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Meeting of MED POL Focal Points

Barcelona (Spain), 18-21 June 2013

Report of nutrient riverine inputs

Delegates are kindly requested to bring their documents to the meeting

UNEP/MAP
Athens, 2013

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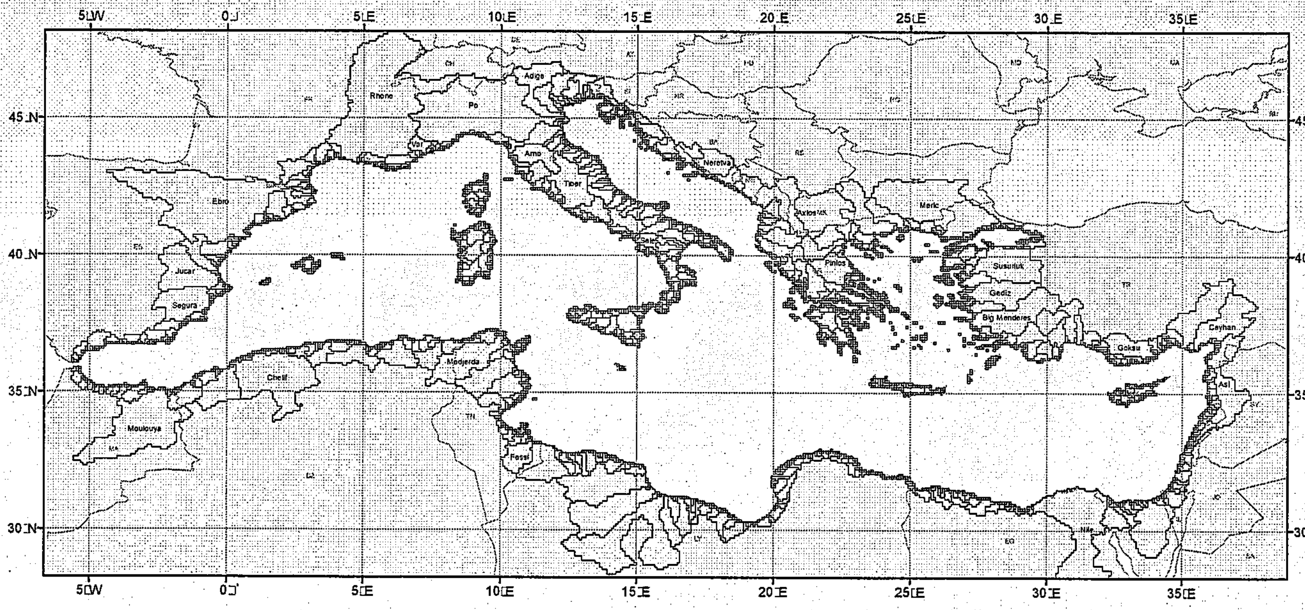
Rivers of the Mediterranean Sea:

Water discharge and nutrient fluxes



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2013

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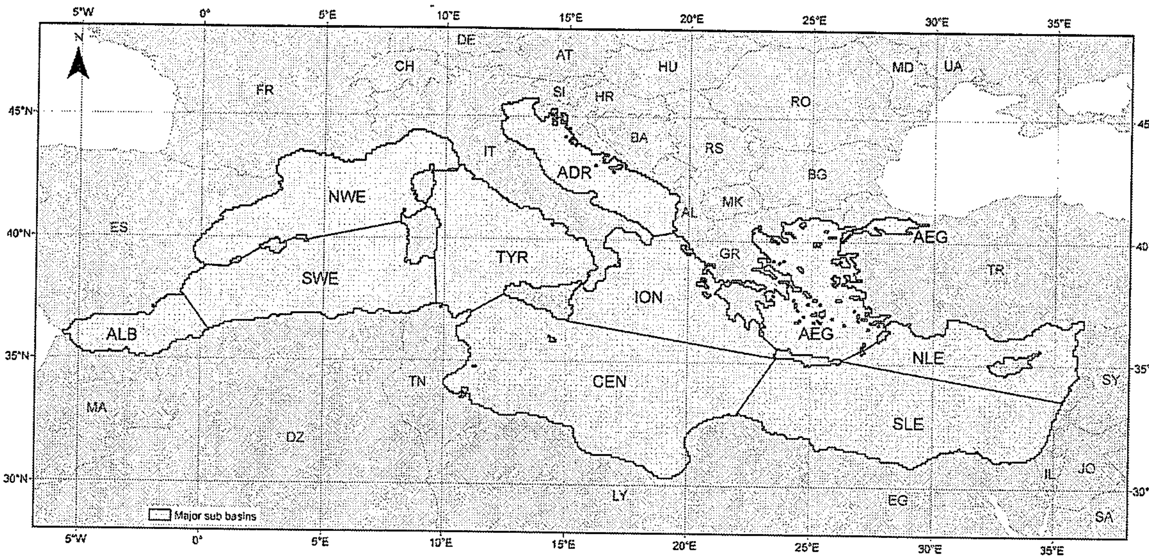


Figure 1 Major sub-basins of the Mediterranean Sea

Table 1 Major sub-basins of the Mediterranean Sea

Basin	Code	Area (10^3 km^2)	Bordering countries
Alboran	ALB	76	Spain, Morocco, Algeria
North-Western	NEW	252	Spain, France, Monaco, Italy
South-Western	SWE	270	Spain, Italy, Algeria, Tunisia
Tyrrhenian	TYR	242	Italy, France, Tunisia
Ionian	ION	184	Italy, Croatia, Albania
Central	CEN	606	Italy, Tunisia, Libya, Malta
Aegean	AEG	202	Greece, Turkey
North-Levantine	NLE	111	Turkey, Cyprus, Syria, Lebanon
South-Levantine	SLE	436	Lebanon, Israel, Egypt, Libya

Table 2 Fluxes of water and nutrients flowing in and out of the Mediterranean Sea from scientific references::*(1) Guerzoni et al. 1999, (2) Boukthir & Barnier 2000, (3) Markaki et al. 2010, (4) Mariotti et al. 2002, (5) Pettenuzzo et al. 2010, (6) Sanchez-Gomez et al. 2011, (7) Ludwig et al. 2010, (8) Dafner, Boscolo & Bryden 2003, (9) Gómez 2003, (10) Baschek et al. 2001, (11) Huertas et al. 2009, (12) Soto-Navarro et al. 2010, (13) Polat & Tugrul 1995, (14) Stanev & Peneva 2002, (15) Tzali et al. 2010, (16) Krom, Herut & Mantoura 2004, (17) Ærtebjerg et al. 2001, (18) Zektser & Loaiciga 1993, (19) Kara et al. 2008.*

Source	Nitrogen (10^3 tN)	Phosphorus (10^3 tP)	Water (km^3)
Atmosphere	1140:1335 (1,3)	65 (1)	825:1485 (2, 4, 5, 6)
River	1285 (7)	126 (7)	340:347 (2,7)
Atlantic	-3135:-1080 (8,9)	-242:-38 (8, 9)	925 :1578 (2, 4, 10, 11, 12)
Black Sea	120:130 (13, 16)	2 (13)	197:311 (14, 15, 19)
Evapotranspiration			2300:2922 (2, 4, 5, 6)
Point source	285 (17)	74 (17)	
Groundwater			50 (18)

Chapter 1 - Introduction

The Mediterranean Sea covers about 2.5 10^6 km², with an average water depth of about 1.5 km. It is commonly divided in ten sub-basins, which are shown in Figure 1 and listed in Table 1. Nitrogen, phosphorus and silicon are crucial elements for maintaining biological productivity in the sea. In the Mediterranean as a whole, concentrations and stocks of these elements are controlled by the exchange through the Straits of Gibraltar and Bosphorus, by atmospheric deposition, by river and groundwater discharge, and by anthropogenic point sources. Nutrient fluxes into and out of the Mediterranean are strongly controlled by the associated water fluxes. By far the greatest exchange rates are observed in the Strait of Gibraltar, where nutrient depleted Atlantic surface water enters the basin and nutrient enriched Mediterranean deep water is exported to the open ocean. Imbalance between both creates a large nutrient deficit which is mainly responsible for the oligotrophic character of the Mediterranean Sea. In **Error! Reference source not found.**, we list the major water and nutrient fluxes into and out of the basin. River water discharge from land to sea accounts only for one tenth of the total water input to the Mediterranean Sea which is about 2.5 10^3 km^3 yr^{-1}. Despite this low river water discharge, rivers account for a large part of nutrients inputs: about 50% for nitrogen and two third for phosphorus.

The general objective of the work of CEFREM is to develop a database and GIS based modeling tool for the assessment of nutrient inputs into the Mediterranean Sea from rivers. Rivers are major pathways for transport of nutrients from terrestrial/ anthropogenic sources to the Sea, and this work is focusing on riverine inputs. River basins integrate the variety of natural and anthropogenic sources that release nutrients (i.e. relevant elements that are necessary to maintain biological productivity) to surface waters, which may successively be transported to the river mouths and hence integrates the marine realm. It is in this sense that rivers can be considered as diffuse nutrient sources to the Sea, not in the sense that point sources (such as urban waste water releases) within the river basins are excluded. At the scale of the entire Mediterranean, diffuse sources from rivers can be opposed to point sources being direct injections of nutrients from industries and/ or big cities along the coastlines. As for atmospheric depositions, these direct nutrient inputs are not considered in the present work.

Chapter 2 - Data availability for freshwater discharge and nutrient concentrations

Creation of a data base on Mediterranean rivers has already been started in the framework of a previous collaboration with MEDPOL (UNEP/MAP/MED POL 2003) and further enlarged via the European integrated research project SESAME (http://www.sesame-ip.eu/). As part of this present RFP, a new and important effort has been made to update the database through:

- screening of the recent scientific literature and existing up-to-date databases
- adding of data for sub-catchments of river basins
- adding of information for each basin and sub-catchment on potential controlling factors of river nutrient fluxes (climate, topography, lithology, land use/land cover and human activities and infrastructures).

The database we created is hence a mixture from different data sources. Not all of these data have been released to the **public domain**; some of them were linked to bilateral agreement between the data owners and CEFREM (Centre de Formation de Recherche sur les environnements méditerranéens), and their further use by third parties needs establishment of individual agreements too. One of our aims is therefore to use this data compilation through reprocessing and statistical analyses (modeling) for the creation of derivation data sets which could then be properly linked to our GIS on Mediterranean rivers, freely available to all end-users.

2.1 Scientific literature

Recent water-quality and discharge data series were collected through a screening of scientific literature in order to compile up-to-date information that has been acquired through independent research activities. *Table* 3 lists the corresponding references (not exhaustive), which are continually updated. Also information and synthesis on factors potentially controlling the spatial and temporal variation of nutrients and water discharge were included in this screening, as well as information on modeling algorithms involving this information. Scientific studies often only allow a punctual and short time view of riverine nutrient concentrations and water and material transfer to the sea, but they are generally more detailed in speciation of different nutrient forms and processes that control their mobilization. In this sense, they are highly complementary to data which have been collected through (public) monitoring networks, as they can help for data quality assessment

Table 3 Recent literature studies on riverine nutrient and water discharge in the Mediterranean region

Data	**Spatial extend**	**References**
Nutrient concentration	Local to regional	Bouza-Deano et al., 2008 ; Cozzi & Giani, 2011 ; de Wit & Bendoricchio, 2001 ; Elewa, 2010 ; Garcia-Esteves et al., 2007 ; Karageorgis et al., 2003 ; Koçak et al. 2010 ; Lassaletta et al., 2009 ; Lopez-Moreno et al 2011; Moran-Tejeda et al., 2011; Moutin et al., 1998 ; Naldi et al., 2010 ; Nikolaidis et al., 2007 ; Oczkowski & Nixon, 2008 ; Skoulikidis et al., 1998 ; Skoulikidis 2002, 2009 ; Snoussi et al., 2002
	Mediterranean Sea	Ludwig et al., 2009, 2010,
	World	Meybeck & Ragu, 1997
Water discharge	Local to regional	Arnell, 1999 ; Bellos et al., 2004 ; Cigizoglu et al., 2004 ; Genev, 2003 ; Giakoumakis & Baloutsos 1997 ; Huss, 2011 ; Kahya & Kalayci, 2004 ; Kuhn et al., 2011 ; Lorenzo-Lacruz et al., 2011 ; Lespinas et al., 2010 ; Ludwig et al., 2004 ; Meddi & Hubert, 2003 ; Mimides et al., 2007 ; Oueslati et al., 2011 ; Quintana-Segui et al., 2011 ; Rees et al., 1997 ; Senatore et al., 2011 ; Shorthouse & Arnell 1997 ; Stahl et al., 2010 ; Touazi & Laborde, 2004 ; Zanchettin et al., 2008
	Mediterranean Sea	Boukthir & Barnier, 2000s ; Chenoweth et al., 2011 ; Cudennec et al., 2007 ; Garcia-Ruiz et al., 2011 ; Gao & Giorgi, 2008 ; Struglia et al., 2004

and identification of major gaps in these networks. Synthesis studies are the basis for large scale extrapolations and trend evaluations.

2.2 Public databases

2.2.1 Nutrient concentrations

The **Waterbase-rivers** dataset (European Environment Agency, http://www.eea.europa.eu/data-and-maps/data/waterbase-rivers-8) contains data on nutrients in water of the WISE-SoE river monitoring stations for all European countries. These data have been assembled from national monitoring programs; they were supplied to EEA through political agreement between EU and associated member states. Alone, it allows a good spatial coverage of nutrient concentrations data in rivers of the Northern Mediterranean sea from the 2000s. This dataset will be regularly updated (last update in 2012). However, the time range of data series is highly variable between countries and rivers of each country.

Largest time range of data series by country: Spain (1990-2010), France (1969-2010), Italy (2000-2010), Slovenia (1990-2010), Croatia (2003-2010), Bosnia and Herzegovina (2000-2010), Montenegro (2009), Albania (1994-2010), Greece (2000-2007), Turkey (only the Big Menderes river, 2005-2010), Cyprus (1997-2010).

The **OECD Environmental Data Compendium** dataset (Organization for Economic Co-operation and Development (http://www.oecd.org/env/environmentalindicatorsmodellingandoutlooks) included time series for some major rivers of the Mediterranean Sea from 1980 to 2004. It helps completing series for some rivers of Italy, Greece and one Turkish River.

2.2.2 Water discharge

The "**Global Runoff Data Center**" datasets (GRDC, http://www.bafg.de) and the **European Water Archive** (EWA, http://www.bafg.de) compile time series of river discharge all over the world for the GRDC dataset and only for European rivers for the EWA dataset. The time series are updated regularly. There are data series for each country of the Mediterranean basin except Bosnia and Herzegovina, Lebanon, Libya and Malta. However, the count of updated data series decline since the 1990s. The data series of water discharge often do not extend during the 2000s except for France, Slovenia and Cyprus. We haven't data since 1990 for Albania, Croatia, Morocco, Tunisia and Turkey.

2.3 National and regional datasets

2.3.1 Nutrient concentrations

Data series are completed using national and regional datasets for the Northwestern Mediterranean basins: Spain (Jucar : http://www.chj.gob.es, Segura : http://www.chsegura.es, Andalusia : http://www.juntadeandalucia.es, Ebro : http://www.chebro.es, Catalonia : http://aca-web.gencat.cat/sdim/init.do), France (http://sierm.eaurmc.fr), Northern Italy (Lazio : http://www.arpalazio.net , Tuscany : http://sira.arpat.toscana.it). There are probably other regional or national datasets but we failed to find them online.

2.3.2 Water discharge

Data series for water discharge were completed using national and regional datasets for the Northwestern Mediterranean basin: Spain (http://hercules.cedex.es/), France (http://www.hydro.eaufrance.fr/), Italy (up to 1996 : https://193.206.192.243/annali, since 1996 (availability limited to the Northern Italy) : Tuscany : http://www.sir.toscana.it, Lazio : http://www.idrografico.roma.it/ (up to 1999), Emilia-Romagna : http://www.arpa.emr.it)) and Slovenia (http://www.arso.gov.si/en/water/data/).

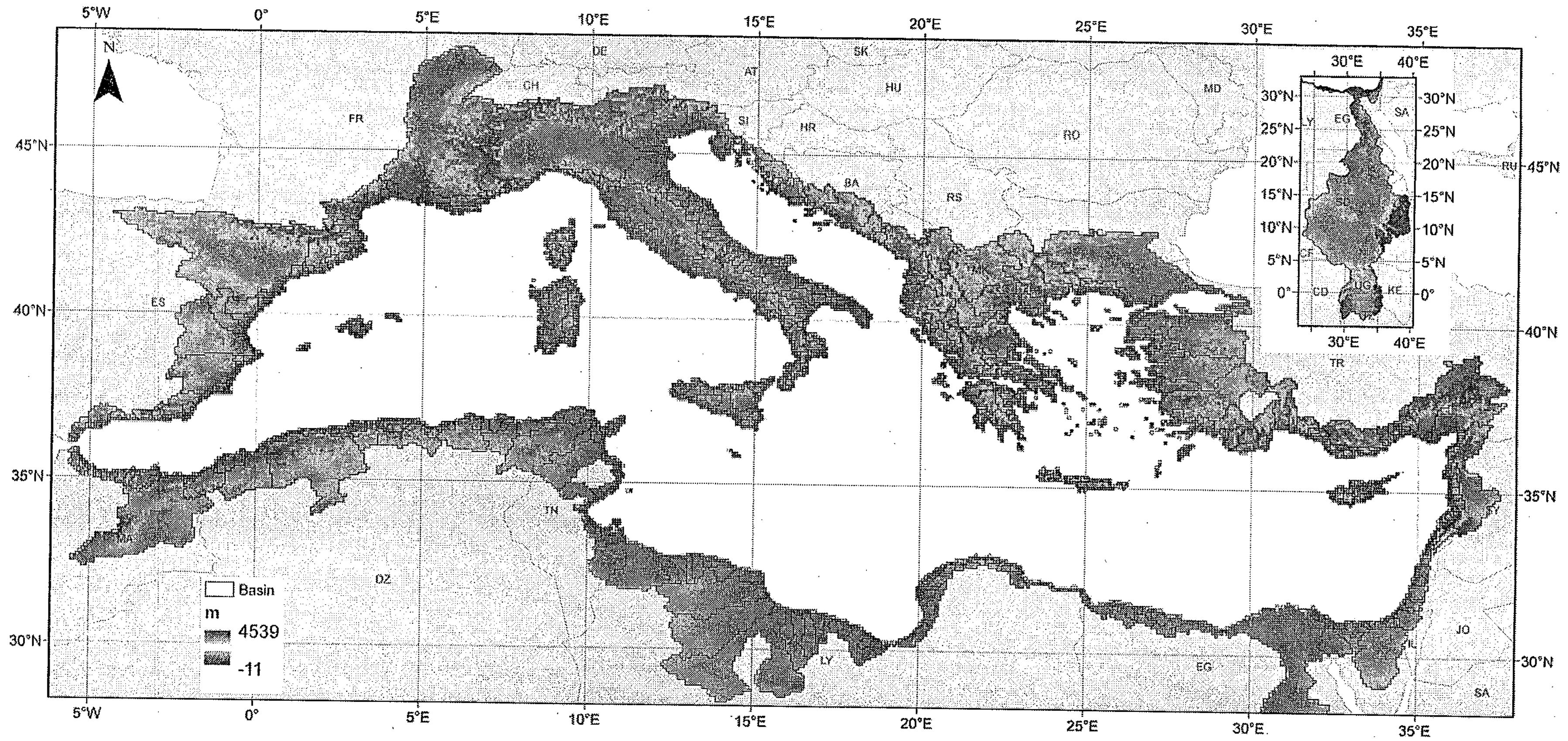


Figure 2 Mediterranean drainage basin, river basins delineation and elevation at 5 arc-minutes resolution. Delineations and elevation were computed from upscaled 15 arc-seconds HydroSHEDS grids, CCM River and Catchment Database and scientific references.

Chapter 3 - River water discharge

3.1 Delineation of Mediterranean River basins

For most rivers, basin boundaries can be evaluated from digital elevation models. HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales) is a mapping product that provides hydrographic information for regional and global-scale applications. It offers a suite of geo-referenced data sets including river basins boundaries, drainage directions, and flow accumulations (Lehner, Liermann & Revenga 2011). HydroSHEDS is based on high-resolution elevation data obtained during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM). In our work, we used the basins boundaries and corrected digital elevation model layers in a 15 arc-second resolution, which is equivalent to a 0.15 km^2 cell area for mid-latitude. We adjusted the basins boundaries and hydrographic network through comparison with other sources, especially in karst and/ or particularly flat areas. For this, we used CCM River and Catchment Database (Vogt 2007) and the European Water Archive for Europe, and scientific references for the whole Mediterranean drainage basin (Bonacci 1999; Bonacci, Jukić & Ljubenkov 2006; Bonacci & Andric 2008). As most data on other drainage basin characteristics are not available at such accurate resolution, we upscaled these basins boundaries at a 5 by 5 minutes resolution. Boundaries are used to constrain the drainage routing grid. These boundaries are the reference delineations for all data extractions out of the data layers considered in this study. The whole Mediterranean drainage area is almost 4.7 10^6 km^2 (Figure 2). In previous studies, this area range from 3.5 10^6 km^2 (Strobl *et al.* 2009) and 5.6 10^6 km^2 (Ludwig *et al.* 2009). This large range is partly due differences in the spatial resolution of digital elevation models and basin delineations in desert regions of the Nile and Northeastern Africa. As no significant runoff or nutrient emissions occur in these desert areas, this uncertainty does not have a major effect on nutrient and water budgeting. The Nile (Table 4), the largest African River, covers roughly 3.0 10^6 km^2, which is one-tenth the area of Africa and 63% of the whole Mediterranean drainage basin. Surrounded by numerous mountain chains (e.g. Atlas, Apennine, Alps, Dinarids, Hellenids, Taurus Mountains), the other Mediterranean River basins are confined to a relative small coastal fringe with steep terrains (Figure 2). This can be seen Figure 3 when ranking the Mediterranean rivers according to basin size, showing that about half of the Mediterranean drainage basin is formed by river basins smaller than 15 000 km^2 (not counting the Nile river).

Table 4 Ten largest river basins flowing to the Mediterranean Sea and countries covered by them (bold: countries of the river mouth)

River name	Drainage area (10^6 km²)	Countries
Nile	2.988	**Egypt**, Ethiopia, Sudan, South Sudan, Rwanda, Tanzania, Uganda, Burundi, D.R..Congo, Eritrea, Kenya
Rhone	0.098	**France**, Swiss
Ebro	0.086	**Spain**
Po	0.074	**Italia**
Moulouya	0.055	**Morocco**
Meric (Evros)	0.053	**Greece, Turkey**, Bulgaria
Chelif	0.045	**Algeria**
Büyük Menderes	0.026	**Turkey**
Axios (Vardar)	0.025	**Greece**, Macedonia
Orontes (Asi)	0.024	**Turkey**, Lebanon, Syria

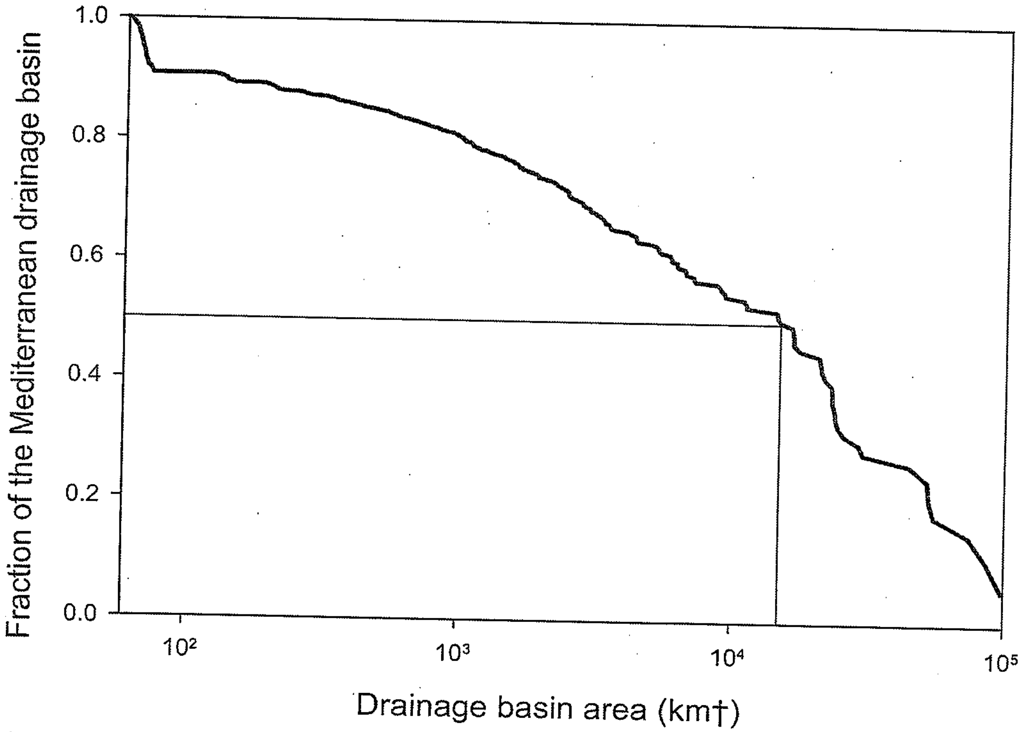


Figure 3 Cumulative distribution of drainage area for Mediterranean River basins (not counting the Nile River)

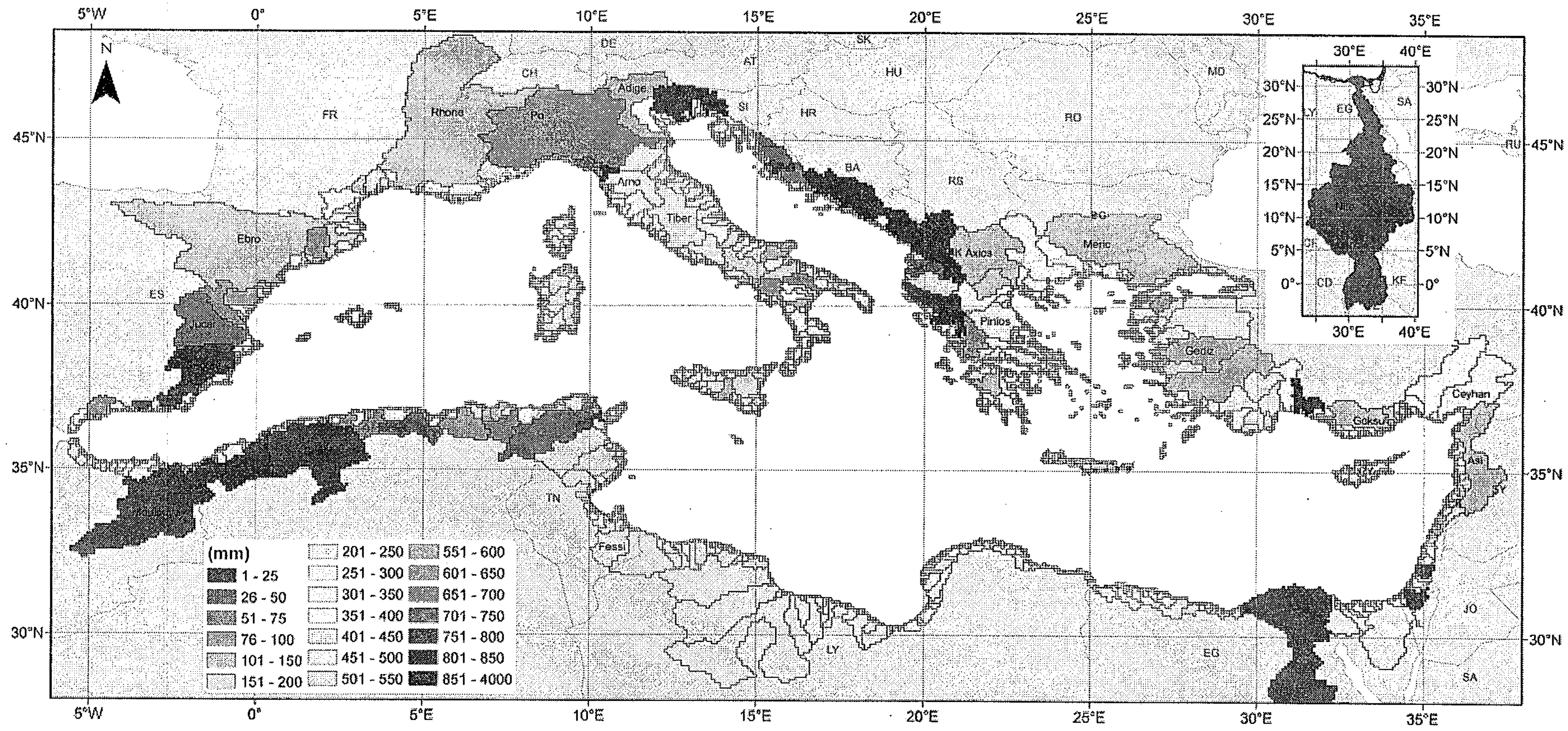


Figure 4 Interannual average of annual river runoff computed with discharge data series from GRDC, EWA, national and regional databases and completed with interannual values from scientific references.

3.2 Spatial variation of river water discharge

Interannual river water discharge and runoff (i.e. water discharge per unit area) is compiled by river in the Annexes

Annexe 1. On average, the rivers for which we found discharge series cover about 85% of the Mediterranean drainage basin and 60% excluding the Nile (Figure 4). Most of lacking data are located in North Africa where runoff is assumed to be closed to zero. Basins, where runoff data are available, catch 90% of total precipitation over the Mediterranean drainage basin (71% excluding the Nile). Using the Pike formulation to estimate lacking data (see 3.3.1), we may estimate than our data cover 83% of the total water discharge (with or without the Nile). Largest freshwater discharge is provided by the Rhone with 52.4 km^3 yr^{-1} in the Northwestern Mediterranean Sea. The second largest freshwater discharge is provided by the Po to the Adriatic Sea (45.3 km^3 yr^{-1}). Both rivers of the Northern Mediterranean Sea provide about 25% of the total continental freshwater discharge. Two other rivers discharge more than 10 km^3 yr^{-1}: Buna-Drini (21.4 km^3 yr^{-1}) and Nile (about 15 km^3 yr^{-1}). Among the fourteen rivers discharging more than 5 km^3 yr^{-1}, six have their mouth along the Adriatic Sea (Po, Buna-Drini, Adige, Soca, Neretva and Vjosa). Others rivers discharging more than 5 km^3 yr^{-1} are in Spain (Ebro), Italy (Tevere) and Turkey (Seyhan, Ceyhan, Meric (mouth on the Greece/Turkey boundary) and Susurluk). The size of the drainage basin is the first factor of the spatial variability in freshwater discharge (Figure 5). Thus, the flow of the Nile, the Rhone, the Po, and Ebro are among the highest. Despite this constraint, we observe a strong heterogeneity of freshwater discharge between rivers irrespective of the drainage area. For example, the Nile freshwater discharge is lower than that of Buna-Drini while its drainage area is more than 100 times larger. Expressed per unit of area, the river runoff roughly decreases from Northern to Southern Mediterranean Sea. Highest runoffs are gauged in karstic area of the Taurus region (Kopru, Manavgat) and the Eastern Adriatic Sea (more than 1000 mm yr^{-1} for Buna-Drini, Neretva, Soca, Trebisjnica, Mati and Arachtos). For the Manavgat, the calculated runoff reaches more than 3000 mm yr^{-1}. This strong discharge (higher than precipitation depth on the topographical drainage area) is probably due to external input of groundwater from farther north endorheic areas. For most African and Southern Spanish rivers, runoff is lower than 25 mm yr^{-1}. The Nile, Moulouya and Chelif, runoff are 5, 8 and 13 mm yr^{-1}. For the Po and Rhone, it reaches 646 and 548 mm yr^{-1}.

