Basin characteristics and nutrient losses: the EUROHARP catchment network perspective

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Abstract

The EC-funded EUROHARP project studies the harmonisation of modelling tools to quantify nutrient losses from diffuse sources. To do so, the performance of nine quantification tools (models) is tested on 17 catchments. This paper describes in detail this set of study areas from geographical conditions, to land use and land management,

geological and hydro-geological perspectives. The status of data availability throughout Europe in relation to the modelling requirements is presented. The relationships between the catchment characteristics and the nutrient export are investigated, using simple data available for all the catchments. In addition, this study also analyses the hydrological representativity of the time series utilised in the EUROHARP project.
KEYWORDS: EUROHARP, nutrient losses.

Introduction

Water is emerging as a key political and scientific issue as degradation of the water quality is putting additional pressure on an already scarce resource. Agriculture is the main source of nitrogen loading to water bodies in Western Europe while agriculture and households contribute the most to phosphorus loading (EEA, 1999). During the last fifteen years, new agricultural policies and environmental regulations have been developed in several European countries in order to reduce agricultural non-point source pollution, improve water quality and protect the stream habitat from eutrophication. The EU Water Framework Directive (CEC, 2000) commits Member States to take specific technical and scientific measures necessary for the practical implementation of general principles and definitions. Member States are required to implement all necessary measures to prevent deterioration of the status of surface water bodies, and to protect and enhance surface water bodies status in view of the achievement of good status by December 2015. At the same time, the program of measures has to ensure compliance with emission limits and controls as set out in other Community legislation, such as the Nitrates Directive (CEC, 1991). In particular, Member States had to conduct a status review by 2004 including an analysis and characteristics of river basin district, register of areas requiring protection, reviewing and assessing significant pressures and impacts from anthropogenic activities, and economic analysis of water use (Murray *et al.,* 2002). The identification of significant anthropogenic pressure should include point and diffuse sources, and address pollution sources from agricultural, industrial and urban activities. There is thus an urgent need at the European level, to develop and validate management tools that help Member States in complying with the Water Framework Directive (Horn *et al.*, 2004), in both assessing the actual environmental status of European waters, and also in evaluating the environmental and economical sustainability of the program of measures. The European initiative, EUROHARP, was taken to develop harmonised methodologies for quantifying and reporting nutrient losses from diffuse sources (Borgvang *et al.*, 2006).

The major objectives of the EUROHARP project were:

- to provide end-users with a thorough and independent scientific evaluation of contemporary quantification tools actually used by Member States to estimate diffuse nutrient (N, P) losses to surface freshwater systems and coastal waters.
- to develop an electronic decision support system providing end-users with guidance concerning the different methodologies available for assessing N and P losses, and their suitability for application to specific catchments.

Nine tools, ranging from process oriented to empirical approaches, were selected and a network of 17 catchments was put in place to support the testing of the various quantification tools (Borgvang *et al.*, 2006, this issue). This paper will describe the network of catchments, focusing on climate, hydrology, management strategies and anthropogenic pressure. The second part of the paper is dedicated to the development of a harmonised database serving as a common repository for all collected information. The last part of the paper will provide an analysis of the relationship between the catchment physical characteristics and the nitrogen and phosphorus export out of the catchments, interpreting the major causes responsible for nutrient losses.

Catchment Network

The major task of the EUROHARP, as a thorough testing environment for the quantification tools, was to set up a network of 17 catchments covering a wide range of environmental issues, climatic conditions, soil and geological characteristics, management approaches, and data availability. Each selected catchment had to be monitored for a time span covering the 1990-2002 period. The criteria for the catchment selection were:

- data availability to perform a calibration and validation of the quantification tools,
- relevance of nutrient as a major source of pollution,
- representativity of the catchment of a larger area with similar environmental conditions and problems.

All models could not be applied on all catchments due to resource limitation. It was thus decided to test each model on three core catchments selected across a climate/land use gradient where clearly more data were available, and randomly test at least three types of models on the remaining fourteen catchments where less data would be required (Borgvang *et al.*, 2006, this issue).

The catchments (Table 1) are spread over 17 countries, with the Vechte, being transboundary (shared by Germany and the Netherlands). The location of the 17 catchments and their associated larger river basin is shown in Figure 1.

The catchments are well spread across the major agricultural regions of Europe (Table 1). The ecoregions for transitional and coastal waters are very well represented with 2 Mediterranean, 3 Atlantic, 5 North Sea, 5 Baltic Sea and 2 Black Sea catchments. (Figure 1).

Catchment Characterisation

The major properties of the catchments are summarized in Table 2. As illustrated in Figure 2, the 17 catchments cover different climatic conditions present across Europe. The annual average temperature varies between 4°C in Finland to 17°C in Spain and Greece, while the average rainfall varies between less than 540 mm/yr in Germany to 1000 mm/yr in Italy, with consistent differences in the intensity (expressed in amount of water falling during a rainy day). The average amount of precipitation on a rainy day varies from 15 mm in Greece to about 3 mm for Finland.

A similar representativity can be observed in the EUROHARP catchment network concerning nutrient pressure. The average chemical fertiliser application ranges between 50 to 170 kg/ha for nitrogen and 8 to 70 kg/ha for phosphorus. The spread of nitrogen mineral fertiliser application in relation to the percentage agricultural area is shown in Figure 3. It is interesting to note the cluster of the three new member states that all have large agricultural areas and low application rates. A detailed description of each of the 17 catchments is given below.

Core Catchments

The Yorkshire Ouse (3314 km^2) is one of the principal river basins in the North east of England. The River Ouse is formed by the confluence of the Rivers Swale, Ure and Nidd. The Ouse flows southeast through the low-lying land of the Vale of York to the catchment outflow at 10 m above ordnance datum. These rivers rise on the Pennies and North Yorkshire Moors to the north and west of the catchment draining predominantly moore land and agricultural areas with low population densities. The largest urban centre is the city of York (~105,000 inhabitants) on the River Ouse. Mean flow at the most downstream gauging station (upstream of York) is 49 m^3/s. The dominant land-use across the catchment is tilled land (arable and mixed farming), interspersed with grassland (cattle and sheep grazing). Rough grazing moore land and heathland are found on the higher ground in the west of the catchment. The fertile Vale of York is used for arable production, wheat potatoes and sugar beet.

The Enza catchment (901 km^2) is located in northern Italy. River Enza, a tributary of the Po river, originates in the Apennines at the border of Tuscany and Emilia-Romagna Regions between the Acuto mountain (1756 m a.s.l.) and the Alpe di Succiso (2016 m a.s.l.). The watershed can coarsely be divided into three parts: a southern mountainous area, a central hilly area and a northern plain area. The mountainous region, in the southern part of the basin, is predominantly covered by hardwood forest. The central hilly region is characterised by pasture and bush while the northern part (plain) by intensive agriculture. The annual rainfall in the catchment is characterised by two periods of significantly higher values, in spring and autumn. The average mean value is about 950 mm. In the mountainous region the mean annual rainfall exceeds 1150 mm while in the lower part of the basin it is around 850 mm. Annual snow precipitation can reach about 60 cm and it usually remains on the ground for about 1 month. In the most upstream part of the watershed agricultural soil is mainly made by clay and silt. Downstream, sandy soils mixed with sandy loam soils are rather diffuse. Spring and winter cereals represent more than one half of the agricultural land use, although sugar beet is also common in this area. Fertiliser application rates are moderately high. The approximate mean annual application is around 20 kg/ha for phosphorus and 170 kg/ha for nitrogen in addition to varying annual quantities of dairy cattle and pig manure spread over the agricultural soils. The population in the catchment is about 275,000 inhabitants. River Enza is a moderately clean river. Diffuse pollution from agriculture is by far the primary source of polluting loads.

