

## **Executive Summary for Scientific Audiences**

### **Background and General Approach**

Knowing the limits of the planet to provide resources and absorb pollutants is directly linked to debates on the limits to growth. Environmental thresholds or tipping points can lead to abrupt changes in the services provided by the ecological system, which, aside from causing undesirable shifts in balance for ecosystems, can have adverse economic and social impacts.

The purpose of this study, carried out by the Ecologic Institute and the Sustainable Europe Research Institute (SERI) on behalf of the European Commission (DG Environment), was to identify a set of environmental thresholds and associated indicators for monitoring unsustainable trends caused by human activity that could lead to the exceedance of environmental thresholds. Attention is also given to the existence of danger zones that would provide accurate warning with lead times long enough to allow decision makers to react and pre-empt the crossing of critical thresholds. Identifying thresholds and danger zones and their monitoring through indicators is therefore of importance in policy making. This study aims to inform the policy debate and support the identification of thresholds and the development of indicators for their monitoring in relevant ecological areas in the EU. This report provides a detailed account of the methodology and findings of the study.

Following an identification of an initial list of seven areas with known threshold behaviours: human exposure to toxic chemicals, fisheries, freshwater quality (with focus on eutrophication), freshwater quantity, land use/land use change and soil erosion, and non-renewable resource use – the team in collaboration with the European Commission (DG Environment) and the European Environment Agency (EEA) selected four threshold issues for more in-depth analysis: freshwater quality with a focus on eutrophication, freshwater quantity, soil erosion, and non-renewable resource use.

### **Selected Threshold Issues**

For each of these areas, the study conducted an assessment of the drivers and scale of the problem in Europe and the state of scientific consensus, supported where available with empirical evidence, with respect to the existence of thresholds and their use in policy-making.

#### **(1) Water quality (with a focus on eutrophication)**

Water quality in Europe (and globally) is especially threatened by eutrophication, a process involving the over-enrichment of water by nutrients, mainly phosphorus and nitrogen and their chemical derivatives. Eutrophication can affect the use of water for many uses, such as drinking, cooking and bathing water, water for industrial use and for maintaining species health and diversity and exhibits strong threshold patterns. The underlying processes are generally well understood and several pieces of European legislation (e.g., Nitrate Directive, Wastewater Directive, and the Water Framework Directive (WFD))

already aim to reduce or eliminate the risk of eutrophication and to mitigate its adverse ecological, economic, health, and other impacts.

## **(2) Freshwater quantity**

Empirical evidence shows that the availability of freshwater in Europe has become increasingly problematic. Over the past 30 years, droughts have noticeably increased in number and intensity, primarily in the southern regions of the EU. The number of areas and people affected by droughts grew by almost 20% between 1976 and 2006 and outpaced population growth. The scarcity of water in some regions also leads to an increasing dependency on water resources from countries outside the EU. Water scarcity and droughts are normally localised and temporal phenomena, as water availability varies during one year and between different regions within a country. According to the EEA<sup>1</sup>, nine European countries are considered water-stressed according to the Water Exploitation Index (WEI): Cyprus, Bulgaria, Belgium, Spain, Malta, FYR Macedonia, Italy, UK, and Germany. These countries jointly account for 46% of the EU's population. In most of them agricultural water abstraction for irrigation and industrial water use for cooling (Germany, UK, Bulgaria, and Belgium) are the main economic areas of water use. According to most climate change predictions the water situation is expected to get worse in those already affected regions and will expand to other regions as well with destructive effects for ecosystems and humans alike.

Consequently, it is important to monitor thresholds and danger zones in the use of freshwater. Thereby, the focus should not only be set on quantities of water abstraction in certain areas but more specifically on the quantities actually consumed (and hence not available any more in the same watershed). Due to data availability and quality issues establishing thresholds for water consumption is a challenge which will heavily rely on the current research in this area.

