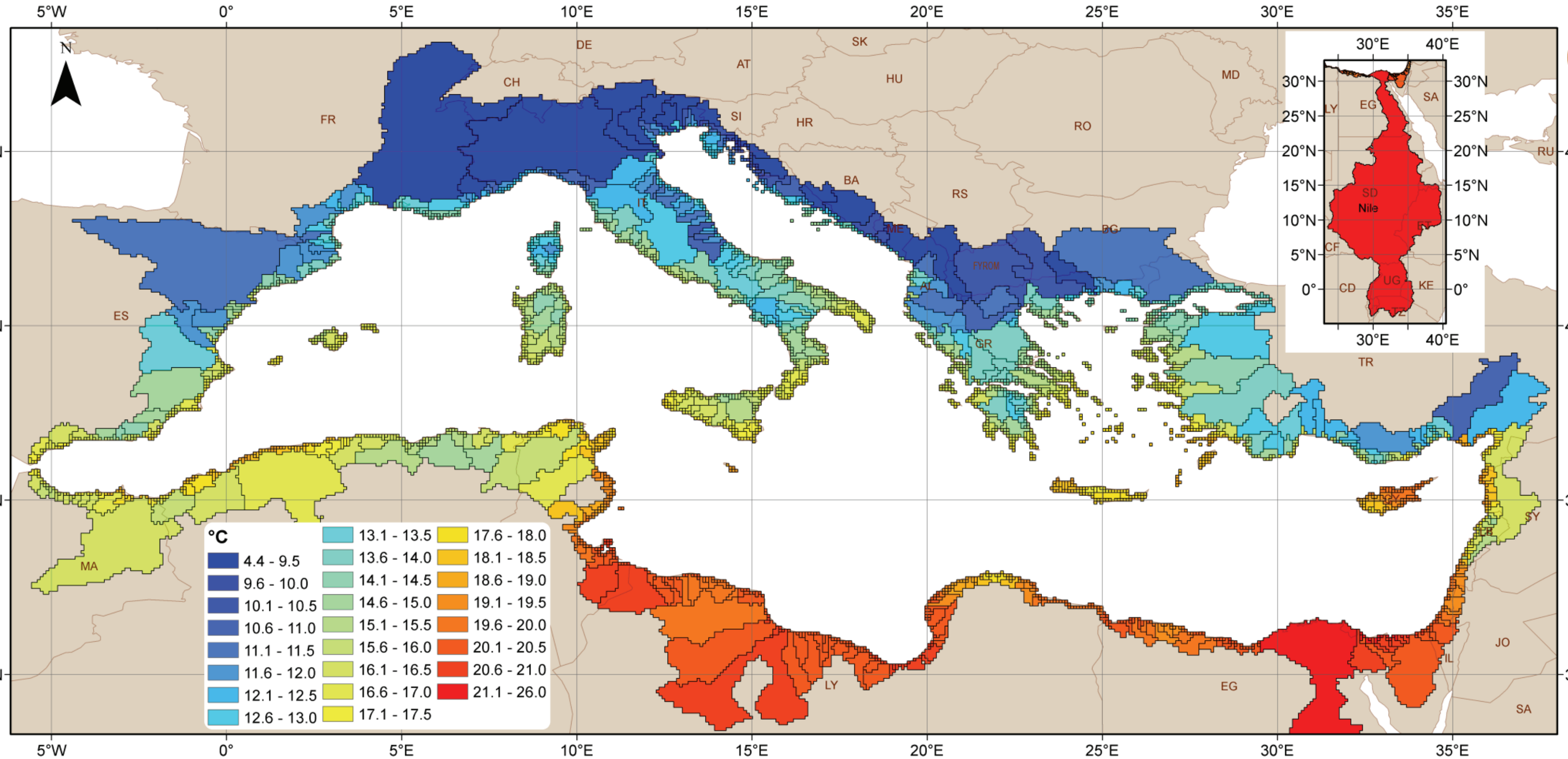


Figure 4 Inter-annual average of average temperature within Mediterranean river basins (1901-2009) calculated from CRU 3.10.1 downscaled at a 5 arc-minutes resolution.



Water use as a driver of spatial change in riverine runoff

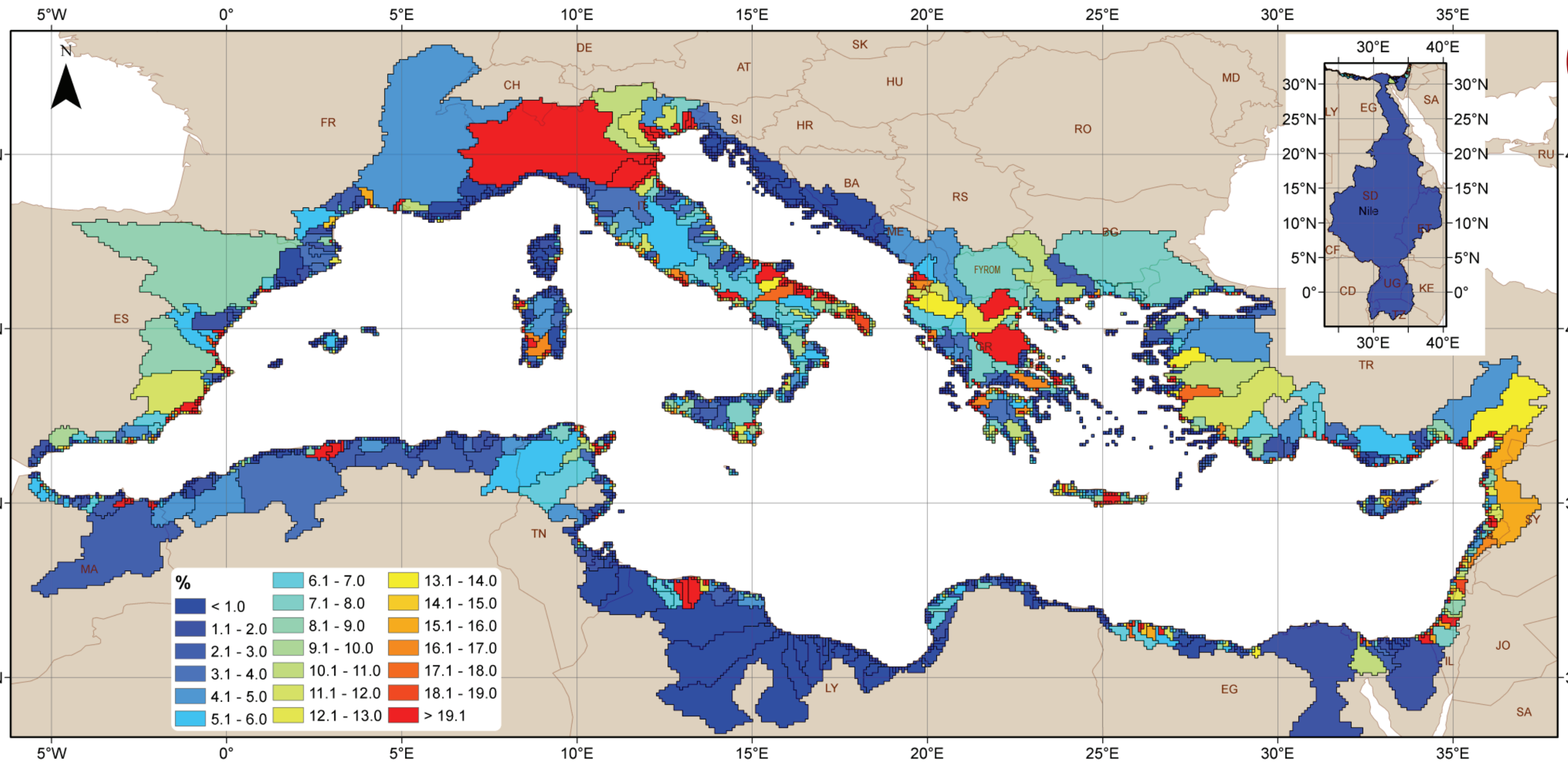
Large amounts of water are needed for agriculture, cities and industry. Especially the agricultural productivity of Mediterranean countries is largely dependent on water availability for crops (Figure 5).