The Vansjø-Hobøl catchment (690 km^2) is located in the Akershus and Østfold counties in South-eastern Norway, and has its outlet in the sea (the Oslo fiord). The annual mean temperature is 6.7ºC, with a minimum of -1.8ºC in January and February and a maximum of 16.9ºC in July. The annual mean precipitation is 860 mm. The wettest months are August through November. The winter season is characterised by periods with frozen soils and snow cover (rarely exceeding 50 cm). The mean annual discharge at the main outlet of the catchment is 11 m^3/s. In high-flow periods areas near the streams may be flooded. The water level of Lake Vansjø is regulated, and the character of the discharge is therefore less “flashy” at the catchment outlet than upstream the lake. On arable land the intensity of artificial drainage is high, resulting in a fast runoff response from these areas. The catchment topography is hilly, with elevations ranging from 25 to 275 m a.s.l. and slopes ranging from 0 – 30 %. The bedrock is predominantly nutrient-poor gneiss. About half the catchment area is exposed bedrock. The remaining area is mainly covered by marine and shore deposits (34 %), humus cover, peat and bog (12 %) and glacial till (1 %). Forest, mostly coniferous forest, covers 70 % of the catchment area, lakes cover 7 %, urban areas 3 % and arable land 15 %. Soil mapping has been carried out on arable land only. The predominant soil classes are Albeluvisols and Luvisols (silt loam and clay loam), Umbrisols and Cambisols (sand and silt), and Histosols (organic soils). About 7 % of the arable soils have been artificially levelled (Anthrosols). Spring and winter cereals are the main crops grown in the catchment, but there are also areas with ley and intensive vegetable and potato production. The amount of N and P applied through mineral fertilisers and manure is estimated at 138 kg N/ha and 27 kg P/ha. The average number of livestock units is estimated at 0.15 per hectare arable land. The main water quality issue in the catchment is eutrophication in Lake Vansjø, which provides drinking water for about 60,000 people, and is an important recreational area. The problem of eutrophication is largely caused by phosphorus runoff through soil erosion from agriculture and loss of dissolved phosphorus from sewage systems. Since the 1970s considerable efforts have been made to reduce the loads, focussing on changing soil tillage methods in agriculture and treatment of waste water, but the water quality has not improved.

NON CORE CATCHMENTS

The Guadiamar catchment (1357 km^2) is located in Andalusia, Southern Spain. The Guadiamar River is the last of the tributaries that the Guadalquivir River receives before it reaches the Atlantic Ocean. Close to its source, running through mountainous terrain, its course appears to be well defined. Having passed the spurs of the Sierra, it "winds around" smoothly and opens into an extensive valley whose river plain becomes flooded during rainy years. The terrain is gently sloping with elevations that range from 4 m to 500 m a.s.l. From a climate point of view, the Guadiamar watershed can be classified as sub-humid Mediterranean climate region of heavy irregularity. Therefore, it has an irregular hydrological regime. The rainfall is around 555 mm, most of it lost through evapotranspiration. The average water flow at the catchment outlet is around 0.03 m^3/s. The soil types are predominantly luvisols and cambisols, with clay texture, and the main land use is arable land, occupying more than 50 % of the total basin area. More than 150,000 people live in the catchment area. An intense human pressure, exercised during the last centuries, has highly altered the river´s environment. As an example, and as consequence of the agricultural pressure, the Guadiamar River has changed and converted into a unique principal bed, loosing a great part of its natural functionality. In April, 1998, the disaster of the Aznalcollar mine, can be considered as an inflexion point in the fate of the basin. Considerable efforts and resources are mobilised; part of them, in the context of the "green corridor" project (Regional Ministry of the Environment of Andalusia, 2002).

The Shannon catchment is the largest in Ireland encompassing an area of 14,700 km^2 from its source in county Cavan to the Shannon estuary. An important feature of the river Shannon is the many lakes along the main channel and on its tributaries. Lough Ree and Lough Derg are the two largest lakes within the Shannon estuary. The catchment of these lakes covers an area of 10,600 km^2. Ireland is characterised by a temperate maritime climate. Mean annual rainfall in the Lough Derg and Lough Ree catchment is 876 mm/ yr though rainfall tends to be relatively higher in the western part of the catchment. Throughflow, the movement of water downslope through soil layers, is the dominant contributor to streamflow in the Lough Derg and Lough Ree catchment. However, surface runoff is also a significant contributor due to impermeable soils, steep slopes in some areas and high rainfall. The karstified limestone area in the southwest of the catchment is characterised by disappearing lakes (turloughs) and rivers during prolonged dry spells. Swallow holes allow surface streams to disappear into the ground to emerge again, possibly miles away, as springs. Less than 2% of the channel length in the Lough Derg and Lough Ree catchment is artificial. Agri-industries are prominent within the region with grassland accounting for 73% of land use. Approximately 3% of the catchment is afforested with a further 11% being covered by worked peat bogs, which have been extensively developed since the 1940s. Navigable over much of its length, the river Shannon system hosts a wide selection of fishery attracting a broad range of visitors. Consequently, concern has mounted regarding the decline in water quality of Lough Derg and Lough Ree over the last 20 years. Principle agglomerations in the catchment, with populations in excess of 5,000, include Athlone, Longford, Ballinasloe and Nenagh. The main problem in the catchment is diffuse nutrient pollution from agricultural sources (RPS, 2001).

The Vilaine catchment cover 10,500 km^2, a third of the surface of the Armorican base. The regime of water of Vilaine knows a capricious cycle resulting from the climatic and geological characteristics of the area, which has consequences on the economic and social activities and the environment. Broad meanders, rock cliffs of schist and sandstone, marsh; the picturesque is combined with the greatest diversity of landscapes in the basin of the Vilaine. The realisation of the dam of Arzal at the mouth of Vilaine, to isolate the lower basin from the sea had radically modified the physiognomy of the lower basin. Certain objectives were achieved like that of public safety, with the reduction of the risk of flood, tourism, marinas, supply of drinking waters, others were called into question (cleansing of the marshes) or did not see the anticipated results (commercial navigation). Annual average precipitation stands between 660 and 950 mm on the basin (average 733). The highest values are on the south West and the weakest on the eastern part of the basin. In summer, the potential evapotranspiration is often largely greater than the precipitation. The left side rivers basins (eastern) are characterised by the schistous nature of the basement (and thus by not productive aquifers) and an attenuated precipitation. The situations of low water levels are regularly very severe. For the Oust branch, the granite nature of under ground makes it possible to observe strong amplitude of the flows and singular low water levels. Population density is 88 inh./km^2, about 75% being connected to WWTP. The basin is widely animal populated with 416,000 dairy cows, 5.8 millions of pigs plus about 170 millions of poultry, the Oust basin and the upper part of Vilaine (upstream of major city Rennes with 210,000 habitants) being the most under animal pressure. This yields to a production approaching 100,000 tons of organic nitrogen and 50,000 tons of organic phosphorus on a potential surface of spreading about 500,000 ha. The organic average charge is thus close to 200 kg/ha for nitrogen and 100 kg/ha for phosphorus (P_2O_5). Taking into account of the surpluses N and P, in the global context of a very high load per hectare, led to seek a withdrawal, by transformation or by export, of the droppings of poultries, which is the organic manure the richest in phosphorus and dry matter.

The Odense Å catchment is situated at the island of Fyn central in Denmark. The upper part of the catchment (486 km^2) is included in the EUROHARP project. Mean annual precipitation is 896 mm and mean annual runoff is 298 mm for the period 1990-2000. The baseflow-index is 0.60 for the station at the outlet of the catchment showing that a relatively large part of the runoff is derived from deeper groundwater aquifers. However, around 70% of the catchment is tile drained so a relatively large part of the runoff is routed very quickly to watercourses. Odense Å is draining lowland areas where agriculture (around 80%) is the dominating land use. Forest and pristine areas (14%), open waters (2%) and urban areas (3%) account for the rest of the catchment. Dominating crops grown are cereals (approx. 2/3). Pig and cattle farming includes 40,000 livestock units (mainly pigs). Sewage outlets from small cities (20,000 inhabitants.) are treated well in sewage treatment plants. However, nutrient concentrations in the main stream course are high due to the intensive agricultural land use (N and P) and sewage outlets from approx. 10,000 inhabitants in rural areas (P) (Fyn County, 2003).

The Vechte river flows into the Zwarte Water catchment, which delivers its water into the Ijsselmeer, the big lake in the central north of the Netherlands. The Vechte catchment belongs to the Rhine basin. The Vechte is a middle size rain river, which originates in Germany. The total length is 167 km, of which 60 km is situated in the Netherlands. The size of the catchment is 3970 km^2, the elevation in the area ranges from 163 MSL in the upper catchment to MSL at the outlet. The average rainfall in the catchment is 780 mm and ranges from 550 mm in dry years to 1100 mm in wet years. It is estimated that 35-40% of the precipitation runs off. The mean discharge at the mouth of the Vechte is 50 m^3/s, with high seasonal variations. The soils in the catchment are mainly sandy; most of the peat soils are situated in the northern part. The Dutch part of the catchment is used more intensively than the German part. Land use in the southern Dutch part is predominantly intensive animal husbandry, with growing of grass and maize. In the northern Dutch part and in the German part there is more arable land, with mainly potato growing. The human pressure on the aquatic environment is high, both from cities and from intensive agriculture. High nutrient inputs in the intensive agriculture result in large nutrient loads to the surface water. Many of the sewage treatment plants discharge into relatively small water bodies. Most of the waters in the catchment, especially in the Dutch part, have been strongly regulated by normalisation and control structures. In large parts of the area water inlets from outside the catchment play an important role for agriculture during drought periods (Arcadis, 2000; Stolte and Wösten, 1991).