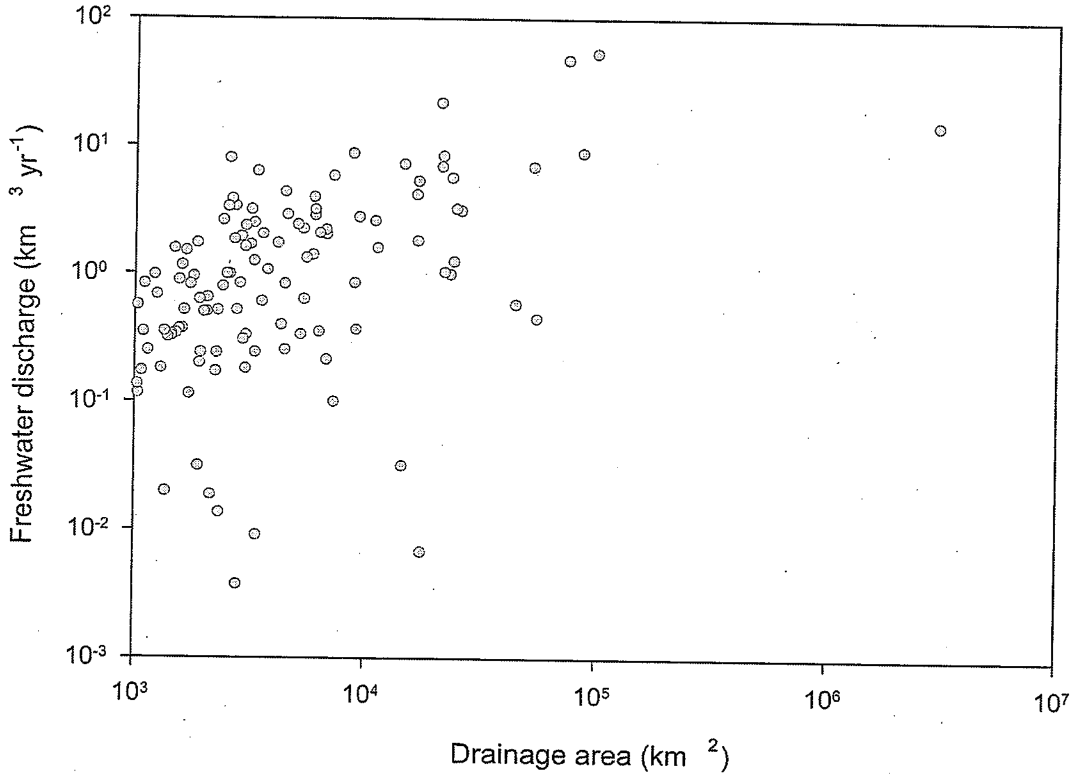


Figure 5 Freshwater discharge and drainage area of Mediterranean rivers

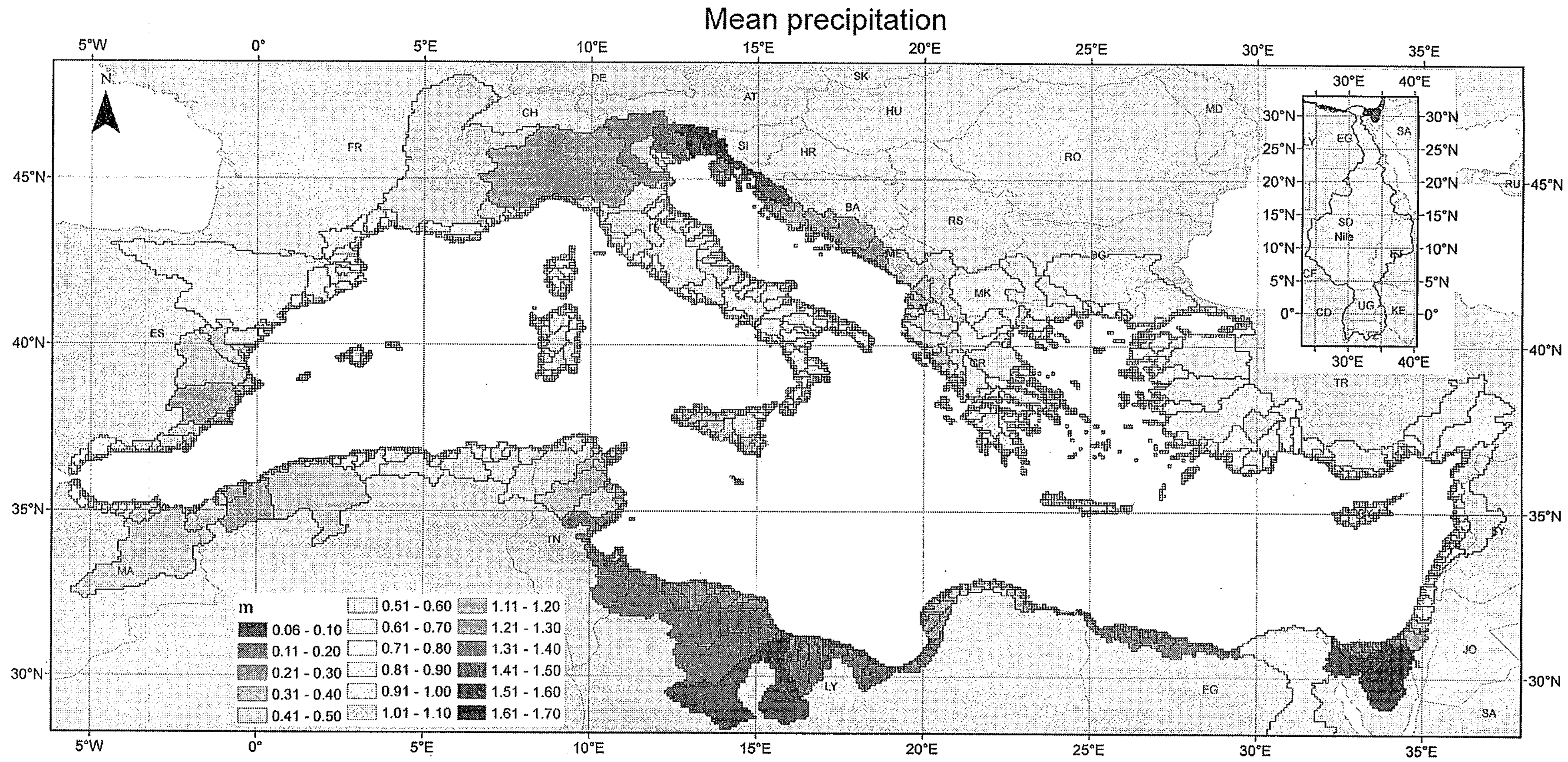


Figure 6 Interannual average of annual precipitation within Mediterranean river basins (1901-2009) calculated from CRU 3.10.1 downscaled at a 5 arc-minutes resolution

3.3 Main drivers of spatial change in riverine runoff

3.3.1 Climate

A major peculiarity of Mediterranean rivers is related to climatic constraints. Probably the most important criterion in defining the Mediterranean climate type (Peel, Finlayson & McMahon 2007) is related to the strong seasonal rainfall contrast between the summer and winter (autumn) seasons. However, spatial coverage of Mediterranean drainage area is not the same that Mediterranean climate and the drainage basin includes some important variations. The Mediterranean climate covers the drainage basins of Southern Italy, Southern Greece, Middle East and Maghreb. In Spain, climate is dryer and is classified as arid. From the Northern Spain to Northern Adriatic Sea, there are no dry seasons and temperatures are colder. The peculiarity of the Nile is the Northern to Southern climatic gradient with an equatorial climate upstream and desert climate at his middle course and near the mouth.

Using 1901-2009 data from CRU 3.10.1 (Mitchell & Jones 2005), total precipitation and potential evapotranspiration volumes over the Mediterranean drainage basin are 3.0 10^3 km^3 yr^{-1} and 7.0 10^3 km^3 yr^{-1}. Average precipitation (Figure 6) and potential evapotranspiration depth were 630 mm yr^{-1} and 1487 mm yr^{-1}. Precipitation depth ranges from less than 49 mm yr^{-1} to more than 1639 mm yr^{-1}. Largest precipitation depths were recorded at the Northern and Eastern Adriatic Sea and in the Rhone basin. Lowest precipitation depths were recorded at the Southern and Southeastern Mediterranean Sea (excluding the Nile). For the five largest basins, the average precipitation depths are 650, 1049, 615, 1233 and 353 mm yr^{-1}. Potential evapotranspiration depth ranges from 485 to 1867 mm yr^{-1}. Largest potential evapotranspiration depth were calculated were precipitation is lowest and in the Nile basin. Lowest potential evapotranspiration depths were calculated for the Northern Adriatic Sea and for the Rhone. For the five largest basins, the average potential evapotranspiration depth is 1702, 798, 1027, 705 and 1419 mm yr^{-1}.

While difference in drainage area explains a large part of the spatial variation in freshwater discharge, precipitation and temperature are the main drivers of spatial variation in runoff, i.e. freshwater discharge per unit of drainage area. Precipitations generate runoff from soils to rivers and temperature influence the potential evapotranspiration from soil to atmosphere. According to Ludwig *et al.* (2009), quantification of the combined effect of precipitation (P) and temperature on Mediterranean river runoff (R_0) can be estimated by the approach of Pike (1964).

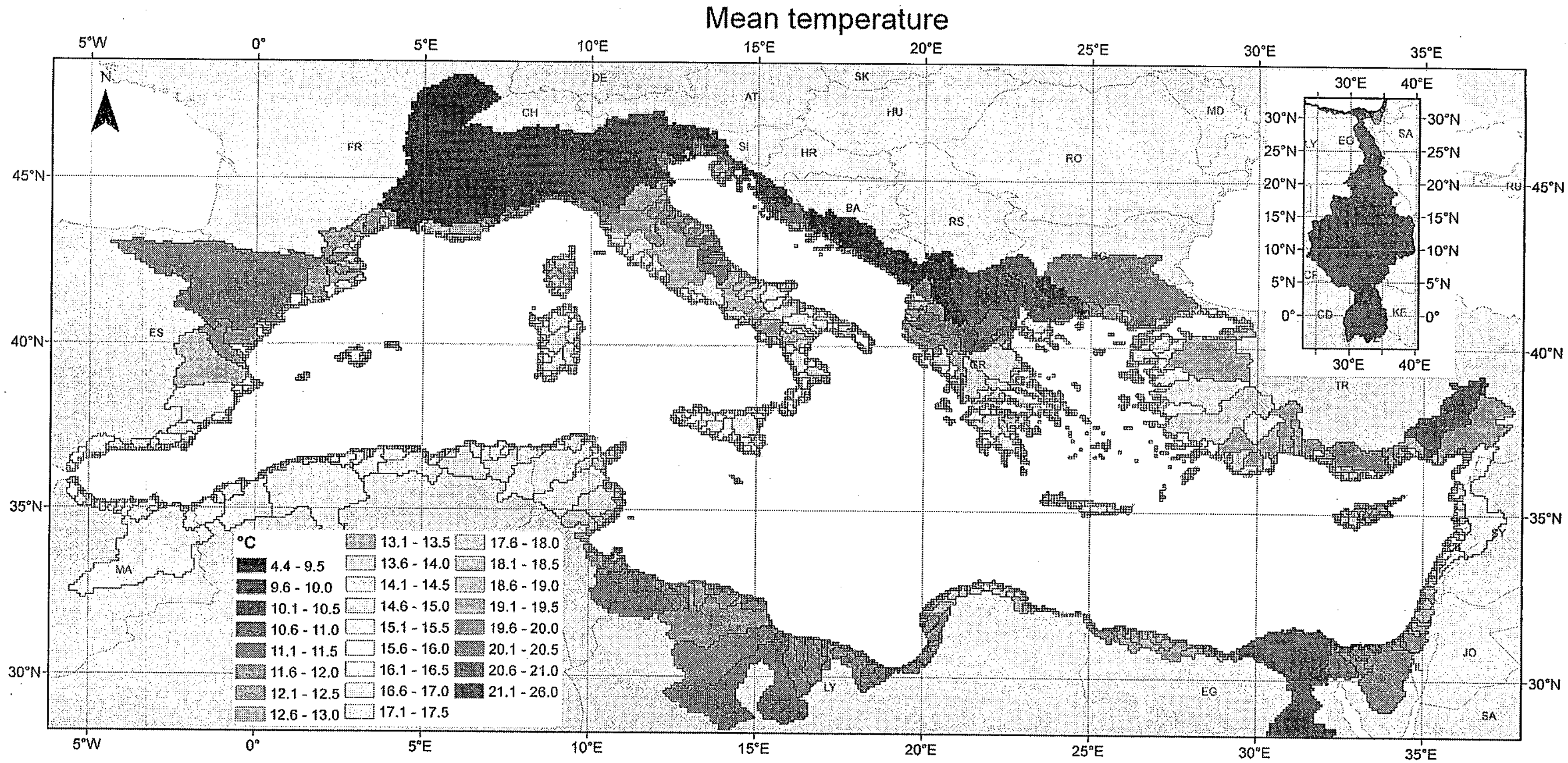
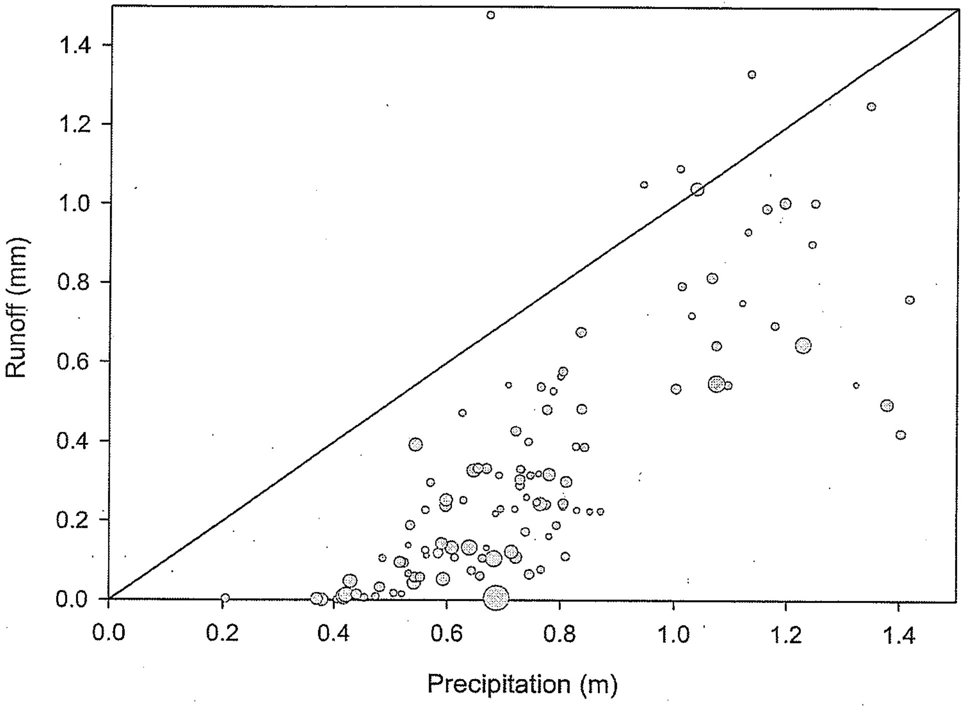


Figure 7 Interannual average of average temperature within Mediterranean river basins (1901-2009) calculated from CRU 3.10.1 downscaled at a 5 arc-minutes resolution

$$R_0 = P \cdot \left(1 - \frac{1}{\left(1 + \left(\frac{P}{58.93 \cdot ABT}\right)^2\right)^{0.5}} \right)$$

ABT is the annual mean of monthly temperature with negative values set to 0.

The Pike formulation allows a good estimation for major rivers (Nile, Ebro, Rhone, and Po). However, we observe a widespread underestimation for the rivers of the Eastern Ionian and Adriatic Seas and the Southern Italy and Turkey. This underestimation may be due to an underestimation of precipitation or to an overestimation of evapotranspiration. In contrast, the modeled flow is greater than the measured flow for most South Mediterranean Rivers and Spanish Rivers. This overestimation can be partly explained by the impact of water withdrawals, including irrigation, on the observed discharge which is not taken into account in this formulation.



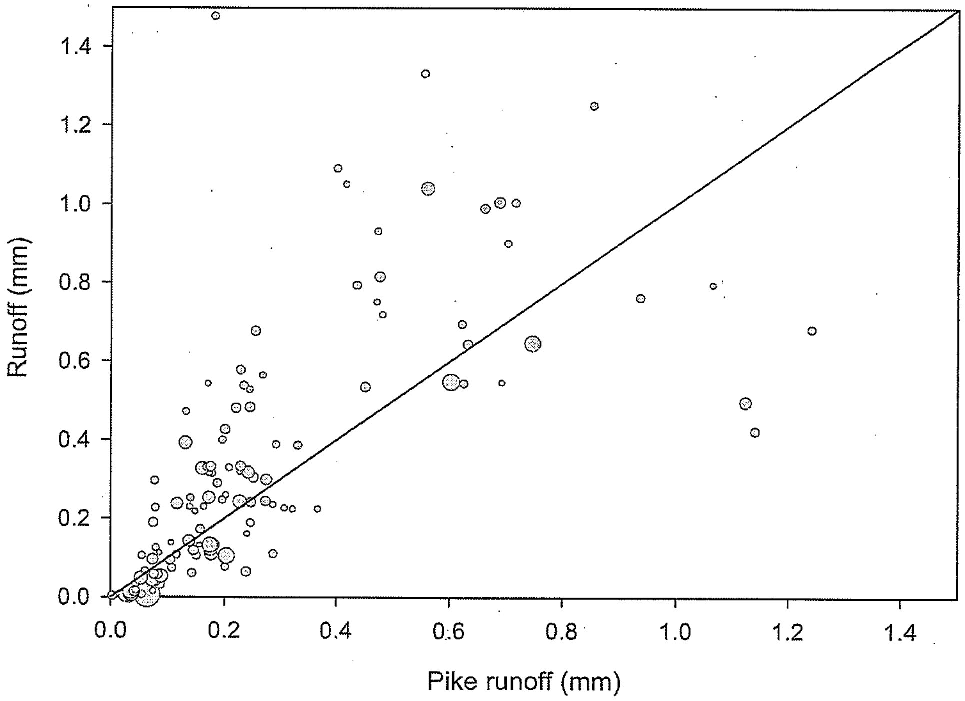


***Figure** 8 Runoff as function of precipitation (up), and Pike runoff (down). Size of the dots is proportional to the drainage area of each basin*

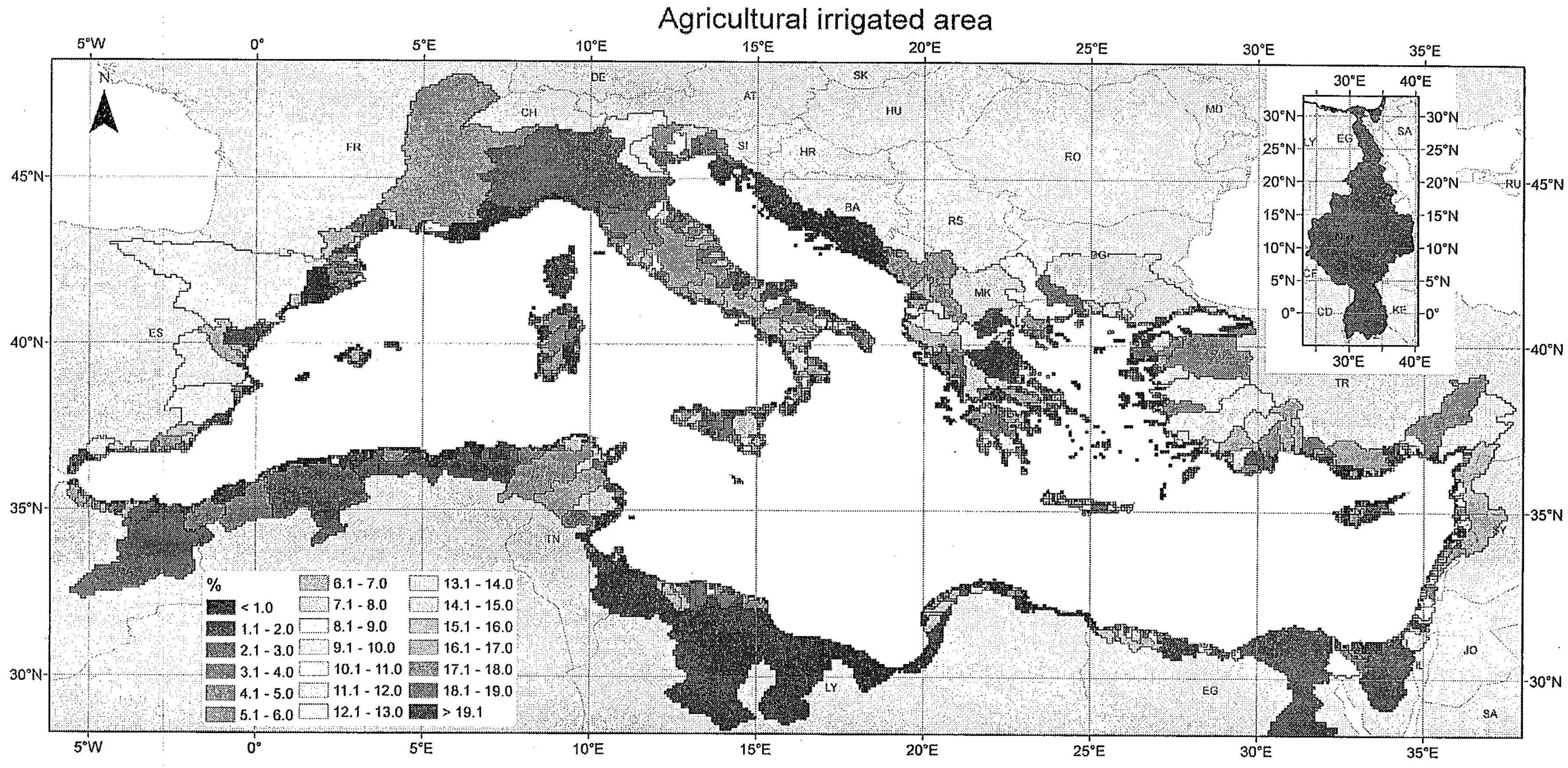


Figure 9 Agricultural irrigated area for each Mediterranean river basin computed from Harmonized World Soil Database

3.3.2 Water use

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. Irrigation existed for millennia in these regions and has been widely developed over the past decades with cultivated areas expansion and intensification. In Spain, 70% of fresh-water demand is devoted to irrigation (Lorite, Mateos & Fereres 2004). Irrigation is responsible for the highest water consumption due to an increased evapotranspiration rate unlike most of drinking water and industrial water returned to rivers. About 99% of water used in agriculture is lost by crops as evapotranspiration (Rana & Katerji 2000). The "Land Use and Land Cover" grid of the Harmonized World Soil Database map the irrigated and rainfed field at the world scale (Fischer *et al* 2008). We used these grids to compute irrigated area for each Mediterranean basin. The large basins with largest irrigation rate (*Figure* 9) are Acheloos (29%), Pinios (24%), Po (22%), Orontes (15%) and Ceyhan (14%). For the Ebro, Rhone and Nile, irrigated areas cover 9%, 4% and 2% of the basin area. Despite a low value for the Nile, irrigated area cover most of the Nile delta. Under the assumption that actual evapotranspiration in irrigated crops is equivalent to the potential evapotranspiration, we can estimate the total evapotranspiration taking into account irrigation effect using this next formulation:

$$R = R_0 - \frac{A_{irri}}{A}(ETP - E_0)$$

For the Nile and other Northeastern African basins (*Figure* 10), the water requirement within irrigated area is stronger than the natural runoff. In Northwestern Africa, this water requirements range from 30 to 100% in Morocco and Eastern Algeria and reach 100% of the natural runoff in Tunisia. For the Orontes, this water accounts for 79% of its natural runoff. Despite a very large irrigated area and as the water deficit is relatively low in the Po basin, the impact of irrigation on the water discharge is relatively low compared to the Southern Mediterranean basins where the irrigated area is lower but the water deficit much stronger. For the Nile, the flux of evaporated water within the delta, since the Aswan Dam construction in 1965, is about 20 km^3 yr^{-1}, i.e. about 60% of the natural runoff at the delta head (Mikhailova 2001).

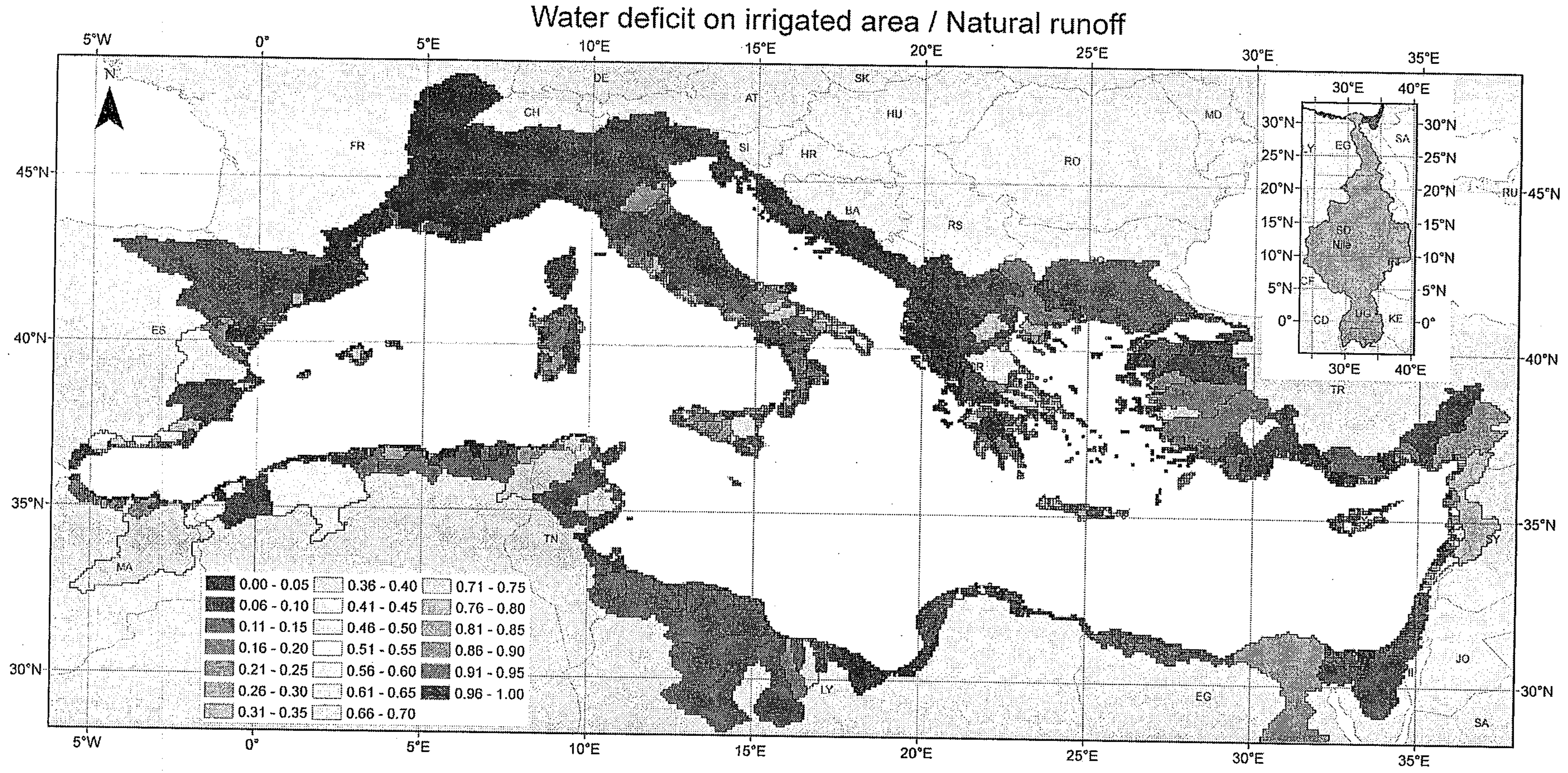

Water deficit on irrigated area / Natural runoff

Figure 10 Water deficit on irrigated area divided by natural runoff computed from Harmonized World Soil Database and the Pike runoff formulation

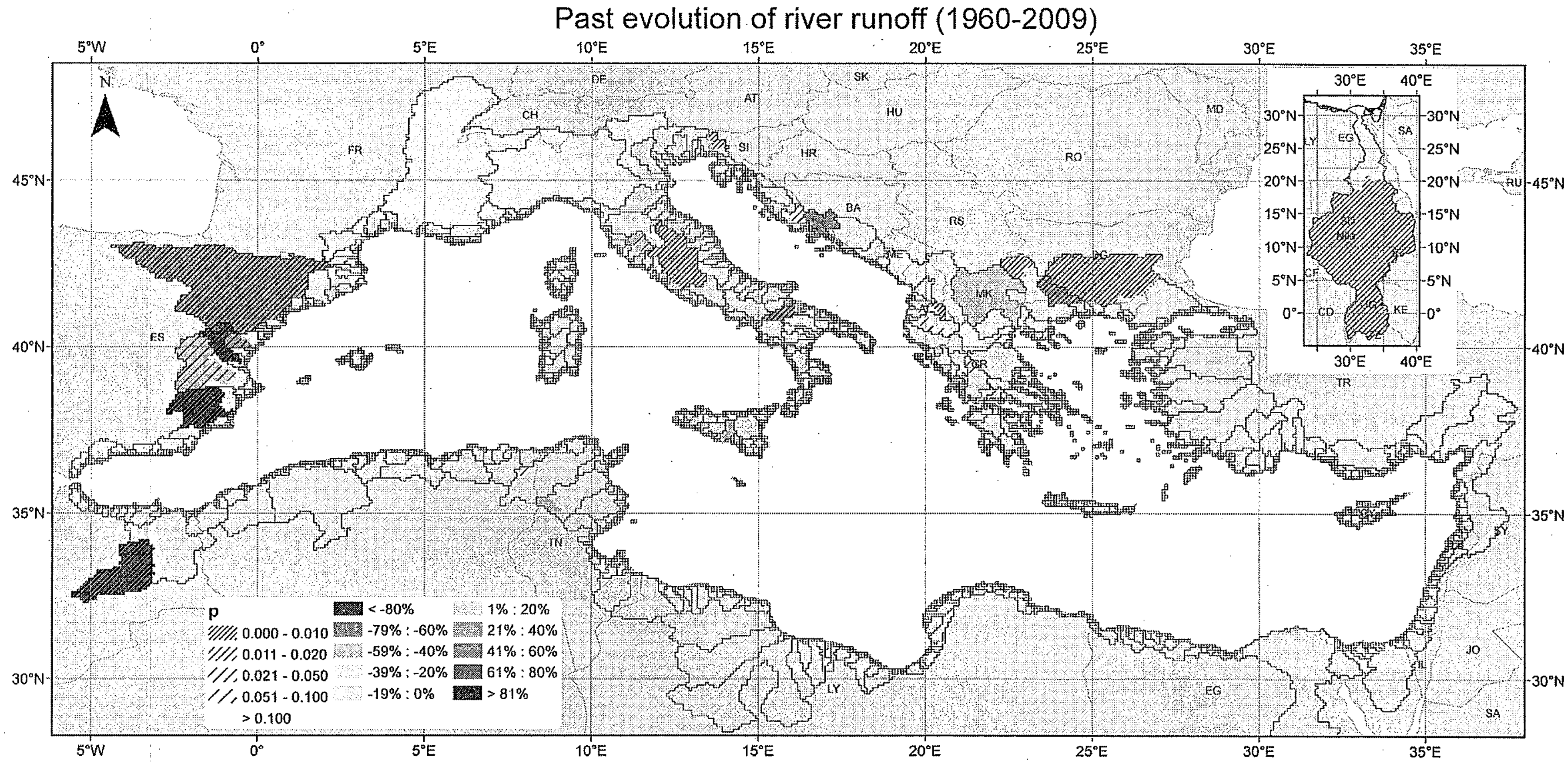


Figure 11 Relative runoff change for Mediterranean rivers between 1960 and 2009 and significance threshold of trends (p). Only data series without gap and longer than 20 years was used to compute trend

3.4 Past evolution of freshwater discharge

We performed trend analyses for water discharge data series using the Yue and Pilon method (Yue *et al.* 2002). The trend slope is estimated with the Theil-Sen approach, if almost equal to zero, then it's not necessary to conduct the trend analysis. If it differs from zero, then it is assumed to be linear and the data is detrended by the slope and the autoregressive model of order 1 is computed for the detrended series. This is referred to as the Trend Free Pre-whitening procedure. The Mann-Kendall test is applied to the blended series to assess the significance of the trend. Only data series without gap and longer than 20 years was used to compute trend.

Most of the Mediterranean rivers in our compilation of discharge series reveal a strong negative trend (*Figure* 11). In Maghreb, a significant decrease is observed for the Moulouya (Morocco, -82%) and Medjerda (Algeria, -39%). For the Nile, upstream of Egypt boundary, a 30% decrease was detected between 1960 and 1995. The strongest decrease is observed in the Segura with more than -99% from 1960 to 2009. For the Turia, this decrease reaches 86%. For all Spanish rivers, the decrease is more than 50%. In Greece, significant decreases are calculated for the Nestos, Meric, Strymon and Acheloos and ranged from 65% for Nestos between 1966 and 1995 and 29% for Strymon between 1968 and 1999. For the other Greek rivers, a non-significant but negative slope is computed (Axios and Aliakmon). In Southern Italy, significant runoff decreases are observed for the Ofanto (-63% from 1960 to 1996) and Tevere (-45% from 1960 to 2008). In the Eastern Adriatic Sea, negative trend was detected for the Soca (Slovenia, -29% from 1960 to 1998), Krka (Croatia, -26% from 1960 to 1998), Shkumbini (Albania, -41% from 1960 to 1990) and Osumi (Albania, -38% from 1960 to 1989). For Northern Italy (Adige, Po, Arno) and the Rhone river, no significant trend was detected in the time series. The only positive value, but non-significant, was computed for the Imera Mediridionale in Sicilia. In *Annexe* 1, river runoff for the last 20 years recorded is lower than value over whole time series for 88% of rivers. Expressed in water depth (*Figure* 12), the highest significant decreases are computed for the Acheloos (-20 mm yr^{-1}), Shkumbini (-15 mm yr^{-1}), Nestos (-9mm yr^{-1}) and Krka (-6 mm yr^{-1}). For the Segura, Turia and Moulouya, where the relative decrease is maximal, the absolute decrease is lower than 2 mm yr^{-1}. This general runoff decrease for Mediterranean rivers was also shown for the whole twentieth century (Milly, Dunne & Vecchia 2005).