The basins with the largest irrigation rate, shown in Figure 5, are Acheloos (29%) and Pinios (24%) in Greece, Po (22%) in Italy, Orontes (15%) starting from Lebanon, passing through Syria and ending up in Turkey, and Ceyhan (14%) also in Turkey. For the Ebro, Rhone and Nile, irrigated areas cover 9%, 4% and 2% of the basin area respectively. Despite a low value for the Nile, irrigated area cover most of the Nile delta.

Irrigation is responsible for the highest water consumption due to an increased evapotranspiration rate, unlike most of drinking water and industrial water returning to rivers.

About 99% of water used in agriculture is lost by crops as evapotranspiration.

Figure 5 Agricultural irrigated area for each Mediterranean river basin computed from Harmonized World Soil Database.



Forms and concentrations of Nitrogen & Phosphorus in rivers

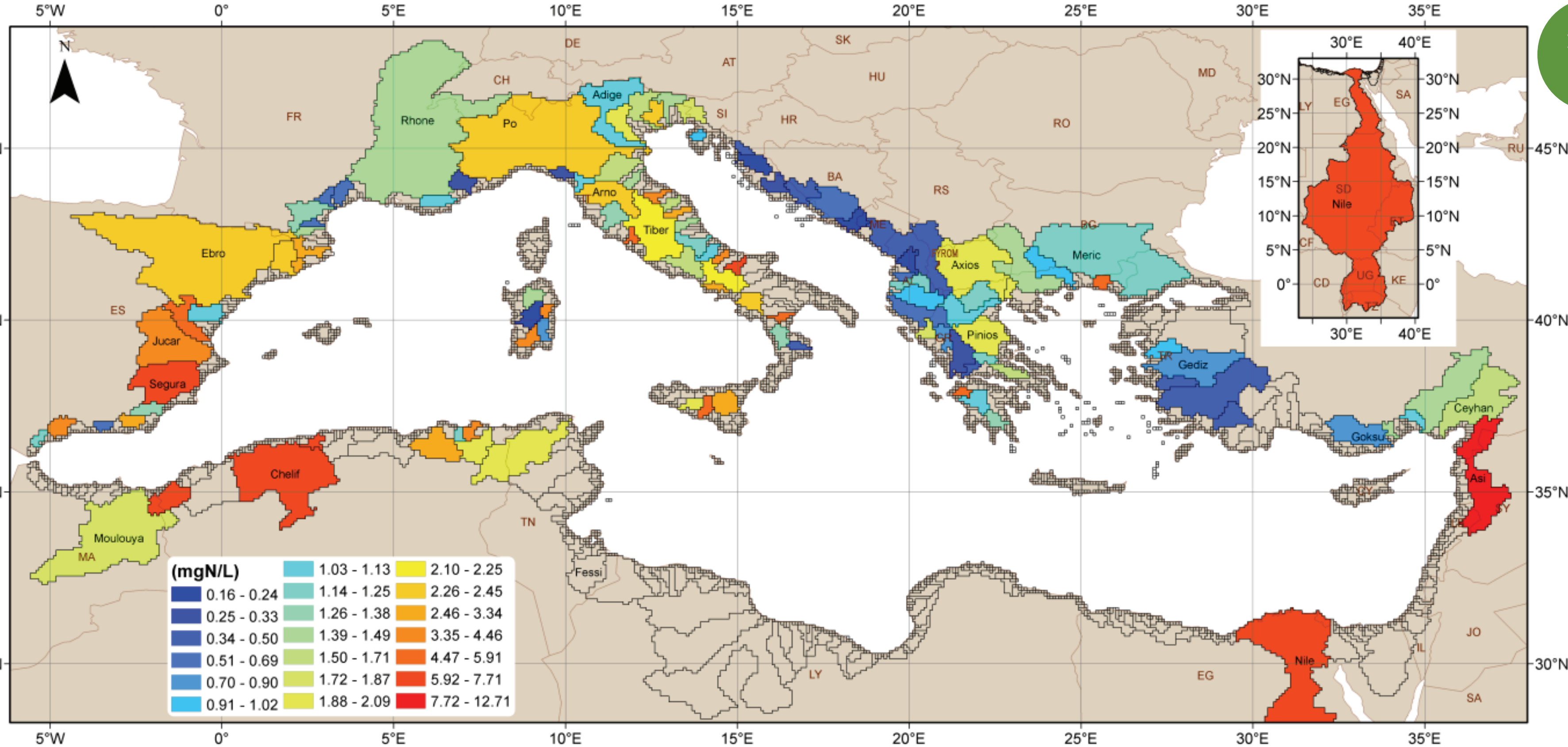
Inorganic Nitrogen compounds include nitrate (NO_3), ammonia (NH_4) and nitrite (NO_2). Nitrate is the most frequently reported form in the Mediterranean Sea and a good indicator for Nitrogen levels, directly related to eutrophication events.

Waste-waters are the main sources for NH_4 and NO_2.

In agricultural areas, fertilizer and manure excess are the main sources for NO_3. Other sources of NO_3 are biological fixation and atmospheric deposition. Nitrite concentrations are, in most cases, very low compared to other inorganic compounds and may be omitted in the Nitrogen budget.

In the following figure (Figure 6), Nitrate concentrations are being presented, because in most cases, NO_3 is the dominant Nitrogen form and its concentration co-varies in space with other Nitrogen compounds. In some rivers, concentrations of NH_4 may be unusually high compared to NO_3, something that indicates strong wastewater emission close to the river mouth and a relatively low water discharge.

Figure 6 Inter-annual average of nitrate concentrations in Mediterranean rivers calculated from available 2000-2010 data or most recent inter-annual value from scientific references.



Forms and concentrations of Nitrogen & Phosphorus in rivers

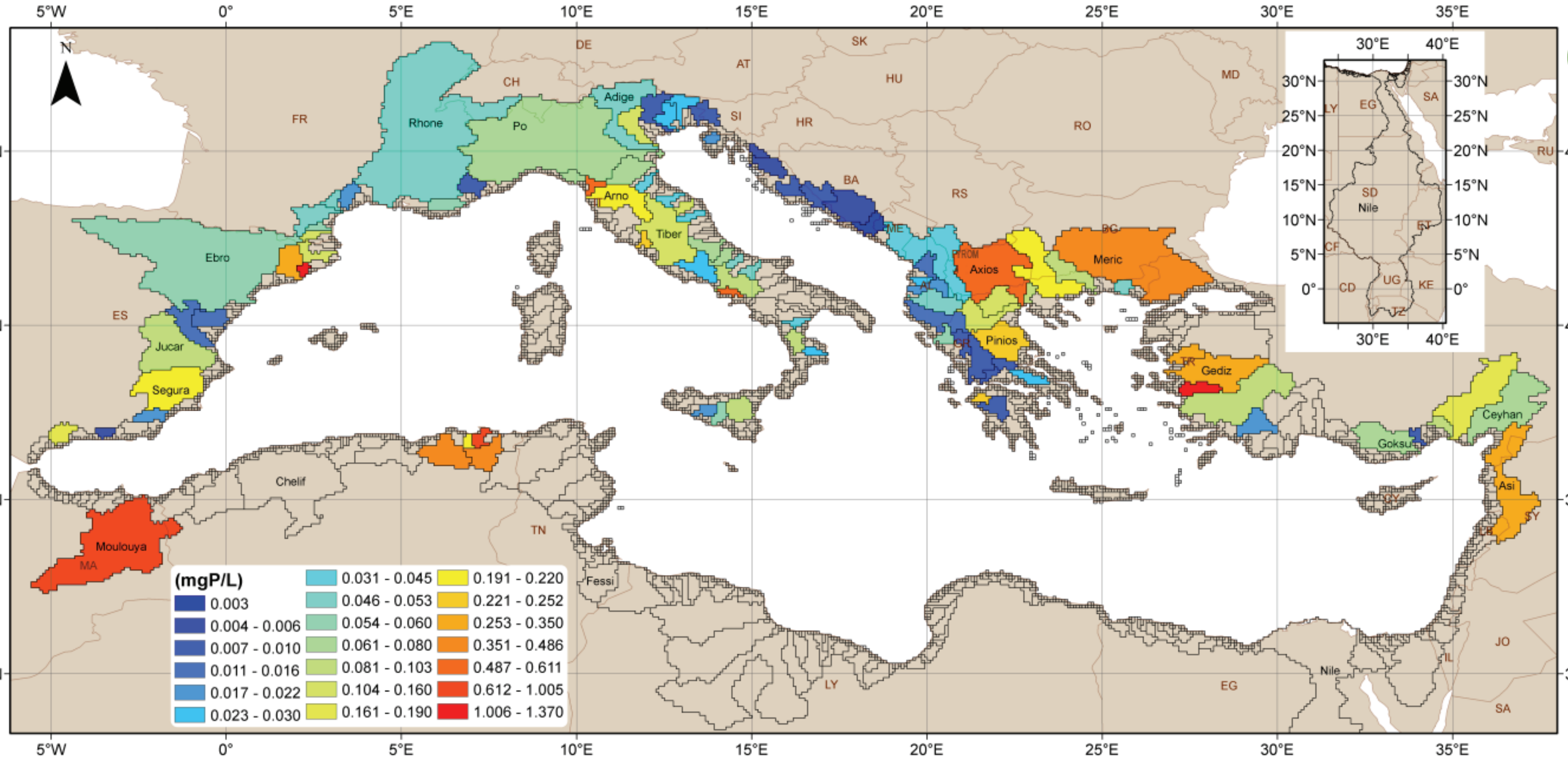
Particulate Phosphorus (PP) accounts for a high fraction of Phosphorus fluxes in rivers because of its strong affinity between orthophosphate (the major dissolved form, PO_4) and particulates.