The Attert basin (297 km^2) is located in the Midwestern part of the Grand Duchy of Luxembourg. It is situated on the contact zone between the schistose Ardennes massif (northern part of the basin) and the sedimentary Paris Basin (southern part of the basin). Mean yearly precipitation is 850 mm (1971-2000) with the major part falling during the winter season as rainfall. The mean yearly temperature is 8.3°C. The catchment is divided in three distinct parts: the schistose part (24% of the basin) dominated by impermeable bedrock, covered with a weathered zone; the central part (68% of the basin) consists of a pseudo plateau of sandy-marls and thin sandstone layers with leached silty-sandy soils in the northern part and a marly depression zone, southern part (8% of the basin), consists of a Luxembourg sandstone plateau, which is covered by marls and sandy to clayey soils supporting mainly forests. Land use consists of cropland and grassland on the plateaus and forest dominate on the steep slopes in the schistose part. In the rest of the basin, the topography is marked by gently sloping hills, supporting mainly grassland and cropland. The discharge regime of the Attert River itself is characterised by high winter flows and sustained base flow during summer, with an average annual discharge of 3.4 m^3/s. No large artificial reservoirs exist in the basin. The main problem concerning pollution is the high number of mechanical WWTP with low efficiency of purification and the nitrogen fertilisation of arable land. In the last years, phosphorus fertilisation has been considerably reduced from 26 tonnes in 1988 to 6 tonnes in 2001.

The Rönne å catchment (1897 km^2) is the second largest catchment in Skåne, the southernmost region of Sweden. The river has its outlet in Kattegatt (the North Sea) close to the city of Ängelholm. The catchment is comparatively densely populated with ~100,000 inhabitants, out of which ~70,000 live in cities. The area is generally considered one of the most favourable for agriculture in Sweden due to highly fertile soils and a long growing season (mean temperature 7ºC, mean precipitation 700 mm). The wettest months are July to December and ~15 % of the precipitation falls as snow. The Lake Ringsjön in the south-eastern part of the catchment is the largest lake but open waters only cover 3 % of the total area. The Rönne å catchment is located on the border between areas characterised by nutrient-poor primary rock and richer soils with limestone content, respectively. Forests cover about half and arable land one third of the total basin area. Due to variations in geology and geomorphology, widely differing landscape elements can be found, ranging from acid and nutrient poor forest brooks to eutrophic agricultural ditches. The region has a history of elevated nutrient loads on surface waters, mainly due to diffuse losses from arable soils. At present dams, wetlands and buffer zones are being constructed to reduce the nutrient loads (VASTRA, 2005).

The Eurajoki catchment (area 1336 km^2) is located in western Finland in the southern boreal zone. The catchment is characterised by a dense river network (total length approximately 800 km) and a great number of lakes (more than 200), although most of them are relatively small. The elevation ranges from 0 to 145 m. The River Eurajoki discharges to the Bothnian Sea of the Baltic and is one of the biggest rivers in Southwest Finland. The mean annual precipitation is 592 mm and the mean annual temperature 4.4 °C for the period 1971-2000. The mean annual discharge of the River Eurajoki near the catchment outlet is 9 m^3/s for the period 1990-2000. During winter (December-April) precipitation usually falls as snow. Lake Pyhäjärvi is the biggest lake in the area and is recognised as a valuable surface water resource for recreation and water supply. Water quality has so far been rated as "good", but eutrophication of the lake has progressed over the last few years, mostly due to diffuse nutrient losses originating from agriculture. Intensive water protection and water quality monitoring programs are carried out in the area. The catchment is mostly covered by forests (60%) and fields (23%). Most common soil types are till in forested areas and clay soils in agricultural areas. There are only few major aquifers (glasiofluvial formations) in the area. Subsurface drainage is common on the fields. Agriculture is intensive, consisting mainly of cereal production and poultry husbandry. Agricultural nutrient loading is the major environmental problem in the area.

The Susve catchment (1165 km^2) is located in the Middle Plain of Lithuania. The topography is relatively flat, the elevations ranging from 30 to 130 m a.s.l. The mean stream slope is 0.086 % typical for the plain basin relief. The climate is transitional between maritime and continental, with mild winters with of little snow and frequent thaws with unstable layers of snow. The annual rainfall is 675 mm and the average annual temperature is 6.2^oC. The sum of daily temperatures exceeding 10^oC lasts 130 to 150 days. Runoff is dominated by snowmelt (51% of total runoff). The annual average runoff at the catchment outlet is around 6.2 m^3/s. The soils are predominantly Calcic Luvisols and Gleyic Cambisols, with sandy loam, sandy light loam and peat textures. An impermeable rock stratum under a 7-10 m thick layer of moraine composes the substratum. The fertile soils and flat topography always allowed an intensive agriculture to take place in the catchment. The cropland, covers an area of 51,000 ha dedicated mostly to perennial pasture, and is drained by subsurface tiles. During the 1990-ies and the recession due to the country transfer from centrally planned to market economy, the agricultural production decreased with about 30 %. There are no large cities in the catchment and the total number of inhabitants is around 20,000 people. There are 29 wastewater treatment plants (WWTP) in the settlements. Agriculture represents the main nitrogen source in the catchment contributing with tile drain the dominant pathway. Concerning phosphorus emission, urban settlements and scattered dwellings not connected to WWTP are the most important loss pathways.

The Zelivka catchment (1187 km^2) is situated in the European ecoregion of Central Highlands at altitude between 318 and 765 m a.s.l.. The climate can be characterised by cold winters with snow cover accumulation (ranges of monthly mean temperature and precipitation totals from December to February are -0.3 - -1.5°C and 34-46 mm, respectively) and relatively humid summers (ranges of monthly mean temperature and precipitation totals from June to August are 15.6-17.6°C and 70-93 mm, respectively). Mean annual rainfall and specific surface runoff are 669 and 173 mm, respectively. The bedrock is formed by nutrient-poor rocks like paragneiss and mica-schist. Soils are mostly Dystric Cambisol and Eutric Gleysol (pH 3.8 to 4.2) with silt-loam texture. The hydrogeology, runoff, and water quality can be described in terms of a three-zone concept (Doležal and Kvítek, 2004). The recharge zones are located on flat tops of hills and their soils are mostly permeable. The groundwater exfiltrates on the lower parts of slopes (transient zone) and in narrow valleys (discharge zone), creating dispersed springs and waterlogged areas. Most of the ploughed farm land of the catchment (50% of total catchment area) is located in the recharge zones, which makes the main problem in water pollution with nitrate, especially during the latest 30 years when a large area of transient and discharged zones were tile drained (Hejzlar *et al.*, 1996). The main land use of the catchment is intensive agriculture with cereal production and breeding of cattle, pigs, and poultry. The fertilisation of arable land dropped by about 50% in the early 1990's, however, no corresponding decrease of the nitrate concentration in streams has been observed. Forests (30% of total catchment area) are cultural, mostly coniferous with dominance of spruce. The population density is 48 inh./km^2. Approximately one half of the population lives in towns and villages with more than 500 inhabitants. Wastewaters from these municipalities are purified in secondary treatment plants. The rest of the population, living in smaller villages and scattered dwellings disposes their sewage in septic tanks. Most standing water bodies in the catchment suffer from eutrophication that is caused by excessive loading with phosphorus, mainly originating from municipal wastewaters. The Želivka River was damned at its lower reach in the 1970s to construct a large reservoir (area: 14 km^2; volume: 270 million m^3; water residence time: 1.3 yr) with the purpose of drinking water supply for more than 1 million people in Prague, the Czech capital.

The **Uecker** catchment (2401 km^2) is the third largest catchment in Northern Germany flowing into the Baltic Sea. The catchment is comparatively scarce populated with about 115,000 inhabitants, out of which about 580,000 live in the four main cities. The area is generally considered favourable for agriculture in Northern Germany due to the highly fertile soils especially in the upper part of the catchement. The biggest lakes are Lake upper and lower Ueckersee in the upper part of the catchment. The Uecker catchment is located in one of the driest region in Germany. The mean runoff varies between 50 and 100 mm. The low precipitation and runoff leads to very long travel times of the groundwater especially in the areas with deep groundwater levels. The soils are mainly characterised by sandy (30%), loamy (41%) and organic (27%) soils. Wetlands with organic soils are mainly located in the lower part of the Uecker and in the main tributary Randow. Most of the catchment area is used for agricultural production (64% arable land; 11% grassland). The intensity of the agricultural land use was changed enormous due to the economic changes around 1990 (N-surplus is reduced from about 100 kg/ha to below 50 within two years).