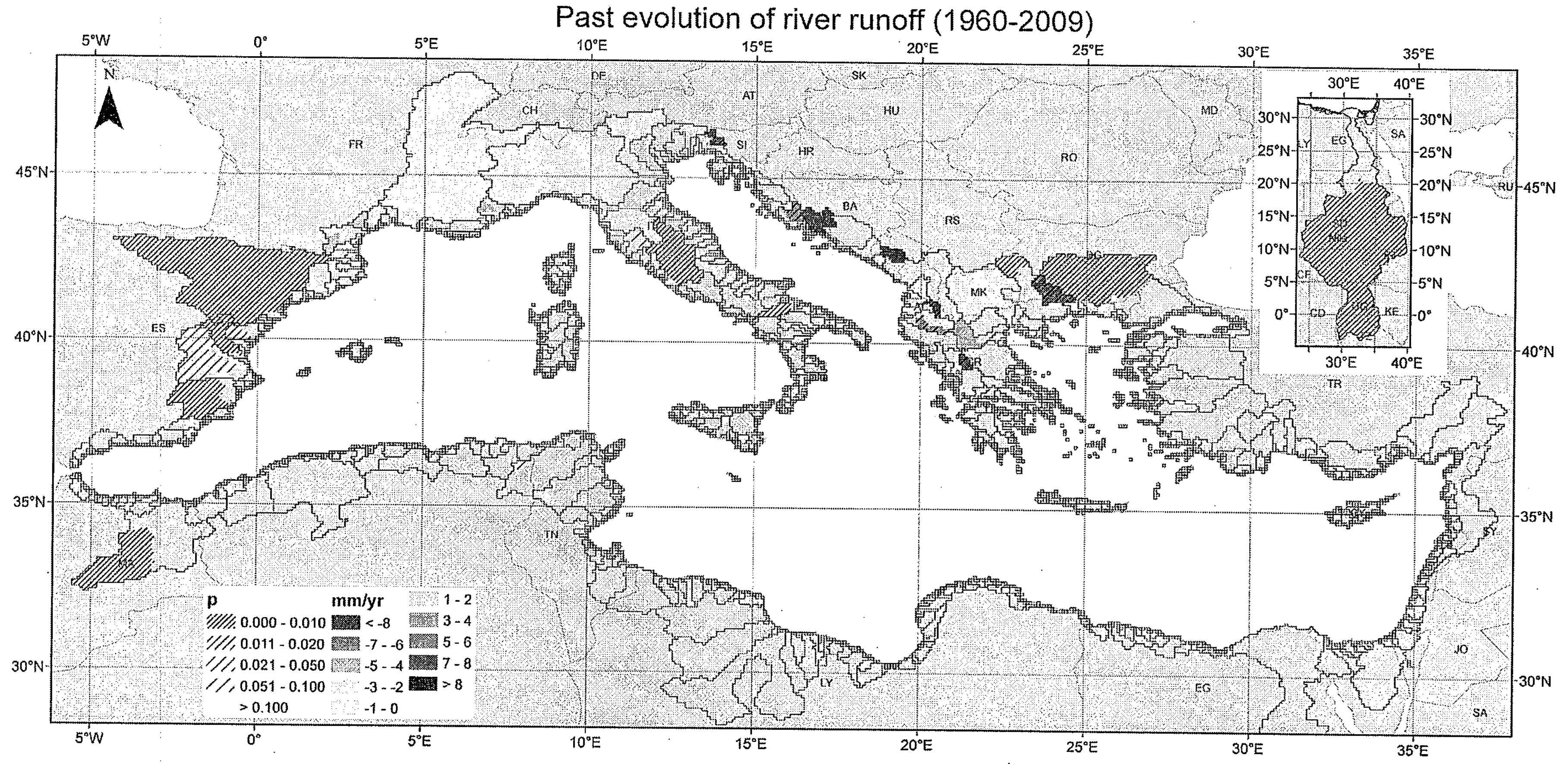


Figure 12 Absolute runoff change for Mediterranean rivers between 1960 and 2009 and significance threshold of trends (p). Only data series without gap and longer than 20 years was used to compute trend

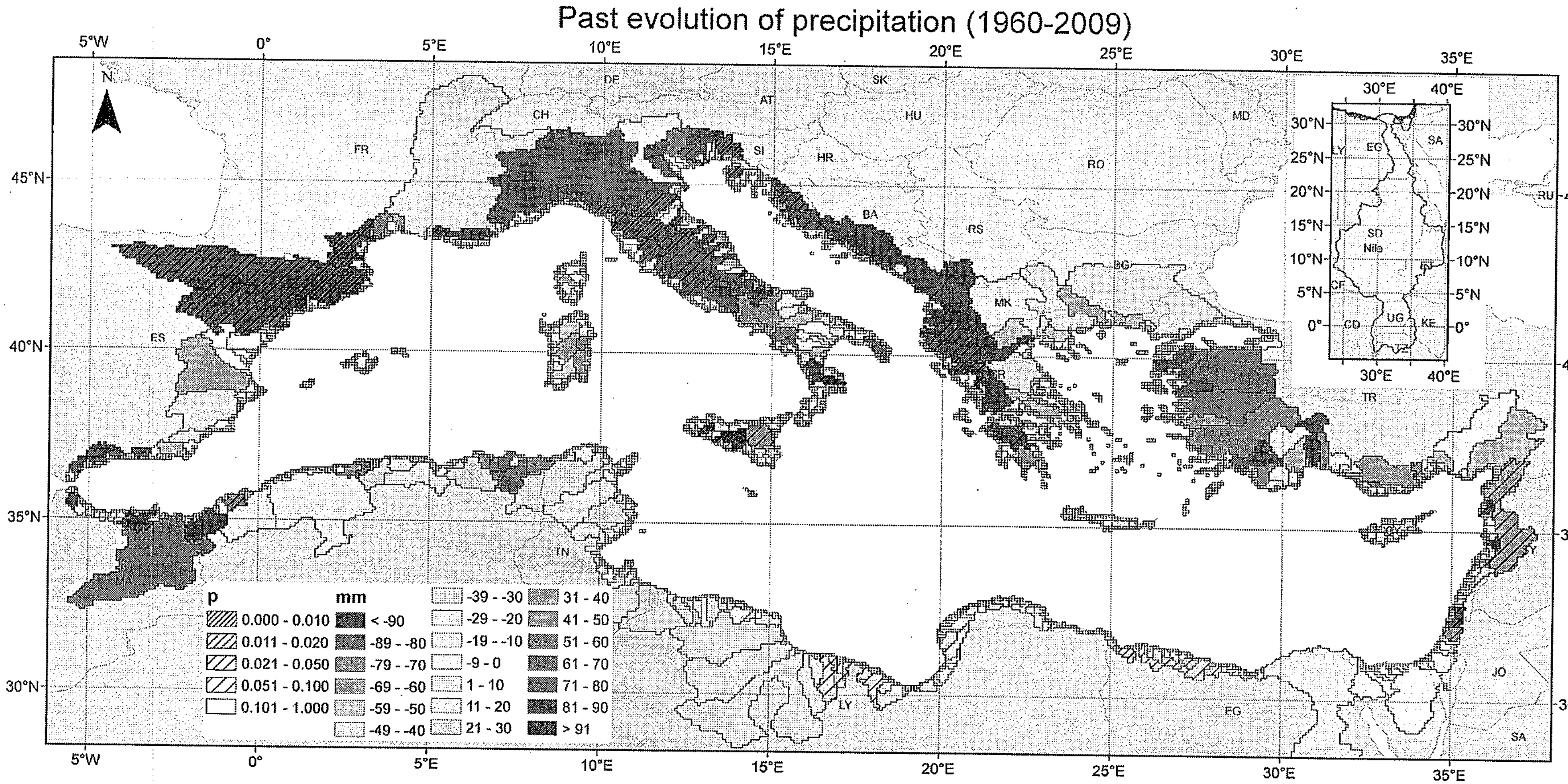


Figure 13 Absolute precipitation change for Mediterranean rivers between 1960 and 2009 computed from downscaled CRU 3.10.1 data and significance threshold of trends (p)

3.5 Main drivers of freshwater discharge evolution

3.5.1 Climate

As for spatial variability, interannual change in freshwater discharge is mainly controlled by precipitation change. Precipitation is highly variable from year to year but long-term trends can be observed. Philandras *et al.* (2011) showed that statistically significant negative trends of the annual precipitation totals exist in the majority of Mediterranean regions during the period 1901–2009, with an exception of northern Africa, southern Italy where slight positive trends (not statistically significant) appear. For the 1960-2009 period, only one significant trend (Ebro) was calculated among the twenty largest Mediterranean basins (Figure 13). However, the slope, non significant, is negative for most of the Mediterranean Rivers except Middle Northern Africa and Southern Italy. Significant decreasing trends are computed for many rivers of the Eastern Adriatic and Ionian Seas, central Italy, Northern Spain and Eastern Levantine Sea.

For Ebro, rainfall decreased by 104 mm in the last 50 years (15% of the interannual average centered on 1960). Decreases greater than 300 mm are calculated for the Serchio and Reno in Italy. By comparing the slope of changes in precipitation and flow rates (Figure 14), we note that for most runoff decreases, we also observe a decrease in precipitation.

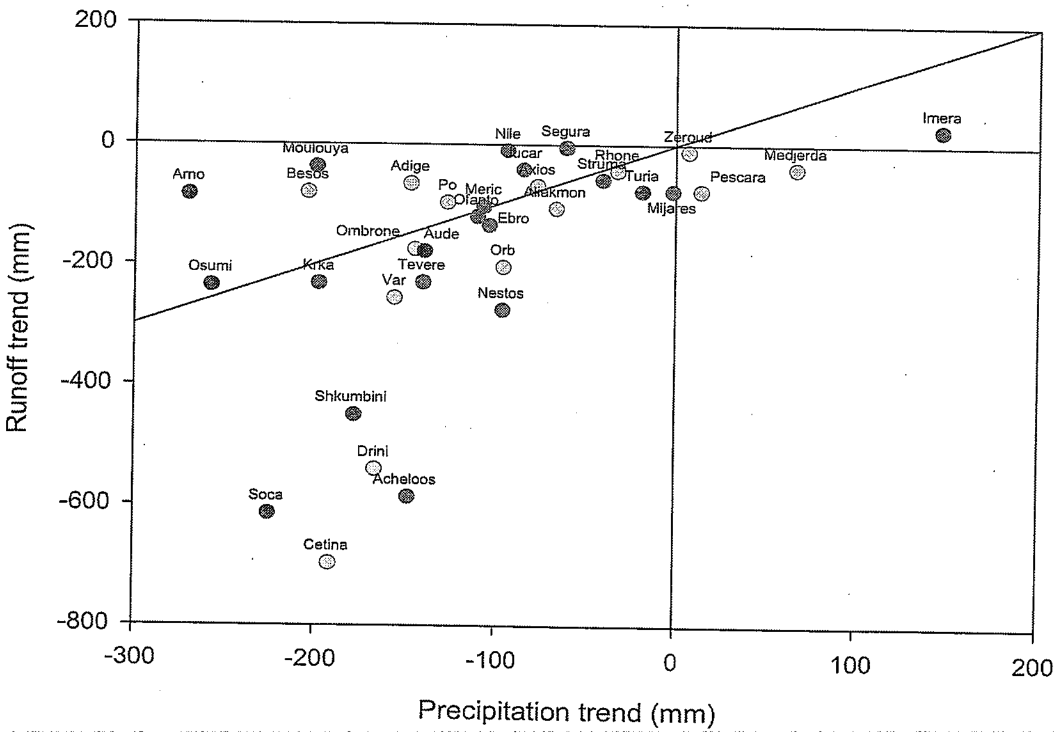


Figure 14 Runoff and precipitation trend between 1960 and 2009 in Mediterranean Rivers. Blue dot: signicant trend for precipitation, green dot: significant trend for runoff, red dot: significant trend for both precipitation and runoff, grey dot: non-significant trends. Only water discharge data series without gap and longer than 20 years was used to compute trend

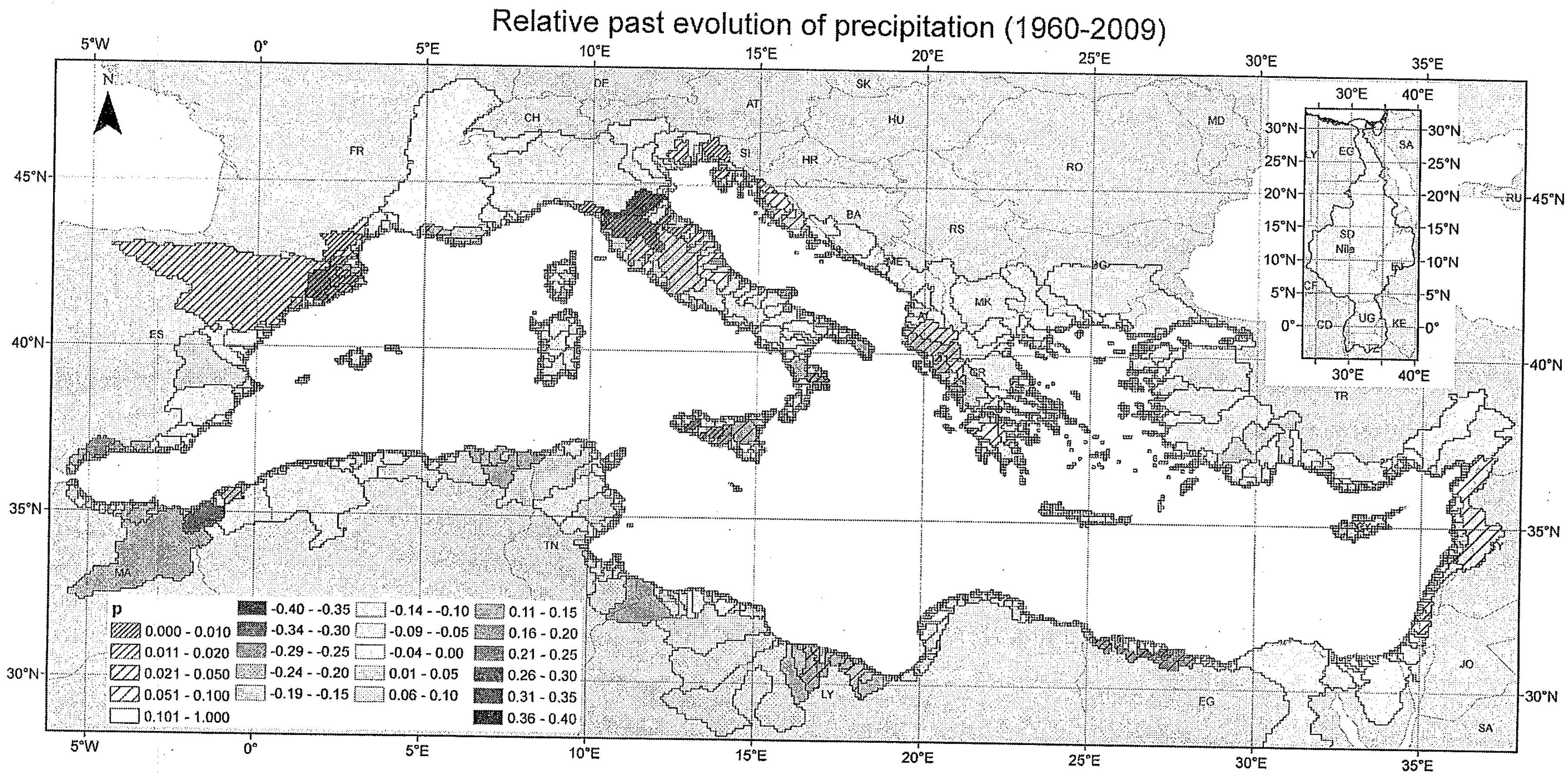


Figure 15 Relative precipitation change for Mediterranean rivers between 1960 and 2009 computed from downscaled CRU 3.10.1 data and significance threshold of trends (p)

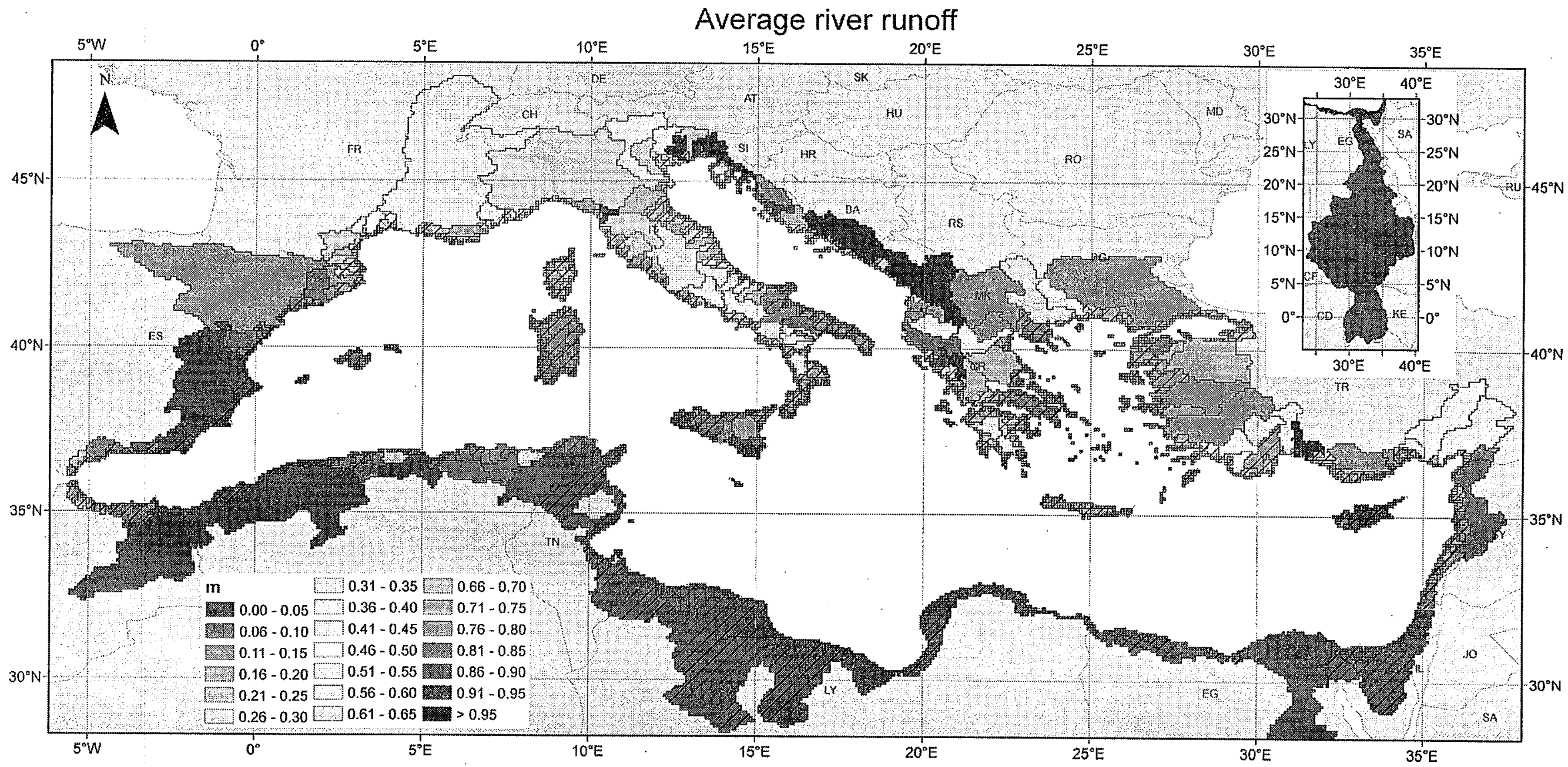


Figure 16 Actual annual river runoff (hatched: Pike runoff calculated with climatic data of IMAGE 2.4 for 2000s, non-hatched: gauged runoff (Figure 4))

3.6 Budget and future scenarios for riverine runoff

To assess the actual water discharge by rivers in the Mediterranean Sea, we used the past 20 years average of annual data series or interannual average when data series are not available. For other rivers, we used the Pike formulation (*Figure* 16). Actual water discharge by rivers is about 402 km^3 yr^{-1}. This estimation is closed to the previous assessment of Margat & Treyer (2004), with 396 km^3 yr^{-1} (not accounting for groundwater discharge). Other values from recent studies are lower and range from 320 (excluding the Nile) to 350 km^3 yr^{-1} (Boukthir & Barnier 2000s; Ludwig *et al.* 2009; Bouraoui, Grizzetti & Aloe 2010). Freshwater discharge to the Adriatic Sea reaches 155 km^3 yr^{-1}, i.e. 38.5% of total freshwater discharge (*Table* 5). The Northwestern Mediterranean Sea, Aegean Sea and Northern Levantine Sea receive 85, 50 and 45 km^3 yr^{-1}. Sum of freshwater provided by the Northern Mediterranean Rivers covers 93% of the total freshwater discharge. With about 15 km^3 yr^{-1}, The Nile discharges 59% of the total freshwater provided by Southern Mediterranean Rivers.

Climatic scenarios used to assess freshwater discharge in 2030s were provided by the IMAGE 2.4 model of the Netherland Environmental Assessment Agency (MNP, 2006). One of the peculiarities of the IMAGE model is that the future climate is directly linked to the socioeconomic development via the release of greenhouse gases to the atmosphere. This implies that climatic scenarios associated with the four socioeconomic scenarios (see 4.6.1) are not the same. For 2030s, we calculate a decrease of 11.6 to 12.0% depending on the scenario used, i.e. a total freshwater discharge between 354 and 360 km^3 yr^{-1}. Other studies show that this decrease is expected to continue during the next decades (Mariotti *et al.* 2008; Elguindi *et al.* 2009). However, these scenarios do not take account of irrigation and reservoir capacity change in the next decades. Due to the demographic growth and intensification of agriculture projected for the Eastern and Southern Mediterranean basins, the decline of water discharge should be stronger than these calculated values.

Table 5 Average actual freshwater fluxes (km^3 yr^{-1}) to the Mediterranean Sea and 2030s scenarios

Sea sub-basin	**2000s**	**2030s TG**	**2030s AM**	**2030s GO**	**2030s OS**
NWE	85	79	78	78	79
TYR	20	18	18	17	18
ION	20	18	17	17	18
ADR	155	144	143	142	143
AEG	50	41	40	40	41
NLE	45	36	35	35	36
SLE	16	16	16	16	16
CEN	2	1	1	1	1
SWE	6	5	5	5	5
ALB	4	3	3	3	3
TOTAL	402	360	356	354	358

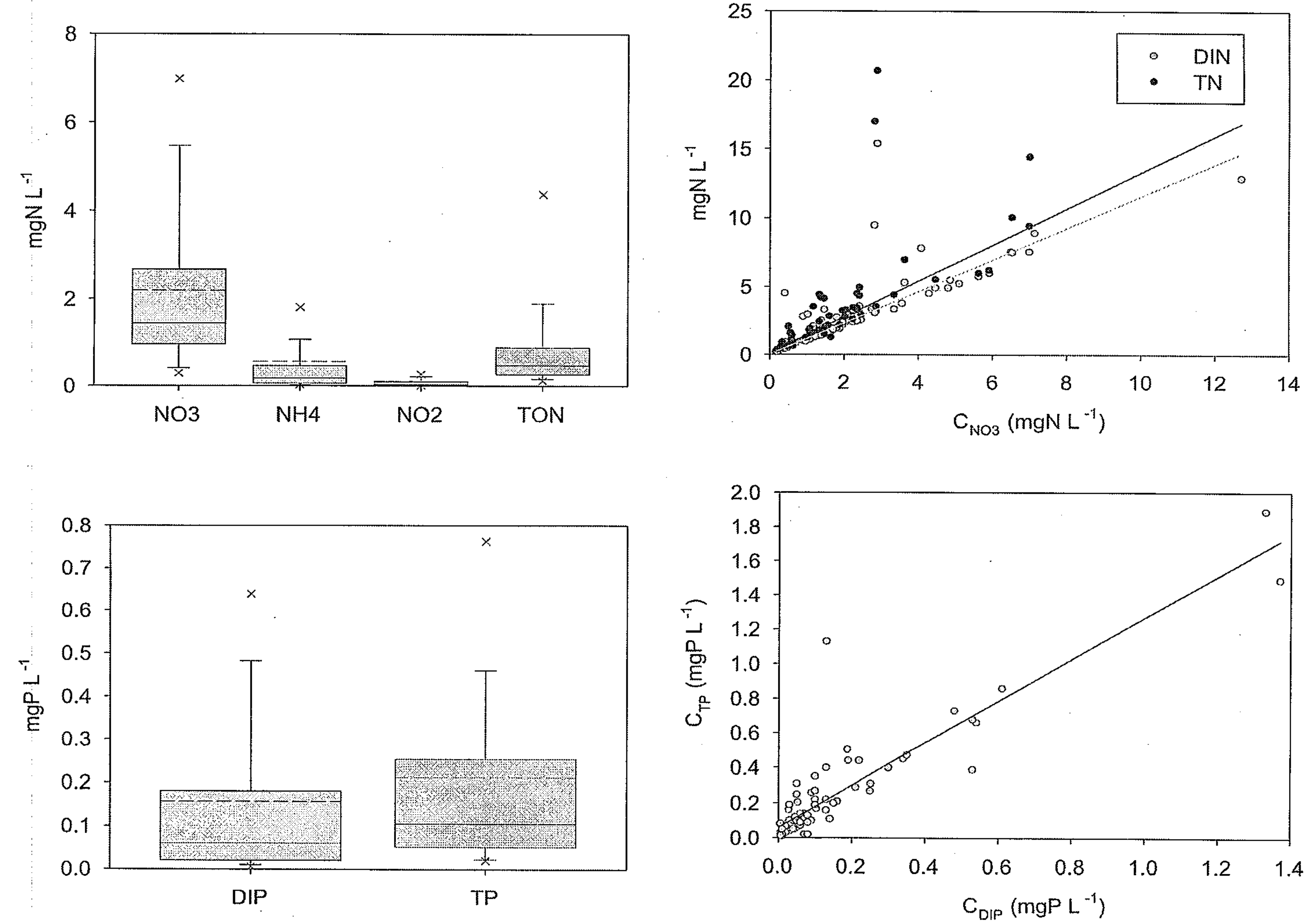


Figure 17 (A) Box plot of concentrations in Mediterranean rivers for phosphorus and nitrogen compounds and (B) concentrations in dissolved inorganic nitrogen as function of nitrate concentrations (up) and total phosphorus as function of dissolved inorganic phosphorus concentrations (down).

Chapter 4 - Nutrient concentrations and fluxes

4.1 Forms and concentrations of nitrogen and phosphorus in rivers

Various organic and inorganic compounds have to be taken into account nitrogen and phosphorus fluxes by rivers. Inorganic nitrogen compounds include nitrate (NO_3), ammonia (NH_4) and nitrite (NO_2). Wastewaters are the main source for NH_4 and NO_2. In agricultural area, fertilizer and manure excess is the main source for NO_3. Other sources of NO_3 are biological fixation and atmospheric deposition. Nitrite concentrations are, in most of case, very low beside other inorganic compounds and may be omitted in the nitrogen budget. From collected data at the basin scale and weighting the nutrient concentration of each basin by their water discharge, the average NO_3, NH_4 and NO_2 concentrations were 1.91 mgN L^{-1}, 0.21 mgN L^{-1} and 0.05 mgN L^{-1}, i.e. an average dissolved inorganic nitrogen (DIN) concentration of 2.17 mgN L^{-1} (*Figure* 17). For dissolved organic nitrogen (DON), the average concentration is 0.92 mgN L^{-1}, i.e. 25% of total dissolved nitrogen (TDN) concentration. Lacking data for other nitrogen compounds than NO_3, we may estimate the DIN and TDN concentrations from NO_3 concentration. Indeed, in most cases, NO_3 is the dominant nitrogen form and his concentration covaries in space with other nitrogen compounds. In some rivers, concentrations of NH_4 and DON may be unusually strong compared to NO_3. This indicates strong wastewater emission closed to the river mouth and a relatively low water discharge. TDN or DIN concentrations may be estimated from NO_3 concentration using the following equations:

$$C_{DIN} = 1.16\,.\,C_{NO3} \text{ (R}^2\text{=0.91, n=102)}$$

$$C_{TDN} = 1.32\,.\,C_{NO3} + 0.13 \text{ (R}^2\text{=0.79, n=51)}$$

Particulate phosphorus (PP) accounts for a high fraction of phosphorus fluxes in rivers because of strong affinity between orthophosphate (majority dissolved from, PO_4) and particulates. At a global scale, dissolved phosphorus only constitutes about 10% of the phosphorus fluxes by rivers (Meybeck 1982). For Mediterranean Rivers, average dissolved inorganic phosphorus (DIP) concentration is 0.16 mgP L^{-1} and 0.10 mgP L^{-1} when concentrations are weighted by water discharge. There are numerous data for total phosphorus (TP). However, the number of measurement and sampling strategy are not suitable for evaluating concentrations or fluxes on an annual basis. In many cases, TP concentrations are measured out of flood periods while TP concentrations are much stronger during floods. From collected data, average TP concentration is 0.21 mgP L^{-1} and 0.10 mgP L^{-1} when concentrations are weighted by water discharge. In fact, average concentrations should be greater and it is likely that the average concentrations of TP measured out during floods are rather representative for total dissolved phosphorus (TDP) concentrations (i.e. dissolved inorganic and organic phosphorus). We note a strong relation between TP and DIP concentrations:

$$C_{TDP} = 1.21 \cdot C_{DIP} + 0.06 \text{ (R}^2\text{=0.82, n=87)}$$

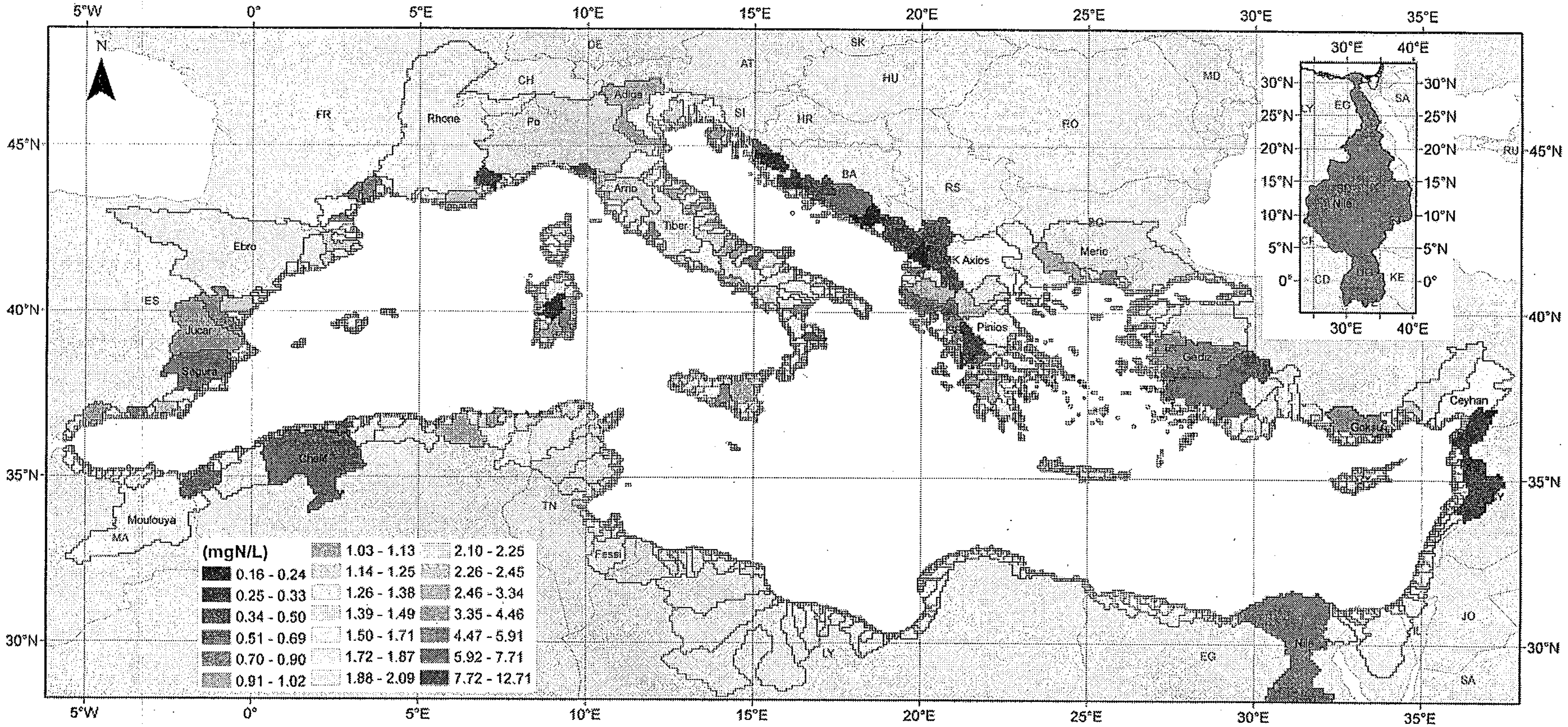


Figure 18 Interannual average of nitrate concentrations in Mediterranean rivers calculated from available 2000-2010 data or most recent interannual value from scientific references

4.2 Spatial variation of nutrient concentrations and fluxes

4.2.1 Nitrogen

4.2.1.1 Nitrogen concentration

Lowest **NO_3** concentrations (*Figure* 18) were found in rivers of the Eastearn Adriatic Sea with most values lower than 0.5 mgN L^{-1} and miminum values lower than 0.2 mgN L^{-1} at the river mouth of Trebisjnica (Bosnia and Herzegovina), Mati (Albania) and Licka (Croatia). Fairly low values were also observed at the Eastern Ionian Sea and Southern Turkey (excluding Orontes). In contrast, Orontes has the strongest concentration of NO_3 with 12.7 mgN L^{-1}. Strong NO_3 concentrations were also recorded in Spanish rivers, especially in the Southern basins, and in the Maghreb. Values were often greater than 4 mgN L^{-1} (Segura, Jucar, Turia, Vinalopo, Tafna, Mazafran and Chelif). In Italia, values greater than 3 mgN L^{-1} were found in southern small coastal basins (Fortore, Metauro, Sinni, Marta, Trigno), in Sicilia (Simeto, Imera) and Sardinia (Flummini Mannu, Cedrino). For the Rhone, Ebro and Po, average NO_3 concentrations were respectively 1.5, 2.5 and 2.4 mgN L^{-1}. Most of the Nile freshwater (15 km^3, Nixon 2003) is discharged to the sea by the drainage network flowing to the coastal lagoons (13.6 km^3, (Oczkowski *et al.* 2008)). The average TDN concentration in drainage water is 14.5 mgN L^{-1} (Khalil, Ouarda & St-Hilaire 2011) with values ranged from 6.8 to 25.3 mgN L^{-1}. Average NO_3 concentration in drainage water is between 4.9 to 10.9 mgN L^{-1} for six categories of drainage water closed to the coastal line (Shaban *et al.* 2010). Weighting these NO_3 concentrations by the respective area covered by these six categories, the average NO_3 concentration in drainage water is 7 mgN L^{-1}. We could deduce an average concentration of Kjeldahl nitrogen (NH_4 and DON) of 7.5 mgN L^{-1}.

For **NH_4** (*Figure* 19), lowest concentrations were also found in the Eastern Adriatic Sea with less than 0.02 mgN L^{-1} in all Croatian rivers (Cetina, Licka, Mirna, Gacka and Krka). Values lowers than 0.10 mgN L^{-1} were recorded at the Northern Adriatic Sea, in France, Spain and, more locally, in Western Greece, Southern Italia and Turkey. Greatest NH_4 concentrations were measured in small basins including a large city closed to the river mouth: 11.6 mgN L^{-1} in Besos closed to Barcelona and 5.9 mgN L^{-1} in Regi Lagni closed to Naples. Concentrations greater than 0.5 mgN L^{-1} were found in most Maghreb rivers, around the Aegean Sea (including the largest basin, Meric), at the Southern Italia (including the two largest basins: Tevere and Arno) and in Spain (as Segura). For the Rhone, Ebro and Po, NH_4 concentrations were 0.07, 0.07 and 0.09 mgN L^{-1}. We have no measured values for the Nile.