At a global scale, Dissolved Phosphorus constitutes probably only about 10% of the Phosphorus fluxes by rivers (Meybeck 1982). There are numerous data for Total Phosphorus (TP).

However, the number of measurements and sampling strategy are not suitable for evaluating concentrations or fluxes on an annual basis, because in many cases TP concentrations are not measured during flood periods, when in fact TP concentrations are normally much stronger. Considering that TP outside floods is rather representative for Total Dissolved Phosphorus (TDP) concentrations, a strong **proportional** relation between TDP and Dissolved Inorganic Phosphorus (DIP) was noticed.

Data on DIP (mostly phosphate) concentrations (Figure 7) are less abundant than for nitrate. The importance of DIP is high as aquatic plants take it up and convert it to organic Phosphorus becoming part of their tissues. In the Mediterranean, the rivers for which we could find data cover about 36% of the drainage basin area (not counting the Nile River).

Figure 7 Average Dissolved Inorganic Phosphorus (DIP) concentrations in Mediterranean rivers calculated from available 2000-2010 data or most recent inter-annual value from scientific references.



Drivers of spatial variations in N & P concentrations and fluxes

Nutrient emissions by natural areas

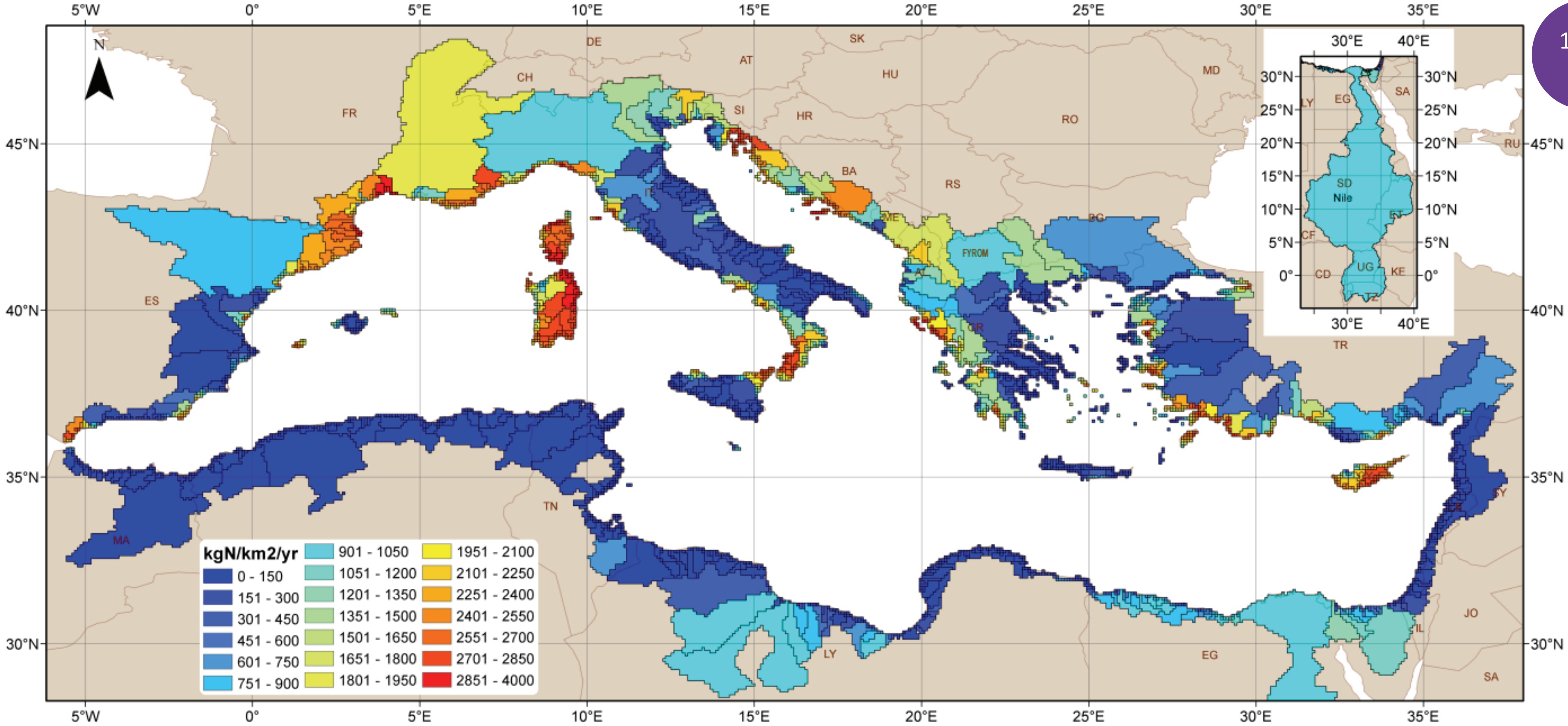
Biological fixation and atmospheric deposition are the main processes accounting for **Nitrogen** emissions into river water, from natural areas, i.e. areas in which natural processes predominate, and human intervention is minimal.

Atmospheric deposition, in general, accounts for different Nitrogen sources, including energy-related biomass burning, and agricultural and natural emissions of Nitrogen oxides and ammonia to air. Under this scope, the emissions accounted to natural areas, when neighboring with agricultural or urban areas, are strongly affected by the emissions produced by the latter ones.

At the scale of the whole Mediterranean drainage basin, these natural emissions reach **35%** of the total diffuse emissions of Nitrogen (Figure 8).

For **Phosphorus**, the atmospheric fluxes are negligible with about 0.5% of inputs to rivers.

Figure 8 Nitrogen emissions by natural areas in 2000s.



Drivers of spatial variations in N & P concentrations and fluxes

Nutrient emissions by agricultural areas

Agriculture has long been a major source of income for many people, but also a major source of pollutants including fertilizers and pesticides, as well as effluent from farming plants.

Manure and fertilizer account for **76%** of the total Nitrogen (NO_3) inputs in agricultural area, and by deducing crop export, total Nitrogen emissions in agricultural area are **95%** of the total diffuse emission (Figure 9).

For Phosphorus, the numbers are equally high (Figure 10).

Elevated agricultural emissions are closely related to water quality. However, for nitrate flux, this link is less obvious as nitrate flux is also greatly controlled by spatial change in water discharge.

Figure 9 Nitrogen emissions by agricultural areas in 2000s.