The Gurk (2602 km^2) is situated in the province of Carinthia, in the south of Austria. The source of the river is in the mountainous region, which is mainly covered with forests. Afterwards it leads through an agricultural used plateau "Krappfeld", which is together with the valleys Mittleres Glantal, Zollfeld and Unteres Gurktal one of the most important areas of agricultural production in the province (Freundl, 2005). The maximum elevation in the catchment is 1820 m. The climate is continental. The annual average rainfall is 930 mm and the mean annul temperature is around 11°C. In total 55 % of the catchment area is forest area (Umweltbundesamt, 1997), and the dominant soil texture there is sandy loam. Mainly corn and barley are grown and agriculture had caused some elevated nitrate concentrations in the groundwater bodies. The river Gurk discharges to a water reservoir (Völkermarkter Stausee) of the river Drava. It is estimated that 2/3 of the rainfall is lost through evapo-transpiration (Eder *et al.*, 2001) and the mean annual runoff is around 31 m^3/s. The catchment has 235,500 inhabitants, mostly concentrated in the capital of the province. There are 11 wastewater treatment plants and one direct discharge (industrial) located in the catchment.

The Kapos catchment (3295 km^2) is located in the Danube River Basin, in the south-western part of Hungary, between the Mecsek and Balaton-hills. It enters the Sió-canal that flows directly to the Danube. The length of the Kapos River is 112.7 km. The climate of the region is moderately warm and wet. The annual sunshine duration is around 2000 hours, but during the winter season, it is only 200. The annual mean temperature is approximately 11°C. The snow cover lasts for 35 days on average with an average depth of 23-24 cm. Between 1993 and 2003, the mean flow was 8.1 m^3/s at the outlet of the Kapos River. The dominant part of the watershed is hilly (~90 % of the catchment is below 200 m a.s.l.). Soils are mostly brown earth on loess sediment. The catchment includes 162 fishponds and 13 reservoirs. Only one reservoir (supplying water to 7 fishing ponds) is located on one of the main rivers (Koppány creek). The shallow groundwater table is between 2 and 4 m below ground in valleys, and between 4 and 6 m in slopes. Groundwater nitrification is significant on the south part of the watershed, but it is less pronounced in case of the left side of the Kapos River. The exploited amount of deep groundwater is moderate nowadays: ~0.12 L/s·km^2. Five cities and 203 villages are located in the catchment with a population of approximately 280,000. Agriculture is the main land use type with ~70%, where the production mainly consists of grain. The main problem of the catchment is diffuse pollution from agriculture areas.

The Pinios catchment (2797 km^2) is located in the northwest Thessaly district, in Greece, and is characterised by a humid and temperate climate with seasonal variations. Mean annual rainfall is 933 mm and varies between 1860 mm in the mountains to 400 mm on the plains with the wettest period falling between October and January. Snowfall occurs rarely during January and February. Mean annual temperature is 17°C and mean annual flow is 39 m^3/s with high flows occurring during winter, while high temperatures and evaporation rates cause low summer flows (Mimikou *et al.*, 2000). Water drains quickly through the natural hydrologic network due to the steep slopes, the low time of concentration and the high duration of solar radiation, which accelerates the rate of evapotranspiration. Groundwater contributes substantially to the river flow, especially in the south-western part of the catchment. The catchment is characterised by high topography variations as the elevation ranges between 75 and 1900 m, the mean elevation being 539 m. Mountainous landscapes appear in the west and north parts, while cultivated plains of the central and southeast part occupy 40% of the total catchment area. More than half of this land is irrigated, mainly by pumping. Cotton, winter wheat, corn, alfalfa, tobacco and sugar beets are the most common crops. Natural grasslands and forests cover approximately 60% of the catchment. Urban land use does not exceed 1% of the total area, as there are only two major towns in the catchment with 120,000 inhabitants in total. The basement of the greater area is part of the old crystalline massif, which extends to the eastern and north-eastern Greece. It is composed of gneiss, schists and marbles of Palaeozoic to Triassic age. The Pinios range in the west consists of limestone and dolomites. The southeast and biggest part of the catchment consists of alluvial material that constitutes the high fertile soil with sandy-loam texture and medium infiltration capabilities. The main water quality issue in the catchment is associated with nitrates from agriculture. Due to the intensive fertilisation, nitrate nitrogen concentrations exceeding 12 mg/L have been observed during the summer months in the river system. Especially in 1999, the catchment was included in the national vulnerable zones due to nitrate contamination, as concentrations exceeding 50 mg/L were detected in groundwater as well.

Catchment Information Repository

In order to run the EUROHARP models effectively a common base of data was needed. The EUROHARP project was organised such that a dedicated Data Management work-package ensured proper catchment data collection before any model is run. An Information System was developed to support the data management task, its ultimate goal being to provide the model users with harmonised sets of data in a timely fashion and with tools to inspect these data. This system is composed of:

- A central catchment database (CDB), which is the core of the system and acts as the single data reference point for the project. The CDB hosts both maps and attribute data as provided by all catchment data owners. This database is seen as the single reference point to extract data from.

- A standalone tool (SAT), which is a GIS like application, holding all or subsets of the data and giving the model users the opportunity to view both map and attribute data within a single application and across different catchments.
- A Web component to distribute to users selective portions of all available data.

The EUROHARP data management consisted in the collection of maps and associated spatial and non-spatial attribute data, inserting these data into the CDB, and distribution of these data in a usable form to the modellers (as separate map and attribute files, as a database and also as data embedded in a standalone tool). Data requirements were specified by the users of the models and a detailed list of more than 500 parameters, linked to a number of maps, was specified. These data were organised in 22 main themes including:

- Catchment boundaries and properties,
- Digital elevation model and river network,
- Soil properties,
- Weather station location and meteo data,
- Surface Water Quality and Quantity monitoring stations and measurements,
- Land Cover,
- Land Management (fertilisation, irrigation),
- Point sources,
- Hydrogeology.

Based on the data requirements, a suitable Object Model was constructed (using Rational Rose) along the themes identified in the requirements phase; this model served for the conceptualisation and visual representation of the database. From the Object Model, a Data Model was produced, first through automatic generation from the Object Model, then manually for further refinement and optimisation; the Data Model was then implemented in a RDBMS (MS SQL Server).

On the basis of data requirements for all models and its organisation in 22 themes and on the basis of the database tables from the Data Model, a data protocol has been defined for the compilation, formatting and interchange of map and attribute data; spreadsheet (MS Excel) templates were constructed and a protocol for sending/receiving data was specified. The protocol also included specifications of map formats and how providers should make the link between maps and attribute data. Specific data import procedures were then developed for transfer of data from files to the database. Import of the data was done through execution of a number of semi-automatic procedures; e.g. execution of dedicated SQL Server Transformation packages for transfer of data from Excel sheets to database tables. The database was then populated and updated as additional data became available or additional requirements rose during the project. The final database includes more than 5 million records.

The common database was the starting point of the modelling exercise for all modelling institutes. There were no other sources of spatial data, although informal communication between modellers and catchment data owners was encouraged to refine agricultural practice data.

The data were typically collated from national organisations responsible for disparate aspects of river and land management, on different spatial and temporal scales. It would become apparent that the data could be 'gap filled' or interpreted differently by individual modellers. This was especially the case when re-formatting and integrating data for input to models (Anthony *et al.*, this volume). For example, time series of weather data at observing stations required interpolation to sub-catchments and the methodology was model specific, and administrative land use datasets were generalised when disaggregated to the spatial units used by a model. Crop and fertiliser practices were also re-interpreted to fit with existing model classifications.

A summary of the water quality parameters stored in the database along the frequency of measurement and number of gauging stations is given in Table 3. Analysing the water quality data available in the EUROHARP database, total phosphorus is the most commonly monitored determinants with a frequency of measurements ranging from daily to annual. The network density for the measurement of total phosphorus is quite variable going from 1215 km^2 per station for the Uecker basin to 25 km^2 per station in the Attert river basin. Ammonium and nitrate are usually monitored simultaneously and were available on all catchments but the Vansjø-Hobøl. Total nitrogen was monitored for fourteen catchments. Dissolved phosphorus is usually monitored as Soluble Reactive Phosphorus (SRP) rather than Molybdate Reactive Phosphorus (MRP). Daily flow was available on all catchments while rainfall was available on a daily basis for all catchments but the Vilaine where only monthly values were provided.

Catchment Analysis

The objectives of the following analysis were twofold:

- to investigate the relationship between the catchment characteristics and the nutrient export, using simple data available for all the catchments, and
- to analyse for selected catchments, the hydrological representativity of the time series used in the simulation.