## **(3) Soil erosion**

Soil erosion rates in Europe have increased in the last 30 years due mainly to intensification of agriculture, the development of tourism in sensitive areas and urban development. Although natural drivers, such as droughts or climate change, are often the direct cause for erosion, human activities also have a critical role to play in the deterioration of the natural resilience of soils. Soil erosion affects the quality of the soil, the biological diversity that is stored or lives in soil, water quantity (loss of water holding capacity of soils) and water quality (turbidity through increased sediments in water). Due to slow soil formation rates, soil should be perceived as a non-renewable resource. Substantial damage to soils can be irreversible. Soil erosion may be a slow progressing process but evidence for thresholds exists, for example in the form of sudden losses of soil productivity. With the impacts and evidence of climate change accumulating in recent years, the problem of soil erosion is likely to increase in the future.

## **(4) Non-renewable resource use**

On the global level, there is a clear trend of steadily increasing extraction and use of both renewable and non-renewable natural resources for the production of goods and services. The larger fraction is that of non-renewable resources, i.e. resources which cannot be produced, re-grown or regenerated on a time

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<sup>1</sup> <http://www.eea.europa.eu/themes/water/featured-articles/water-scarcity> (11 October 2010).

scale which can sustain their consumption rate (e.g. fossil fuels, metal ores, phosphorus, uranium). Humanity's rapidly growing consumption of these resources is causing severe environmental damage, including land use changes and the production of toxic waste and emissions to air and water. For example, air emissions such as SO<sub>2</sub> and NO<sub>x</sub>, for which ceilings have been set in the EU, are associated with harm to human health, the acidification and eutrophication of water and soils, and consequently damage to natural ecosystems, cultural heritage and agricultural crops. Often these are transboundary effects, as pollutants in the air can travel a considerable distance away from their source.

Establishing thresholds for the use of non-renewable resources is a novel approach. It requires linking current amounts of resource use with negative environmental impacts which show threshold phenomena. This would allow determining a maximum level of non-renewable resource use viewed from the maximum levels of the related impacts that can still be sustained by the ecosystem.

### **Thresholds and data availability for threshold indicators**

The extensive literature review and detailed conversations with experts in threshold research led the team to conclude that while threshold phenomena in the selected areas are known to exist and have been quantified in certain cases, none of the four areas is currently sufficiently developed to provide comprehensive, timely, and accurate information about threshold values and danger zones within the EU territory. Data availability varies greatly. Comparatively large databases are available for eutrophication including all 27 EU Member States. As data compilation of blue/green water consumption is currently being pushed by various international institutions such as Eurostat and UN Statistics, the calculation of the suggested indicators for water quantity will soon be feasible. To determine which land areas are at risk of reaching intolerable rates of erosion, estimates derived through modelling are currently the best available means. Systematically measured and harmonised data on soil losses (for all agents of erosion) across the EU would clearly be preferable but are not yet available. Only selective and spatially as well as temporally restricted information is available on soil erosion. The national emission ceilings (interpreted as approximate thresholds in this study) lack of scientific legitimacy, as they were not set on a purely scientific basis but are also a result of political negotiations. In practice this situation means that timely and accurate monitoring of the selected environmental thresholds is not yet in sight, especially in the latter two areas.

Concerted action and investments into (a) research, (b) data collection and harmonisation, and (c) capacity building in local and regional areas to sustain threshold monitoring will be required to fill existing knowledge and data gaps. However, the study also finds that first steps have already been taken by scientists and public policy-makers to move thresholds into the mainstream of environmental management and conservation. Existing data can already be used to make limited analyses of the status and trends in the sustainability of resource use and quality.

The following paragraphs summarise the known thresholds and suggest how they can be monitored by indicators. Danger zones are indicated where possible as well as the data requirements to generate accurate, timely and meaningful information on these threshold indicators.