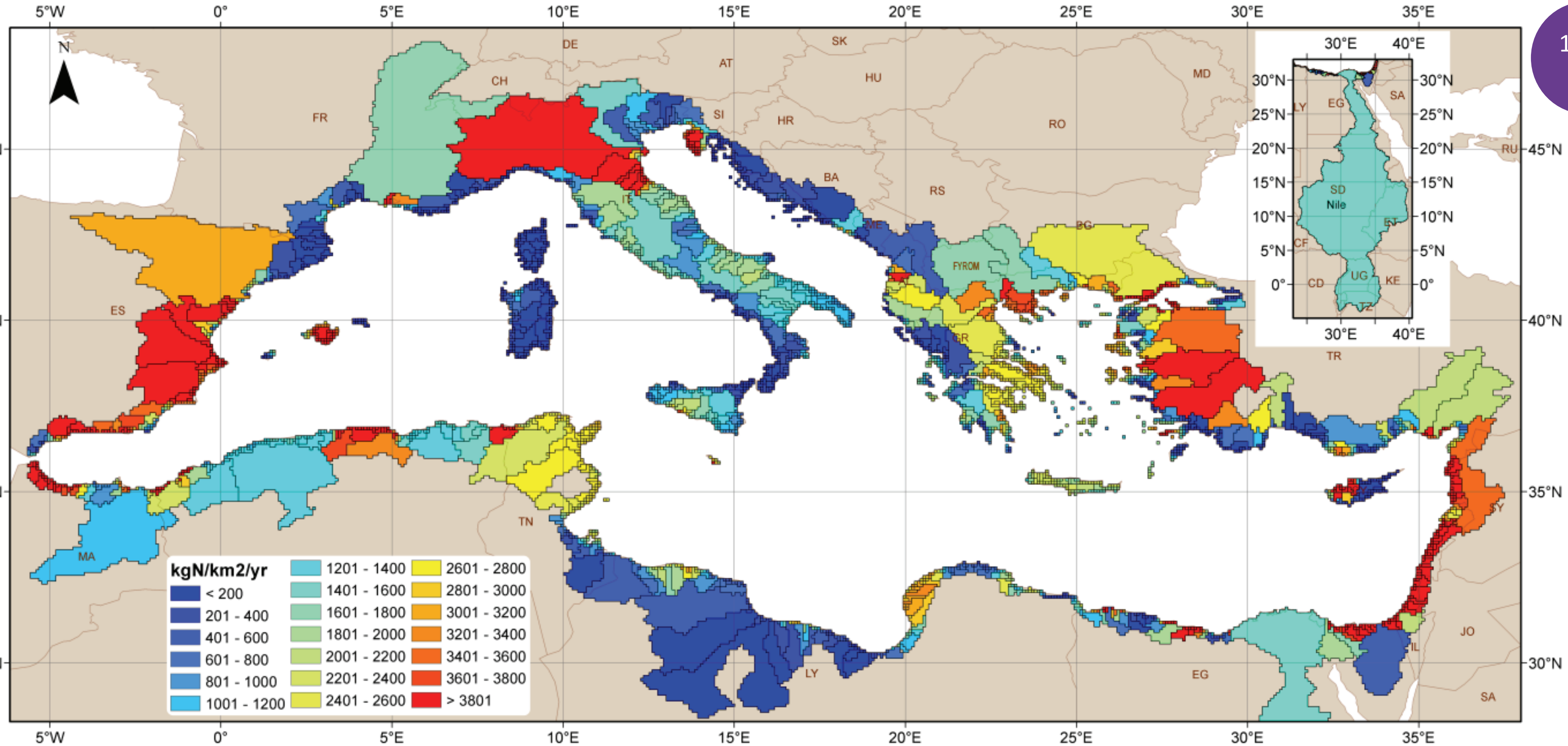
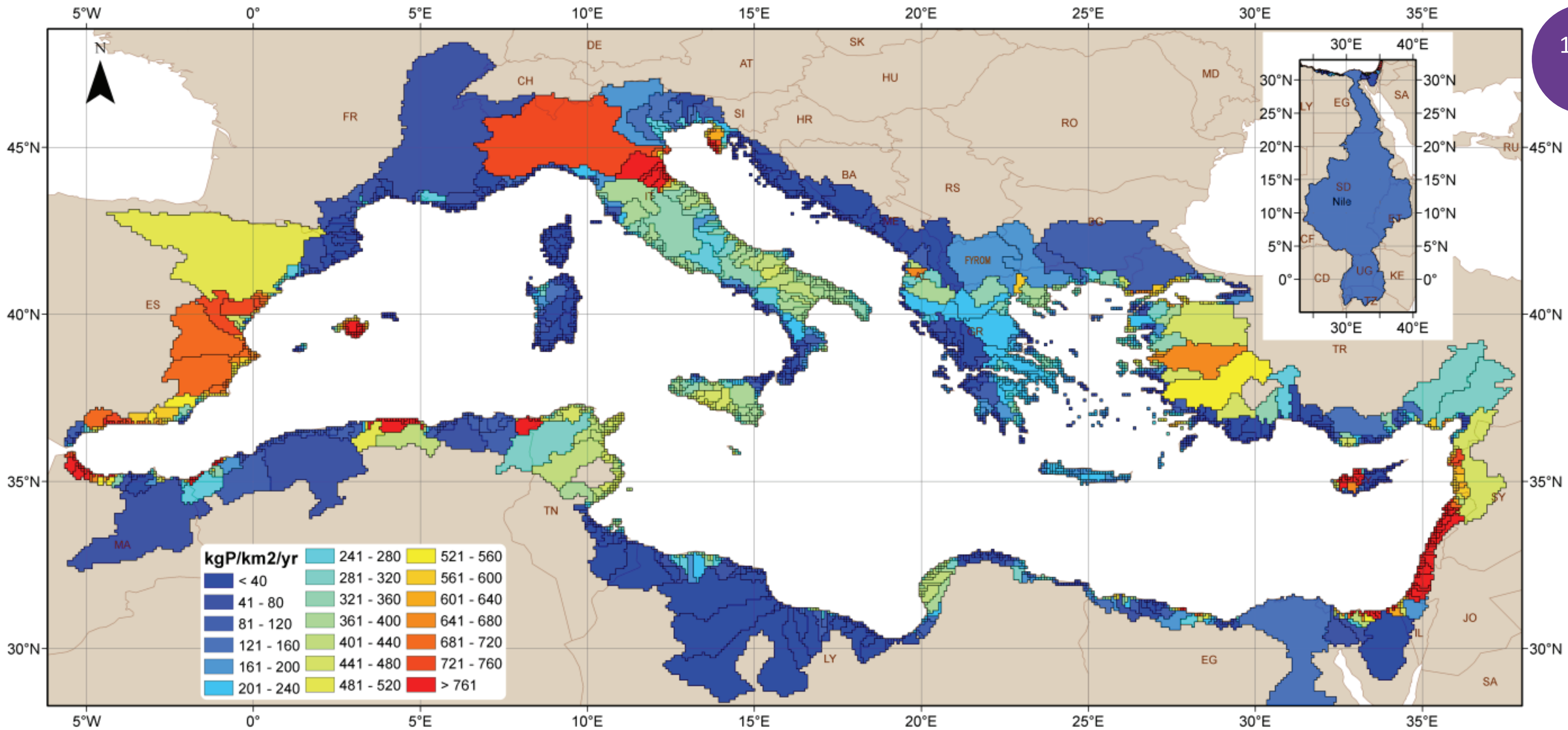


Figure 10 Phosphorus emissions by agricultural areas in 2000s.



Drivers of spatial variations in N & P concentrations and fluxes

Nutrient emissions by wastewaters

Wastewaters, the liquid wastes deriving from domestic, commercial and industrial activities of an **urban** settlement, are the main source of NH_4 and NO_2 into the rivers.

Nutrient emissions by wastewaters account for **5%** and **6%** of total emissions of **Nitrogen** (Figure 11) and **Phosphorus** (Figure 12) respectively, for the whole Mediterranean drainage basin (including diffuse emissions in agricultural and natural areas).