NUTRIENT LOSSES ANALYSIS

The relationship between the catchment characteristics and the nutrient export was investigated by the Principal Component Analysis (PCA) (Frank and Todeschini, 1994). This analysis was performed to understand the principal processes responsible for nitrogen and phosphorus losses into surface waters and evaluate how these processes affect each individual catchment. The variables analysed included climatic characteristics, catchment properties and nutrient losses expressed as concentrations and loads. The variables representing the climate characteristics were the annual precipitation and temperature, the number of rainy days during the year (called "Rainy days" in the analysis), the average rain falling during a rainy day (called "Daily rain" in the analysis). The number of rainy days and the daily rain are parameters that inform on the typology of the rainfall, giving information on the rainfall distribution and intensity, respectively. The population density and the surface of agricultural land were included as variables indicating the potential pressure in the catchment, while the water surface was considered as it can account for the effect of lakes and reservoirs on water quality.

These variables were analysed together with the nitrogen and phosphorus concentration and load measured at the catchment outlet.

Three principal components were extracted from the eleven variables included in the analysis, explaining 74% of the variance of the original data. The rotated component matrix (Table 4) shows the relationship between the variables and each component. The values range between –1 and 1, with larger absolute values indicating stronger relationships between the variable and the component.

Each component can be interpreted according to the variables that are better represented in it. The main variables contributing to each component, highlighted in Table 4, are: for the first component temperature, rainy days, daily rain, the population density and phosphorus concentration; for the second component water surface, agricultural surface nitrogen concentration, and partially the population density; and for the third component precipitation, and nitrogen and phosphorus export.

The first component indicates that rainfall intensity (daily rain) increases with temperature and decreases with the number of rainy days. Therefore this component may represent a climatic gradient from Nordic humid catchments to warmer Mediterranean catchments, where the precipitations are intense and concentrated in a short period. The second component is linked to the factors that may control the losses of nutrients via diffuse sources, such as agriculture, and partially by point sources, such as the discharges from wastewater treatment plants (population density being a proxy indicator of point source emissions). The third component represents the variation of the amount of rainfall, which is an indicator of the hydrology of the catchments, higher rainfall leading to higher water flow at the catchment outlet.

Excluding the variables related to nutrient load and concentration, the extracted components confirm the presence of two principal gradients of variation in the network of catchments: the climate, represented by the first and the third components, and the pressures, indicated by the second component. It is interesting to note that the total precipitation and temperature, daily rain and rainy days do not fall in the same components, highlighting that these two sets of variable explain different processes in the analysis.

Analysing the relationship between the nutrient concentration and load and the three components some hypothesis can be formulated on the processes and pathways responsible for nutrient losses into waters. The concentration of phosphorus is positively correlated to the rainfall intensity and the population density, contributing to the first component, while the nitrogen concentration is positively correlated to the agricultural surface (second component). Both phosphorus and nitrogen concentrations are negatively correlated to the water surface, indicating that lakes and reservoirs may contribute to the nutrient retention. The phosphorus and nitrogen export are mainly represented on the third component, showing a positive relationship with the precipitation, although they contribute also to the first and second component respectively. This indicates that hydrology plays a key role when assessing nutrient losses in terms of loads, while concentration of nitrate is mostly controlled by the agricultural intensification. Phosphorus concentration is explained in major parts by the rain intensity and discharges from agglomerations. The erosion, being associated to the rainfall intensity, could be the main process controlling the phosphorus export, while the runoff and leaching could be responsible for the nitrate movement.

The analysis of the scores allows understanding how the cause-effect relationships discussed so far affect each catchment. Indeed, the scores represent the new coordinates of the catchments in the space of the principal components. The representation of the catchment scores for the first versus the second components (Figure 4) may be used to screen the type of pressure which is more significant for each catchment, as the phosphorus and nitrogen concentrations are associated to the first and the second component, respectively. The catchment location with respect to the axes representing the zero value for score may help in this analysis. In the graphic, the catchments having negative scores on both the components are characterised by low nutrient concentrations. The catchments having positive scores on the first component (x axis) are those catchments with a higher value of daily rain or point sources and thus present an increase of phosphorus concentration, while the catchments having positive scores on the second component (y axis) are characterised by higher nitrogen concentration, due to agriculture.

Considering the catchment scores, a spatial pattern emerges in the catchment behaviour linked to the geographical location (highlighted by circles in Figure 4). In fact Scandinavian catchments (catchments 11, 2 and 10) present lower concentrations, Mediterranean catchments (catchments 3, 4 and 17) are more affected by “Daily Rain”, and thus potential phosphorus pollution, and most of the catchments of Central Europe (catchments 7, 8, 13, 6, 1, 9 and 12) present mainly a problem with nitrogen in waters, with different degree of pollution depending on the sources of pressure. This analysis describes a spatial pattern of nitrogen and phosphorus pressions, however similar pressions do not produce the same impacts on the aquatic ecosystem, as the pollution is linked to effects, sensitivity and natural state of the ecosystem.

CLIMATE AND HYDROLOGICAL REPRESENTATIVITY

As detailed in the previous section, nutrient loads are mostly linked to the hydrology of a catchment, and in particular to water flow. It is thus of particular importance to evaluate if the time period used in the EUROHARP project is representative of an average climate and hydrology or if it is significantly different and thus inducing large variations in nutrient losses not due to agricultural management and practices. Consequently, the second type of analysis conducted aimed at assessing if the time series used in the EUROHARP project were representative of a longer time period. To do so, the catchments with the longest time series of rainfall, average temperature, and flow were selected. Four catchments had longer time series covering the 1980-2000 period and include the Vansjø-Hobøl, the Eurajoki, the Uecker, and the Kapos. The Vansjø-Hobøl, and the Kapos had no missing data, while for the Uecker temperature data was missing for 1991 and 1992. The Eurajoki had no data for the year 1980. To include a southern catchment, the Pinios was added to the analysis. However, the time series available covered the 1977-1996 period. The data summarising the properties of the climate and flow time series is given in Table 5.

All catchments are exhibiting a lower temperature during the first decade (1980-1989) than the second decade (1990-2000). Comparing these two decades, all catchments, but the Pinios exhibit a decreased water flow at the outlet, even though the precipitation had not changed or even increased for the Kapos. To better understand the distribution of the climatic variables, the annual rainfall and temperature deviations from the twenty-year average mean (higher than the 95% confidence interval of the twenty-year average rainfall and temperature) were computed and are shown in Figure 5.

A close analysis of the results (Figure 5) indicates that 1996 is a cold year for almost all catchments across Europe, while for the same year there is no clear pattern for precipitation. The most extreme frequent deviations are found in the upper left part of the graph, indicating a dryer and hotter climate. The second cluster of deviations is found in the upper right part of the graph indicating again a hotter climate, however with more rainfall. This analysis shows that the 1990-2000 period is hotter than the 1980-2000 average. To refine the analysis, the Mann-Kendall non-parametric test (Hirsh *et al*., 1982) was performed to detect the presence (absence) for the annual time series of rainfall, flow and temperature. This test does not make any assumption regarding the data distribution and deals with incomplete, seasonal data with serial dependence, and any type of trend (linear and non-linear). A significant (5% level of significance) increasing trend was detected for annual average temperature for the Vansjø-Hobøl and Eurajoki. Kapos exhibits a significant increasing trend for precipitation. No trend was detected for any of the catchments concerning flow. So the period of interest for the EUROHARP simulation seems to be representative of a longer time period, with no significant changes taking place over a twenty-year period for flow and precipitation, and a significant increase of annual average temperature in the Nordic countries. In addition to the trend statistical test, Dixon's test (Dixon and Massey, 1982) was performed to detect any extreme values (outliers) in the mean annual flow. The test assumes a normal distribution of the analysed variable. Where necessary, the annual flow was transformed in order to get a normal distribution. The only significant extreme value was found for Kapos (Hungary) and corresponded to the flow of 1999. This year was subject to extreme flood events.

Conclusions

A network of 17 catchments across Europe was put together to support the analysis of nine quantification tools actually in use to estimate the losses of nutrients from diffuse sources. An information system was developed to centralise the data collection, storage and distribution of the collected data. The information gathered for all 17 catchments was analysed using a screening Principal Component Analysis to understand the major pressures and processes leading to diffuse losses of nutrients. Two major factors emerged from the analysis: climatic variables and in particular the total rainfall explained most of the variance found in the nutrient load measured at the catchment outlet. Dissolved inorganic nitrogen concentration is mainly controlled by the extent of the agricultural area. On the other hand, phosphorus concentrations are mostly controlled by the precipitation intensity (calculated here as the amount of rainfall falling during a rainy day) and the population density. An analysis of the climatic variables in the context of a longer time series showed that the decade included in the EUROHARP project (1990-2000) is warmer than the twenty-year average for the period 1980-2000. No trend was found for either flow or precipitation. Only one outlier was found for all annual climatic and flow data and corresponded to the annual flow of the Kapos river basin. So no extreme events are expected to significantly modify the results coming out of the EUROHARP analysis.

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Table 1. Catchment location and major land use attribute.