### **(1) Water quality (with a focus on eutrophication):**

The most clear-cut thresholds related to nitrogen and phosphorus are the 1980 Drinking Water Directive (80/778/EEC repealed 5 years after entry into force of Directive 98/83/EC) maximum allowable concentrations for nitrates of 50 mg NO<sub>3</sub>/l and for Nitrogen of 1 mg/l.<sup>2</sup> For phosphorus the maximum allowable concentration is set to 5000 P<sub>2</sub>O<sub>5</sub> µg/l. The Nitrates Directive (91/676/EEC) concerning the protection of waters against pollution caused by nitrates from agricultural sources sets the maximum concentration permitted to 50 mg/l. These blanket restrictions are aimed to limit the worst health and environmental effects but they do not aim to maintain or restore the health of diverse ecosystems. The latter is the purview of the 2000 Water Framework Directive (EC/2000/60), which aims to achieve “good ecological status” by 2015, using a holistic and watershed specific approach, of which eutrophication is only one aspect. So far, no comprehensive set of maximum allowable concentrations of nitrogen and phosphorus is available, but Member States are making progress in implementing the Directive’s provisions. Moreover, a large-scale intercalibration exercise aims to produce comparable threshold values for the four water quality classes specified in the Directive.

In the US eutrophication thresholds are set via the Total Maximum Daily Loadings (TMDL) approach, which estimates the total permissible influx of nutrients into a watershed from point sources of pollution relative to the absorptive capacity of the waterbody.

The study proposes to use the Maximum Allowable Concentration (MAC) concept as the threshold for eutrophication, i.e., applying it to both nitrogen and phosphorus concentrations. A simple and policy-relevant indicator would then be to monitor the ratio of the observed concentration and the MAC. Danger zones are more difficult to establish for this ratio indicator. We suggest using a cautionary approach tailored to the specific watershed under consideration, i.e., one that derives a safety factor using the watershed’s historical trajectory of eutrophication, local hydrological, and the types and density of sources of influx of nitrogen and phosphorus.

In general, the proposed threshold indicators based on either MAC or TMDLs have not been applied widely in the EU yet, with the exception of the MAC of 50 mg/l for Nitrate in the Drinking Water Directive. As per a 2007 report on the implementation of the Nitrate directive (EC, 2007c), it can be said that information on eutrophication has improved compared to the previous reporting period both in terms of the density of the monitoring stations as well as with respect to the comparability and reliability of the measurements. There are now 3201 monitoring stations for 33 countries in the EEA’s Waterbase for WISE<sup>3</sup>, up from fewer than 1500 in 1995. Nonetheless, the total number of monitoring stations varies greatly from 2 in Malta to 754 in Spain.

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<sup>2</sup> Kjeldahl nitrogen, excluding N in NO<sub>3</sub> and NO<sub>2</sub>. Kjeldahl nitrogen is the amount of nitrogen calculated using a method developed by Johan Kjeldahl. It is the sum of organic nitrogen, ammonia (NH<sub>3</sub>), and ammonium (NH<sub>4</sub><sup>+</sup>) in the chemical analysis of soil, water, or wastewater.

<sup>3</sup> Cf. EEA’s Waterbase for Lakes, available at <http://www.eea.europa.eu/data-and-maps/data/waterbase-lakes-3> (5 December 2010) and Waterbase for Rivers, available at <http://www.eea.europa.eu/data-and-maps/data/waterbase-rivers-6> (5 December 2010).