For both Phosphorus and Nitrogen, strongest emission rates are located in small basins including large cities.

Some large basins of Italy, Northern Maghreb and Southwestern Turkey have relatively high nutrient emission rates (Figures 11 and 12).

Figure 11 Nitrogen emissions by wastewaters in 2000s.

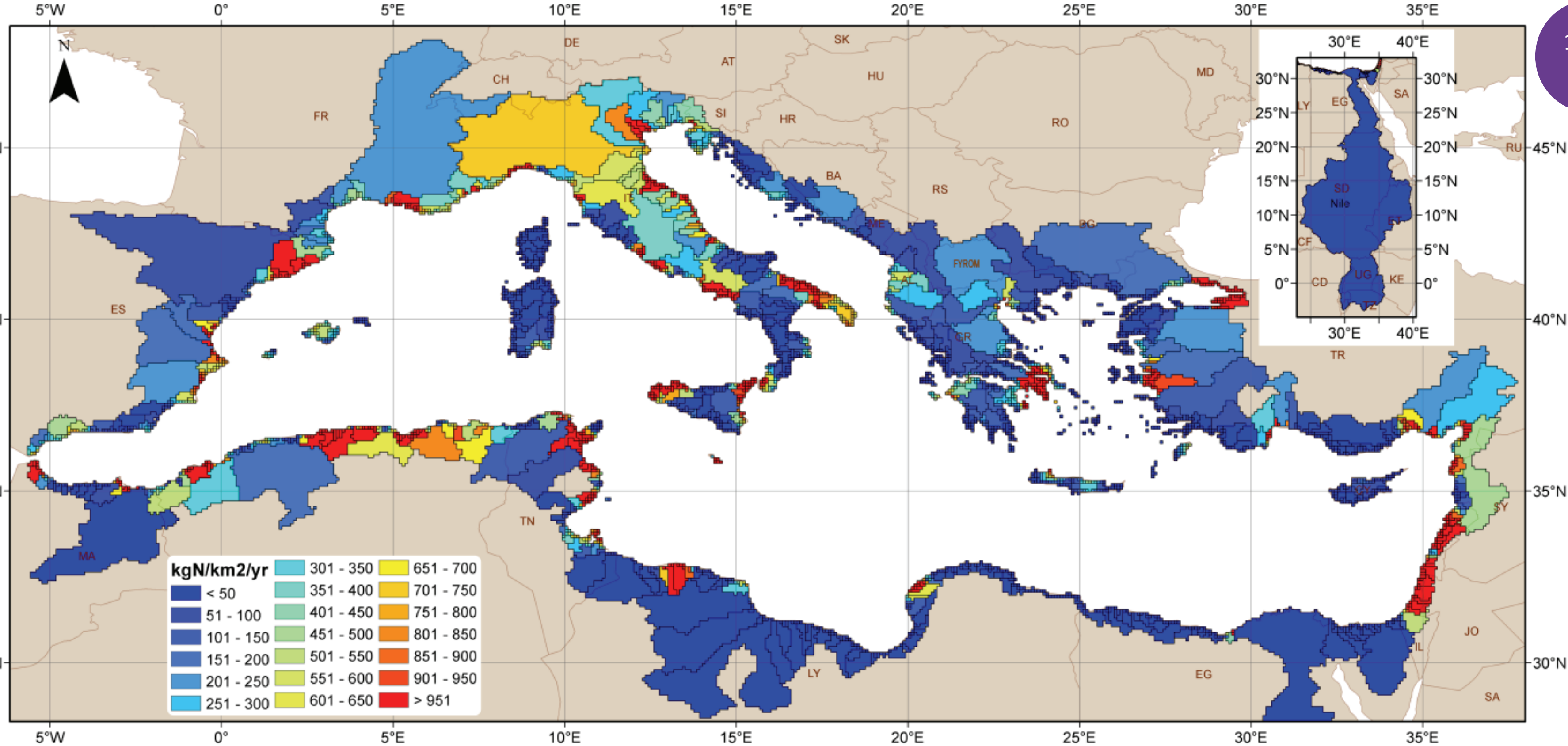
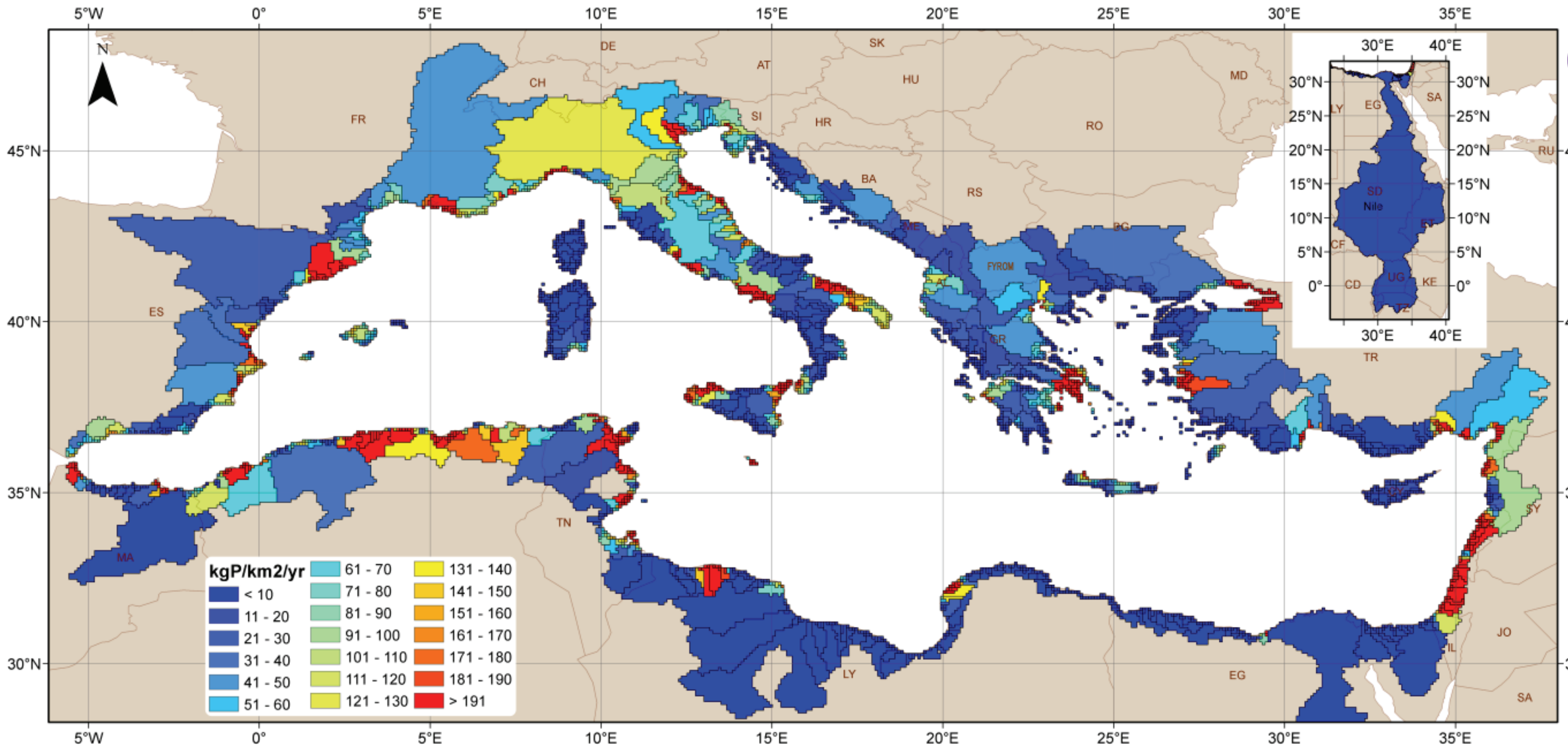


Figure 12 Phosphorus emissions by wastewaters in 2000s.