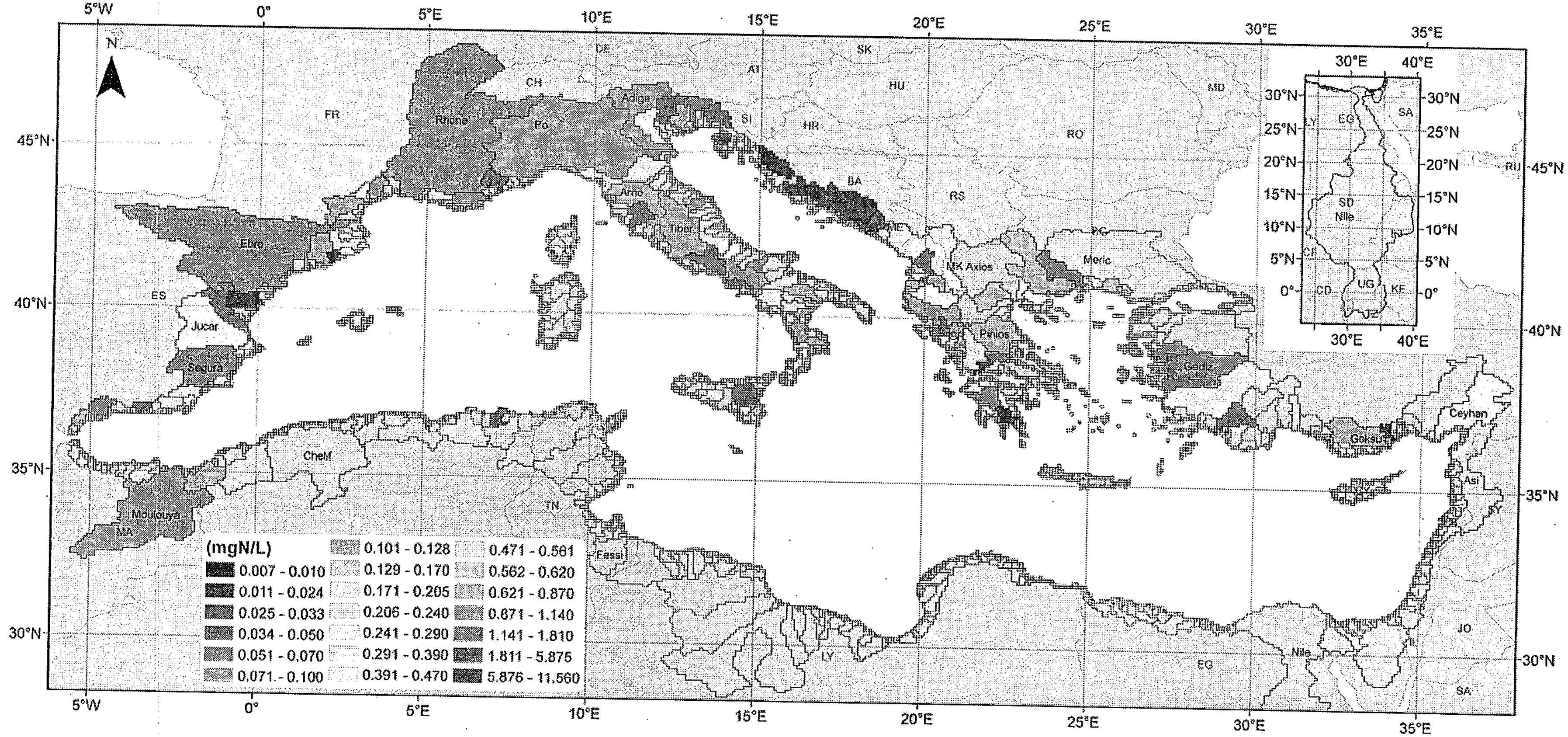


Figure 19 Average ammonium concentrations in Mediterranean rivers calculated from available 2000-2010 data or most recent interannual value from scientific references

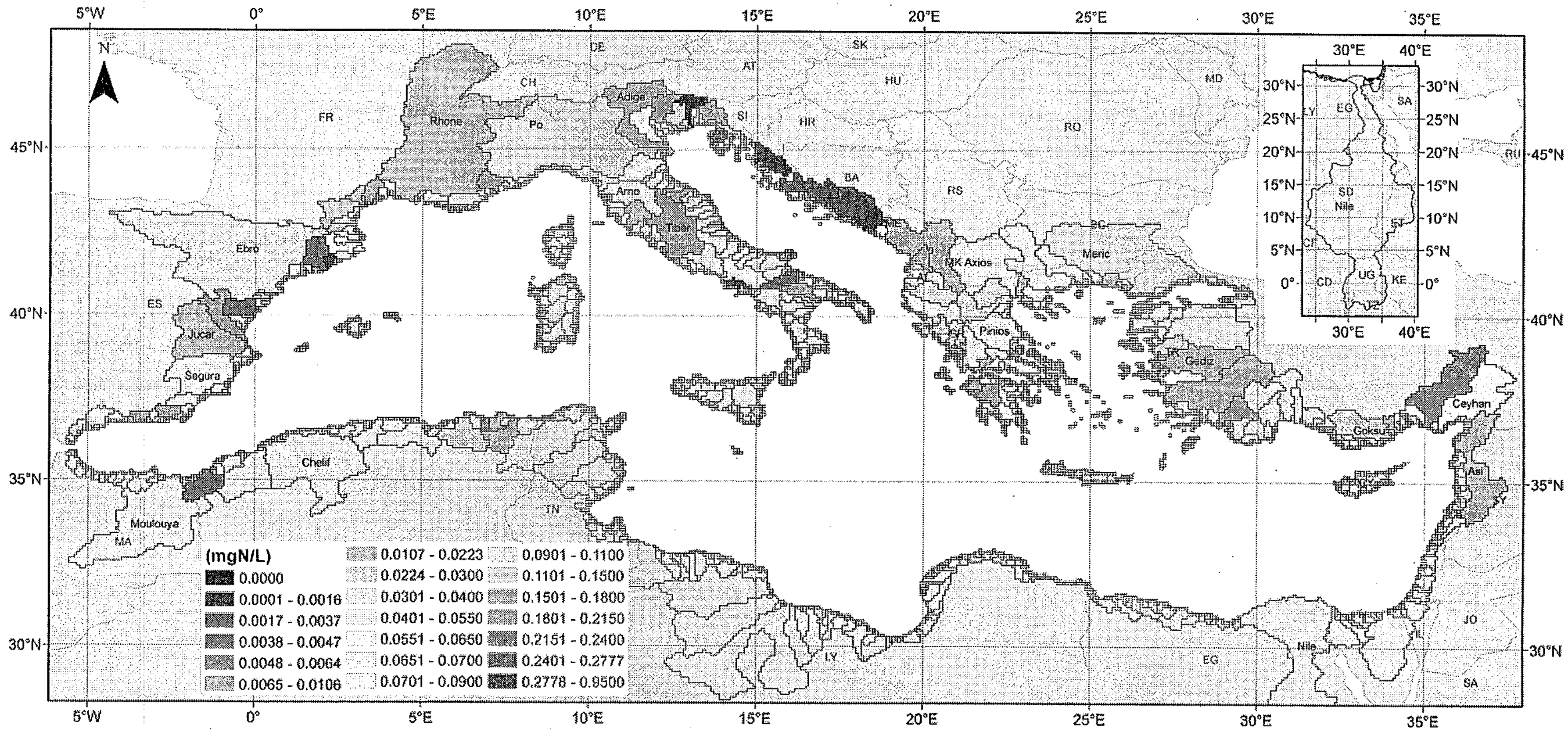


Figure 20 Average nitrite concentrations in Mediterranean rivers calculated from available 2000-2010 data or most recent interannual value from scientific references

Regarding **DON** (*Figure* 21), data coverage is limited to Western Mediterranean Sea. As other nitrogen forms, lowest values were observed at the Eastern Adriatic Sea with less than 0.25 mgN L^{-1}. Strongest values were recorded, as NH_4, in Besos and Regi Lagni with, respectively, 5.3 and 7.5 mgN L^{-1}. In Southern Spain, concentrations higher than 1 mgN L-1 were recorded in Guadalhorce, Almanzora and Vinalopo. In Northern Italia, Arno and Po have strong DON content with 1.9 and 2.0 mgN L^{-1}. In Ebro and Rhone, organic nitrogen concentrations were 0.47 and 0.35 mgN L^{-1}.

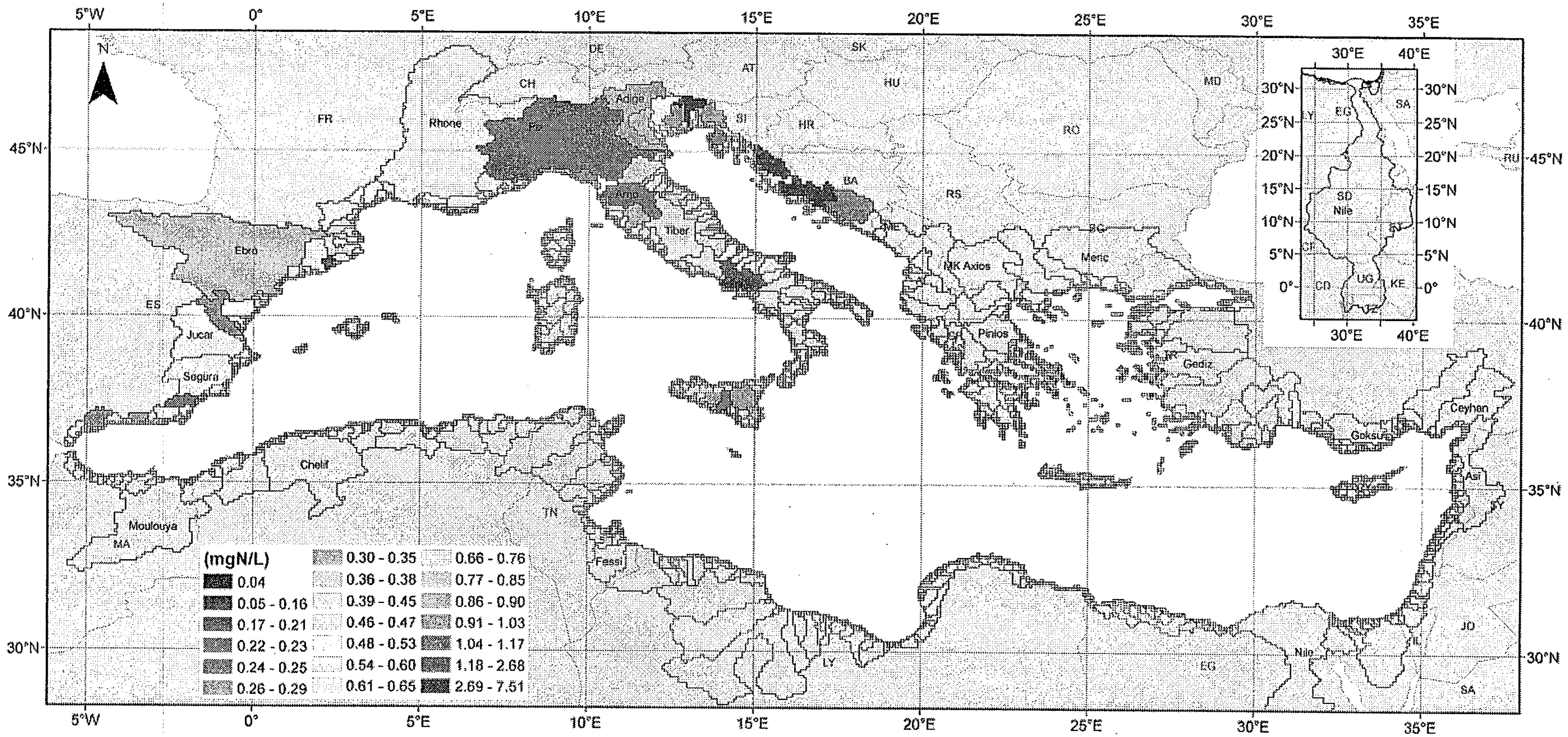


Figure 21 Average dissolved organic nitrogen concentrations in Mediterranean rivers calculated from available 2000-2010 data or most recent interannual value from scientific references

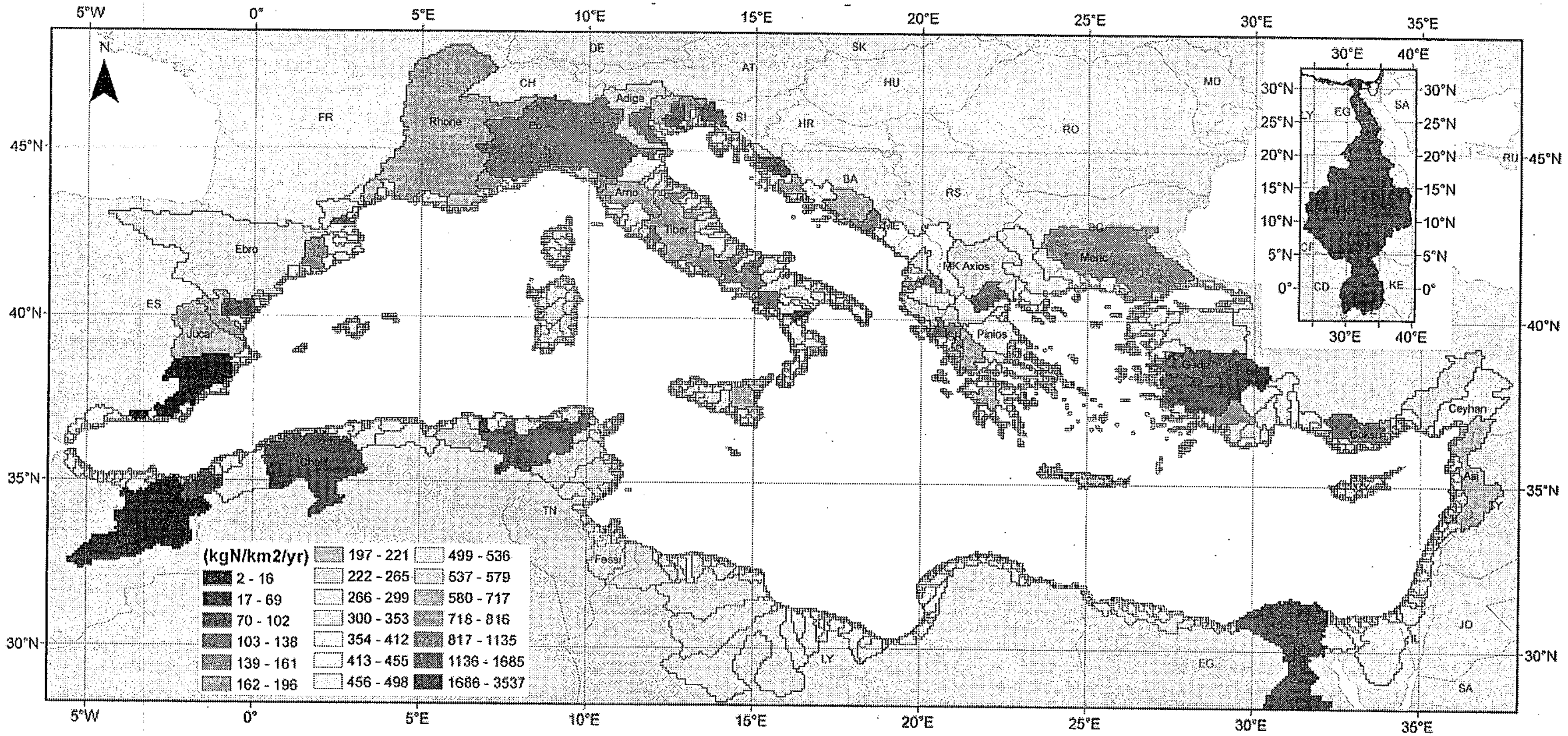


Figure 22 Average nitrate flux by Mediterranean Rivers calculated from available 2000-2010 data for nutrient concentrations and average water discharge on the last 20 years or most recent interannual value for nutrient and water discharge from scientific references

4.2.1.2 Nitrogen fluxes

Strongest river fluxes of **NO_3** (*Figure* 22) are provided by the four largest basins with 106 10^3, 105 10^3, 78 10^3 and 21 10^3 tN yr^{-1} for the Nile, Po, Rhone and Ebro. Expressed as specific fluxes, among the thirteen basins with a flux stronger than 1000 kgN km^{-2} yr^{-1}, twelve are Italian basins. More than 3000 kgN km^{-2} yr^{-1} is found for the rivers Soca and Livenza (Northern Adriatic Sea). Excluding some small coastal basins, fluxes are always greater than 500 kgN km^{-2} yr^{-1} in Italian rivers. NO_3 flux of the Rhone is also elevated with 820 kgN km^{-2} yr^{-1}. Other fluxes greater than 500 kgN km^{-2} yr^{-1} are found in rivers of the Eastern Adriatic and Ionian Seas (Thyamis, Alfeios, Sperchios, Erzeni, Mirna) and of the Southwestern Turkey (Seyhan, Ceyhan, Orontes). Lowest fluxes are measured on the South Mediterranean Rivers, Southern Spain, South and Western Turkey with, for most rivers, less than 100 kgN km^{-2} yr^{-1}.

For **NH_4** (*Figure* 23), greatest fluxes are not provided by largest basins. Greatest NH_4 flux is provided by Drini (Southern Adriatic Sea) with 8.1 10^3 tN yr^{-1}. Then, respectively, the next important fluxes are 4.8 10^3, 4.1 10^3, 4.0 10^3 and 3.9 10^3 tN yr^{-1} for Küçük Menderes, Po, Tevere and Meric. In Rhone and Ebro, NH_4 fluxes are 3.7 10^3 and 0.6 10^3 tN yr^{-1}. Per unit area, fluxes higher than 200 kgN km^{-2} yr^{-1} were found in Italia (Tevere, Arno, Sele, Magra, Crati, Fortore and Serchio). Other values higher than 200 kgN km^{-2} yr^{-1} were found in Têt (France), West Kebir (Algeria), and Küçük Menderes (Turkey). Greatest NH_4 flux is observed in the Besos with more than 1500 kgN km^{-2} yr^{-1}. Around the Aegean Sea, flux is higher than 100 kgN km^{-2} yr^{-1} in Pinios, Acheloos (Greece) and Gediz (Turkey). In Southeastern Turkey, NH_4 fluxes are about 100 kgN km^{-2} yr^{-1} (Seyhan, Ceyhan, Berdan). Lowest fluxes were calculated for Western Maghreb and Spain with, for most rivers, less than 10 kgN km^{-2} yr^{-1}.

Five rivers discharge more than 1.0 10^3 tN yr^{-1} of **NO_2** (*Figure* 24): Rhone, Po, Meric, Seyhan and Tevere. Per unit area, maximum values were calculated at the Eastern Ionian Sea with more than 100 kgN km^{-2} yr^{-1} in Thyamis, Alfeios (Greece) and Shkumbini (Albania). fluxes for most other rivers of the Eastern Ionian Sea were stronger than 20 kgN km^{-2} yr^{-1}. In the Besos, flux is also stronger than 100 kgN km^{-2} yr^{-1}. Values stronger than 20 kgN km^{-2} yr^{-1} were found for numerous Italian rivers (Tevere, Bacchiglione, Volturno, Sele, Ofanto, Livenza, Magra, Serchio, Sangro, Tronto, Trigno). For Seyhan and Ceyhan (Southeastern Turkey), NO_2 flux is also strong. Around the Aegean Sea, values range between 10 and 20 kgN km^{-2} yr^{-1}. Minimal values are found in the Northeastern Adriatic Sea, Spain, Maghreb and Southern Turkey with less than 5 kgN km^{-2} yr^{-1} for most rivers. Fluxes for Po, Rhone, Ebro and Meric are 19, 11, 3 and 20 kgN km^{-2} yr^{-1}.

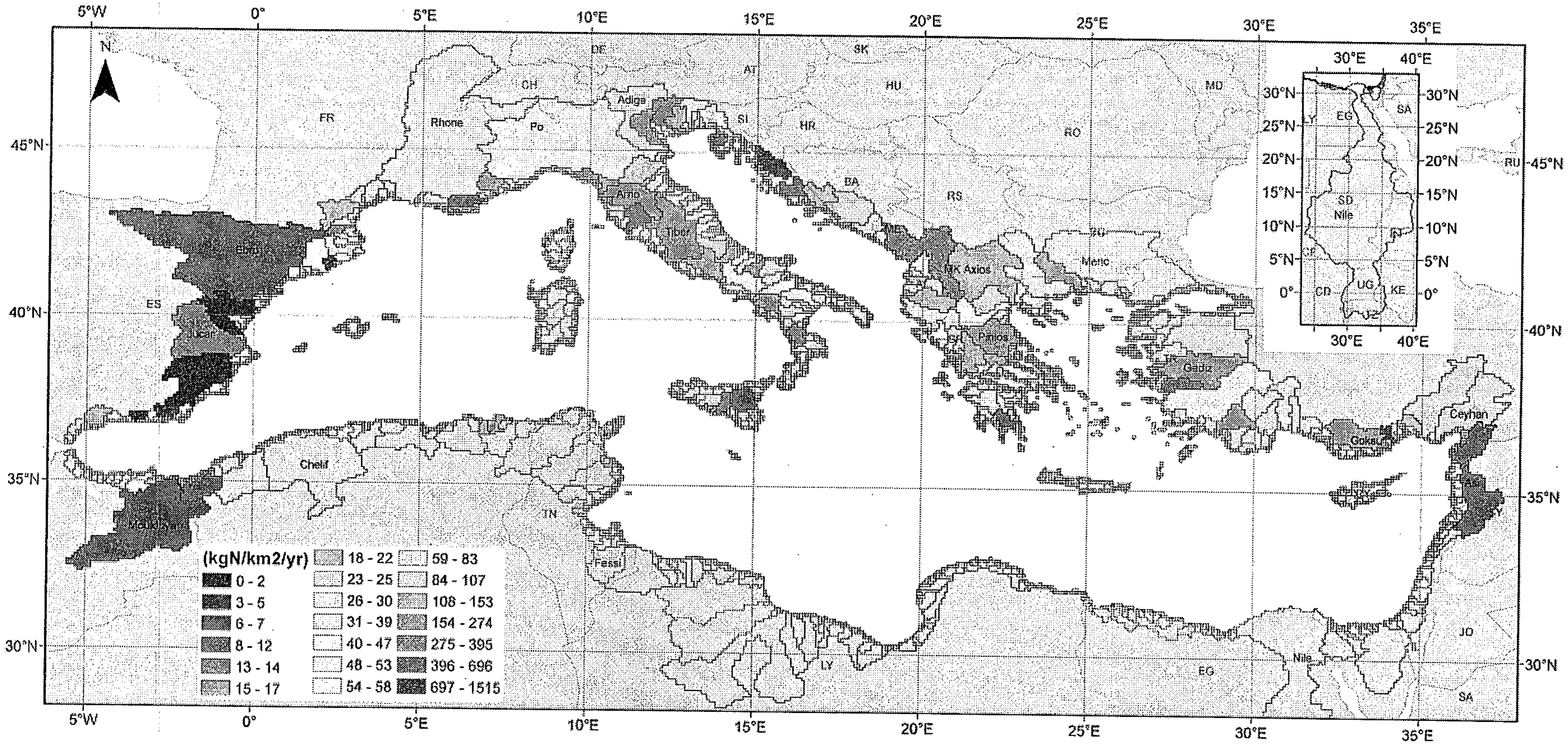


Figure 23 Average ammonium flux by Mediterranean Rivers calculated from available 2000-2010 data for nutrient concentrations and average water discharge on the last 20 years or most recent interannual value for nutrient and water discharge from scientific references

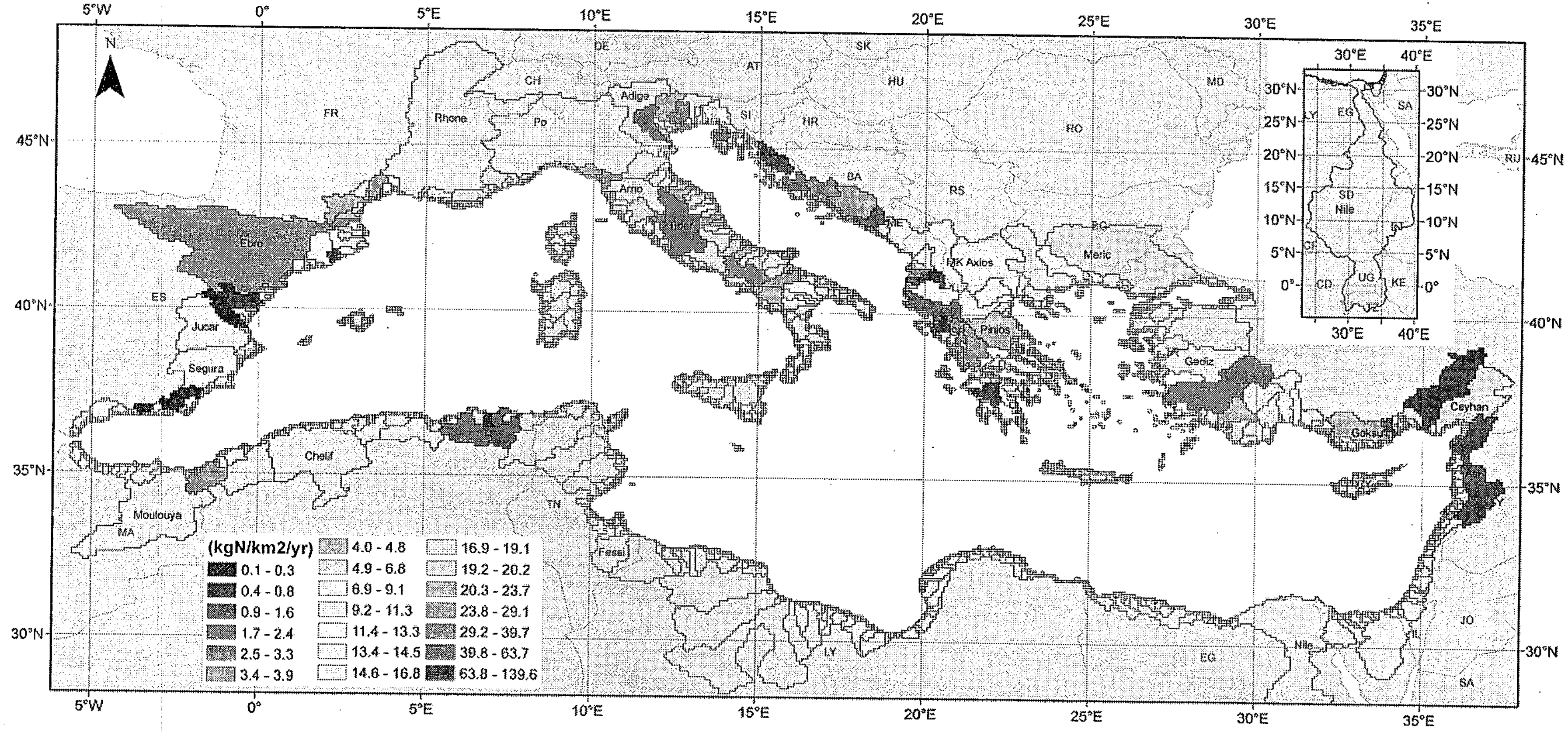


Figure 24 Average nitrite flux by Mediterranean Rivers calculated from available 2000-2010 data for nutrient concentrations and average water discharge on the last 20 years or most recent interannual value for nutrient and water discharge from scientific references

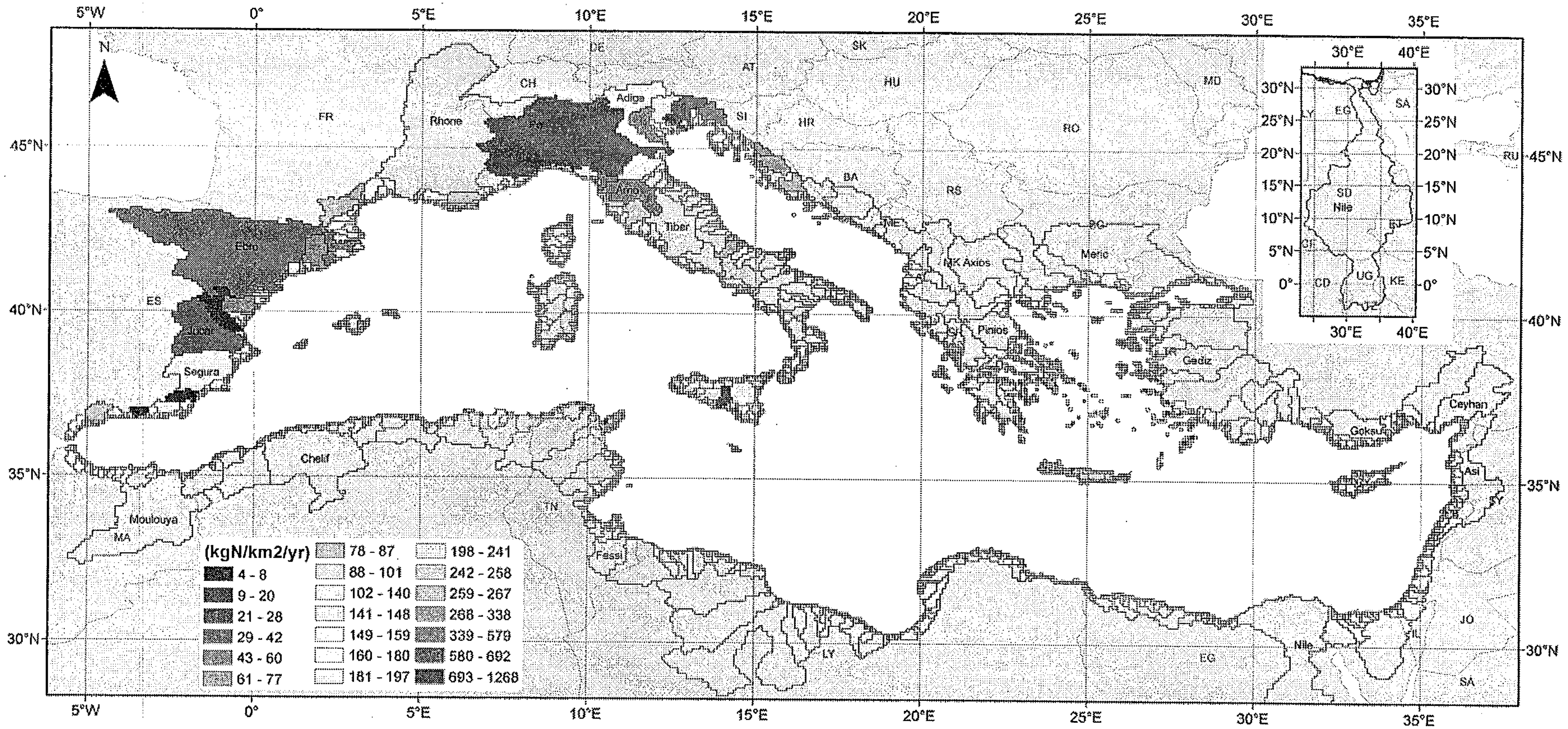


Figure 25 Average dissolved organic nitrogen flux by Mediterranean Rivers calculated from available 2000-2010 data for nutrient concentrations and average water discharge on the last 20 years or most recent interannual value for nutrient and water discharge from scientific references

For **DON** (*Figure* 25), fluxes of Rhône, Po and Ebro are 24.6 10^3, 90.1 10^3 and 3.0 10^3 tN yr^{-1}. Strongest fluxes per unit area are calculated in the Northern Adriatic Sea with 1268 kgN km^{-2} yr^{-1} in Po and 1202 kgN km^{-2} yr^{-1} in Livenza. In Spain, excluding Besos where flux reaches 258 kgN km^{-2} yr^{-1}, values are lower than 100 kgN km^{-2} yr^{-1}.

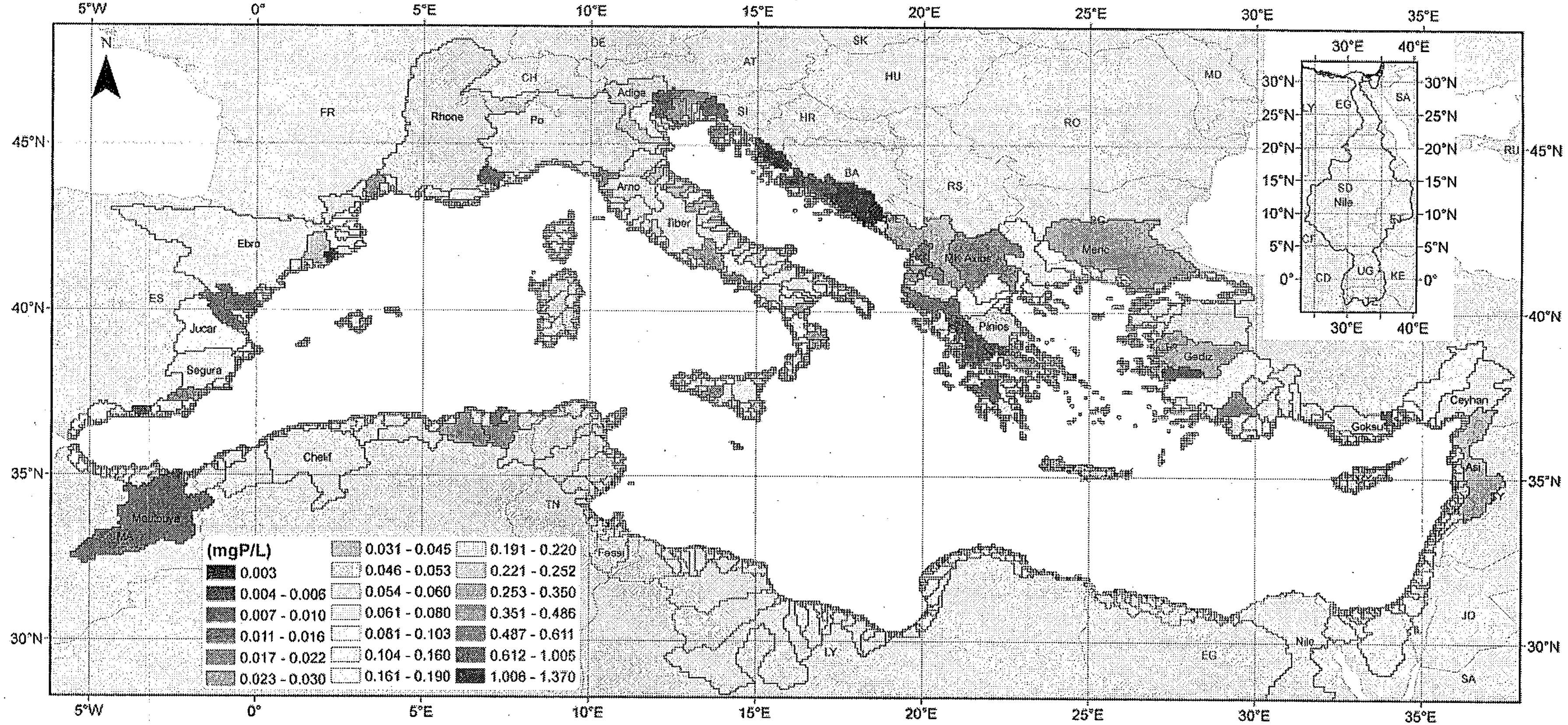


Figure 26 Average dissolved inorganic phosphorus concentrations in Mediterranean rivers calculated from available 2000-2010 data or most recent interannual value from scientific references

4.2.2 Phosphorus

4.2.2.1 Phosphorus concentrations

DIP concentrations range from 0.01 mgP L^{-1} to 1.40 mgP L^{-1} (*Figure* 26). Minima were found in the rivers of the Eastern Adriatic and Aegean Seas with less than 0.05 mgP L^{-1} pour for most rivers. In France, concentrations are also low with in average 0.05 mgP L^{-1}. Around the Aegean Sea, concentrations are often stronger than 0.20 mgP L^{-1} and reach 0.54 mgP L^{-1} for Axios, 0.48 mgP L^{-1} for Meric, 0.34 mgP L^{-1} for Gediz and 1.34 mgP L^{-1} for Küçük Menderes. Strong concentrations were measured in Maghreb with 0.80 mgP L^{-1} in Moulouya and 0.49 mgP L^{-1} in Kebir-Rhumel. Some other levels greater than 0.30 mgP L^{-1} were found in Asi (Turkey), Besos (Spain), Llobregat (Spain), Regi Lagni and Serchio (Italy). In Rhone, Po and Ebro, concentrations are 0.05, 0.07 and 0.06 mgP L^{-1}.

For **TP** (*Figure* 27), concentrations range from less than 0.01 mgP L^{-1} and 1.89 mgP L^{-1}. Most of concentrations stronger than 0.40 mgP L^{-1} are around Aegean Sea (Meric, Axios, Gediz, Strymon, Aliakmon, Küçük Menderes, Loudias and Bakir). Other rivers with so strong concentrations are Besos (maximum concentration), Llobregat and Guadalhorce in Spain, Regi Lagni and Ofanto in Italy, and Seyhan in Turkey. In Italia, TP concentrations are often stronger than 0.10 mgP L^{-1} and stronger than 0.20 mgP L^{-1} for Po, Tevere and Arno. In Northern Spain and France, concentrations are lower than 0.10 mgP L^{-1} for most rivers, with 0.07 mgP L^{-1} for Ebro and 0.08 mgP L^{-1} for Rhône.