## **(2) Freshwater quantity:**

Currently, a prominent indicator to give guidance on water scarcity is the WEI (Water Exploitation Index). This indicator compares water actually extracted with available freshwater resources. However, this indicator does not reflect a comprehensive picture. The EEA (2009) assumes that 80 % of total water abstracted for agriculture, 20% for urban use, 20% for industry and 5% for energy production is consumed and not returned to the water bodies from where it was abstracted. Future threshold values for an environmentally sustainable use of freshwater should therefore set limits to the maximum amount of consumption (not only extraction) of different types of water – non-renewable water, blue water (surface water), and green water (rainwater) – in relation to available water resources. These three threshold variables look at water scarcity from a consumption perspective. They could allocate a specific amount of consumable water per accounting unit (time and space) to each economic sector and thus help to ensure that sustainable limits are not surpassed. However, so far specific values for these variables are yet not available, as data availability (especially sectoral disaggregation) is limited. Alternatively, threshold variables could also be used for the monitoring of the impacts of water consumption, monitoring groundwater and river levels. Such values are partly available already in the River Basin Management Plans of different Member States. The latter values could also be used to calibrate the first three threshold values.

For a reasonable identification of threshold values it will be necessary to combine information on actual available freshwater resources, the amounts of water specific sectors consume for their activities as well as the related impacts of this water consumption. While there are reliable data available concerning available freshwater resources and extraction of blue water, data on actual consumption (and not only extraction) of blue and green water is still scarce. However, data compilation of blue/green water consumption is being pushed by various international institutions such as Eurostat and UN Statistics. Consequently, the calculation of the suggested indicators is likely to become feasible soon.

## **(3) Soil erosion:**

About one-third of the land used for agriculture at global level has been affected by soil degradation, most of it caused by water and wind erosion. The resilience of soils and their functions (e.g. buffering capacity, filtering and absorption of contaminants) makes it difficult to detect damage at its early stages (EEA, 2000). As stated above and due to slow soil formation rates, soil should be perceived as a non-renewable resource and substantial damage to soils can be irreversible. The concept of danger zones, therefore does not apply well to the process of soil erosion due to the temporal scale variations characterising it.

There is currently no scientific evidence that could justify a particular alert value for soil erosion. Based on reported values of soil formation rates, an upper limit of approximately 1t/ha/year for mineral soils is proposed as a reference threshold value throughout Europe. In addition to this approximate upper limit, relevant local components of soil functions that are impacted by soil erosion (e.g. surface water turbidity effects on aquatic wildlife or siltation of reservoirs) can be used to set tolerable soil erosion rates below the upper limit determined by soil formation rates (Verheijen et al. 2009). The proposal for the Soil Framework Directive does not set threshold values and according to the subsidiarity and proportionality principles leaves the definition of risk reduction targets to the discretion of Member States. However, the draft proposal requires the identification of risk areas based on a common methodology, taking measures

to prevent further soil degradation by reducing its risk, and the restoration of degraded soils in order to preserve soil functions.

Currently, systematically measured and harmonised data on soil losses (for all agents of erosion) across the EU are not available. Estimates, derived through modelling, are thus the best means available to determine which land areas are at risk of reaching intolerable rates of erosion. However, there is still clearly a need to increase erosion measurement and observation to continue the calibration and validation of models. The establishment of a network of benchmark erosion monitoring sites across the EU would significantly improve current erosion assessments for Europe and the monitoring of regional threshold levels of erosion.

#### **(4) Non-renewable resource use:**

Despite the plethora of available indicators and approaches to measure and monitor quantitative resource use and its environmental consequences, and despite evidence of the fact that human resource use has surpassed a level that the planet's biocapacity can sustain, there are no rigorously and scientifically established suggestions as to the overall levels of non-renewable resource use that may be sustained. In order to derive threshold-type indicators for non-renewable resource use, we elaborate a proxy approach which links current amounts of non-renewable resource use with negative environmental impacts that show threshold phenomena. This approach is based on a methodology to evaluate the environmental impacts of resource use developed for Germany, the so-called "Environmental Impact Load" (EVIL), which is for the first time upscaled to the European level in this report.