Drivers of spatial variations in N & P concentrations and fluxes

Nutrient storage/removal within reservoirs and dams

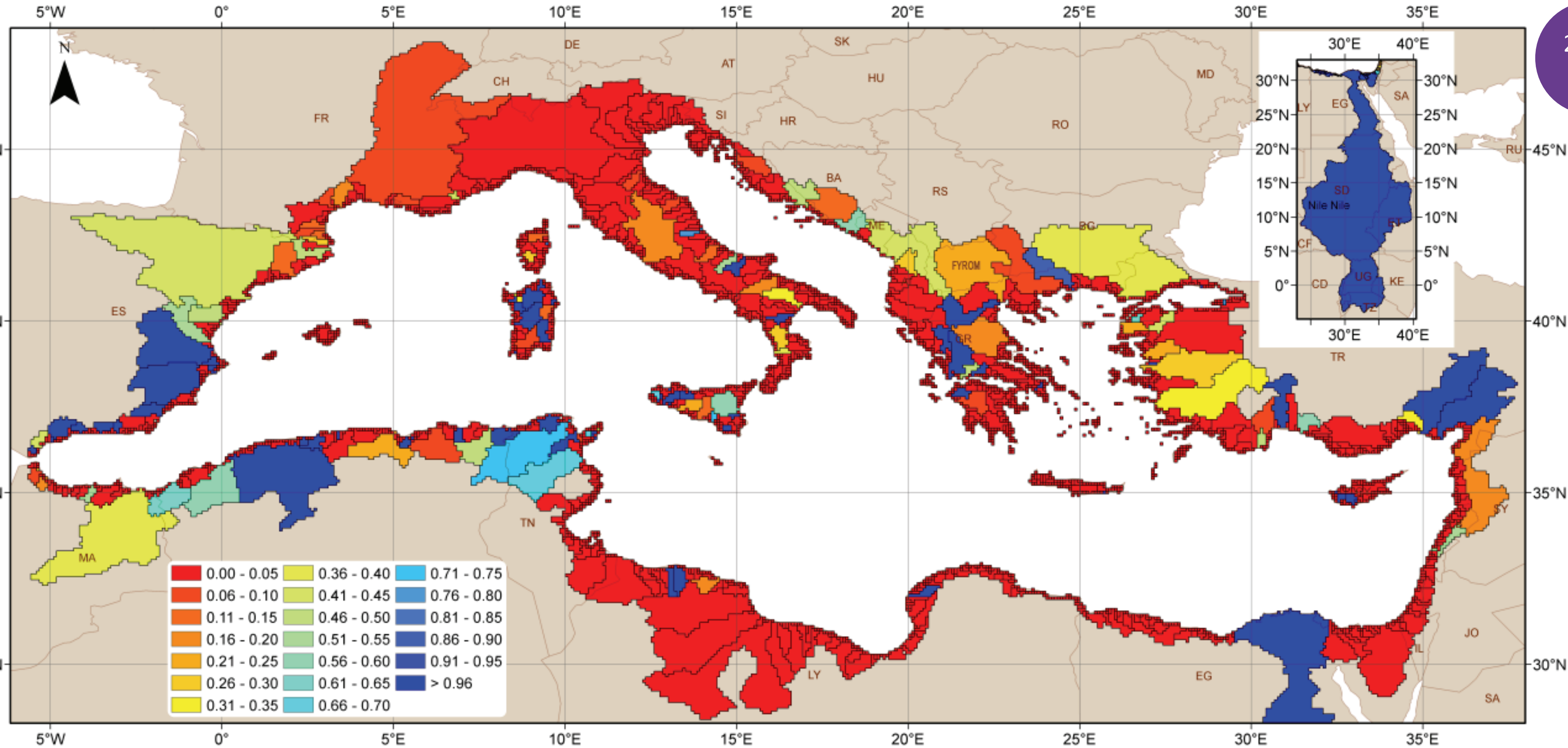
During the last centuries, people have been changing the natural course of rivers via damming in order to serve their own purposes (irrigation, protection from flooding, hydropower etc.).

Lentic water bodies (**lakes and reservoirs**) can potentially act as important sources of Nitrogen and Phosphorus as these are transported across the landscape, because they offer ideal conditions for Nitrogen or Phosphorus burial in sediments or permanent loss of Nitrogen via denitrification.

Therefore, the importance of water residence time, i.e. the average time a water mass resides in a lentic system, is noted, as it has been often suggested to affect nutrient cycling and in general water quality (Figure 13).

Nutrient storage/removal within reservoirs and dams may be estimated via statistical analysis.

Figure 13 Water residence time in reservoirs (years).



Future scenarios

Forecast scenarios are important tools that can provide insight in evaluating future trends, thus contributing to preventive policies and related measures. In order to predict nutrient fluxes for the years 2030s for the ten Mediterranean sub-basins, four Millennium Ecosystem Assessment (MEA) scenarios have been implemented in IMAGE (Figure 14).

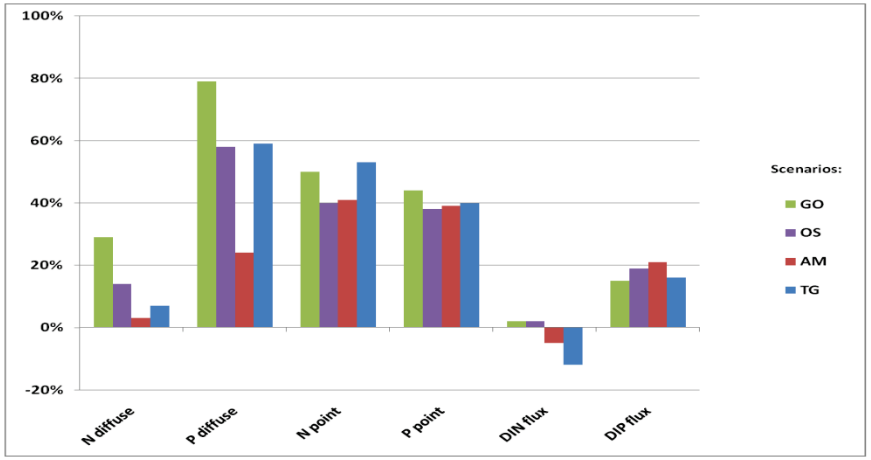


Figure 14 Expected changes in diffuse emissions of Nitrogen and Phosphorus (N diffuse and P diffuse respectively), in point emissions of Nitrogen and Phosphorus (N point and P point respectively) and in the fluxes of Dissolved Inorganic Nitrogen and Dissolved Inorganic Phosphorus (DIN flux and DIP flux respectively) in the Mediterranean Sea by the year 2030, according to the four different MEA scenarios.

Each scenario represents a possible socioeconomic development of the world in the near future and is named according to its major characteristics:

- **Global Orchestration (GO)**
- **Order from Strength (OS)**
- **Adapting Mosaic (AM) and**
- **Technogarden (TG).**

In two scenarios (**TG, AM**), societies generally have a proactive approach to environmental problems, whereas a reactive approach is dominant in the two other scenarios (**GO, OS**). In 2030s, **a decrease in water discharge** between 11.6 to 12.0% can be expected, according to all 4 scenarios.

Future scenarios

Global Orchestration

Approach for Sustainability	Economic Approach	Social Policy Foci	Dominant Social Organizations
sustainable development; economic growth; public goods	fair trade (reduction of tariff boundaries), with enhancement of global public goods	improve world; global public health; global education	transnational companies; global NGO and multilateral organizations

Table 2 Defining characteristics of the GO scenario.