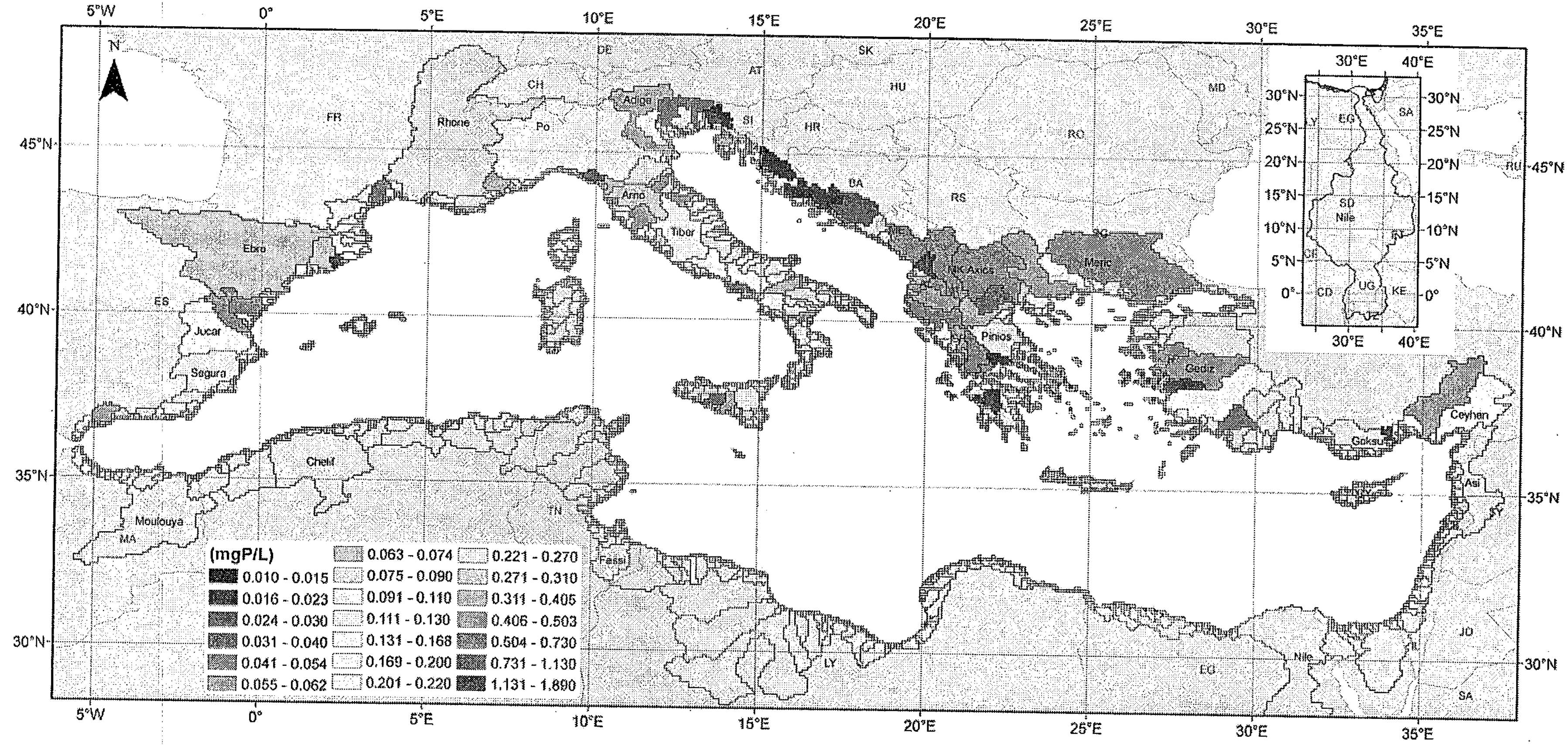


Figure 27 Average total phosphorus concentrations in Mediterranean rivers calculated from available 2000-2010 data or most recent interannual value from scientific references

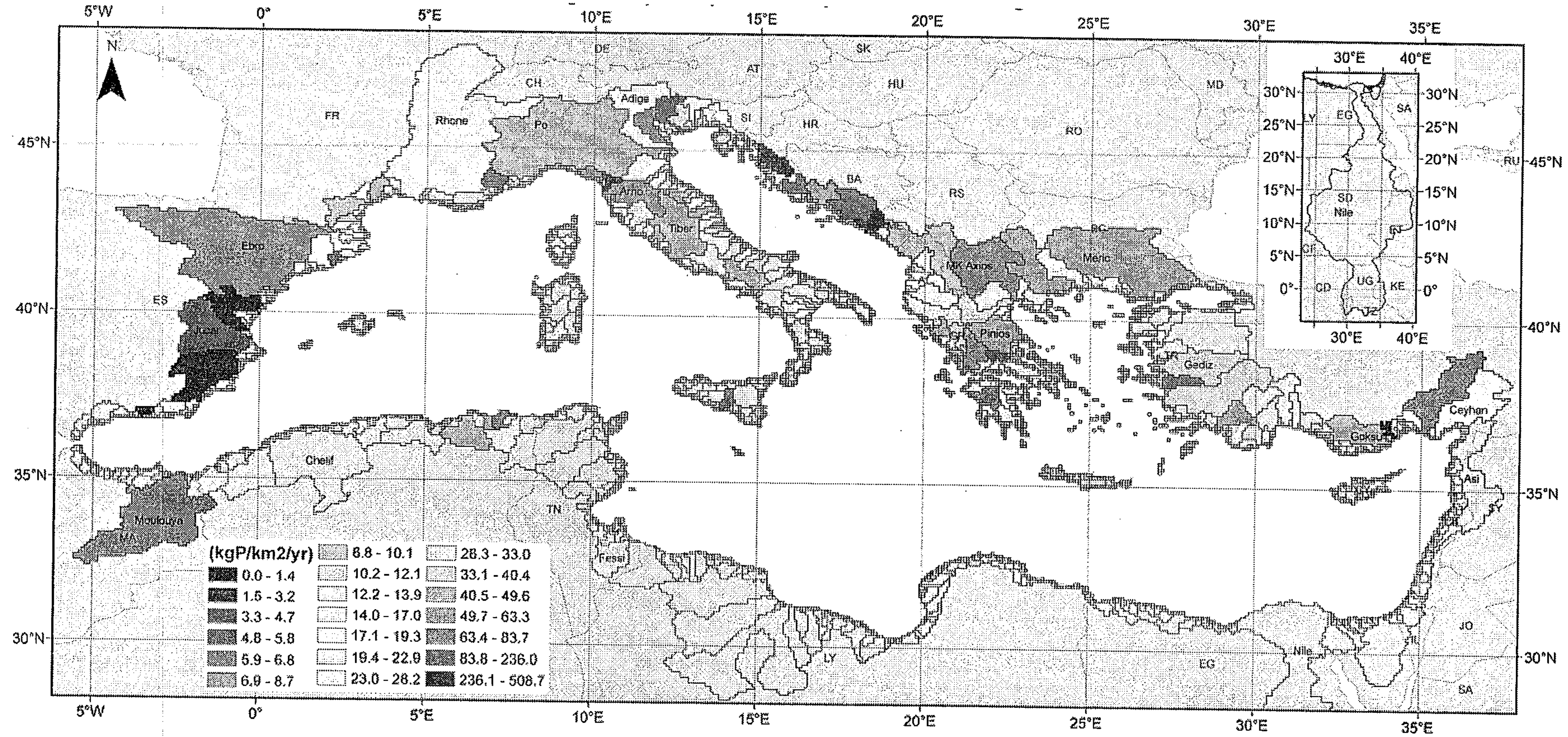


Figure 28 Average dissolved inorganic phosphorus flux by Mediterranean Rivers calculated from available 2000-2010 data for nutrient concentrations and average water discharge on the last 20 years or most recent interannual value for nutrient and water discharge from scientific references

4.2.2.2 Phosphorus fluxes

The highest **DIP** flux (*Figure* 28) is calculated for the Meric and Po with more than 3 10^3 tP yr^{-1}. Four other rivers have a DIP flux stronger than 1 10^3 tP yr^{-1} : the Rhône, Axios, Seyhan and Küçük Menderes. For the Ebro, the flux is only 0.5 10^3 tP yr^{-1}. Per unit area, highest values are observed in Italy, around the Aegean Sea, in the Southeastern Turkey and Northeastern Maghreb. Values are higher than 50 kgP km^{-2} yr^{-1} for the Axios, Meric, Strymon, Pinios and Thyamis in Greece, for the Küçük Menderes and Seyhan in Turkey, for the Arno, Bacchiglione, Serchio, Magra and Marta in Italy, for the West Kebir in Algeria and for the Besos in Spain. In the Rhone, Po and Ebro, flux is respectively 27, 45 and 6 kgP km^{-2} yr^{-1}. Minimales values are observed in the Southeastern Spain and Eastern Adriatic Sea with less than 5 kgP km^{-2} yr^{-1}.

Strongest **TP** fluxes are measured in the Po, Meric and Rhone with 9.1 10^3, 5.1 and 4.2 tP yr^{-1} (*Figure* 28). Fluxes higher than 1 tP yr^{-1} are observed in the Axios, Aliakmon and Strymon in Greece, the Ceyhan, Seyhan and Küçük Menderes in Turkey, the Buna-Drini in Albania and the Tevere in Italy. Per unit area, we observe the same spatial change than for DIP with value ranged from 1 (Guadalfeo, Spain) to 374 kgP km^{-2} yr^{-1} (Küçük Menderes, Turkey). For the Rhone, Ebro, Po and Meric, this flux is 44, 8, 127 and 96 kgP km^{-2} yr^{-1}.

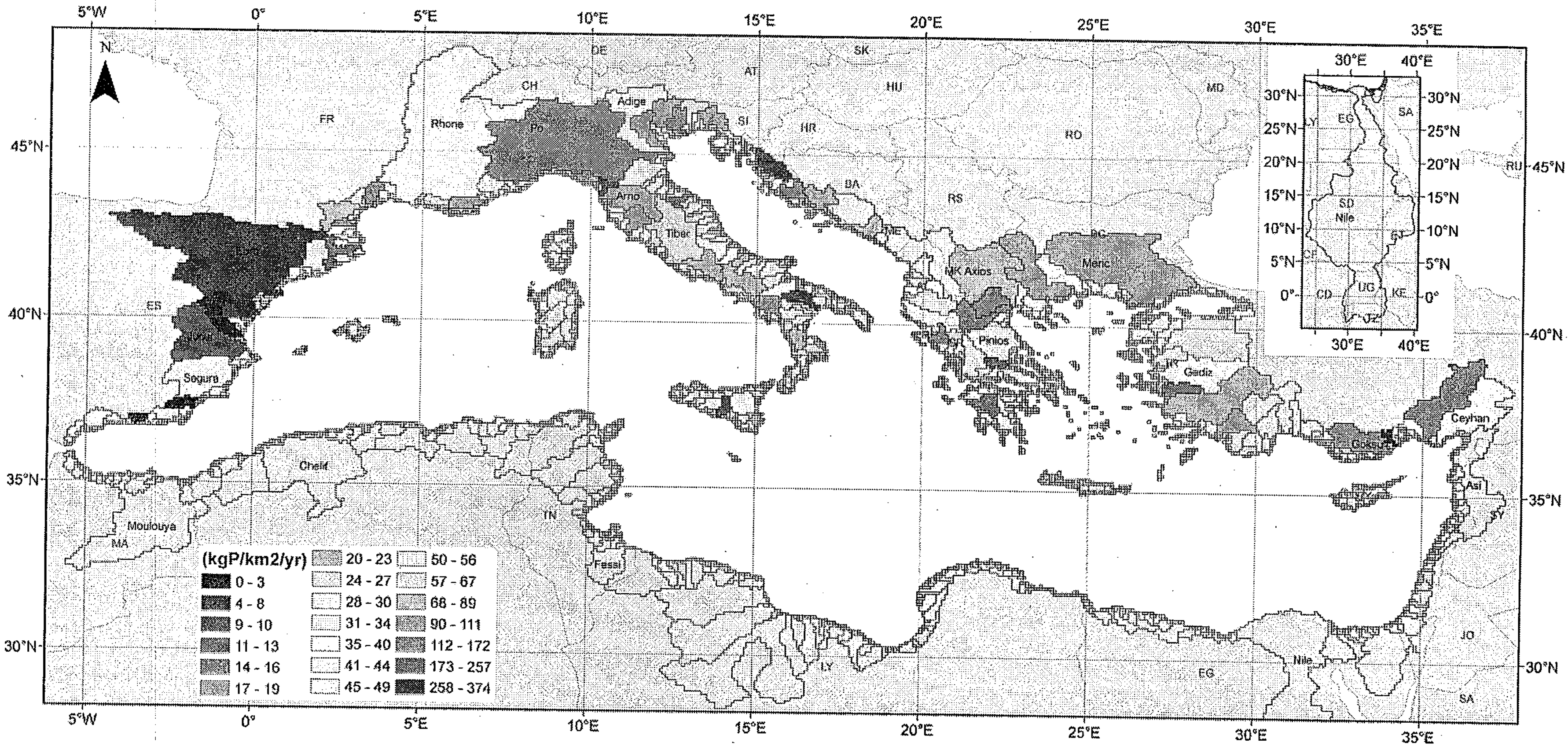


Figure 29 Average total phosphorus flux by Mediterranean Rivers calculated from available 2000-2010 data for nutrient concentrations and average water discharge on the last 20 years or most recent interannual value for nutrient and water discharge from scientific references

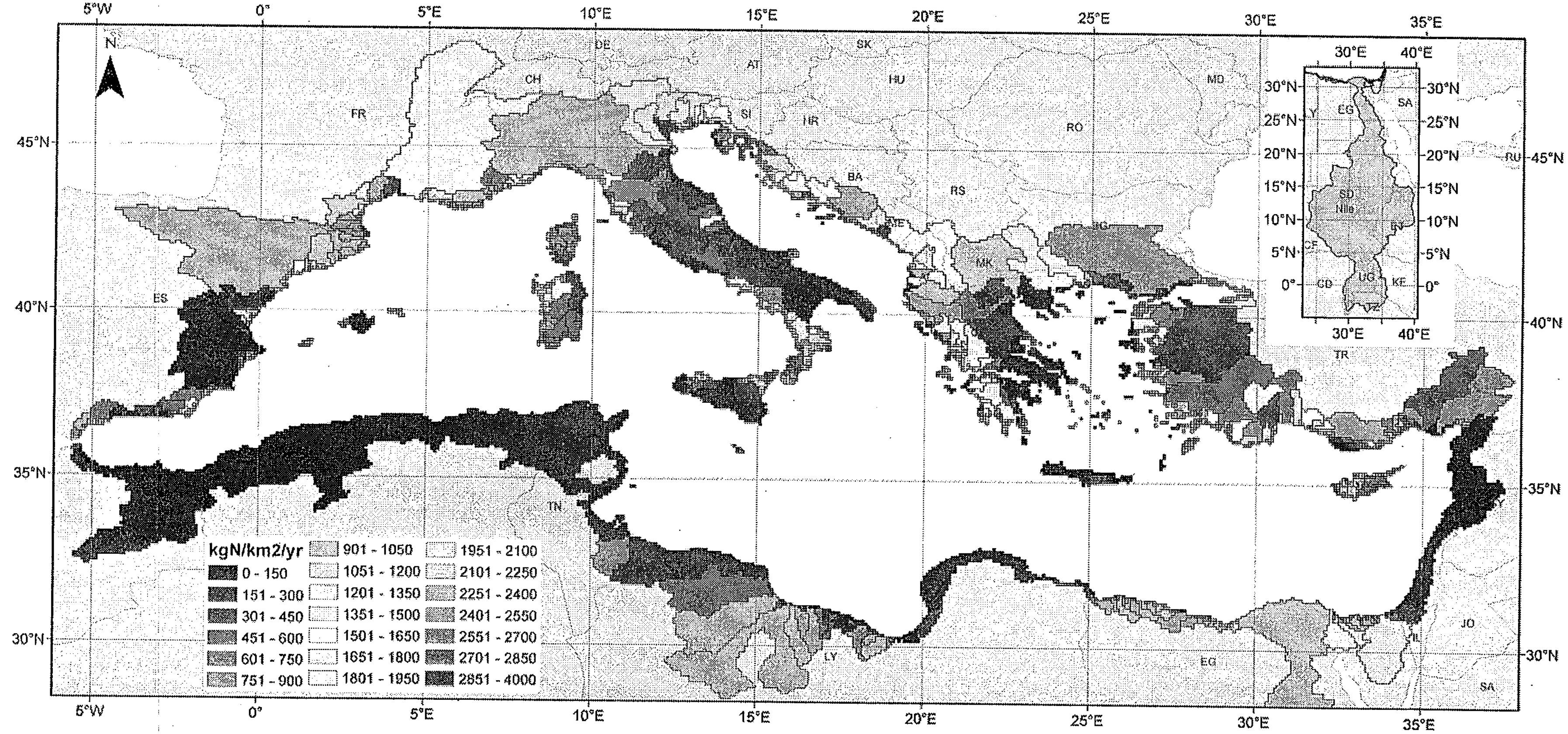


Figure 30 *Nitrogen emissions by natural areas in 2000s*

4.3 Main drivers of spatial variations in nutrient concentrations and fluxes

4.3.1 Nutrient emissions

4.3.1.1 Data sources

Nutrient balance data was provided by the IMAGE 2.4 model of the Netherland Environmental Assessment Agency (MNP, 2006). Point sources of nutrient were calculated using the conceptual relationship of Van Drecht *et al.* (2009) between per capita human N and P emission from human excreta and other household and industrial wastes, and per capita income. The amount of phosphorus or nitrogen discharged to surface water is estimated using removal of nutrient in wastewater treatment (expressed as a fraction of nutrient effluent to treatment plants) and the fraction of population connected to sewage systems. Non-point nutrient balance includes nutrient inputs and outputs for a given area of land. Nutrient inputs include application of synthetic fertilizer and animal manure for both phosphorus and nitrogen by crop category. It also includes biological fixation and atmospheric deposition only for nitrogen. Nutrient outputs include crop exportation. This nutrient balance not take into account evolution of nutrient storage and removal within soil and groundwater. These data produced at a 0.5 by 0.5 degrees were downscaled at a 5 by 5 minutes using a simple bilinear interpolation. New data produced in the framework of PERSEUS (http://www.perseus-net.eu/site/content.php) would be produced from IMAGE at 5 by 5 minutes and would allow a better estimation of nutrient balance at this spatial resolution.

4.3.1.2 Nutrient emissions in natural areas

Processes accounting for nitrogen emission in natural area are atmospheric deposition and biological fixation. Atmospheric deposition accounts for different nitrogen sources including energy-related, biomass burning, agricultural and natural emissions of nitrogen oxides and ammonia to air (Bouwman et al., 2002). So, emissions within closed agricultural and urban area have a strong effect on nutrient emissions within natural area. Natural nitrogen emissions (*Figure* 30) range from <1 to 3060 kgN km^{-2} yr^{-1}. At the scale of the whole Mediterranean drainage basin, theses emissions reach 4.3 10^6 tN i.e. 35% of the total diffuse emissions. For the five largest river basins of the Mediterranean Sea, natural emissions account for 39, 54, 22, 20 and <1% of total diffuse emissions for, respectively, the Nile, Rhone, Po, Ebro and Moulouya rivers.

For phosphorus, the atmospheric fluxes are negligible with about 0.5 percent of inputs to rivers (Meybeck 1982). Globally, natural weathering account for 24% of the

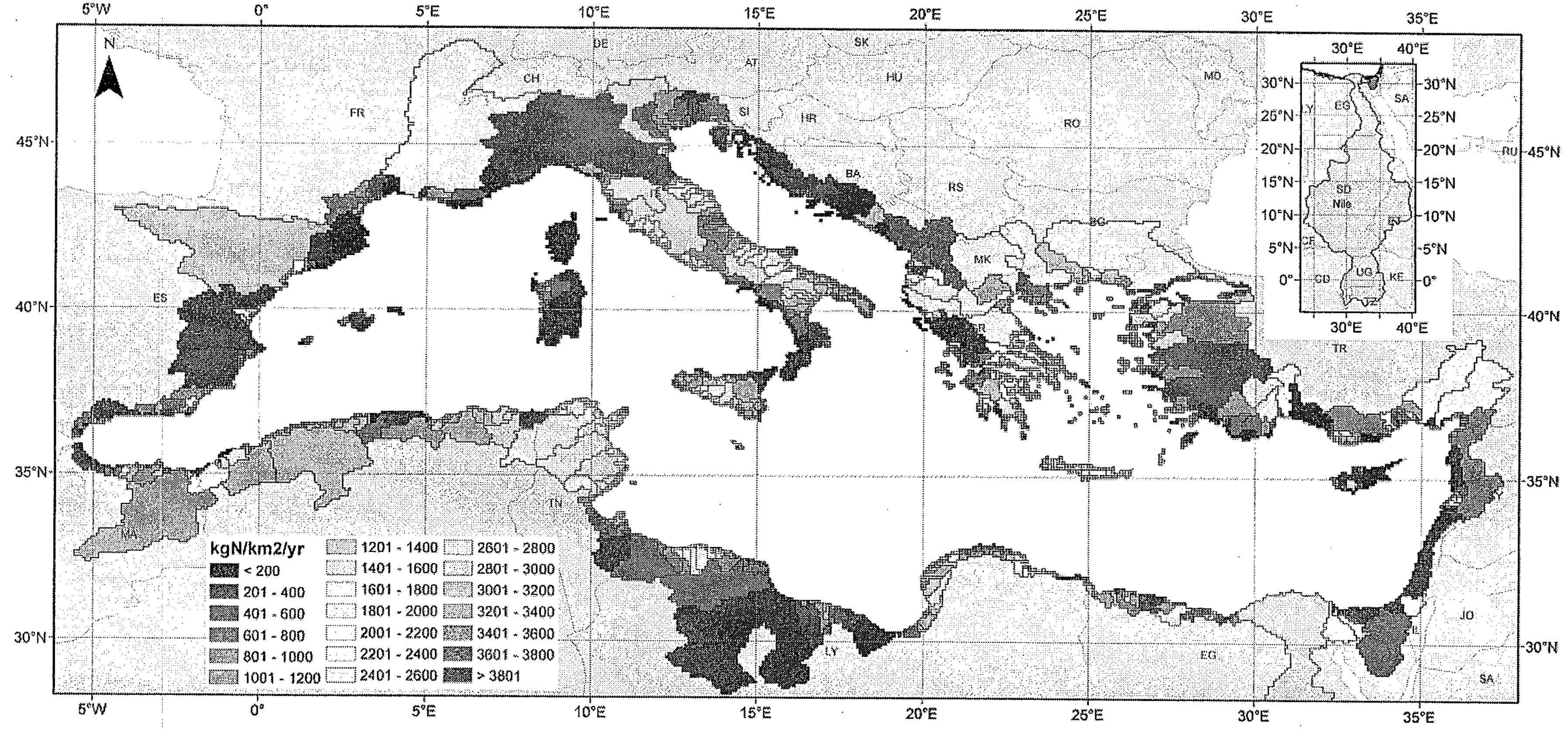


Figure 31 Nitrogen emissions by agricultural areas in 2000s

dissolved inorganic phosphorus delivered to the ocean (Harrison *et al.* 2010), i.e. 26 kgP km^{-2} yr^{-1}. We have no data to estimate spatial variation of phosphorus emissions by weathering within the Mediterranean area.

4.3.1.3 Nutrient emission in agricultural area

Total nitrogen input in agricultural area reach 14.3 10^{6} tN yr^{-1} and 1.9 10^{6} tP yr^{-1} in the Mediterranean drainage basin. Manure and fertilizer account for 6.9 and 3.9 10^{6} tN yr^{-1} i.e. 76% of the total nitrogen inputs in agricultural area, and, for phosphorus, 0.7 and 1.2 10^{6} tP yr^{-1}. Atmospheric deposition and biological fixation of nitrogen are 1.9 and 1.6 10^{6} tN yr^{-1}. Deducing crop export, total nitrogen and phosphorus emissions in agricultural area are 12.3 10^{6} tN yr^{-1} i.e. 95% of the total diffuse emission of nitrogen and 0.8 10^{6} tP yr^{-1}.

Emissions per unit area range from <1 to 26400 kgN km^{-2} yr^{-1} for nitrogen (Figure 31) and from <1 to 26.5 10^{3} kgP km^{-2} yr^{-1} for phosphorus (Figure 32). Strongest emissions, for both phosphorus and nitrogen, are observed in Southern Spain, Northern Italia, Western Turkey, Israel, Lebanon and Syria.

For the five largest river basins, respectively the Nile, Rhone, Ebro, Po and Moulouya, nitrogen emission in agricultural area are 2.5 10^{3}, 3.5 10^{3}, 3.9 10^{3}, 5.0 10^{3} and 1.1 10^{3} kgN km^{-2} yr^{-1} and phosphorus emissions are 0.12 10^{3}, 0.07 10^{3}, 0.48 10^{3}, 0.76 10^{3} and 0.06 10^{3} kgN km^{-2} yr^{-1}.

Several studies confirm this elevated agricultural emissions and their relation with water quality. In the Valencia region (Spain), nitrogen emissions range from 15000 to 30000 kgN km^{-2} yr^{-1} under vegetables crops (Ramos, Agut & Lidón 2002). In the Almeria region, nitrate concentration in groundwater is atmost 100 mgN L^{-1} under greenhouses (Thompson *et al.* 2007) . More than 20 mgN L^{-1} are measured in groundwater of the Low Almanzora. In Lebanon, the nitrogen emissions is higher in the Litani valley with atmost 78000 kgN km^{-2} yr^{-1} under vegetables crops and nitrate concentration in groundwater higher than 38 mgN L^{-1}. In the Po valley, phosphorus emissions in agricultural area reach 11000 kgP km^{-2} yr^{-1} (Torrent, Barberis & Gil-Sotres 2007). High nitrate concentration in rivers is always linked with strong nitrogen emissions due to agricultural practices. However, for nitrate flux, this link is less obvious as nitrate flux is also greatly controled by spatial change in water discharge.

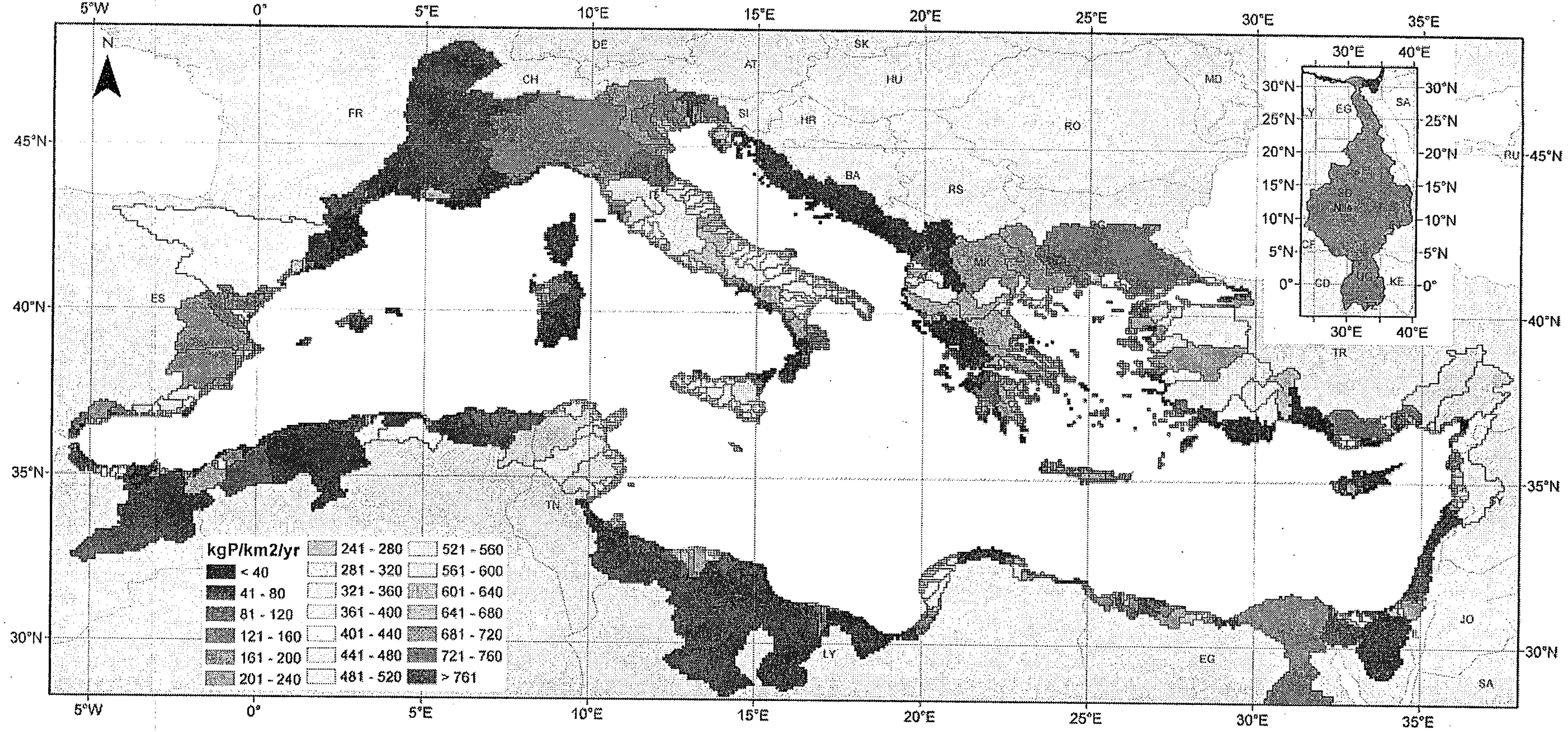


Figure 32 Phosphorus emissions by agricultural areas in 2000s

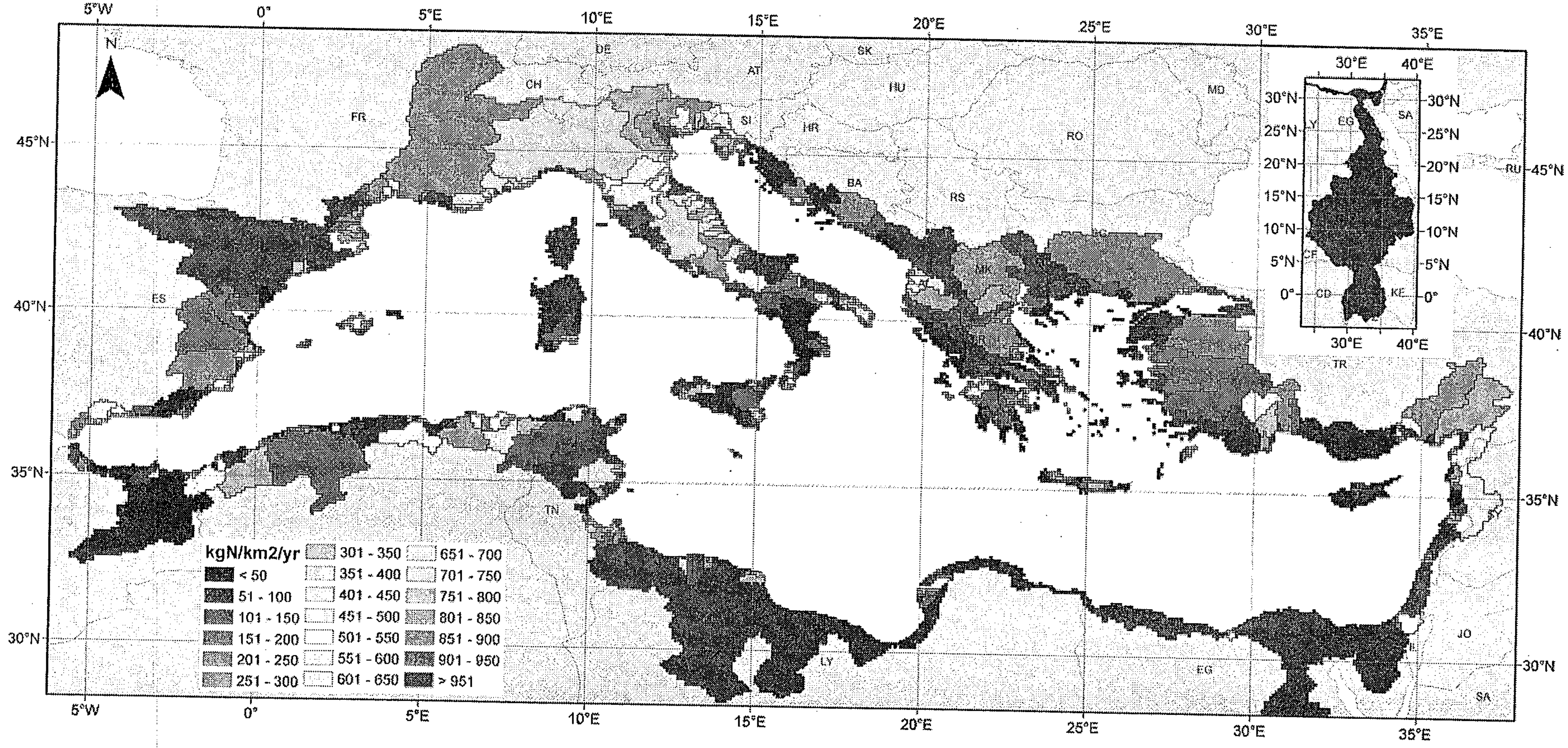


Figure 33 Nitrogen emissions by wastewaters in 2000s

4.3.1.4 Nutrient emission by wastewaters

Nutrient emission by wastewaters is 0.6 10^6 tN yr^{-1} and 0.1 10^6 tP yr^{-1} for the whole Mediterranean drainage basin, i.e. 5% and 6% of total emissions (including diffuse emissions in agricultural and natural areas). Emissions per unit area range from <1 to 11 10^3 kgN km^{-2} yr^{-1} for nitrogen and from <1 to 2.4 10^3 kgP km^{-2} yr^{-1} for phosphorus. For both phosphorus and nitrogen, strongest emission rates are located in small basin including large cities (*Figure* 33, *Figure* 34). Some large basins of Italy, Northern Maghreb and southwestern Turkey have emission rates larger than 0.4 10^3 kgN km^{-2} yr^{-1} and 0.1 10^3 kgP km^{-2} yr^{-1}. For the Nile, Rhone, Ebro, Po and Moulouya basins, nitrogen emission by wastewaters are 0.03, 0.24, 0.10, 0.75 and 0.03 10^3 kgN km^{-2} yr^{-1} and phosphorus emission are 0.01, 0.05, 0.02, 0.13 and 0.01 10^3 kgP km^{-2} yr^{-1}.