Catchment name	Location	Agricultural Region [2]	Major land use
1-Yorkshire Ouse[1]	England (UK)	British Isles	Arable/Grass
2- Vansjø-Hobøl[1]	Norway	Scandinavia	Forest
3- Enza[1]	Italy	Mediterranean	Agriculture
4-Guadiamar	Spain	Mediterranean	Arable
5- Lough Derg and Ree	Ireland	British Isles	Grass
6- Vilaine	France	Western Europe	Arable
7- Odense	Denmark	Western Europe	Arable
8-Vechte	The Netherlands/ Germany	Western Europe	Arable
9- Attert	Luxembourg	Western Europe	Arable
10- Rönne å	Sweden	Scandinavia	Forest/Arable
11- Eurajoki	Finland	Scandinavia	Forest/Arable
12- Susve	Lithuania	Eastern	Arable
13- Zelivka	Czech Republic	North Eastern	Arable
14- Uecker	Germany	Western Europe	Arable
15- Gurk	Austria	Alpine	Forest
16- Kapos	Hungary	South Eastern Europe	Arable
17- Pinios	Greece	Mediterranean	Forest/Arable

[1] Core catchment, [2] classification after Olesen and Bindi (2002).

Table 2. Major catchments characteristics

Catchment name	Area (km^2)	Elevation (m)	Agricultural area (%)	Population Density (inhab./km^2)	Mean Precipitation (mm/year)	Mean Annual Temperature (°C)	Discharge (mm)
1-Yorkshire Ouse	3314	5-680	60	98	923	10	523
2- Vansjø-Hobøl	690	25-275	17	20	810	6	452
3- Enza	901	20-1800	48	325	1000	13	350
4-Guadiamar	1357	4-500	52	114	555	17	1
5- Lough Derg and Ree	10797	0-150	73	25	1150	10	558
6- Vilaine	10533	0-311	40	103	773	12	231
7- Odense Å	486	12-112	71	124	740	9	298
8-Vechte	3970	0-163	73	200	730	10	397
9- Attert	254	240-548	51	50	900	8	422
10- Rönne Å	1897	0-200	33	49	700	7	416
11- Eurajoki	1336	0-145	23	20	559	4	241
12- Susve	1165	30-130	62	18	675	7	168
13- Zelivka	1187	318-765	64	45	669	8	173
14- Uecker	2430	1-149	64	82	540	9	86
15- Gurk	2602	393-1820	35	90	905	11	376
16- Kapos	3295	100-660	62	46	690	11	78
17- Pinios	2797	50-1900	40	43	993	17	541

Table 3. Frequency, duration and number of monitoring stations (in brackets) for water flow, rainfall gauges and water quality determinands collected during the EUROHARP project.

Catchment name	flow	rain	NH4	NO3	TOTN	MRP	SRP	TOTP
1-Yorkshire Ouse	d 90-00 ***(5)***	d 90-00 **(13)**	bw 90-00 **(6)**	bw 90-00 **(6)**		bw 90-00 **(6)**	w 94-96 **(5)**	w 94-96 **(5)**
2- Vansjø-Hobøl	d 90-00 **(2)**	d 90-02 **(12)**			w 90-01 **(3)**	w 90-01 **(3)**		w 90-01 **(3)**
3- Enza	d 91-00 **(6)**	d 90-98 **(13)**	bw 90-01 **(7)**	bw 90-01 **(7)**		bw 90-01 **(7)**		bw 90-01 **(7)**
4-Guadiamar	d 90-98 **(4)**	d 95-98 **(7)**	m 91-99 **(2)**	m 91-99 **(9)**			m 91-94 **(1)**	m 91-99 **(9)**
5- Lough Derg	w 98-01 **(324)**	d 91-02 **(1)**	w 98-01**(324)**	w98-01 **(324)**		w 98-01 **(324)**		w 98-01**(324)**
6- Vilaine	d 90-02 **(10)**	m 90-97 **(87)**	m 90-01 **(14)**	m 90-01 **(15)**	m 90-01**(13)**		m 90-01 **(15)**	m 90-01 **(14)**
7- Odense	d 90-01 **(8)**	d 90-01 **(1)**	d 90-01 **(8)**	d 90-01 **(8)**	d 90-01 (**8**)		d 90-01 **(8)**	d 90-01 **(8)**
8-Vechte	d 90-01 **(1)**	d 90-01 **(18)**	bw 90-01 **(46)**	bw 90-01 **(47)**	bw 90-01 **(45)**		bw 90-01 **(45)**	bw 90-01 **(46)**
9- Attert	d 96-02 **(5)**	d 95-01 **(15)**	a 95-00 **(10)**	a 95-00 **(10)**			a 95-00 **(10)**	a 95-00 **(10)**
10- Rönne å	d 90-01 **(8)**	d 90-02 **(21)**	tm 91-96 **(6)**	m 97-00 **(33)**	m 91-01 (**40)**			m 91-01 **(40)**
11- Eurajoki	d 90-01 **(6)**	d 90-00 **(13)**	bw 90-01 **(20)**	bw 90-01 **(15)**	bw 90-01 **(20)**			bw 90-01 **(20)**
12- Susve	m 90-01 **(2)**	d 90-00 **(1)**	m 96-01 **(1)**	m 96-01 **(1)**	m 96-01 **(1)**	m 96-01 **(1)**		m 96-01 **(1)**
13- Zelivka	d 69-00 **(14)**	d 90-01 **(4)**	bw 93-00 **(25)**	bw 93-00 **(25)**	bw 93-00 **(25)**		bw 93-00 **(14)**	bw 93-00 **(25)**
14- Uecker	d 90-00 **(2)**	d 90-01 **(8)**	bw 90-00 **(2)**	bw 90-00 **(2)**	bw 90-00 (2)		bw 90-00 **(2)**	bw 90-00 **(2)**
15- Gurk	d 91-01 **(4)**	d 90-01 **(9)**	m 92-01 **(8)**	m 92-01 **(8)**				m 92-01 **(8)**
16- Kapos	d 90-00 **(8)**	d 90-00 **(2)**	bw 90-00 **(8)**	bw 90-00 **(8)**	bw 94-00 **(1)**		bw 90-00 **(8)**	bw 90-00 **(8)**
17- Pinios	d 90-97 **(3)**	d 90-97 **(8)**	m 90-98 **(5)**	m 90-98 **(5)**	m 90-98 **(5)**			m 90-98 **(5)**

d = daily measurements, w =weekly measurements, bw =bi-weekly measurements, m =monthly measurements, a =annual measurements, tm = trimestrial measurements, 00 refers to years 2000, 01 refers to year 2001, 02 refers to year 2002

Table 4. Loading matrix of the Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization (performed with SPSS). DIN means Dissolved Inorganic Nitrogen.

	Component		
Variable	1	2	3
Temperature (C)	**0.899**	0.106	0.106
Precipitation (mm/yr)	0.162	-0.095	**0.849**
Rainy days (number)	**-0.832**	0.228	0.407
Daily rain (mm/day)	**0.924**	-0.252	0.186
Population density (inh./km^2)	**0.411**	0.344	0.149
Agricultural surface (%)	0.089	**0.749**	-0.092
Water surface (%)	-0.562	**-0.656**	-0.185
DIN concentration (mg/L)	-0.181	**0.835**	0.106
Tot_P concentration (mg/L)	**0.744**	0.26	0.021
DIN export (kg/ha)	-0.25	0.477	**0.746**
Tot_P export (kg/ha)	0.629	-0.013	**0.637**

Table 5. Summary of the climatic and flow characteristics of the five selected basins for different time periods.