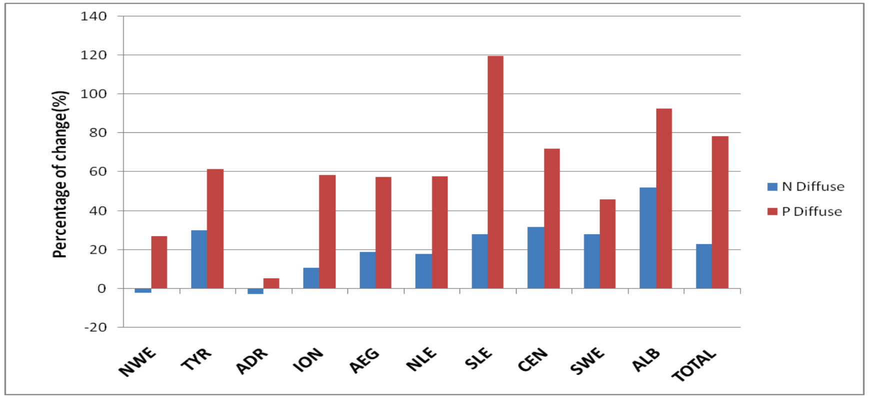


Figure 15 *Expected changes in diffuse emissions of Nitrogen and Phosphorus (N diffuse and P diffuse respectively) by the year 2030, according to the Global Orchestration (GO) scenario, in the different Mediterranean sub-basins*.*

Global Orchestration (GO) depicts a worldwide connected society in which global markets are well developed. Supranational institutions are well placed to deal with global environmental problems. However, their reactive approach to ecosystem management makes them vulnerable to surprises arising from delayed action or unexpected regional changes. Environmental problems that threaten human well-being (such as pollution, erosion and climate change) are dealt with only after they become apparent (Table 2).

According to the **GO** scenario (Figure 15), there will be an increase of diffuse Nitrogen emissions in 2030s, reaching 23% for the whole Mediterranean drainage area. In contrast, emissions will decrease for both the Adriatic and the NEW drainage area, but they will increase reaching 52% in the Alboran sub-basin. For Phosphorus, the increase of emissions for 2030s reaches 79%, with SLE sub-basin showing the highest increase.

**The different sub-basins are shown in Figure 1*

Future scenarios

Approach for Sustainability	Economic Approach	Social Policy Foci	Dominant Social Organizations
reserves; parks; national-level policies; conservation	regional trade blocs; mercantilism	security and protection	multinational companies

Table 3 Defining characteristics of the OS scenario.

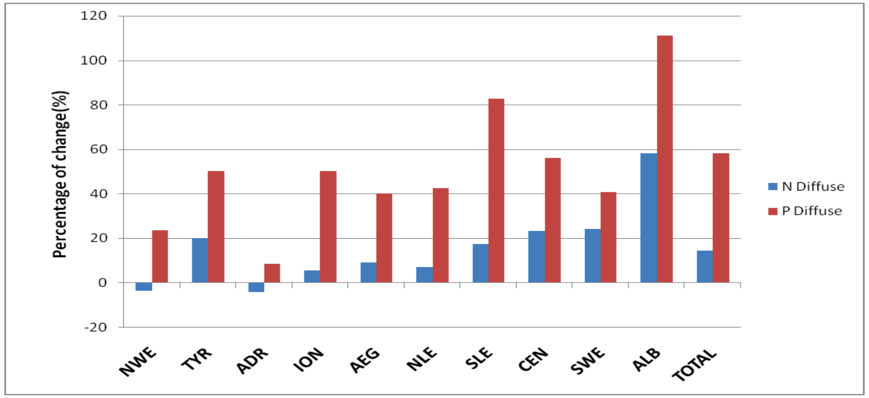


Figure 16 Expected changes in diffuse emissions of Nitrogen and Phosphorus (N diffuse and P diffuse respectively) by the year 2030, according to the Order from Strength (OS) scenario, in the different Mediterranean sub-basins.*

Order from Strength

Order from Strength (OS) represents a regionalized and fragmented world concerned with security and protection, emphasizing primarily regional markets and paying little attention to common goods, and with an individualistic attitude toward ecosystem management.

People in this scenario see the environment as secondary to their other challenges. They believe in the ability of humans to bring technological innovations to bear as solutions to environmental challenges after these emerge (Table 3).

According to the **OS** scenario (Figure 16), there will be an increase of diffuse Nitrogen emissions in 2030s, about 14% for the whole Mediterranean drainage area but with an increase of 58% for the Alboran sub-basin and a decrease for the Adriatic. For Phosphorus, the increase of emissions for 2030s is expected to reach 58% with the Alboran sub-basin being again the major contributor for this increase.

**The different sub-basins are shown in Figure 1*

Future scenarios

Adapting Mosaic

Approach for Sustainability	Economic Approach	Social Policy Foci	Dominant Social Organizations
local-regional co-management; common-property institutions	integration of local rules regulate trade; local nonmarket rights	local communities linked to global communities; local equity important	cooperatives, global organizations

Table 4 Defining characteristics of the AM scenario.

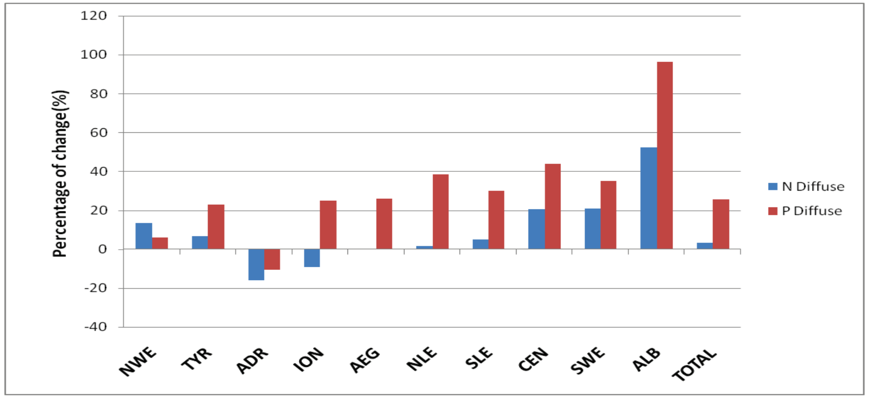


Figure 17 Expected changes in diffuse emissions of Nitrogen and Phosphorus (N diffuse and P diffuse respectively) by the year 2030, according to the Adapting Mosaic (AM) scenario, in the different Mediterranean sub-basins.*

Adapting Mosaic (AM) depicts a fragmented world resulting from discredited global institutions. It sees the rise of local ecosystem management strategies and the strengthening of local institutions. Investments in human and social capital are geared towards improving knowledge about ecosystem functioning and management.

Problems like climate change, overfishing, and pollution increase, and global environmental surprises become common. Communities slowly realize that they cannot manage their local areas because global problems are infringing, and they begin to develop networks among communities, regions, and even nations to better manage the global commons (Table 4).

According to the **AM** scenario (Figure 17), there will be an increase of diffuse Nitrogen emissions in 2030s, reaching 3% for the whole Mediterranean drainage area with a major increase in the Alboran sub-basin. For Phosphorus, the increase of emissions for 2030s is expected to reach 24% but in the Adriatic sub-basin there is a notable decrease of 13%.

**The different sub-basins are shown in Figure 1*

Future scenarios

Approach for Sustainability	Economic Approach	Social Policy Foci	Dominant Social Organizations
green technology; eco-efficiency; tradable ecological property rights	global reduction of tariff boundaries; fairly free movement of goods, capital, and people; global markets in ecological property	technical expertise valued; follow opportunity; competition; openness	transnational professional associations; NGOs

Table 5 Defining characteristics of the TG scenario.

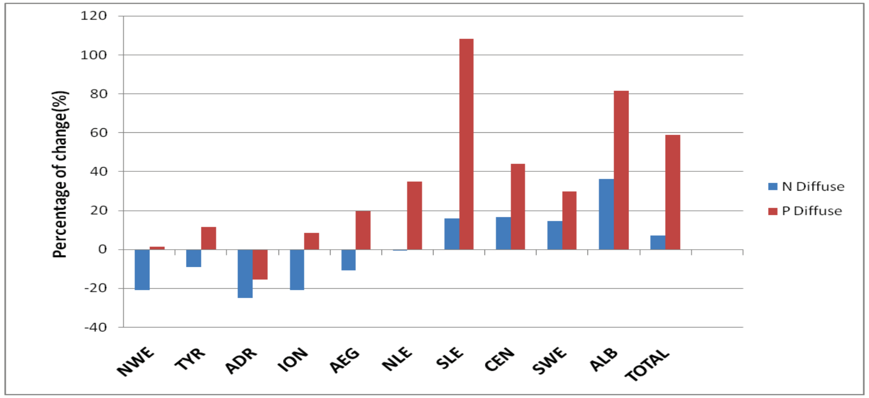


Figure 18 Expected changes in diffuse emissions of Nitrogen and Phosphorus (N diffuse and P diffuse respectively) by the year 2030, according to the Technogarden (TG) scenario, in the different Mediterranean sub-basins.*

Technogarden (TG) depicts a globally connected world relying strongly on technology and on highly managed and often engineered ecosystems to deliver needed goods and services. Overall, eco-efficiency improves, but it is shadowed by the risks inherent in large-scale human made solutions.