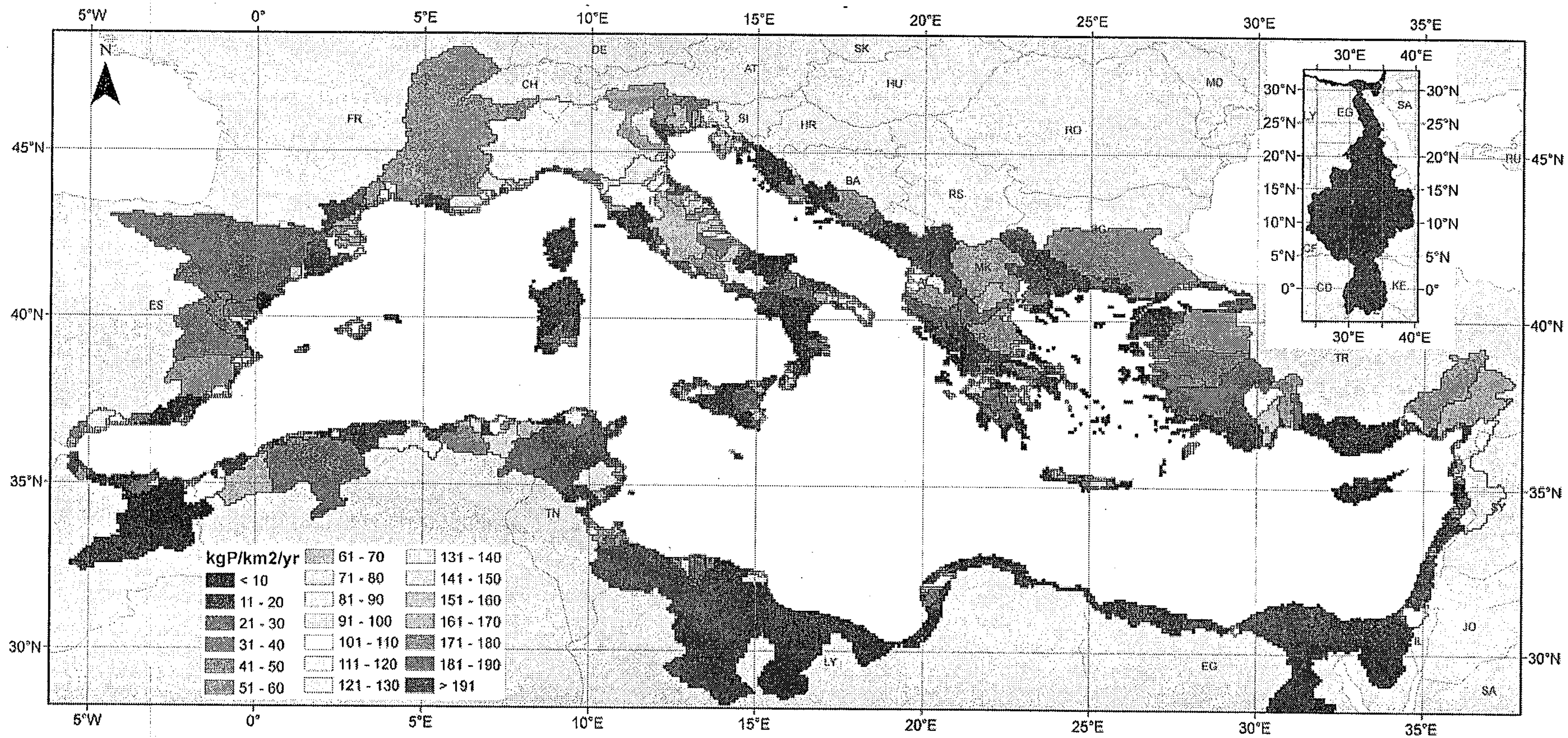


Figure 34 Phosphorus emissions by wastewaters in 2000s

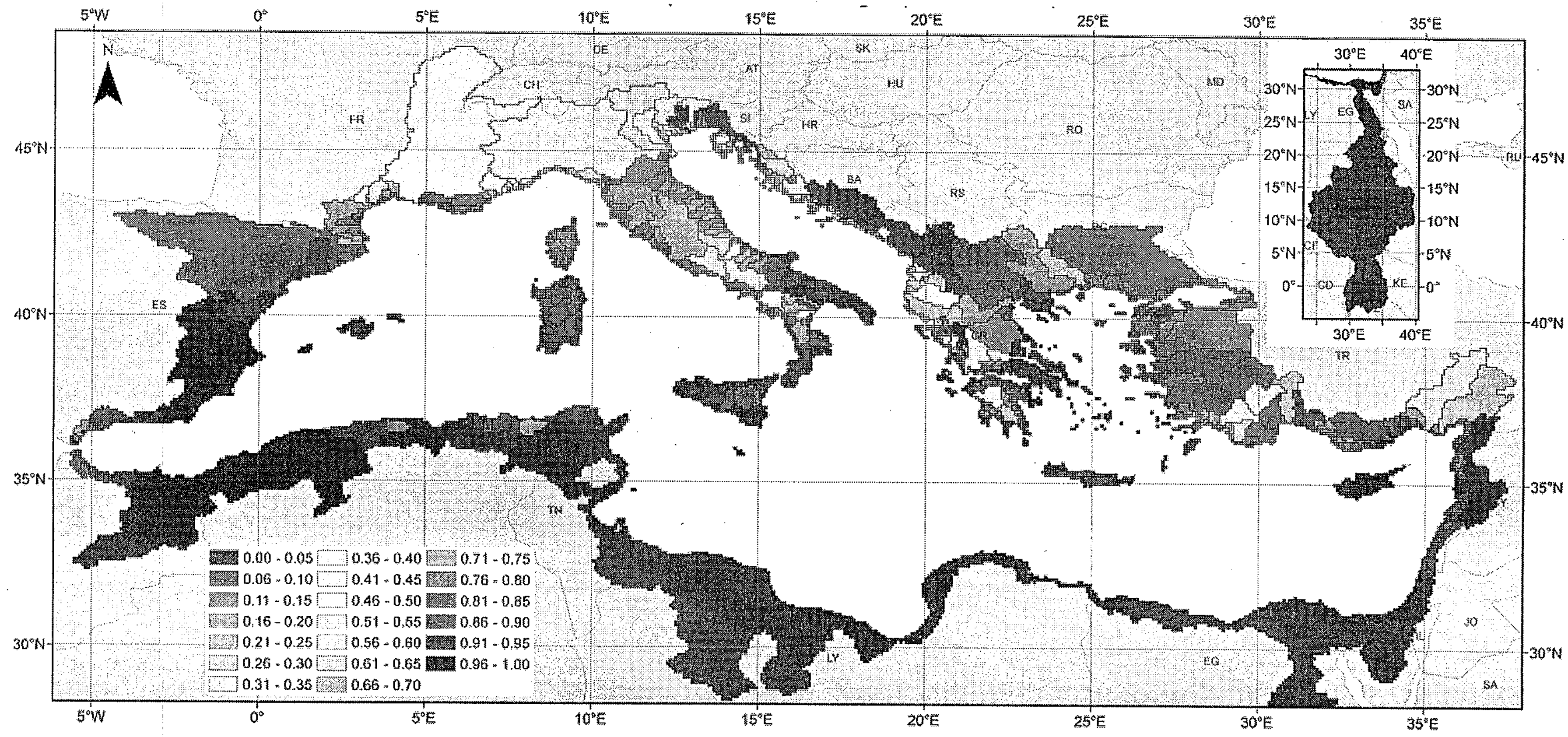


Figure 35 Retention fraction of diffuse nitrogen sources

4.3.2 Nutrient leaching, storage and removal

Only a limited fraction of the total anthropogenic inputs of nutrient to watersheds is actually exported by rivers to the coastal zone. This accounts for the net effect of various biogeochemical processes responsible for temporary or permanent removal from the water phase (such as biological uptake and biomass production, sedimentation and denitrification for nitrogen) or removal from the land phase (such as gaseous losses by denitrification and nitrification, volatilization and storage in permanent vegetation, soils and groundwater).

4.3.2.1 Nutrient leaching, storage and removal within soil and subsoil

Main driver of nutrient leaching from soils to rivers are precipitation or runoff. At the global, regional scale or for the Mediterranean drainage area, the spatial variability of the nitrogen retention could be correlated with precipitation or river runoff (Howarth *et al.* 2006; Billen *et al.* 2009; Ludwig *et al.* 2010). The ratio of diffuse source discharged to river as dissolved inorganic form may be estimated using these conceptual formulations (Dumont *et al.* 2005; Harrison *et al.* 2010):

$$C_{DIN,soil/subsoil} = 0.94 \cdot R$$

$$C_{DIP,soil/subsoil} = \frac{0.04}{1 + \left(\frac{R}{0.85}\right)^{-2}}$$

For nitrogen (*Figure* 35), less than 1% of diffuse source are discharged as dissolved inorganic nitrogen (DIN) to Southern Mediterranean Rivers. In the Northern Mediterranean Rivers, this rate increase with more than 10% for Eastern Adriatic Rivers. For the Nile, Rhone, Ebro, Po and Moulouya rivers, it reach <1%, 54%, 10%, 63% and 1%. For phosphorus (*Figure* 36), diffuse emission of dissolved inorganic phosphorus (DIP) account for less than 10% of diffuse sources for most basins. For the Nile, Ebro and Moulouya, emission of diffuse source to rivers is less than 1%. For the Rhone and Po rivers, it reaches 9 and 11%. Regardless of the nitrogen and phosphorus diffuse emissions, basins of Eastern Adriatic and Ionian Seas have the highest risk of nitrogen and phosphorus leaching from soil to rivers. Because of the relatively low diffuse emissions of nitrogen and phosphorus in Eastern Adriatic, the flux of diffuse nitrogen and phosphorus from soils to rivers is low relative to other regions previously cited, especially in the Northern Adriatic. This vulnerability is increased for nitrogen as diffuse emissions are the main source of nitrogen discharged to the rivers.

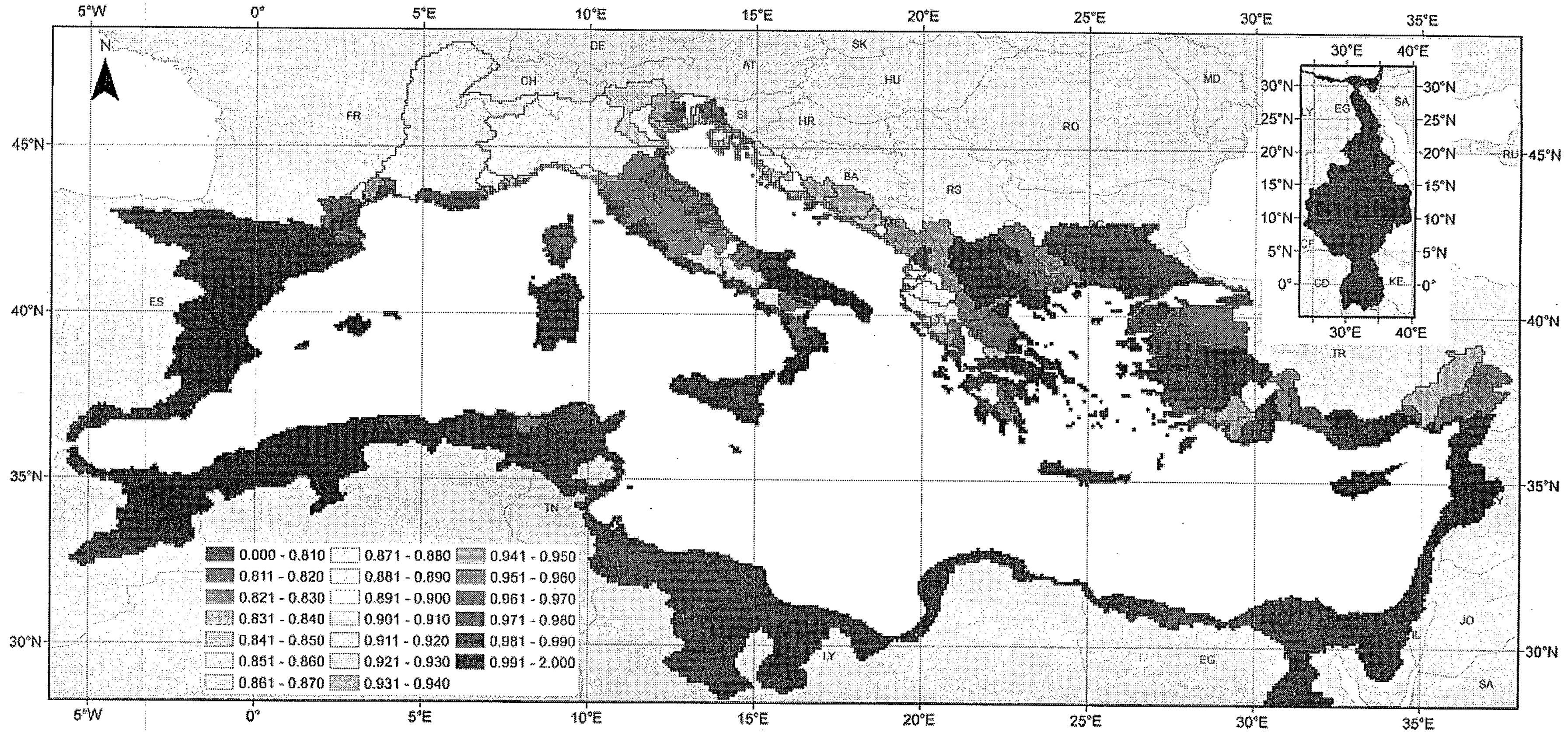


Figure 36 ***Retention fraction of diffuse phosphorus sources***

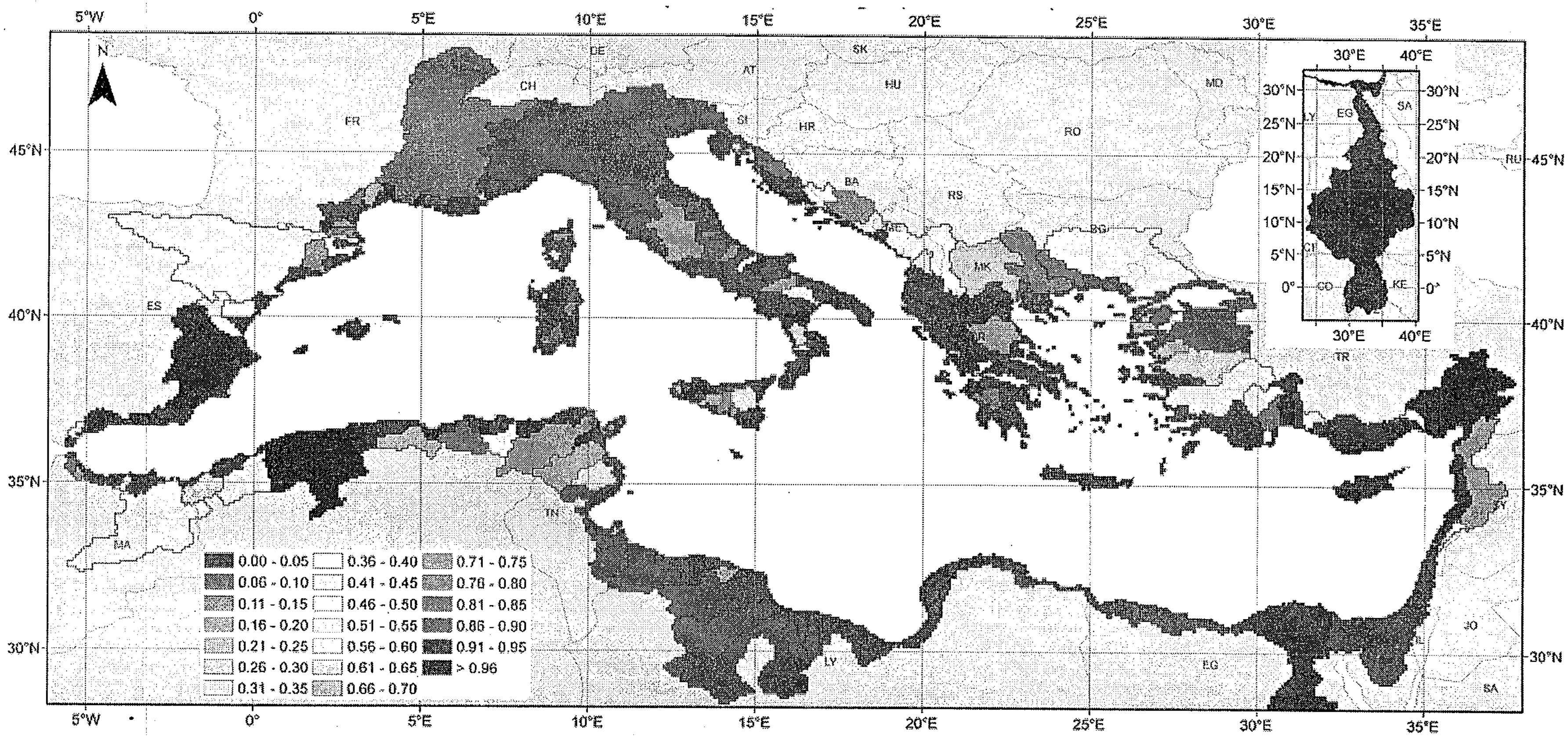


Figure 37 Water residence time in reservoirs (years)

4.3.2.2 Nutrient storage/removal within reservoir and dams

Lentic water bodies (lakes and reservoirs) have the potential to act as important sources for nitrogen and phosphorus as it is transported across the landscape because they offer ideal conditions for nitrogen or phosphorus burial in sediments or permanent loss of nitrogen via denitrification (Harrison *et al.* 2008). The Global Reservoir and Dam Database 1.1 (Lehner *et al.* 2011) compiles reservoirs with a storage capacity of more than 0.1 km^3. The recent version contains 429 spatially explicit records of reservoirs for the Mediterranean drainage basin and gives information in their storage volume. Estimation of nutrient storage/removal within reservoirs and dams may be estimated using calibrated conceptual formulation at a global scale (Wilhelmus, Bernhardt & Neuman 1978, Seitzinger *et al.* 2002) :

$$C_{DIP,res} = 1 - 0.85 \cdot \left(1 - e^{-0.0807 \cdot 365 \cdot \frac{V_{res}}{R_0}}\right)$$

$$C_{DIN,res} = 1 - 0.8845 \cdot \left(\frac{Z_{res}}{\frac{V_{res}}{R_0}}\right)^{-0.3677}$$

$\frac{V_{res}}{R_0}$ is the average residence time of water in reservoirs (effective reservoir volume divided by average annual discharge, (*Figure* 37)). Z_{res} is the average reservoirs depth. $C_{DIP,res}$ and $C_{DIN,res}$ are export fractions for dissolved inorganic phosphorus and dissolved inorganic phosphorus.

For nitrogen (*Figure* 38), the retention fraction reaches almost 100% for the Nile, Segura and Almanzora rivers. Retention higher than 30% is calculated for some large basins of Algeria (Chelif and Macta-Hammam), Tunisia (Medjerba, Joumine, Miliane) and Spain (Guadalhorce and Guadalfeo). In Spain, this retention fraction is higher than 20% for all large basins. Retention fraction is higher than 20% in Morocco (Mouloiya), Southern Italia (Bradano, Fortore, Flumendosa), in Greece (Meric, Acheloos, Aliakmon), in Turkey (Orontes). As the only reservoirs with storage capacity higher than 0.1 km^3 are listed in the Global Reservoir and Dam Database 1.1, retention fraction for small basins could be much higher than calculated value.

For phosphorus (*Figure* 39), the calibrated formulation induces a very low spatial variation of retention fraction and for most basins the retention fraction reaches the maximum retention fraction of the formulation (i.e.: 85%). Lowest retention fraction (excluding null value due to no reservoirs or lack of data for small reservoirs) is calculated for Northern Adriatic including the Po with 60%.

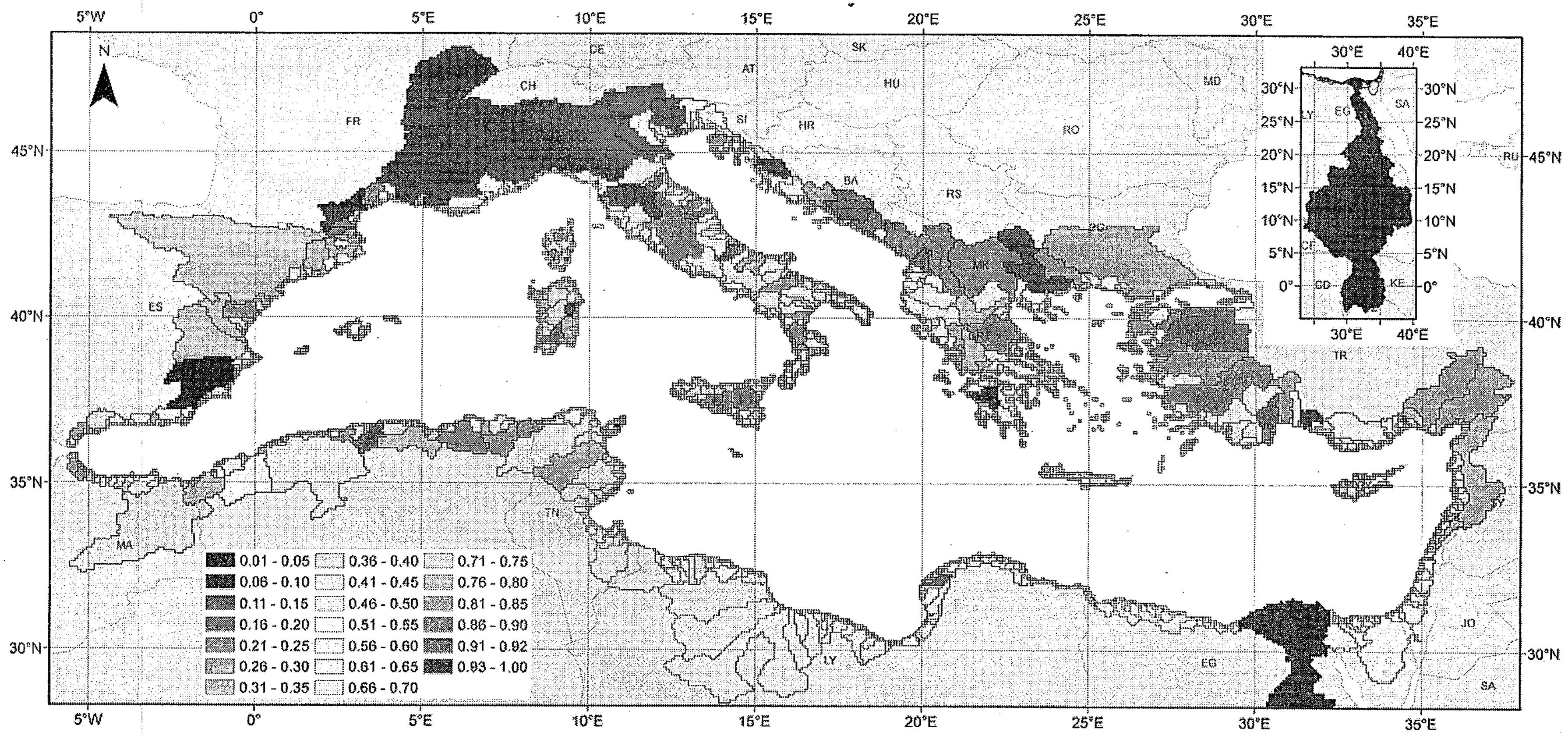


Figure 38 Retention fraction of nitrogen by reservoirs

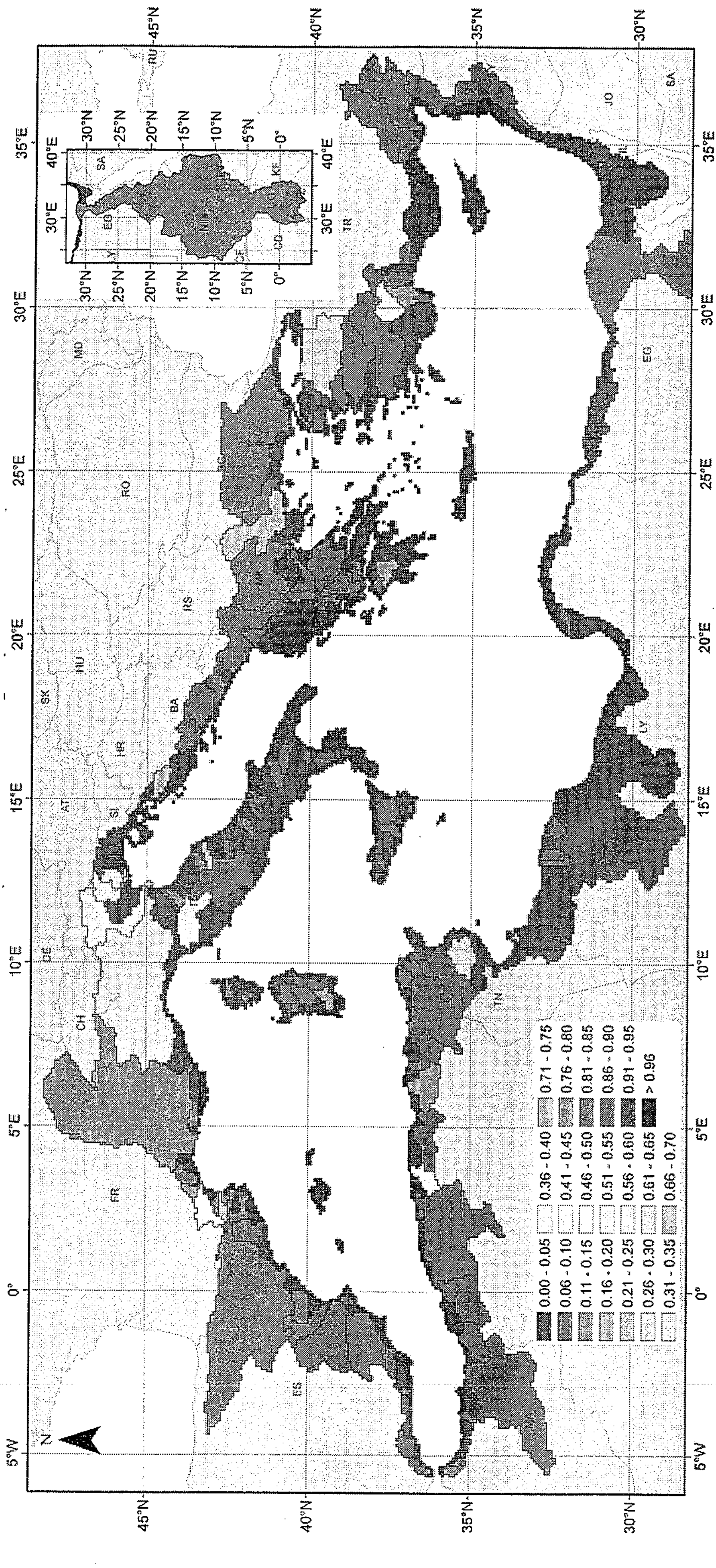


Figure 39 Retention fraction of phosphorus by reservoirs

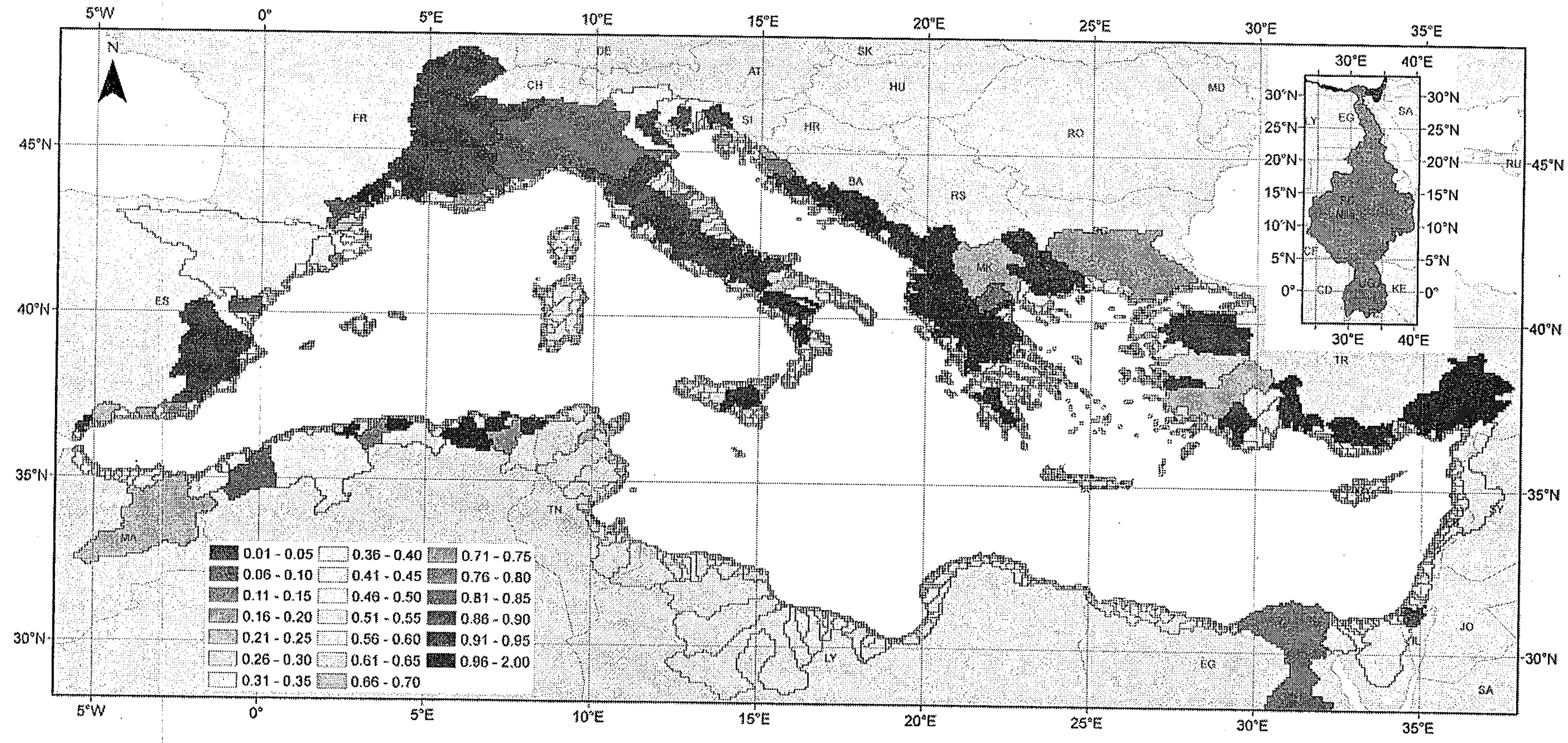


Figure 40 Ratio between gauged runoff and natural runoff

4.3.2.3 Nutrient storage/removal by water abstraction

Water removed from rivers for human consumption or irrigation and domestic and industrial use may be returned to the river or lost (consumed) permanently, primarily through evapotranspiration on irrigated lands and interbasin transfers. Biogeochemical constituents associated with net, consumptive water use are assumed to be permanently removed from the river system. So, the fraction of river flux remove consumptively (C_{abs}) could be estimated from total river discharge at the mouth before (R_0) and after (R) the implementation of large-scale irrigation and other water withdrawal schemes (Mayorga *et al.* 2010):

$$C_{abs} = 1 - \frac{R}{R_0}$$

Length of discharge data series are often too short for estimate the natural river discharge before these implementations. Approximation of the natural runoff (R_0) may be done using conceptual rainfall/runoff model. Here, we used the Pike formulation (see 3.3.1) to estimate this natural runoff as done in previous studies for the Mediterranean drainage basin (Ludwig *et al.* 2009, 2010). Greatest water abstractions are calculated for the Nile, the Eastern Maghreb and Southern Spain (*Figure* 40). Less of 10% of natural runoff discharges to the Sea for the Nile, Segura, Macta and Almanzora rivers. Other significant water abstraction for large basins is calculated for the Moulouya (77%), Chelif (62%), Ebro (49%) and Orontes (40%). For other large basin, the calculated water abstraction is lower but reach 9%, 13% 24% for the Rhone, Po and Meric. Summing natural and actual discharges, the water abstraction reaches 15% of the natural runoff for the whole Mediterranean drainage basin.

The Mediterranean region is one of the most affected regions in the world by anthropogenic river flow alterations and reservoir management (Döll, Fiedler & Zhang 2009). Agricultural demand is the most important cause of this water abstraction. In the Segura, the total water demand reaches 1.9 $km^3 yr^{-1}$ with 87% for agriculture use (CHS, 2008) while calculated runoff is only 0.6 $km^3 yr^{-1}$. While irrigation has always existed in the Nile delta, its magnitude has considerably increased, especially since the creation of the Aswan High Dam in 1965 (Nixon 2003) with a 50% decrease of discharge at the delta head. In the Orontes, a 50% decrease of discharge is observed between a Lebanese gauging station and the Syria boundary (ESCWA-BGR Cooperation 2012). In Morocco, after the construction of Mohamed V reservoir, the water discharge at the Moulouya River reduced by about 47% (Snoussi, Haïda & Imassi 2002). Then, nutrient removal or storage due to water abstraction is one of the main drivers of spatial change in nutrient flux. Given these processes commensurate with water abstraction, approximately 15% of the nutrient flux is removed before reaching the Mediterranean Sea.

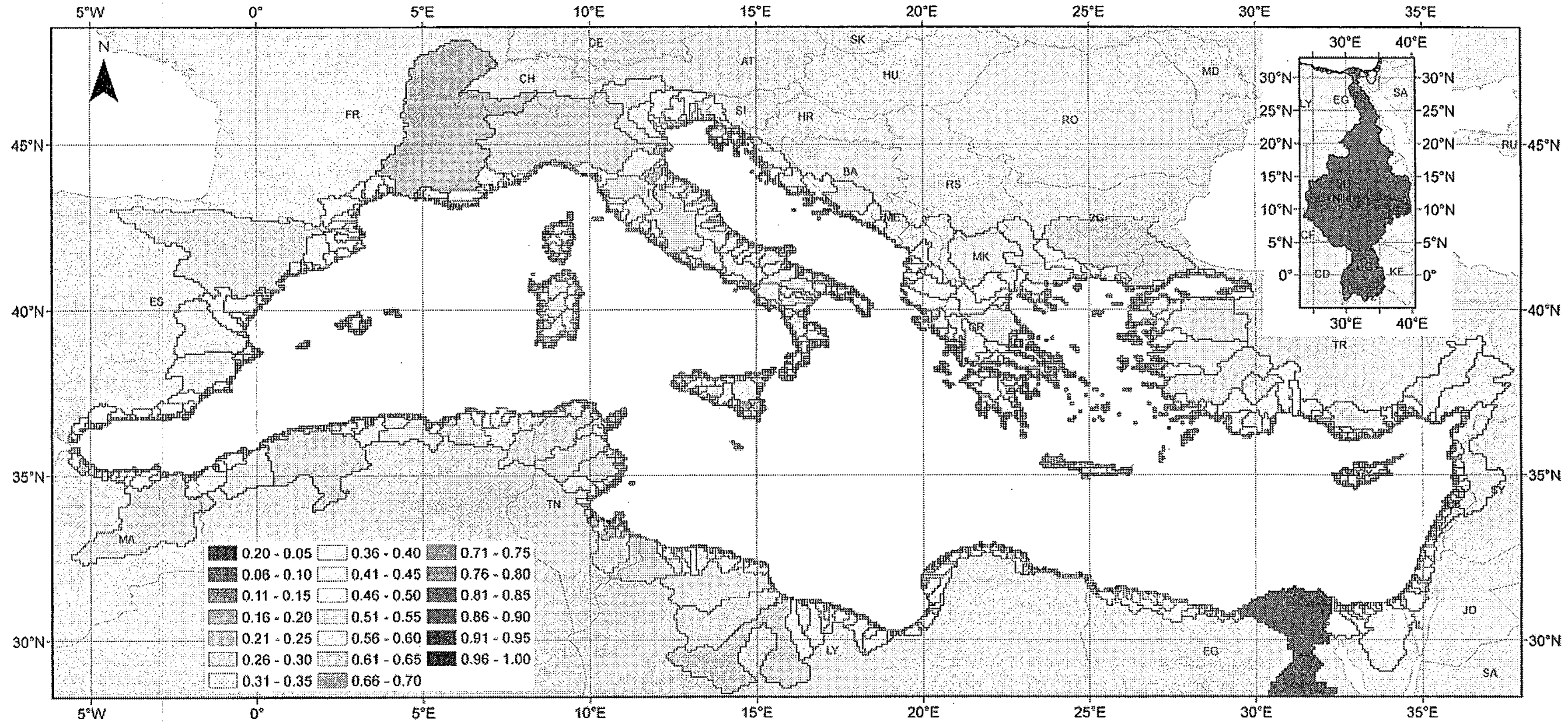


Figure 41 Retention fraction of nitrogen by instream processes

4.3.2.4 Nutrient storage/removal by instream processes

At the global scale, 13% of the nitrogen emissions is removed by river denitrification (Seitzinger *et al.* 2006). The denitrification rate is proportional of the average water travel time within basins. Here, we used a first approximation linking basin area with the dissolved nitrogen removal (Dumont *et al.* 2005):

$$C_{DIN,instream} = 1 - (0.0605 \cdot ln(Area) - 0.0443)$$

The maximum instream retention rate was calculated for the Nile with 85%. For This rate ranges from 60 to 65% for the Rhone, Po, Ebro, Moulouya, Meric and Chelif and approaches 0% for the smallest basins (*Figure* 41).