	Vansjø-Hobøl			Pinios			Uecker			Eurajoki			Kapos		
	Rain mm	Temp °C	Q m^3/s	Rain mm	Temp °C	Q m^3/s	Rain mm	Temp °C	Q m^3/s	Rain mm	Temp °C	Q m^3/s	Rain mm	Temp °C	Q m^3/s
average 1980-2000	866.2	5.4	11.2	702.7[1]	14.2[1]	43.1[1]	463.2	4.9	10.4	603.7	8.9	4.4	641.3	11.5	7.6
average 1980-1989	871.3	4.8	11.9	721.6[2]	14.1[2]	42.8[2]	454.6	4.4	12.0	609.3	8.7	5.1	598.5	11.3	7.7
average 1990-2000	861.6	6.0	10.6	711.8[3]	14.4[3]	49.3[3]	470.1	5.4	9.1	598.6	9.2	3.9	680.2	11.8	7.6
average 1990-1994	810.6	5.7	9.5	636.1	14.7	47.9	452.2	5.3	8.6	632.9	9.3	3.5	625.6	12.1	4.7
average 1995-2000	904.0	6.3	11.5	900.9[4]	13.6[4]	52.8[4]	485.1	5.4	9.6	570.0	9.1	4.2	725.7	11.5	10.0
Significant trend	no	+[5]	no	no	no	no	no	no	no	no	+	no	+	no	no

[1] data relative to the 77-96 period,

[2] data relative to the 77-87 period,

[3] data relative to the 88-96 period,

[4] data relative to the 95-96 period

[5] indicates a significant increasing trend (5% level of significance)

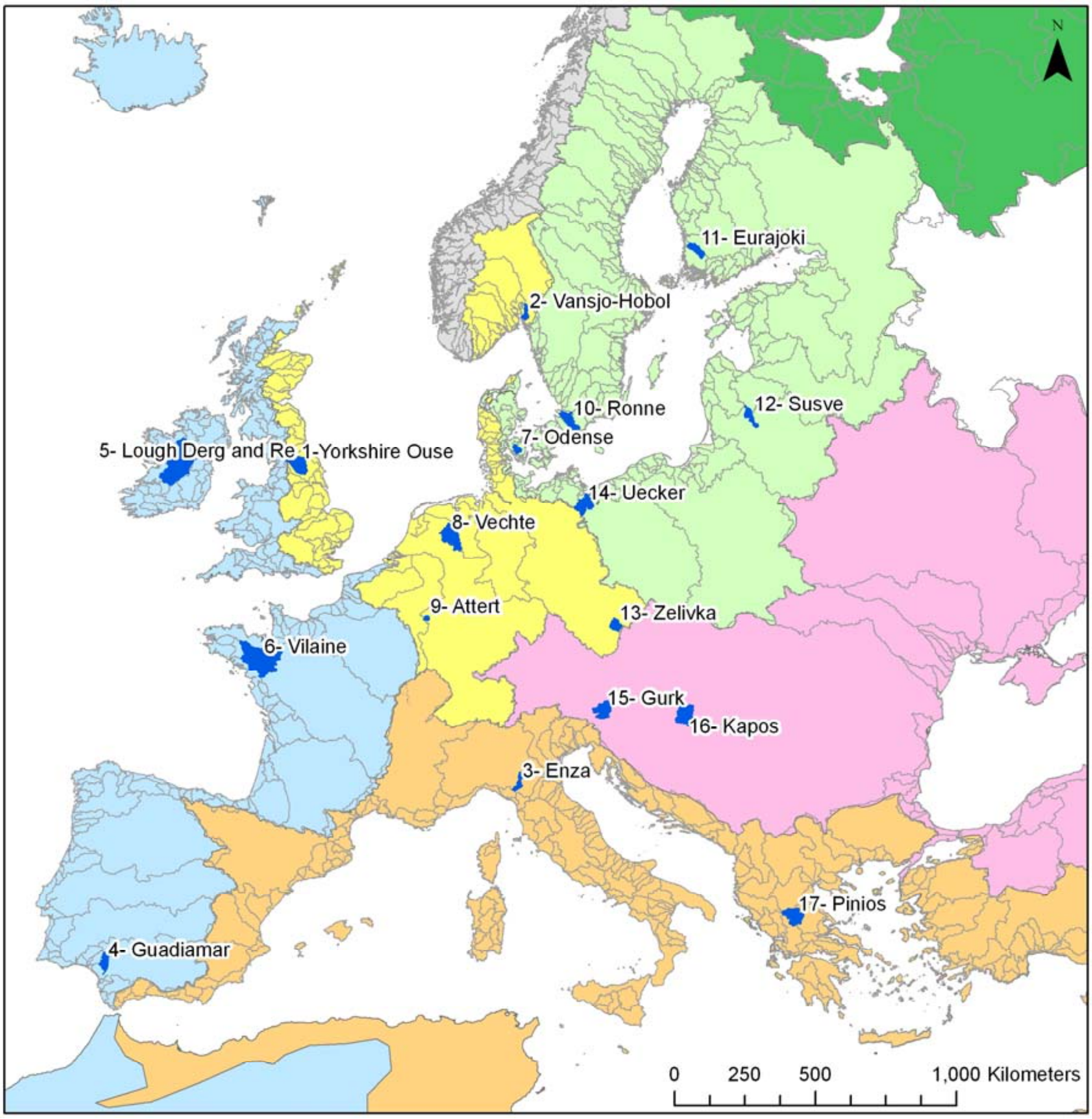

Figure 1. Location of the 17 catchments of the EUROHARP network, and associated larger river basins. Colours indicate different ecoregions.

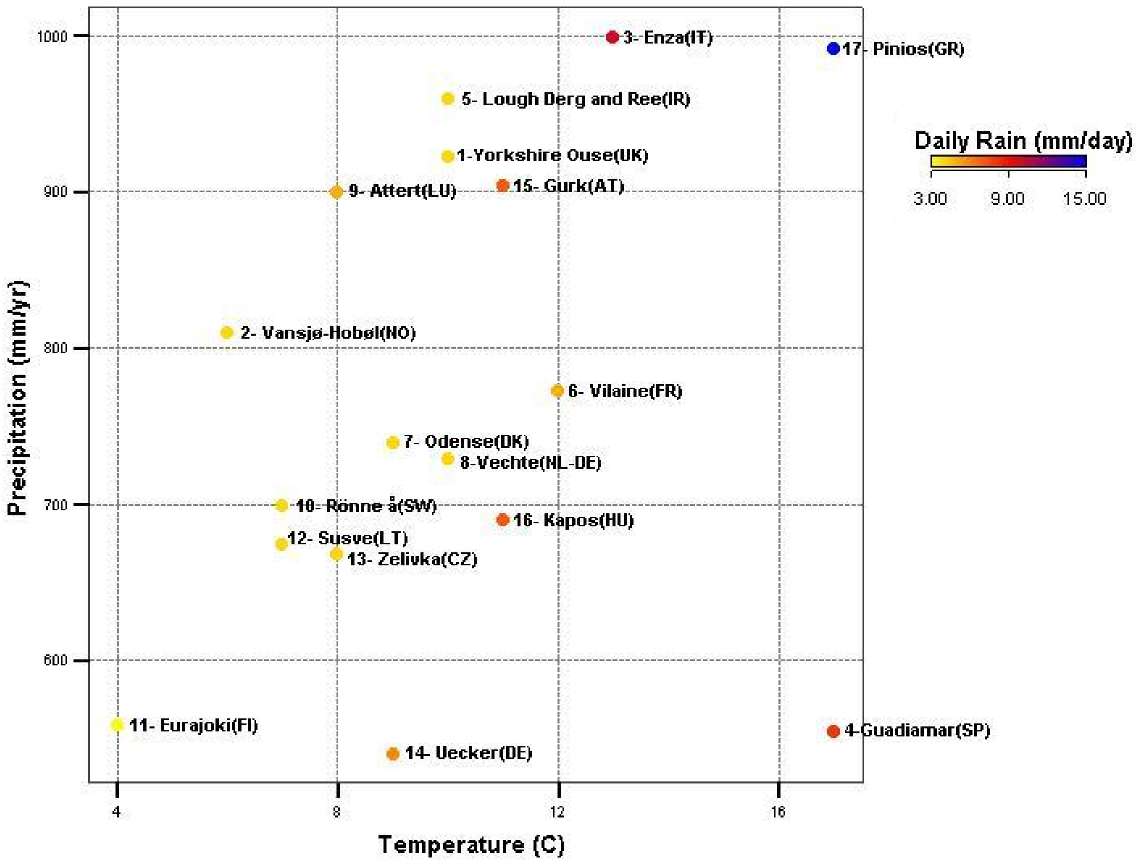

Figure 2. Climatic characteristics of the EUROHARP catchment network. The graphic reports mean annual values of precipitation and temperature.