In this scenario, technology and market-oriented institutional reform are used to achieve solutions to environmental problems, by reducing the environmental impact of goods and services in combination with improvements in ecological engineering, optimizing the production of ecosystem services.

According to this scenario (Figure 18), there will be an increase of diffuse Nitrogen emissions in 2030s, reaching 7% for the whole Mediterranean drainage area, but a decrease is calculated for the Northern Mediterranean and the Adriatic sub-basins. For Phosphorus, the increase of emissions for 2030s will reach 59%, with the Adriatic sub-basin showing a decrease.

Technogarden

**The different sub-basins are shown in Figure 1*

Recommendations

Even though this inventory has allowed building the most complete dataset on the Mediterranean basin for nutrient concentrations and water discharges related to rivers and to the sea, there are significant **gaps in water discharge data** and nutrient concentrations particularly for Southern Italy, Eastern Adriatic Sea, Greece, Turkey and the Nile, impeding the assessment processes of **global nutrient inputs** in the Mediterranean Sea.

Water discharge has declined in the last 50 years partly because of a decreasing trend in precipitation. However, increases in reservoir capacity and irrigated area are also drivers of this decline.

Water discharge should continue to decline in the coming decades, regardless of change in water use. Demographic growth and intensification of agricultural practices in Eastern and Southern Mediterranean Sea should induce a larger decrease in water discharge.

Agricultural activity accounts for increasing the concentrations of Nitrogen and Phosphorus in the river basins, more than wastewater loads.

Among the four scenarios proposed, **Technogarden** is the scenario limiting most of the nutrient export. This is a very important finding, since it shows how the use of **technology** can be applied towards a **viable solution** of the environmental problems.

Recommendations

The river water discharge in the **Southern Mediterranean Sea**, accounts only for 7% of all Mediterranean Rivers (3% excluding the Nile). These low inputs suggest a **low impact of changes in nutrient fluxes** compared to the total river discharge.

In the **Northwestern Mediterranean Sea** and **Northern Adriatic Sea**, despite low trends of nutrient emissions within basins regarding the other Mediterranean regions, their impact should be stronger as high precipitation increases the nutrient leaching from soil to the river mouth.

In the areas around **the Aegean Sea** and **Northern Levantine Sea**, there is an intermediate situation with a relatively large demographic and agricultural growth and moderate leaching rate of nutrients.

River water discharge is one of the crucial parameters in **monitoring the quality** of water masses ending up in the sea. It is also a meaningful parameter in the evaluation of **socio-economic pressures** on the rivers and eventually on the sea. Despite the importance of this parameter, information and data availability on water discharge in Mediterranean rivers is strongly decreasing in recent years. It is therefore recommended to foster all initiatives driven by international political agreements on **nature protection**, in order to monitor water discharge data in Mediterranean rivers and to fill the increasing data gap.

Recommendations

Water quality in rivers cannot be evaluated on concentration values alone but also requires calculation of **fluxes.** To this end, it is crucial to automatically associate water quality parameters with regular gauging of water discharge at the same stations when monitoring. In general, monitoring of nutrients should be designed according to the measured fraction. More specifically, **special monitoring strategies** should be adopted for the monitoring of particulate nutrients.

Silica concentrations data are missing from most monitoring programs. It is highly recommended to establish a regular monitoring scheme of dissolved Silica in Mediterranean rivers.

Overall, **intercomparison / standardization of monitoring methods and analytical protocols** between national networks should be established to minimize the uncertainly in the determination of water quality parameters related to different analytical methods and approaches used by them.

It is noteworthy that among the regional hot spots that are likely to influence water quality and ecosystem changes in the **future**, the lower Nile is an important one, characterized by very high and still increasing population densities, imposing an increasing anthropogenic pressure on the riverine water resources. Future efforts are needed to fill the data gaps on the lower Nile River, in order to draw a more precise picture on the quality and quantity of nutrients that are discharged to the Mediterranean Sea.

Glossary

Evapotranspiration | Discharge of water from the earth's surface to the atmosphere by evaporation from lakes, streams and soil surfaces and by transpiration from plants. Also known as fly-off. (Terminology source: http://www.eionet.europa.eu)

Eutrophication | A process of pollution that occurs when a lake or stream becomes over-rich in plant nutrient; as a consequence it becomes overgrown in algae and other aquatic plants. The plants die and decompose. In decomposing the plants rob the water of oxygen and the lake, river or stream becomes lifeless. Nitrate fertilizers which drain from the fields, nutrients from animal wastes and human sewage are the primary causes of eutrophication. They have high biological oxygen demand (BOD). (Terminology source: http://www.eionet.europa.eu)

Biological fixation | Biological Nitrogen Fixation (BNF) is the process whereby atmospheric Nitrogen (N=N) is reduced to ammonia in the presence of nitrogenase. (Terminology source: http://www.fao.org)

Atmospheric deposition | The transfer of substances in air to surfaces, including soil, vegetation, surface water, or indoor surfaces, by dry or wet processes. (Terminology source: http://www.eionet.europa.eu)

Biomass | Biomass refers strictly speaking to the total weight of all the living things in an ecosystem. However, it has come to refer to the amount of plant and crop material that could be produced in an ecosystem for making biofuels and other raw materials used in industry, for example. (Terminology source: http://www.eionet.europa.eu)

Lentic water bodies | Lentic water bodies include freshwater lakes, saline lakes, ponds, marshes, swamps and billabongs. They may be temporary or permanent in nature. Artificial lentic water bodies include large water infrastructure dams, weirs, farm dams and other storage reservoirs. (Terminology source: The State of Queensland (Department of Agriculture and Fisheries))

Denitrification | The loss of Nitrogen from soil by biological or chemical means. It is a gaseous loss, unrelated to loss by physical processes such as through leachates. (Terminology source: http://www.eionet.europa.eu)

References

•Andradottir, H.O., Rueda, F. J., Armengol, J. and Marce, R., (2012), Characterization of residence time variability in a managed monomictic reservoir, WaterResour.Res., 48, W11505, doi:10.1029/2012WR012069

•GRID-Arendal, (2013), State of the Mediterranean Marine and Coastal Environment

•Ludwig, W., Dumont, E., Meybeck, M. and Heussner, S., (2009), River discharges of water and nutrients to the Mediterranean and Black Sea: Major drivers for ecosystem changes during past and future decades, Prog. Oceanogr. 80, 199-217

•Ludwig, W. and Montreuil, O., (2013), SES land-based runoff and nutrient load data (1980 - 2000). PERSEUS Project Deliverable 4.3. http://www.perseus-net.eu/site/content.php?artid=675

•Millennium Ecosystem Assessment (MA), (2005), Ecosystems and human well-being: (Chapter 8, Scenarios), Island Press, Washington, D.C., USA

•Monsen, N. E., Cloern, J. E., Lucas, L. V. and Monismith, S. G., (2002), A comment on the use of flushing time, residence time, and age as transport time scales, Limnol. Oceanogr. 47, 1545–1553

•Simek, K., Comerma, M., Garca, J. C., Marce, R., Nedoma, J. and Armengol J., (2011), The effect of river water circulation on the distribution and functioning of reservoir microbial communities as determined by a relative distance approach, Ecosystems, 14, 1–14

•Struglia, M.V., Mariotti, A. and Filogrosso, A., (2004), River discharge into the Mediterranean Sea: Climatology and aspects of the observed variability, Journal of Climate 17, 4750-4751

•UNEP(DEPI)/MED WG 379.Inf.7, (2013), Report of nutrient riverine inputs

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The image of the cover illustrates the Nile delta, and its conjuction with the Mediterranean Sea (mosaic satellite image, source: http://www.eosnap.com/)

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