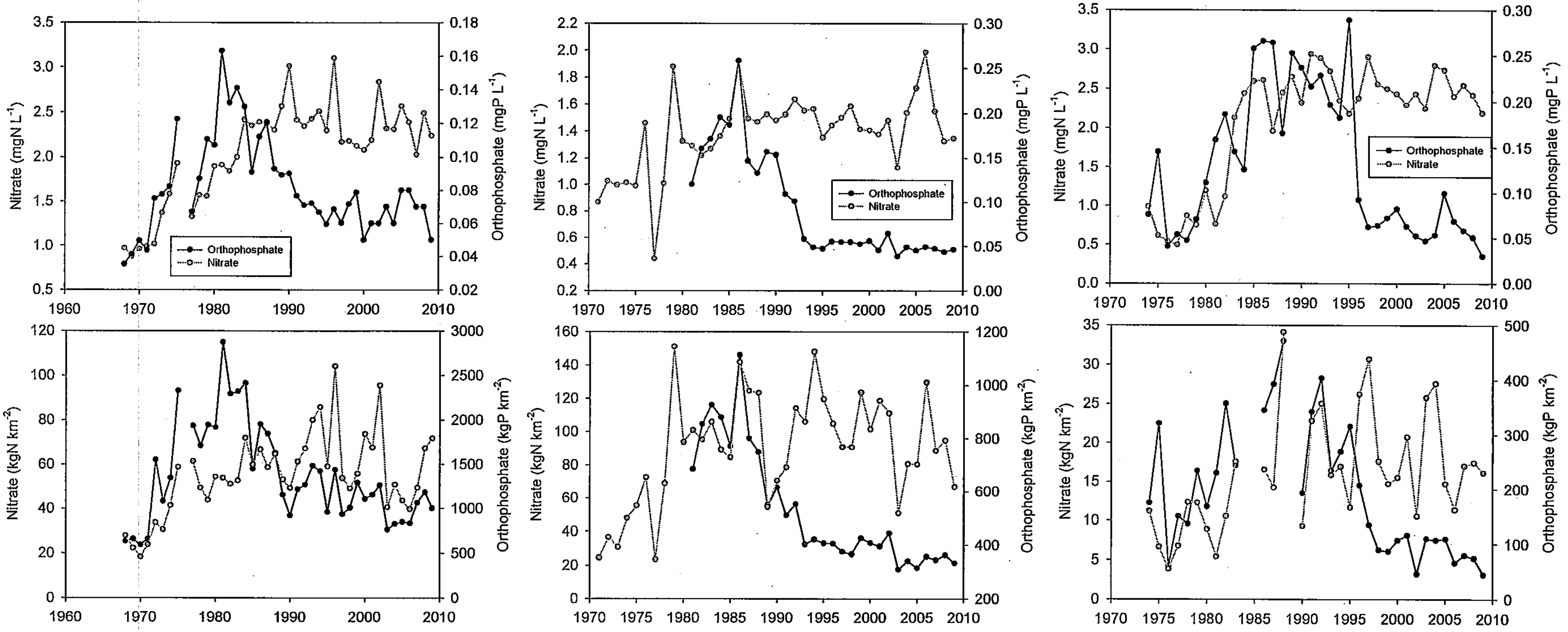


Figure 42 Concentration (A) and annual specific flux evolution of the Po (left), Rhone (Middle) and Ebro (Right) from 70's to 2009

4.4 Past change in nutrient concentrations and fluxes

Monitoring programs for large rivers are generally better developed than for small rivers, and water quality data are more easily available. Another advantage is that large river basins integrate the variety of human activities at regional scales, making them more representative than smaller basins. For these reason, we focus in our trend evaluation first of all at the evolution of the nutrient concentrations in the Rhone, Po and Ebro rivers (*Figure* 42). For nitrate, concentrations increased steadily from the beginning of the 1970s's in all three rivers. Only since the beginning of the 1990s, the values seem to remain at more or less constant concentrations. The increase was more important in the Ebro and Po rivers than in the Rhone River. Also, the annual nitrate loads increased on average in all three rivers. These trends are in good agreement with the situation in other European rivers. At many sites, annual concentrations are approaching a steady state, after two decades of rapid increase. On the basis on linear correlation of the loads and time, it can be estimated that for the 1970s to 1995 period, the nitrate loads increased on average by about 10% per year in the Ebro River. In the Rhone and Po rivers, this increase was about 4% and 5% per year, respectively.

For phosphate, the trends are more diversified. There is also a strong increase of the phosphate concentrations in the Po, Rhone and Ebro rivers at the beginning of the 1970s, even more pronounced than in the case of nitrate. But about 10 to 20 years later, this evolution stops and the values started to decrease again. It is remarkable that in all three rivers, the phosphate concentrations at the end of the 1990s meet again the values that have been encountered at the beginning of the 1970s. When taking the mean of the phosphate loads in the three rivers, one can estimate that phosphate loads from 1975 to 1985 increased on average by about 15% by year. From 1985 to 1995, they decreased again about the initial value. But the evolution is not completely in phase between the three rivers, since the start of the decrease is different. This can be seen best when looking at the phosphate loads. The decline started earliest in the Po river (about 1980), followed than by the Rhone river (around 1985) and finally the Po river (around 1993). Phosphorus concentrations in European Union and Accession country rivers generally declined by 30-40% during the 1990s, with greatest reductions in areas with formerly high phosphorus concentration. Evolution to better water quality was more rapid in Western Europe than in Southern Europe.

Table 6 Change in nutrient emissions between 1970s and 2000s (10^3 t yr^{-1})

Sea Sub-basin	N diffuse	N point	N total	P diffuse	P point	P total
NWE	75	4	79	-26	-4	-30
TYR	-53	-7	-59	-18	-5	-22
ION	-52	-3	-54	-14	-1	-16
ADR	-168	-28	-195	-61	-15	-77
AEG	137	40	178	-16	8	-8
NLE	175	36	211	28	7	35
SLE	2102	83	2184	296	17	313
CEN	48	17	64	4	3	7
SWE	90	37	127	12	7	19
ALB	20	21	40	1	4	5
TOTAL	2374	201	2575	206	21	227

4.5 Main drivers of change in nutrient concentrations and fluxes

4.5.1 Nutrient emissions

For phosphorus (*Table* 6), the decreasing trend observed in the European rivers could be linked with change in phosphorus emissions in the past decades. While increase in population density was low, point source of phosphorus were largely decreased with the upgrading of wastewater treatment, cleaner technology in industry and interdiction of phosphorus use in detergents. The use of phosphorus in fertilizer also decreased due to adjustments of agricultural practices and increase of the fertilizer costs. In other Mediterranean countries, the demographic evolution and increase of agricultural area, induced an increase of diffuse and point emission of phosphorus. In the total Mediterranean drainage basin, phosphorus emissions increased of 227 10^3 tP yr^{-1} between 1970s and 2000s. For nitrogen, we also observed a decrease in nitrogen emission for basins of the Tyrrhenian, Ionian and Adriatic Seas. However, looking evolution of nitrogen flux for the Po River, this decrease did not induce a decreasing trend for nitrogen flux. This is probably due to the inertia of the hydrochemical response. For the other Mediterranean regions, we observed an increase of both diffuse and point emissions of nitrogen. As for phosphorus, these increased are due to the increase in fertilizer use and population density.

4.5.2 Nutrient storage and removal

As nutrient leaching is controlled by the water discharge within basins, it is likely that decreasing runoff trends for most of Mediterranean Rivers promote a decrease in the nutrient flux.

4.6 Budget and future scenarios for nutrient fluxes

4.6.1 Scenarios

Four MEA scenarios have been implemented in IMAGE for the years 2030s. Each scenario represents a possible socioeconomic development of the world in the near future and is named according to its major characteristics (for a detailed description, see Alcamo et al. (2006)): Global Orchestration (GO), Order from Strength (OS), Adapting Mosaic (AM) and Technogarden (TG). 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. 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. AM depicts a fragmented

Table 7 Diffuse emissions of nitrogen by sea sub-basin for 2000s and 2030s

Sea sub-basin	10^3 tN yr^{-1}					kgN km^{-2} yr^{-1}				
	2000s	2030 TG	2030 AM	2030 GO	2030 OS	2000s	2030 TG	2030 AM	2030 GO	2030 OS
NWE	1072	846	928	1051	1032	3585	2829	3103	3515	3451
TYR	209	190	223	272	251	2090	1900	2230	2720	2510
ADR	794	594	666	773	760	3350	2506	2810	3261	3206
ION	128	101	116	142	135	1984	1566	1798	2201	2093
AEG	1002	893	1006	1192	1092	3299	2940	3312	3924	3595
NLE	452	449	459	533	484	2889	2870	2934	3407	3093
SLE	7778	9019	8157	9963	9126	2537	2942	2661	3250	2977
CEN	315	367	380	415	388	1261	1469	1521	1661	1553
SWE	294	337	355	376	365	3281	3761	3962	4197	4074
ALB	287	391	437	436	454	1800	2452	2741	2735	2848
TOTAL	12330	13187	12727	15153	14088	2609	2791	2693	3207	2981

Table 8 Diffuse emissions of phosphorus by sea sub-basin for 2000s and 2030s

Sea sub-basin	10^3 tP yr^{-1}					kgP km^{-2} yr^{-1}				
	2000s	2030 TG	2030 AM	2030 GO	2030 OS	2000s	2030 TG	2030 AM	2030 GO	2030 OS
NWE	85	86	90	108	105	284	288	301	361	351
TYR	26	29	32	42	39	260	290	320	420	390
ADR	95	80	85	100	103	401	338	359	422	435
ION	12	13	15	19	18	186	202	233	295	279
AEG	92	110	116	145	129	303	362	382	477	425
NLE	52	70	72	82	74	332	447	460	524	473
SLE	385	802	500	846	703	126	262	163	276	229
CEN	25	36	36	43	39	100	144	144	172	156
SWE	37	48	50	54	52	413	536	558	603	580
ALB	27	49	53	52	57	169	307	332	326	358
TOTAL	834	1323	1049	1489	1318	176	280	222	315	279

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 toward improving knowledge about ecosystem functioning and management. TG finally depicts a globally connected world relying strongly on technology and on highly managed and often engineered ecosystems to deliver needed goods and services. Overall, ecoefficiency improves, but it is shadowed by the risks inherent in large-scale human made solutions. Note that in two of the scenarios, societies generally have a proactive approach to environmental problems (TG, AM), whereas a reactive approach is dominant in the two other scenarios (GO, OS).

4.6.1.1 Evolution of nutrient diffuse emission

In 2000s, the total diffuse emission of nitrogen within the Mediterranean drainage basin is about 12.3 10^6 tN yr^{-1}. Due to the size of the Nile basin, SLE account for 63% of this total emission. Nitrogen emissions for Northern Mediterranean basins account for 30%. Per unit area, the strongest emissions are in the Northern Mediterranean drainage area, with more than 3000 kgN km^{-2} for NWE, ADR and AEG. Lowest emissions per unit area are observed in CEN. Whatever the scenario, we have an increase of diffuse emissions in 2030s, ranged from 3% (AM) to 23% (GO) for the whole Mediterranean drainage area. In contrast, for the Adriatic drainage area, these emissions decrease for the four scenarios. For the TG scenario, decrease is calculated for all the Northern Mediterranean sub-basin. Per unit area, emissions within SWE drainage area should be the strongest in 2030s and ranged from 3800 to 4200 kgN km^{-2}.

For phosphorus, the diffuse emission in 2000s is about 843 10^3 tP yr^{-1}. SLE accounts for 46% of these emissions and Northern Mediterranean basins for 43%. As nitrogen, emission increase for the four scenarios, with an increase ranged from 26% (AM) to 79% (GO). In the Northwestern, emissions are in a steady state or increase slowly. In the Northeastern and Southern Mediterranean Sea, the emission increase is stronger.

Table 9 Point emissions of nitrogen by sea sub-basin for 2000s and 2030s

Sea sub-basin	10^3 tN yr^{-1}					kgN km^{-2} yr^{-1}				
	2000s	2030 TG	2030 AM	2030 GO	2030 OS	2000s	2030 TG	2030 AM	2030 GO	2030 OS
NWE	81	71	78	76	77	271	237	261	254	257
TYR	42	45	45	46	44	420	450	450	460	440
ADR	105	93	92	99	87	443	392	388	418	367
ION	12	16	16	17	15	186	248	248	264	233
AEG	83	120	118	119	115	273	395	388	392	379
NLE	41	59	63	57	62	262	377	403	364	396
SLE	115	324	233	302	232	38	106	76	99	76
CEN	26	44	43	41	43	104	176	172	164	172
SWE	58	85	94	80	94	647	949	1049	893	1049
ALB	33	59	64	55	66	207	370	401	345	414
TOTAL	596	916	846	892	834	126	194	179	189	176

Table 10 Point emissions of phosphorus by sea sub-basin for 2000s and 2030s

Sea sub-basin	10^3 tP yr^{-1}					kgP km^{-2} yr^{-1}				
	2000s	2030 TG	2030 AM	2030 GO	2030 OS	2000s	2030 TG	2030 AM	2030 GO	2030 OS
NWE	16	11	12	11	12	54	37	40	37	40
TYR	7	8	8	8	8	70	80	80	80	80
ADR	18	15	16	16	15	76	63	68	68	63
ION	2	3	3	3	3	31	47	47	47	47
AEG	17	25	25	24	24	56	82	82	79	79
NLE	8	12	13	12	13	51	77	83	77	83
SLE	25	66	48	61	48	8	22	16	20	16
CEN	5	9	9	8	9	20	36	36	32	36
SWE	12	17	19	16	19	134	190	212	179	212
ALB	7	11	13	11	13	44	69	82	69	82
TOTAL	118	176	164	170	163	25	37	35	36	34

4.6.1.2 Evolution of nutrient emission by wastewaters

For the four scenarios, we obtain an increase in point source emissions of nitrogen and phosphorus in 2030s. For nitrogen, future emissions range from 0.83 10^6 tN yr^{-1} (OS) to 0.92 10^6 tN yr^{-1} (TG). For phosphorus, emissions are ranged from 0.16 to 0.18 tP 10^6 tP yr^{-1}. These increases are explained by the strong demographic growth for the countries of North Africa in the coming decades. Especially for SLE, including the Nile, emissions are between 25 and 30% of the emissions for the whole Mediterranean drainage area. For NWE and ADR, emissions decrease with the four scenarios for both phosphorus and nitrogen. Expressed per unit area, the highest nitrogen emissions are between 0.95 10^3 and 1.05 10^3 kgN km^{-2} for SWE. The low values observed for SLE must be weighted by the location of emissions. Indeed, a large part of point source emissions of nitrogen is due to population within the Nile delta. Emissions in ADR and TYR remain relatively high with values between 0.37 10^3 and 0.46 10^3 kg N km^{-2}.

***Table* 11 Fluxes of dissolved inorganic nitrogen (10^3 tN yr^{-1}) in 2000s and 2030s scenarios**

Sea sub-basin	10^3 tN yr^{-1}					kgN km^{-2} yr^{-1}				
	2000s	2030 TG	2030 AM	2030 GO	2030 OS	2000s	2030 TG	2030 AM	2030 GO	2030 OS
NWE	165	119	131	146	145	552	398	438	488	485
TYR	62	50	57	66	62	620	500	570	660	620
ADR	257	192	210	238	243	1084	810	886	1004	1025
ION	36	30	32	37	35	558	465	496	574	543
AEG	126	122	127	138	133	415	402	418	454	438
NLE	84	88	90	93	92	537	562	575	594	588
SLE	19	26	28	25	28	6	8	9	8	9
CEN	18	28	27	27	27	72	112	108	108	108
SWE	37	47	51	45	51	413	525	569	502	569
ALB	17	22	23	21	24	107	138	144	132	151
TOTAL	821	724	776	836	840	174	153	164	177	178

***Table* 12 Fluxes of dissolved inorganic phosphorus fluxes (10^3 tP yr^{-1}) in 2000s and 2030s scenarios**

Sea sub-basin	10^3 tP yr^{-1}					kgP km^{-2} yr^{-1}				
	2000s	2030 TG	2030 AM	2030 GO	2030 OS	2000s	2030 TG	2030 AM	2030 GO	2030 OS
NWE	9.1	6.5	7.2	6.9	7.2	30	22	24	23	24
TYR	5.5	5.2	5.3	5.5	5.2	55	52	53	55	52
ADR	10.1	8.6	8.8	9.1	8.6	43	36	37	38	36
ION	2.1	2.4	2.5	2.6	2.4	33	37	39	40	37
AEG	19.2	25.2	25	25.1	24.4	63	83	82	83	80
NLE	5.7	7.8	8.3	7.5	8.2	36	50	53	48	52
SLE	5.6	7.4	8	6.9	8	2	2	3	2	3
CEN	3.8	6.2	6.2	5.8	6.1	15	25	25	23	24
SWE	5.8	7.9	8.9	7.3	8.9	65	88	99	81	99
ALB	2.9	4	4.6	3.7	4.6	18	25	29	23	29
TOTAL	70	81.3	84.6	80.5	83.5	15	17	18	17	18

4.6.2 Model framework and future budgets

For simulation of the future nutrient fluxes to the Mediterranean Sea, we used the model Global NEWS 2 which has been recalibrated on the basis of our data. Global NEWS 2 is a global, spatially explicit, multi-element and multi-form model of nutrient exports by rivers (Mayorga *et al.* 2010). NEWS distinguished point sources, which include wastewater emissions from households and industries, and non-point or diffuse sources, including loading of rivers from agricultural land use and natural ecosystems. The NEWS formulation for dissolved inorganic nitrogen (DIN) and phosphorus (DIP) is:

$$F_{X,river} = C_{abs} \cdot C_{X,instream} \cdot C_{X,res} \cdot \left(C_{X,soil/subsoil} \cdot \left(F_{X,diffuse} + F_{X,weathering}\right) + F_{X,point}\right)$$

All components have been previously described (see 4.3.2). $F_{X,weathering}$ is set to 0 for DIN and 26 for DIP. For DIP, $C_{X,instream}$ is set to 1. When water discharge and nutrient concentration are available for actual period, modeled values for 2030s are corrected by the ratio between observed and modeled values for actual period and observed values were used for actual period when available.

The total DIN flux for 2000s is about 821 10^3 tN yr^{-1} (*Table* 11). 31% are discharged in the Adriatic Sea, 20% in the Northwestern Mediterranean Sea and 15% in the Aegean Sea. The Northern Mediterranean Rivers discharge 89% of the total DIN flux. However, for the Nile the modeled DIN flux is zero. As nitrate concentration is about 7 mgN L^{-1}, the DIN flux for the Nile should be stronger than 105 10^3 tN yr^{-1}. Then, the total DIN flux is probably closed to 1 10^6 tN yr^{-1}. For DIP, the total flux to the Mediterranean Sea is about 70 10^3 tP yr^{-1} (*Table* 12). 27% of the DIP flux is discharged to the Aegean Sea. DIP flux in the Northwestern Mediterranean Sea and the Adriatic Sea are 13 and 14% of the total DIP flux. The Northern Mediterranean Rivers discharge 74% of the total DIP flux.

For 2030s, we computed a decrease in DIN fluxes with the TG (-12%) and AM (-4%) scenarios and an increase for the GO (+2%) and OS (2%) scenarios. For DIP, we computed an increase of fluxes for the four scenarios ranged from +16% for TG and +21% for AM. Whatever the scenario, DIN and DIP fluxes should be lower in the Northwestern Mediterranean Sea and the Adriatic Sea. In contrast, an increase of DIN and DIP fluxes should occur in the Eastern and Southern Mediterranean Sea.

Chapter 5 - Conclusions and perspectives

This inventory has allowed building the most complete dataset on the Mediterranean basin for nutrient concentrations and water discharge in rivers. These data allow estimation of average river nutrient fluxes for many rivers of the Mediterranean basin in 2000s.

However, there are significant gaps. Particularly for Southern Italy, Eastern Adriatic Sea and Greece, we do not have water discharge data after 2000s when we have values for nutrient concentrations in subsequent years. So, nutrient fluxes calculated for these rivers with older values for water discharge could not depict actual values if significant climatic or anthropogenic change occurred in the last decade. For Turkey, we lack data for both nutrient concentrations and water discharge. Data exist but only the inter-annual values are available. It is the same for Eastern and Southern Mediterranean where times series for water discharge are no more updated and only few data for nutrient concentrations are available in the scientific literature.

The two main gaps to assess **global nutrient inputs** in the Mediterranean Sea are water discharge and nutrient concentration data for the Turkish rivers and the Nile. Despite the very strong decline in water discharge since the construction of the Aswan Dam, the strong population density and intensive agriculture in the delta induce high concentration of nutrient emissions.

To assess **regional nutrient inputs**, we need water discharge data from 2000s for the Adriatic and Aegean Seas basins and the northern Africa basins. It is necessary to have data of nutrient concentrations and water discharge for nearby or similar stations near the river mouth.

Otherwise many data collected via previous datasets cannot be used to assess a nutrient flux or to consider the value as representative of nutrient inputs in the sea. This is especially true for the Mediterranean where many cities are found along the coast and water withdrawals or urban sewage near the sea can have a significant impact on the basin nutrient budget.

Modeling allows us to estimate the water discharge and nutrients fluxes for rivers without observations for nutrient or water discharge data. While models produce accurate results for water discharge and nitrogen flux, it is important to improve models for phosphorus.

Trend analysis highlight **decline of water discharge in the last 50 years.** This decline results in largely part to a decreasing trend of precipitation. However, increases in reservoir

capacity and irrigated area are also a driver of this decline. Different climate scenarios show that regardless of change in water use, the **water discharge should continue to decline in the coming decades**. Demographic growth and intensification of agricultural practices in eastern and southern Mediterranean Sea should induce a larger decrease in this water discharge.

In the **Southern Mediterranean Sea**, the river water discharge account for only 7% of whole Mediterranean Rivers (3% excluding the Nile). These low inputs suggest a **low impact of changes in nutrient fluxes** compared to the total river discharge. The Nile is a specific case as it accounts for almost 4% of the water discharge by rivers and as nutrients emissions are very strong closed to the river mouth. Nitrate flux from the Nile is about 105 10^3 tN yr^{-1}, i.e. 11% of total inorganic nitrogen discharge. Given the future trends in agriculture and population for Egypt, the **Nile should remain a major river** on for nutrient discharged to the Mediterranean Sea.

In the **Northwestern Mediterranean Sea and Northern Adriatic Sea**, despite low trends for nutrient emissions within basins regarding the other Mediterranean regions, their impact should be stronger as the higher precipitation increase the nutrient leaching from soil to the river mouth. Between these two regions, around the **Aegean Sea and Northern Levantine Sea**, we have an intermediate situation with a relatively large demographic and agricultural growths and moderate leaching rate of nutrient. Among the four scenarios proposed, Technological Garden is the scenario limiting most of the nutrient export with a decreasing flux of inorganic nitrogen and a low increase of phosphorus flux.

Chapter 6 - References

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Chapter 7 - Annexes

Annexe 1 Interannual average runoff and last 20 years runoff for Mediterranean Rivers. Station: name f the gauging station, Area: gauged area (km^2), T_{all}: time coverage for annual river discharge calculation, Q_{all}: average annual water discharge (km^3 yr^{-1}), R_{all}: interannual average of annual runoff (mm yr^{-1}), T_{recent}: time coverage of the last 20 years annual data, R_{recent}: average annual runoff for the last 20 years (mm yr^{-1}). Bold values: recent values lower than average on all values.

Country	River	Station	Area (km²)	T_{all}	Q_{all}	R_{all}	T_{recent}	R_{recent}	Source
Spain	Guadiaro	unspecified	*1515*	11-00	0.34	229			Liquete *et al.* 2005
		Central Corchado	572	12-92	0.35	613	73-92	**477**	CMAJA, 2012[1]
	Guadalhorce	unspecified	unspecified	11-00	0.23	73			Liquete *et al.* 2005
		Gobantes	211	35-72	0.10	101	53-72	105	CMAJA, 2012
	Guadalfeo	unspecified	unspecified	42-00	0.02	14			Liquete *et al.* 2005
	Andarax	unspecified	2188	42-00	0.01	6			Liquete *et al.* 2005
		El Chono	616	36-92	0.01	10	72-92	**7**	CMAJA, 2012
	Almanzora	unspecified	2611	unspecified	<0.01	1			Barragan-Alarcon 2010
		Santa Barbara	1850	63-08	0.02	10	75-08	**6**	CMAJA, 2012
	Segura	Guardamar del Segura	14925	27-09	0.09	6	90-09	**<1**	CEH, 2012[2]
	Vinalopo	Aspe	1639	17-69	0.01	8	49-69	10	CEH, 2012
	Jucar	Huerto Mulet	21497	47-06	1.02	48	85-07	**30**	CEH, 2012
	Turia	La Presa	6294	17-08	0.37	59	87-08	**32**	CEH, 2012
	Mijares	Villareal	4018	20-31	0.75	185			CEH, 2012
		Villareal	2504	20-08	0.23	92	89-08	**61**	CEH, 2012
	Ebro	Tortosa	84230	17-09	13.66	162	90-09	**104**	CEH, 2012
	Llobregat	Sant Joan Despi	4915	00-09	0.32	65			ACA, 2012[3]
	Besos	Santo Coloma de Gramenet	1039	03-09	0.14	131			ACA, 2012
	Ter	Torroella de Montgri	3010	01-09	0.33	110			ACA, 2012

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[1] http://www.agenciamedioambienteyagua.es

[2] http://hercules.cedex.es/general/default.htm

[3] http://aca-web.gencat.cat/sdim/visor.do

Country	River	Station	Area	T_{all}	Q_{all}	R_{all}	T_{recent}	R_{recent}	Source
France	Têt	Perpignan	1338	71-09	0.33	249	90-09	**227**	Banque Hydro 2012[4]
	Agly	Rivesaltes	1040	71-87	0.17	160			Banque Hydro 2012
	Aude	Moussan	4838	64-08	1.34	278	83-08	**244**	Banque Hydro 2012
	Orb	Beziers	1330	66-09	0.74	557	90-09	564	Banque Hydro 2012
	Herault	Agde	2550	52-09	1.33	520	84-09	**388**	Banque Hydro 2012
	Rhône	Beaucaire	95590	20-09	53.52	560	89-09	**548**	Banque Hydro 2012
	Argens	Roquebrune	2530	71-09	0.58	228	87-09	**189**	Banque Hydro 2012
	Var	Nice	2820	74-09	1.53	544	82-09	**543**	Banque Hydro 2012
Italy	Magra	unspecified	unspecified	51-67	1.22	719			ISTAT 2006
	Serchio	Vecchiano	1565	05-09	1.50	1050			ARPA, 2012[5]
	Arno	San Giovanni alla Vena	8186	24-09	2.77	339	90-09	**299**	ARPA 2012
	Ombrone	unspecified	unspecified	unspecified	1.00	339			ISTAT 2006
		Sasso d'Ombrone	2657	26-09	0.73	274	89-09	**199**	ARPA 2012
	Marta	unspecified	unspecified	unspecified	0.23	218			ISTAT 2006
	Tevere	Ripetta - Roma	16545	21-08	6.81	412	88-08	**317**	ARPA 2012
	Garigliano	unspecified	unspecified	unspecified	2.84	482			ISTAT 2006
		Sora (Liri)	1329	29-93	0.56	423	60-93	**407**	ARPA 2012
	Volturno	Cancello e Arnone	5558	31-93	2.87	517	60-93	**481**	ARPA 2012
	Sele	Albanella	3235	66-93	2.06	636	66-93	**538**	ARPA 2012
	Crati	unspecified	unspecified	unspecified	0.85	330			ISTAT 2006
	Sinni	Valsinni	1142	37-76	0.64	561	57-76	**543**	ARPA 2012
	Agri	unspecified	unspecified	unspecified	0.58	351			ISTAT 2006
	Basento	Menzena	1405	29-71	0.44	315	51-71	**277**	ARPA 2012
	Bradano	Tavole Palatine	2743	33-71	0.19	68	52-71	**60**	ARPA 2012
	Ofanto	San Samuele du Cafiero	2716	30-96	0.41	153	76-96	**105**	ARPA 2012
	Candelaro	Ponte 13 Luci	2560	56-95	0.27	107			PEER-EurAqua 2012[6]
	Fortore	unspecified	1650	<94	0.38	230			ISTAT 2006
	Biferno	Altopantano	1215	35-01	0.47	316	72-01	**213**	ARPA, 2012

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[4] www.hydro.eaufrance.fr/selection.php

[5] http://www.arpa.fvg.it/index.php?id=198

[6] http://www.peer.eu/about_peer/euraqua_collaboration/network_of_hydrological_observatories

Country	River	Station	Area	T_{all}	Q_{all}	R_{all}	T_{recent}	R_{recent}	Source
Italy	Trigno	unspecified	1089	<94	0.35	319			ISTAT 2006
	Sangro	Paglieta	1478	77-94	0.78	527			ARPA 2012
	Pescara	Santa Teresa	2125	92-01	1.21	567			ARPA 2012
	Tronto	unspecified	1211	<07	0.27	224			Syvitski & Kettner 2007
	Chienti	unspecified	1255	<07	0.28	224			Syvitski & Kettner 2007
	Metauro	unspecified	1438	<07	0.34	235			Syvitski & Kettner 2007
	Reno	unspecified	4925	<06	1.19	241			ISTAT 2006
	Po	Pontelogoscuro	70091	18-09	47.25	674	88-09	**646**	ARPA 2012
	Adige	Boara Pisani	11954	22-09	6.78	560	90-09	**490**	ARPA 2012
	Brenta	unspecified	5840	47-82	3.76	645			Cozzi & Giani 2011
	Piave	Ponte di Piava	4100	56-65	1.73	422			Cozzi & Giani 2011
	Livenza	Meduna di Livenza	2222	56-65	2.78	1251			Cozzi & Giani 2011
	Tagliamento	Pioverno	2274	67-74	1.99	875			Cozzi & Giani 2011
	Soca	Pieris	3400	56-65	6.43	1891			Cozzi & Giani 2011
	Simeto	unspecified	4186	unspecified	0.79	189			Longhitano & Colella 2007
	Imera	Drasi	1782	60-97	0.19	105	0.20	112	ARPA 2012
Croatia	Mirna	Portonski Most	458	55-87	0.25	546			Cozzi & Giani 2011
	Gacka	Vivoze	584	51-05	0.46	788			Bonacci & Andric 2008
	Licka	Skolpe	1014	51-05	0.77	759			Bonacci & Andric 2008
	Zrmanja	Jankovica Buk	1367	53-90	1.23	900			Bonacci 1999
	Krka	Skradinski Buk gornji	2285	61-09	1.74	759	80-09	**694**	EWA 2012[7]
	Cetina	Mouth	3700	unspecified	3.66	989			Štambuk-Giljanović 2009
		Tisne Stine	1456	60-09	1.00	689	80-09	**342**	MED-HYCOS 2012[8]
	Neretva	unspecified	8700	unspecified	8.74	1005			Skoulikidis 2009
	Trebisjnica	unspecified	3151	unspecified	3.16	1004			Skoulikidis 2009
	Drini	unspecified	20585	unspecified	21.4	1040			Skoulikidis 2009
		Podgorica	2628	48-90	4.70	1790	70-90	1896	MED-HYCOS 2012
Albania	Mati	unspecified	2441	unspecified	3.25	1332			Cullaj *et al.* 2005
	Erzeni	unspecified	760	unspecified	0.57	751			Cullaj *et al.* 2005

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[7] http://www.bafg.de/nn_267044/GRDC/EN/02__Services/05__Special__DBs/EWA/ewa__node.html?__nnn=true

[8] http://medhycos.mpl.ird.fr/

Country	River	Station	Area	T_{all}	Q_{all}	R_{all}	T_{recent}	R_{recent}	Source
Albania	Shkumbini	unspecified	2444	unspecified	1.94	794			Cullaj *et al.* 2005
		Murash	1289	50-90	1.10	853	71-90	**779**	MED-HYCOS 2012
	Seman	unspecified	5649	unspecified	3.02	535			Cullaj *et al.* 2005
	Vjosa	unspecified	6813	unspecified	5.55	815			Skoulikidis 2009
		Dorez	5420	65-84	4.60	849			GRDC 2012[9]
Greece	Thyamis	unspecified	*1831*	unspecified	1.70	931			Kotti *et al.* 2005
	Arachtos	unspecified	*1907*	unspecified	2.08	1091			Skoulikidis 2009
	Acheloos	unspecified	*6478*	unspecified	4.38	676			Skoulikidis 2009
		Avlaki	1349	66-94	1.63	1207	1.52	**1125**	GRDC 2012
	Alfeios	unspecified	*3637*	unspecified	2.10	577			Skoulikidis 2009
	Evrotas	unspecified	*2418*	unspecified	0.76	314			Skoulikidis 2009
	Sperchios	unspecified	1493	unspecified	0.70	471			Skoulikidis 2009
	Pinios	unspecified	10743	unspecified	2.55	237			Skoulikidis 2009
	Aliakmon	unspecified	8880	unspecified	2.70	304			Skoulikidis 2009
		Il Arion	5005	63-87	1.59	317	68-87	**303**	GRDC 2012
	Loudias	unspecified	5345	unspecified	0.63	118			
	Axios	Chalastra	24484	unspecified	3.24	132	81-00	**121**	Karageorgis *et al.* 2004
	Struma	unspecified	17087	unspecified	4.31	252			Skoulikidis 2009
	Nestos	unspecified	6265	unspecified	2.08	332			Skoulikidis 2009
		Temenos	4393	66-95	1.25	285	76-95	**249**	GRDC 2012
Greece/ Turkey	Meric	unspecified	53078	unspecified	7.00	132			Skoulikidis 2009
Turkey	Susurluk	unspecified	22399	64-94	5.43	242			Kahya & Kalayci 2004
	Gonen	unspecified	2174	<99	0.55	247			Kazanci *et al.* 1999
	Biga	unspecified	2300	<97	0.18	77			Ergin *et al.* 1997
	Gediz	unspecified	18000	64-94	1.95	108			Kahya & Kalayci 2004
	Little Menderes	unspecified	6907	64-94	1.19	172			Kahya & Kalayci 2004
	Big Menderes	unspecified	24976	64-94	3.03	121			Kahya & Kalayci 2004
	Dalaman	unspecified	5380	unspecified	2.29	426			Gunai 1988
	Esen	unspecified	2450	unspecified	0.98	399			Gunai 1988