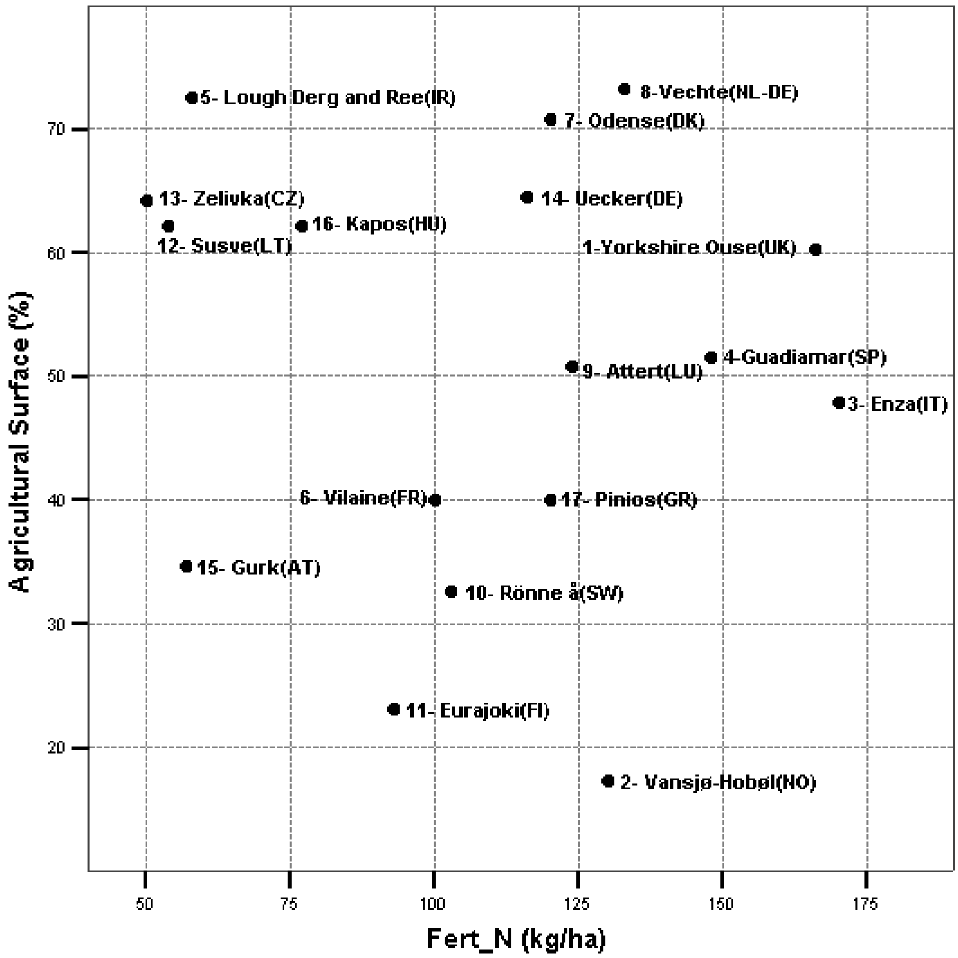

Figure 3. Percentage agricultural area and mineral nitrogen application rate across the EUROHARP catchment network.

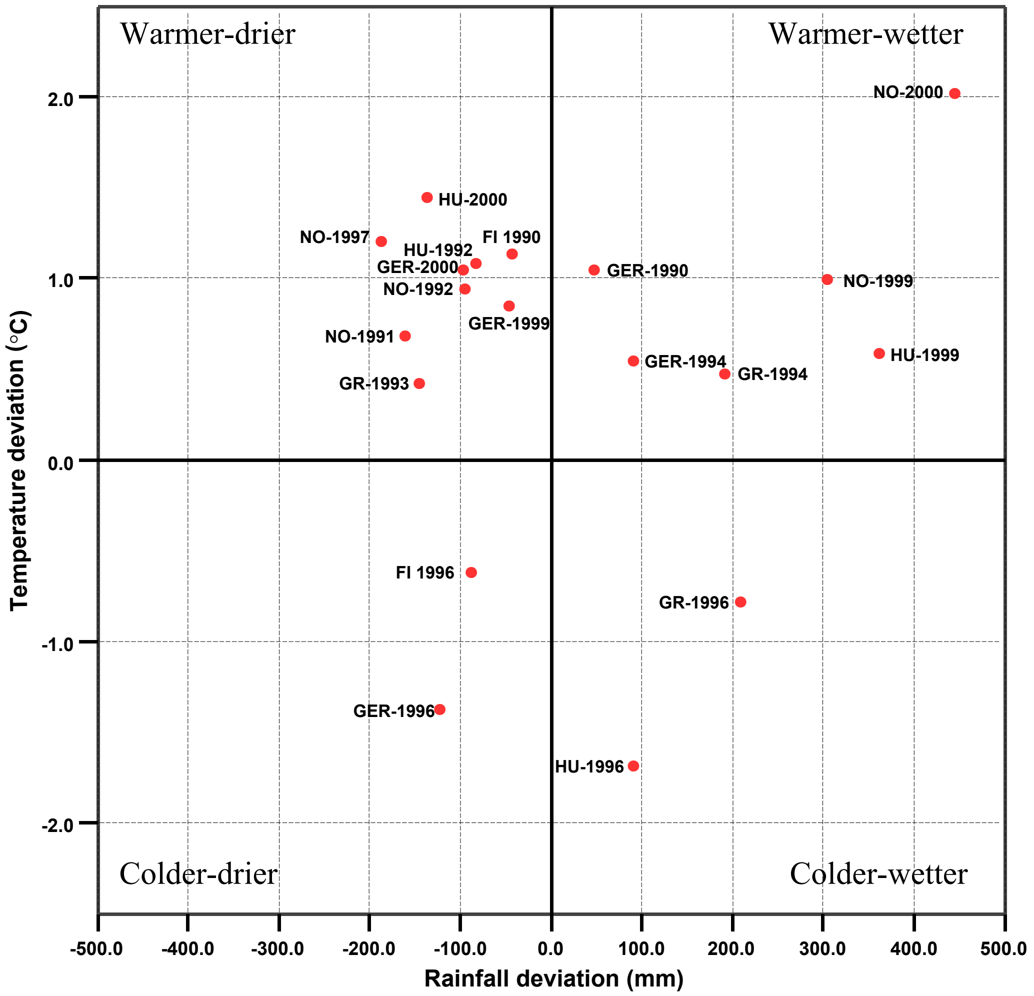

Figure 5. Plot of the mean annual rainfall deviations vs. the mean annual temperature deviation (only the deviations higher in absolute values than the 95% confidence interval of the 20 year mean rainfall and temperature are plotted)

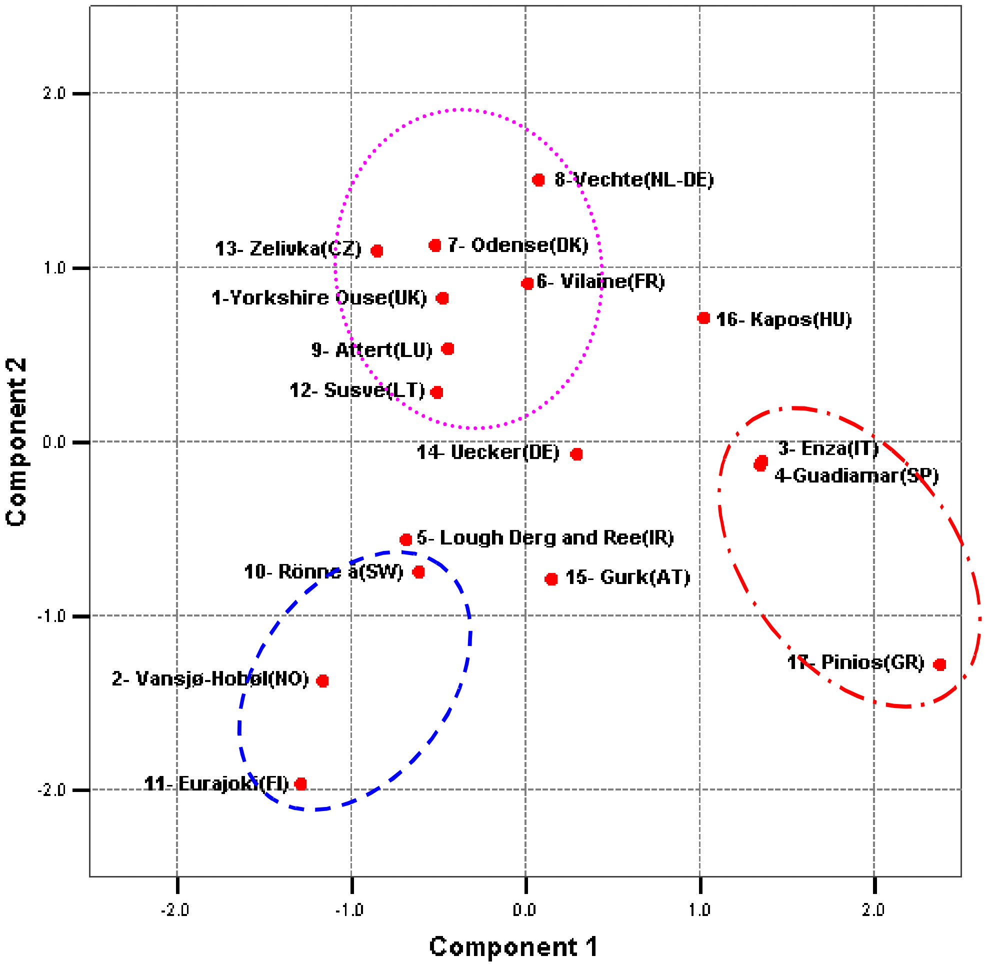

Figure 4. Score for the first two component of the PCA analysis for the EUROHARP catchments.