As an illustrative example, we select four types of air emissions ( $\text{SO}_2$ ,  $\text{NO}_x$ ,  $\text{NH}_3$ , and NMVOC), which are reported under the National Emission Ceilings Directive (NECD) and for which emission ceilings are published by the EEA. Our analysis shows that the absolute amounts of per capita non-renewable resource consumption provide no direct indication whether or not a country is reaching its emission ceilings. This can be explained by the cause-impact relationship in the case of non-renewable resources being very complex. Typically, several categories of non-renewable resources contribute to one environmental problem (for example, one type of air emissions). Furthermore, the negative consequences, such as waste and emissions, are not linked to the amounts of resource use in a linear way, but are dependent on, inter alia, the (pollution abatement) technologies applied. The examples in the report illustrate these limits. They show that a clear link between non-renewable DMC and air pollutants emissions cannot be observed. We conclude that in order to derive specific policy actions a more detailed analysis of the links between specific non-renewable resources and specific environmental impacts showing threshold phenomena is required. Moreover, the proxy threshold indicator suggested in this study would gain in robustness if emission ceilings derived only from a scientific perspective were available (instead of the currently available threshold levels resulting from policy decisions based on those scientific levels).

## Summary of Suggested Threshold Indicators

The following table summarises the proposed threshold indicators, values (where available) and data availability for indicators on freshwater quality (eutrophication), freshwater resources, soil erosion, and non-renewable resource use.

Threshold theme	Suggested threshold indicator	Available threshold values	Data availability
Water quality	Ratio of observed maximum concentration of nitrogen to maximum allowable concentration of nitrogen Ratio of observed maximum concentration of phosphorus to maximum allowable concentration of phosphorus Ratio of observed daily load to Total Maximum Daily Load of nitrogen Ratio of observed daily load to Total Maximum Daily Load of phosphorus	50 mg N/l (Nitrate Directive) Watershed-specific thresholds for permissible N and P concentrations as a result of WFD implementation.	EU27 countries and annual (and more frequent) time series data available from national or sub-national water quality monitoring databases; EEA Waterbase; WISE; EIONET, WFD for boundary values of water quality classes; Increase in spatial resolution required in some countries and local areas with high eutrophication pressures
Water quantity	Maximum blue water consumption Maximum green water consumption Maximum non-renewable water use Groundwater quantitative status Hydrological pressures on streams	No threshold values have been defined so far	Water Footprint Network – on an aggregated level (modelled); also planned for new Eurostat Standard Tables by 2012 (partly measured partly modelled data); EXIOPOL database available from 2011 for 44 countries and regions (measured and modelled data)
Soil erosion	Estimated soil loss by water (rill, inter-rill, and sheet) erosion vs. Tolerable soil erosion rate  Complementary indicator: Total estimated soil loss by water, tillage and wind erosion vs. Tolerable soil erosion rate	Upper limit of tolerable soil erosion (equal to soil formation): ca. 1.4 t/ha/year; lower limit: ca. 0.3 t/ha/year (for hill slope soils overlying hard rock parent material); average tolerable erosion rate: 1 t/ha/year for mineral soils under a precautionary approach	European soil database for rough estimation of areas most at risk of erosion; CORINE land cover, climate data from models (e.g., MARS), and digital elevation data. More high-resolution and frequently updated data needed as input to models. Estimated 17.5% of EU's soil erode at rate exceeding 1 t/ha/yr.
Non-renewable resources	DMC <sub>non-renewable</sub> per capita in relation to SO <sub>2</sub> , NO <sub>x</sub> , NH <sub>3</sub> , and NMVOC emissions	Thresholds of national emission ceilings (for NO <sub>x</sub> , SO <sub>2</sub> , NH <sub>3</sub> , NMVOC) exist; but derived thresholds for DMC <sub>non-renewable</sub> per capita have not yet been defined	DMC data available from EUROSTAT; non-renewable share of DMC can be calculated from available DMC data by material group; Data on national SO <sub>2</sub> , NO <sub>x</sub> , NH <sub>3</sub> , and NMVOC emissions available for all 27 Member States since 2006.