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[9] http://www.bafg.de/cln_030/nn_266934/GRDC/EN/01__GRDC/03__Database/database__node.html?__nnn=true

Country	River	Station	Area	T_{all}	Q_{all}	R_{all}	T_{recent}	R_{recent}	Source
	Aksu	Boztepe	2852	53-67	0.95	331			
	Kopru	Beskonak	1942	78-86	2.87	1478			GRDC 2012
	Manavgat	unspecified	1300	unspecified	4.10	3154			Meybeck & Ragu 1996
	Goksu	unspecified	10000	unspecified	1.42	142			Koçak *et al.* 2010
	Lamas	unspecified	1306	unspecified	0.18	138			Yemenicioglu *et al.* 2007
	Berdan	unspecified	1592	unspecified	0.40	251			Yemenicioglu *et al.* 2007
	Seyhan	unspecified	20450	64-94	8.01	392			Kahya & Kalayci 2004
	Ceyhan	unspecified	21982	64-94	7.18	327			Kahya & Kalayci 2004
	Asi	unspecified	23000	unspecified	1.20	52			ESCWA-BGR Cooperation 2012
Israel	Yarcon	unspecified	unspecified	1800	0.03	17			
	Besor	unspecified	unspecified	3700	0.01	3			
Egypt	Nile	unspecified	2984 10^3	>1965	15.0	5			Nixon 2003
Tunisia	Miliane	unspecified	2283	unspecified	0.02	9			GRDC 2012
	Medjerda	unspecified	22000	unspecified	0.94	43			GRDC 2012
Algeria	Kebir Est	Ain El Assel	680	72-94	0.20	296			Mebarki 2010
	Seybouse	Mirebeck	5955	72-94	0.34	57			Mebarki 2010
	Kebir Ouest	Ain Charchar	1130	72-94	0.14	125			Mebarki 2010
	Saf Saf	Khemakhem	322	72-94	0.04	112			Mebarki 2010
	Kebir-Rhumel	El Ancer	8735	72-94	0.83	95			Mebarki 2010
	Soummam	Sidi Yahia	4050	72-94	0.16	41			Mebarki 2010
	Sebaou	Baghlia	2501	76-79	0.57	227			GRDC 2012
	Isser	Lakdharia	3615	76-78	0.21	58			GRDC 2012
	Mazafran	Fer à cheval	1912	76-94	0.13	66			GRDC 2012
	Chelif	Sedi Belatar	43750	76-00	0.57	13			GRDC 2012
	Macta	Hacine & Sidi Ali Ben Youb	12950	unspecified	0.03	2			Mohamed & Talia 2011
	Tafna	Pierre du Chat	7245	76-00	0.10	14			GRDC 2012
Morocco	Moulouya	Saf-Saf	49920	70-96	0.41	8			Snoussi *et al.* 2002
		Dar el Caid	24422	60-88	0.66	27	69-88	**23**	GRDC 2012

Annexe 2 Nutrient concentration in Mediterranean rivers calculated with available 2000-2010 data series or most recent interannual average (nitrogen: mgN L^{-1}, phosphorus: mgP L^{-1}). NO_3: nitrate, NO_2: nitrite, NH_4: ammonium, DIN: dissolved inorganic nitrogen, DKN: dissolved kjeldall nitrogen, DON: dissolved organic nitrogen, TDN: total dissolved nitrogen, DIP: dissolved inorganic phosphorus, TP: total phosphorus

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP	Source
Spain	Guadario	1.17	0.11	0.03	1.31					0.13	CMAJA 2012[10]
	Guadalhorce	3.63	0.10	1.58	5.31	2.75	1.17	6.98	0.19	0.50	EEA 2012[11]
	Guadalfeo	0.59	0.01	0.05	0.65	0.28	0.27	0.69	0.01	0.08	EEA 2012
	Andarax	2.74	0.01	0.62	3.37						CMAJA 2012
	Almanzora	1.33	0.05	0.36	1.74	3.04	2.68	4.42	0.02	0.08	CMAJA 2012
	Segura	7.13		1.81					0.20		CHJ 2012[12]
	Vinalopo	6.99	0.32	0.26	7.58	2.19	1.86	9.44	0.53	0.68	EEA 2012
	Jucar	4.46	0.18	0.29	4.88	0.68	0.38	5.53	0.10	0.22	CHJ 2012
	Turia	5.91	0.01	0.05	5.97	0.29	0.24	6.21	0.02	0.05	CHJ 2012
	Mijares	1.09	<0.01	0.02	1.12	0.60	0.60	1.57	0.01	0.05	CHJ 2012
	Ebro	2.45	0.03	0.07	2.54	<1.00	<0.3	2.60	0.06	0.07	CHE 2012
	Llobregat	2.41	0.26	0.90	3.57	1.66	0.76	4.33	0.30	0.40	ACA 2012[13]
	Besos	2.88	0.95	11.6	15.39	16.84	5.28	20.67	1.33	1.89	ACA 2012
	Ter	2.87	0.11	0.23	3.21	0.60	0.29	4.04	0.14	0.24	ACA 2012
France	Têt	1.46	0.18	1.69	3.33	2.5	0.81	4.13	0.15	0.20	AERMC 2012[14]
	Agly	0.56	0.03	0.17	0.76				0.06	0.09	AERMC 2012
	Aude	1.32	0.02	0.19	1.44				0.05	0.11	AERMC 2012
	Orb	0.60	0.02	0.06	0.81				0.05	0.10	AERMC 2012
	Hérault	0.57	0.01	0.07	0.64				0.02	0.04	AERMC 2012
	Rhone	1.49	0.02	0.07	1.57				0.05	0.08	EEA 2012
	Argens	1.13	0.03	0.06	1.22	0.53	0.47	1.68	0.06	0.09	AERMC 2012
	Var	0.33	0.01	0.03	0.37				0.01	0.06	AERMC 2012

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[10] http://www.juntadeandalucia.es/medioambiente/site/rediam/

[11] http://www.eea.europa.eu/data-and-maps/data/waterbase-rivers-8

[12] http://www.chj.es/es-es/medioambiente/redescontrol/Paginas/RedesdeControl.aspx

[13] http://aca-web.gencat.cat/sdim/visor.do

[14] http://sierm.eaurmc.fr/eaux-superficielles/index.php

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP	Source
Italy	Magra	0.33	0.03	0.29	0.65	0.54	0.25	0.90	0.08	0.02	EEA 2012
	Serchio	1.06	0.03	0.24	1.33	0.93	0.65	1.78	0.53	0.39	ARPAT 2012[15]
	Arno	2.41		0.87	3.10	2.51	1.85	4.95	0.21	0.29	ARPAT 2012
	Ombrone	1.33	0.02	0.04	1.39	0.91	0.87	2.43		0.06	ARPAT 2012
	Marta	5.91		0.13	6.04				0.25	0.31	EEA 2012
	Tevere	2.25	0.21	0.76	3.22	1.23	0.46	3.47	0.16	0.21	ISPRA 2010[16]
	Garigliano	1.63		0.04	1.67				0.03	0.16	EEA 2012
	Volturno	2.24	0.07	0.10	2.40	0.30	0.21	2.61	0.10	0.17	EEA 2012
	Regi Lagni	2.82	0.80	5.88	9.49	13.39	7.51	17.00	0.61	0.86	EEA 2012
	Sele	2.36	0.04	0.46	2.86	0.90	0.44	3.31		0.19	EEA 2012
	Neto	0.50		0.12	0.62			2.07	0.03	0.19	EEA 2012
	Crati	1.38		1.14	2.52			4.20	0.10	0.27	EEA 2012
	Sinni	4.80		0.12	4.92				0.04	0.06	EEA 2012
	Bradano		0.22	0.71						0.09	EEA 2012
	Ofanto		0.28	0.43						0.41	EEA 2012
	Fortore	6.53		0.99	7.52			10.07	0.05	0.20	EEA 2012
	Biferno										EEA 2012
	Trigno	3.56	0.07	0.16	3.79				0.05	0.25	EEA 2012
	Sangro	1.09	0.04	0.26	1.39	0.79	0.53	1.92	0.08	0.09	EEA 2012
	Pescara	1.17		0.27	1.44			3.53	0.08	0.13	EEA 2012
	Tronto	1.41	0.13	0.37	1.91					0.14	EEA 2012
	Chienti	2.83	0.07	0.21	3.10				0.05	0.12	EEA 2012
	Esino	1.71	0.03	0.09	1.83				0.13	0.22	EEA 2012
	Metauro	4.29	0.02	0.22	4.53				0.04	0.06	EEA 2012
	Uniti	1.49	0.06						0.04	0.05	EEA 2012
	Reno	1.60	0.04	0.38	2.02	1.20	0.82	2.84	0.08	0.13	EEA 2012
	Po	2.35	0.03	0.09	2.46	2.08	1.99	4.50	0.07	0.02	ISPRA 2010
	Adige	1.12	0.02	0.08	1.22	0.40	0.32	1.59	0.05	0.07	EEA 2012
	Brenta	2.04	0.08	0.28	2.40	1.18	0.90	3.30	0.13	0.16	EEA 2012

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[15] http://sira.arpat.toscana.it/sira/acqua.php

[16] http://annuario.isprambiente.it/sites/default/files/pdf/2011/annuario/8%20Idrosfera.pdf

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP	
Italy	Piave	1.57	0.01	0.03	1.61	0.60	0.57	2.18	0.01	0.04	EEA 2012
	Livenza	2.35	0.03	0.11	2.49	1.07	0.96	3.45	0.03	0.10	EEA 2012
	Tagliamento	1.46	0.00	0.04	1.50	0.08	0.04	1.54	0.03	0.04	EEA 2012
	Soca	1.87	0.01	0.03	1.91	0.32	0.29	2.20	0.01	0.01	EEA 2012
	Coghinas	1.40									Cidu *et al.* 2007
	Cedrino	4.05									Cidu *et al.* 2007
	Flumendosa	0.86									Cidu *et al.* 2007
	Flumini Mannu	4.40									Cidu *et al.* 2007
	Tirso	0.24									Cidu *et al.* 2007
	Simeto	3.34		0.03	3.37	1.06	1.03	4.40	0.09	0.26	EEA 2012
	Imera	5.62		0.15	5.77	0.38	0.23	6.00	0.06	0.07	EEA 2012
	Platani	2.02		0.46	2.48	0.78	0.32	2.80	0.02	0.03	EEA 2012
Croatia	Mirna	0.96	<0.01	0.02	0.98	0.27	0.25	1.23	0.02	0.07	EEA 2012
	Gacka	0.47	<0.01	0.01	0.48	0.12	0.11	0.59	0.01	0.01	EEA 2012
	Licka	0.20	<0.01	0.01	0.21	0.17	0.16	0.37	0.01	0.01	EEA 2012
	Krka	0.29	<0.01	0.02	0.31	0.15	0.13	0.44	0.01	0.02	EEA 2012
	Cetina	0.48	<0.01	0.02	0.50	0.17	0.15	0.65	0.01	0.02	EEA 2012
	Neretva	0.62	<0.01	0.02	0.64	0.26	0.24	0.88	0.01	0.03	EEA 2012
	Trebisjnica	0.16	<0.01	0.03	0.19				<0.01	0.08	EEA 2012
	Drini	0.39	0.02	0.38	0.79				0.05	0.05	EEA 2012
Albania	Mati	0.18	0.01	0.04	0.23				0.01	0.02	EEA 2012
	Erzeni	0.58	0.05	0.16	0.79				0.03	0.07	EEA 2012
	Shkumbini	1.25	0.14	0.11	1.50				0.02	0.05	EEA 2012
	Seman	0.99	0.03	0.27	1.29				0.05	0.06	EEA 2012
	Vijosa	0.69	0.07	0.09	0.85				0.02	0.05	EEA 2012
Greece	Thyamis	1.81	0.15	0.05	2.01				0.06	0.14	EEA 2012
	Arachtos	0.90	0.03	0.09	1.02				0.01	0.06	EEA 2012
	Acheloos	0.29	0.04	0.19	0.52				0.01	0.05	EEA 2012
	Evinos	0.39	0.02	0.02	0.43				0.01	0.05	EEA 2012
	Pineios	4.86	0.20	0.42	5.48				0.25	0.27	EEA 2012
	Alfeios	1.10	0.20	0.06	1.36				0.01	0.02	EEA 2012
	Evrotas	1.31	0.05	0.02	1.38						EEA 2012

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP	Source
Greece	Kifisos	1.70	0.04	0.15	1.89				0.03	0.19	EEA 2012
	Sperchios	1.23	0.04	0.04	1.31				0.01	0.02	EEA 2012
	Pinios	2.09	0.10	0.76	2.95				0.70	0.60	EEA 2012
	Aliakmon	1.07	0.03	0.15	1.25				0.13	0.40	EEA 2012
	Loudias	1.17	0.13	0.77	2.07				0.13	1.13	EEA 2012
	Axios	1.96	0.11	0.14	2.21				0.54	0.66	EEA 2012
	Gallikos	1.96	0.02	0.39	2.37	1.27	0.88	3.25	0.10	0.35	Voutsa *et al.* 2001
	Struma	1.40	0.04	0.12	1.56				0.22	0.44	EEA 2012
	Nestos	0.96	0.04	0.05	1.05				0.09	0.10	EEA 2012
	Lissos	5.10	0.02	0.12	5.24				0.05	0.31	EEA 2012
Greece/Turkey	Meric	1.16	0.15	0.56	1.87				0.48	0.73	EEA 2012
Turkey	Bakir	1.02	0.14	1.80	2.96				0.35	0.47	UNEP/MAP personal communication
	Gediz	0.89	0.17	1.75	2.81				0.34	0.45	UNEP/MAP personal communication
	Little Menderes	0.40	0.09	4.04	4.53				1.37	1.49	UNEP/MAP personal communication
	Big Menderes	0.42	0.02	0.47	0.91				0.10	0.19	UNEP/MAP personal communication
	Dalaman	0.44	0.01	0.04	0.49				0.02	0.04	UNEP/MAP personal communication
	Goksu	0.90	0.03	0.12	1.05				0.07	0.11	UNEP/MAP personal communication
	Lamas	1.39	0.01	0.02	1.42				0.01	0.02	UNEP/MAP personal communication
	Berdan	1.07	0.08	0.61	1.76				0.10	0.19	UNEP/MAP personal communication
	Seyhan	1.42	0.24	0.24	1.90				0.19	0.44	UNEP/MAP personal communication
	Ceyhan	1.64	0.06	0.29	1.99				0.07	0.14	UNEP/MAP personal communication
	Asi	12.7	0.02	0.18	12.9				0.31		Tepe *et al.* 2005
Egypt	Nile	7.00				7.45		14.45			Khalil *et al.* 2011
Tunisia	Medjerda	2.00									Bouraoui *et al.* 2005
Algeria	Seybouse	1.96	0.56	0.02	2.54				0.42		Mebarki 2000
	West Kebir	4.07	3.73	0.02	7.83				1.01		Mebarki 2000
	Saf Saf	1.19	0.61	0.01	1.80				0.22		Mebarki 2000
	Kebir-Rhumel	2.81	0.36	0.03	3.20				0.49		Mebarki 2000
	Mazafran	7.52									Boudjadja, Messahel & Pauc 2003
	Chelif	7.71									Boudjadja, Messahel & Pauc 2003
	Tafna	6.49	0.80	0.28	7.56						Taleb, Belaidi & Gagneur 2004
	Moulouya	1.80	0.95		2.75				0.80		Makhoukh *et al.* 2011

Annexe 3 Nutrient fluxes by Mediterranean rivers calculated with available 2000-2010 data series or the most recent interannual average for nutrient concentration, and with interannual average of water discharge computed with last 20 years data series or most recent interannual average (nitrogen: tN yr^{-1}, phosphorus: tP yr^{-1}). NO$_3$: nitrate, NO$_2$: nitrite, NH$_4$: ammonium, DIN: dissolved inorganic nitrogen, DKN: dissolved kjeldahl nitrogen, DON: dissolved organic nitrogen, TDN: total dissolved nitrogen, DIP: dissolved inorganic phosphorus, TP: total phosphorus

Country	River	NO$_3$	NO$_2$	NH$_4$	DIN	DKN	DON	TDN	DIP	TP
Spain	Guadario	403	10.3	37.9	451					44.8
	Guadalhorce	839	23.1	365	$1.23\ 10^3$	635	270	$1.61\ 10^3$	43.4	116
	Guadalfeo	9.85	0.150	0.756	10.8	4.56	4.46	11.5	0.0918	1.37
	Andarax	34.6	0.126	7.83	42.5					
	Almanzora	7.18	0.270	1.94	9.40	16.4	14.5	23.9	0.108	0.432
	Segura	41.0		10.4	51.4				1.17	
	Vinalopo	93.8	3.50	4.33	102	29.3	25.0	127	7.11	9.12
	Jucar	$1.74\ 10^3$	70.5	139	$2.01\ 10^3$	377	239	$2.25\ 10^3$	41.4	100
	Turia	$1.19\ 10^3$	2.13	9.20	1.2010^3	48.7	57.9	1.2510^3	3.27	10.8
	Mijares	409	1.77	8.13	409	226	226	588	4.78	17.2
	Ebro	$21.5\ 10^3$	263	614	$22.4\ 10^3$			$25.9\ 10^3$	531	647
	Llobregat	769	82.9	287	$1.14\ 10^3$	530	242	$1.38\ 10^3$	95.7	128
	Besos	392	129	$1.57\ 10^3$	$2.09\ 10^3$	$2.29\ 10^3$	718	$2.81\ 10^3$	181	257
	Ter	946	33.2	73.0	$1.05\ 10^3$	199	126	$1.18\ 10^3$	46.5	36.5
France	Têt	443	54.6	513	$1.01\ 10^3$	759	246	$1.25\ 10^3$	45.5	60.7
	Agly	93.5	5.01	28.4	127				10.0	15.0
	Aude	$1.56\ 10^3$	23.6	118	$1.70\ 10^3$				59.0	130
	Orb	450	15.0	143	608				37.5	75.0
	Hérault	533	6.05	51.1	590				22.2	36.5
	Rhone	$78.0\ 10^3$	$1.05\ 10^3$	$3.67\ 10^3$	$82.7\ 10^3$				$2.62\ 10^3$	$4.19\ 10^3$
	Argens	540	14.3	28.7	583	253	224	802	28.7	43.0
	Var	444	7.03	68.0	519				5.95	32.0
Italy	Magra	402	36.5	353	792	658	305	$1.10\ 10^3$	97.4	24.4
	Serchio	$1.59\ 10^3$	45.1	360	$2.00\ 10^3$	$1.40\ 10^3$	976	$2.67\ 10^3$	796	586
	Arno	$5.90\ 10^3$		$2.13\ 10^3$	$7.58\ 10^3$	$6.14\ 10^3$	$4.53\ 10^3$	$12.1\ 10^3$	514	709
	Ombrone	$1.34\ 10^3$	20.2	40.4	$1.40\ 10^3$	918	878	$2.45\ 10^3$		60.5
	Marta	$1.38\ 10^3$		29.9	$1.41\ 10^3$				58.7	72.1

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP
Italy	Tevere	11.8 10^3	1.10 10^3	3.98 10^3	16.9 10^3	6.45 10^3	2.41 10^3	18.2 10^3	839	1.10 10^3
	Garigliano	4.64 10^3		114	4.75 10^3				79.6	454
	Volturno	5.97 10^3	180	254	6.40 10^3	813	559	6.96 10^3	276	449
	Regi Lagni									
	Sele	4.11 10^3	69.6	801	4.98 10^3	1.57 10^3	773	5.75 10^3		331
	Neto									
	Crati	1.17 10^3		969	2.14 10^3			3.57 10^3	85	230
	Sinni	2.93 10^3		74.4	3.05 10^3				24.8	37.2
	Bradano		35.7	119						14.5
	Ofanto		78.2	122						115
	Fortore	2.47 10^3		375	2.84 10^3			3.81 10^3	20.0	77.5
	Biferno									
	Trigno	1.24 10^3	24.3	55.6	1.32 10^3				17.4	86.8
	Sangro	850	31.2	203	1.08 10^3	616	413	1.50 10^3	62.4	70.2
	Pescara	1.41 10^3		326	1.74 10^3			4.26 10^3	96.5	157
	Tronto	383	35.3	100	518					38
	Chienti	795	18.3	57.6	871				12.6	33.7
	Esino									
	Metauro	1.45 10^3	6.75	74.3	1.53 10^3				13.5	19.3
	Uniti									
	Reno	1.90 10^3	47.4	451	2.40 10^3	1.42 10^3	973	3.37 10^3	94.9	154
	Po	106 10^3	1.36 10^3	4.08 10^3	111 10^3	94.2 10^3	90.1 10^3	204 10^3	3.17 10^3	906
	Adige	6.64 10^3	119	474	7.24 10^3	2.37 10^3	1.90 10^3	9.43 10^3	297	415
	Brenta	7.67 10^3	301	1.05 10^3	9.02 10^3	4.44 10^3	3.38 10^3	12.4 10^3	489	602
	Piave	2.7 10^3	17.3	51.9	2.79 10^3	1.04 10^3	986	3.77 10^3	17.3	69.2
	Livenza	6.53 10^3	83.4	306	6.92 10^3	2.97 10^3	2.67 10^3	9.59 10^3	83.4	278
	Tagliamento	2.91 10^3		79.6	2.99 10^3	159	79.6	3.06 10^3	59.7	79.6
	Soca	12.0 10^3	64.3	193	12.3 10^3	2.06 10^3	1.86 10^3	14.1 10^3	64.3	64.3
	Coghinas									
	Cedrino									
	Flumendosa									
	Flumini Mannu									

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP
Italy	Tirso									
	Simeto	$2.64\ 10^3$		23.7	$2.66\ 10^3$	835	811	$3.47\ 10^3$	71.0	205
	Imera	$1.05\ 10^3$		28.0	$1.08\ 10^3$	70.3	42.3	$1.12\ 10^3$	11.2	13.0
	Platani									
Croatia	Mirna	240	1.12	5.07	245	67.5	62.5	308	4.98	16.9
	Gacka	218	0.56	3.41	223	55.7	51.0	274	2.64	5.4
	Licka	155	1.25	7.89	162	131	124	286	4.46	11.4
	Krka	460	5.39	26.9	492	238	206	698	12.5	33.9
	Cetina	$1.76\ 10^3$	12.4	80.0	$1.83\ 10^3$	622	549	$2.38\ 10^3$	32.3	83.4
	Neretva	$5.42\ 10^3$	32.5	212	$5.59\ 10^3$	$1.27\ 10^3$	$2.10\ 10^3$	$7.69\ 10^3$	46.1	255
	Trebisjnica	506	3.44	103	601				10.0	249
	Drini	$8.35\ 10^3$	324	$8.13\ 10^3$	$16.6\ 10^3$				965	$1.08\ 10^3$
Albania	Mati	585	30.1	130	748				45.7	72.3
	Erzeni	331	30.2	91.4	451				17.0	40.0
	Shkumbini	$2.43\ 10^3$	272	213	$2.91\ 10^3$				43.2	97.0
	Seman	$2.99\ 10^3$	90.6	815	$3.90\ 10^3$				151	181
	Vijosa	$3.83\ 10^3$	389	500	$4.72\ 10^3$				89	278
Greece	Thyamis	$3.08\ 10^3$	256	85.2	$3.43\ 10^3$				102	239
	Arachtos	$1.87\ 10^3$	62.4	187	$2.12\ 10^3$				20.8	158
	Acheloos	$1.27\ 10^3$	175	832	$2.28\ 10^3$				43.8	219
	Evinos									
	Pineios									
	Alfeios	$2.31\ 10^3$	420	126	$2.86\ 10^3$				21.0	42.0
	Evrotas	995	38.0	15.2	$1.05\ 10^3$					
	Kifisos									
	Sperchios	865	28.1	28.1	921				7.03	14.1
	Pinios	$5.33\ 10^3$	255	$1.94\ 10^3$	$7.52\ 10^3$				$1.79\ 10^3$	$1.53\ 10^3$
	Aliakmon	$2.89\ 10^3$	81.0	405	$3.38\ 10^3$				351	$1.08\ 10^3$
	Loudias	739	82.1	486	$1.31\ 10^3$				82.1	713
	Axios	$6.35\ 10^3$	356	454	$7.16\ 10^3$				$1.75\ 10^3$	$2.14\ 10^3$
	Gallikos									
	Struma	$6.03\ 10^3$	172	517	$6.72\ 10^3$				948	$1.90\ 10^3$

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP
Greece	Nestos	$2.00\ 10^3$	83.2	104	$2.18\ 10^3$				187	208
	Lissos									
Greece/Turkey	Meric	$8.12\ 10^3$	$1.05\ 10^3$	$3.92\ 10^3$	$13.1\ 10^3$				$3.36\ 10^3$	$5.11\ 10^3$
Turkey	Bakir									
	Gediz	$1.74\ 10^3$	331	$3.41\ 10^3$	$5.48\ 10^3$				663	877
	Little Menderes	476	107	$4.81\ 10^3$	$5.39\ 10^3$				$1.63\ 10^3$	$1.77\ 10^3$
	Big Menderes	$1.27\ 10^3$	60.6	$1.42\ 10^3$	$2.76\ 10^3$				303	576
	Dalaman	$1.01\ 10^3$	22.9	91.7	$1.12\ 10^3$				45.9	91.7
	Goksu	$1.28\ 10^3$	42.6	170	$1.49\ 10^3$				99.4	156
	Lamas	250	1.80	3.60	256				1.80	3.60
	Berdan	428	32.0	244	704				40.0	76.0
	Seyhan	$11.3\ 10^3$	$1.92\ 10^3$	$1.92\ 10^3$	$15.2\ 10^3$				$1.52\ 10^3$	$3.52\ 10^3$
	Ceyhan	$11.8\ 10^3$	431	$2.08\ 10^3$	$14.3\ 10^3$				503	$1.01\ 10^3$
	Asi	$15.3\ 10^3$	24.0	216	$15.5\ 10^3$				372	

Annexe 4 Specific nutrient fluxes by Mediterranean rivers calculated with available 2000-2010 data series or the most recent interannual average for nutrient concentration, and with interannual average of water discharge computed with last 20 years data series or most recent interannual average (nitrogen: kgN km^{-2} yr^{-1}, phosphorus: kgP km^{-2} yr^{-1}). NO_3: nitrate, NO_2: nitrite, NH_4: ammonium, DIN: dissolved inorganic nitrogen, DKN: dissolved Kjeldahl nitrogen, DON: dissolved organic nitrogen, TDN: total dissolved nitrogen, DIP: dissolved inorganic phosphorus, TP: total phosphorus

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP
Spain	Guadario	268	6.86	25.2	300					29.7
	Guadalhorce	266	7.34	116	390	202	85.9	512	13.8	36.9
	Guadalfeo	8.56	0.130	0.657	9.35	3.97	3.88	9.98	0.0800	1.19
	Andarax	16.0	0.0584	3.62	19.7					
	Almanzora	1.78	0.0670	0.483	2.33	4.08	3.59	5.93	0.0268	0.107
	Segura	2.74		0.70	3.44				0.08	
	Vinalopo	55.5	2.07	2.56	60.1	17.3	14.8	74.9	4.20	5.39
	Jucar	80.6	4.11	5.95	89.2	17.5	11.1	100	1.76	4.62
	Turia	188	0.338	1.46	190	9.20	7.74	198	0.52	1.72
	Mijares	102	0.440	2.02	104	56.1	56.1	146	1.19	4.17
	Ebro	255	3.12	7.29	266			308	6.30	7.68
	Llobregat	155	16.8	58.0	230	107	49.0	279	19.3	25.8
	Besos	378	125	1.52 10^3	2.02 10^3	2.21 10^3	693	2.72 10^3	175	248
	Ter	314	11.0	24.3	350	66.2	41.9	392	15.4	12.1
France	Têt	331	40.8	383	756	567	184	937	34.0	45.4
	Agly	89.9	4.82	27.3	122				9.63	14.5
	Aude	322	4.88	24.4	351				12.2	26.8
	Orb	338	11.3	107	457				28.2	56.4
	Hérault	221	3.88	23.3	248				7.76	15.5
	Rhone	816	11.0	38.4	866				27.4	43.8
	Argens	213	5.66	11.3	230	100	88.7	317	11.3	17.0
	Var	180	5.44	16.3	201				5.44	32.7
Italy	Magra	237	21.6	209	467	388	180	647	57.5	14.4
	Serchio	1.11 10^3	31.5	252	1.40 10^3	977	683	1.87 10^3	557	410
	Arno	720		260	926	750	553	1.48 10^3	62.8	86.7
	Ombrone	384	5.78	11.6	402	263	251	702		17.3
	Marta	1.29 10^3		27.9	1.31 10^3				54.8	67.3

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP
Italy	Tevere	713	66.5	241	$1.02\ 10^3$	390	146	$1.10\ 10^3$	50.7	66.5
	Garigliano	788		19.3	807				13.5	77.2
	Volturno	$1.07\ 10^3$	32.4	45.6	$1.15\ 10^3$	146	101	$1.25\ 10^3$	49.6	80.9
	Regi Lagni									
	Sele	$1.27\ 10^3$	21.5	247	$1.54\ 10^3$	486	239	$1.78\ 10^3$		102
	Neto									
	Crati	455		376	831			1.39	33.0	89.0
	Sinni	$2.60\ 10^3$		65.1	$2.67\ 10^3$				21.7	32.6
	Bradano		13.0	43.2						5.29
	Ofanto		28.8	45.0						42.4
	Fortore	$1.50\ 10^3$		227	$1.73\ 10^3$			$2.31\ 10^3$	12.1	47
	Biferno									
	Trigno	$1.13\ 10^3$	22.3	51.0	$1.21\ 10^3$				15.9	79.7
	Sangro	575	21.1	137	733	417	280	$1.01\ 10^3$	42.2	47.5
	Pescara	451		104	556			$1.36\ 10^3$	30.9	50.2
	Tronto	316	29.1	82.9	428					31.4
	Chienti	633	14.6	45.9	694				10.1	26.9
	Esino									
	Metauro	$1.01\ 10^3$	4.7	51.7	$1.06\ 10^3$				9.39	13.4
	Uniti									
	Reno	385	9.63	91.5	486	289	197	684	19.3	31.3
	Po	$1.52\ 10^3$	19.4	58.2	$1.59\ 10^3$	$1.34\ 10^3$	$1.29\ 10^3$	$2.91\ 10^3$	45.2	12.9
	Adige	556	9.92	39.7	605	198	159	789	24.8	34.7
	Brenta	$1.31\ 10^3$	51.5	180	$1.55\ 10^3$	760	579	$2.12\ 10^3$	83.7	103
	Piave	662	4.22	12.7	679	253	241	920	4.22	16.9
	Livenza	$2.94\ 10^3$	37.5	138	$3.12\ 10^3$	$1.34\ 10^3$	$1.20\ 10^3$	$4.32\ 10^3$	37.5	125
	Tagliamento	996		27.3	$1.02\ 10^3$	54.6	27.3	$1.05\ 10^3$	20.5	27.3
	Soca	$3.54\ 10^3$	18.9	56.7	$3.61\ 10^3$	605	548	$4.16\ 10^3$	18.9	18.9
	Coghinas									
	Cedrino									
	Flumendosa									
	Flumini Mannu									

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP
Italy	Tirso									
	Simeto	630		5.65	636	199	194	829	17.0	49.0
	Imera	588		15.7	604	39.4	23.7	627	6.27	7.32
	Platani									
Croatia	Mirna	524	2.44	11.1	535	147	136	671	10.9	36.9
	Gacka	373	0.96	5.84	381	95.3	87.4	469	4.52	9.27
	Licka	153	1.23	7.78	160	130	122	282	4.39	11.3
	Krka	201	2.36	11.8	215	104	90.3	306	5.46	14.8
	Cetina	475	3.34	21.6	495	168	148	643	8.73	22.6
	Neretva	623	3.73	24.3	643	261	241	884	5.30	29.3
	Trebisjnica	161	1.09	32.7	191				3.18	79.1
	Drini	405	15.8	395	821				46.9	52.3
Albania	Mati	240	12.3	53.3	306				18.7	29.6
	Erzeni	436	39.7	120	594				22.3	52.6
	Shkumbini	992	111	87.3	1.19 10^3				17.7	39.7
	Seman	529	16.0	144	690				26.7	32.1
	Vijosa	562	57.0	73.3	692				13.1	40.7
Greece	Thyamis	1.68 10^3	140	46.5	1.87 10^3				55.9	130
	Arachtos	982	32.7	98.2	1.11 10^3				10.9	67.3
	Acheloos	196	27.1	128	352				6.76	33.8
	Evinos									
	Pineios									
	Alfeios	635	115	34.6	785				5.77	11.6
	Evrotas	412	15.7	6.29	434					
	Kifisos									
	Sperchios	579	18.8	18.8	617				4.71	9.42
	Pinios	496	23.7	180	700				166	142
	Aliakmon	325	9.12	45.6	380				39.5	122
	Loudias	138	15.4	90.9	244				15.4	133
	Axios	258	14.5	18.4	291				71.1	86.9
	Gallikos									
	Struma	353	10.1	30.3	393				55.5	111

Country	River	NO_3	NO_2	NH_4	DIN	DKN	DON	TDN	DIP	TP
Greece	Nestos	319	13.3	16.6	349				29.9	33.2
	Lissos									
Greece/Turkey	Meric	153	19.8	73.9	247				63.3	96.3
Turkey	Bakir									
	Gediz	96.4	18.4	190	304				36.8	48.8
	Little Menderes	68.9	15.5	696	780				236	257
	Big Menderes	51.0	2.4	57.0	110				12.1	23.1
	Dalaman	188	4.26	17.1	209				8.52	17.1
	Goksu	128	4.26	17.0	149				9.94	15.6
	Lamas	192	1.38	2.76	196				1.38	2.76
	Berdan	269	20.1	153	442				25.1	47.74
	Seyhan	556	94.0	94.0	744				74.4	172
	Ceyhan	536	19.6	94.7	650				22.9	45.7
	Asi	663	1.04	9.39	674				16.2	