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Living with coastal erosion in Europe: Sediment and Space for Sustainability

PART III – Methodology for assessing regional indicators

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1. INTRODUCTION

This document aims at providing a description of the contents, specifications, technical and methodological aspects of the indicators produced upon available EUROSION data. This document is meant to provide readers with an exhaustive description of the concepts (RICE explanation), the illustrated methodology to derive those indicators, based on the following scheme:

- the sources used (layers/info of the database)
- step-by-step conceptual and technical methodology (illustrated with examples/screenshoots)
- limitations and future recommendations

Readers interested in should refer to the following documents:

[REF 1] "Quick Start to EUROSION Database" also available at www.eurosion.org/project/quickstart.pdf for more in-depth descriptions on EUROSION available layers.

[REF2] "Land Cover – Annual Topic update 2000", pp 15-16, Topic Report n°4/2001, ETC/LC, EEA.

And, as for Technical Reference Documents:

[TRD 1] "Hydrodynamic data along the European Coast", ref. A279, RIKZ. March 2003

[TRD 2] "Using CORINE Land Cover to map population density", Gallego J., Peedell S., Joint Research Centre. Joint Research Centre. 2000

[TRD 3] "Definition and Realization of Vertical Reference Systems - The European Solution EVRS/EVRF 2000", Augath W., Ihde J.

2. FRAMEWORK FOR THE ASSESSMENT

The main objective of this report is to provide a comprehensive description of the calculation of the EUROSION Indicators (technical and conceptual) which will support the rating of European regions in terms of exposure to coastal erosion.

Identification of a set of reference indicators

The identification of a set of reference indicators aims to provide a meaningful and measurable "snapshot" – as of 2002 – of the major details of coastal erosion processes throughout Europe. This was based upon the DPSIR model (Driving forces - Pressure - State - Impact - Responses) as recommended by the European Environment Agency (EEA). Because of the complexities of the interactions a simplified PSIR approach has been adopted as a basis for policy recommendations for specific stretches of coast, based upon an identification of the most important reference indicators for the Pressures acting on the physics of the coast, for its physical State, for the potential Impact of these pressures (to life, economy and environment) and, finally, for the Responses implemented from a technical point of view. As a preliminary to this process, the project found it convenient to introduce the concept of radius of influence of coastal erosion (RICE).

Radius of influence of coastal erosion

The EUROSION project found it convenient to introduce the concept of radius of influence of coastal erosion (RICE). The exposure of population, infrastructure and ecological valuable areas to the effects of erosion (and or flooding) depends on their direct and surrounding physical location. In order to come to a first assessment of these exposed areas and their related level of risks, the quantity, quality and location has been determined.

The RICE concept is meant to provide a proxy of the terrestrial areas, which may potentially be subject to coastal erosion or flooding in the coming period of 100 years. To determine this radius a distinction between the two most important flooding and erosion parameters is made.

The definition of RICE and its methodological delimitation are presented in chapter 3 and 4.

Once defined the concept of RICE, the approach led to consider 13 indicators in relation with the current and expected future exposure to coastal erosion and flooding (see table 2.2.)

Calculation of indicators at the regional level

The above mentioned list of indicators has been calculated and reported at the regional level. By regional level, the project means, as a general rule, the executive level which operates directly below the national level. With reference to the Nomenclature of Territorial Units (NUTS) defined by Eurostat, this may correspond to NUTS 1 level (e.g. Belgium, Germany, United Kingdom) or NUTS 2 level (e.g. France, Spain, Italy) depending on the country. In some cases, small countries have been considered as a whole (e.g. Denmark, Baltic countries). It is also important to notice that "executive level" does not necessarily mean that a "regional government" exists at that level. This is in particular the case for England where the regional level is a level of representation of the central government in the fields (via government offices) and not a level of devolution as such. A comprehensive list of such European coastal regions is provided in table 2.1.

Table 2.1. List of European coastal regions considered within the framework of the project

Country	Region	NUTS code
BELGIQUE-BELGIË		
	Vlaams Gewest	BE2
DANMARK		
	Denmark	DK00
DEUTSCHLAND		
	Bremen	DE5
	Hamburg	DE6
	Mecklenburg-Vorpommern	DE8
	Niedersachsen	DE9
	Schleswig-Holstein	DEF
ELLADA		
	Anatoliki Makedonia, Thraki	GR11
	Kentriki Makedonia	GR12
	Thessalia	GR14
	Ipeiros	GR21
	Ionia Nisia	GR22
	Dytiki Ellada	GR23
	Sterea Ellada	GR24
	Peloponnisos	GR25
	Attiki	GR30
	Voreio Aigaio	GR41
	Notio Aigaio	GR42
	Kriti	GR43
ESPAÑA		
	Galicia	ES11
	Prinicipado de Asturias	ES12
	Cantabria	ES13
	Pais Vasco	ES21
	Cataluña	ES51
	Comunidad Valenciana	ES52
	Islas Baleares	ES53
	Andalucia	ES61
	Region de Murcia	ES62
	Canarias	ES70
FRANCE		
	Picardie	FR22
	Haute-Normandie	FR23
	Basse-Normandie	FR25
	Nord-Pas-de-Calais	FR30
	Pays de la Loire	FR51
	Bretagne	FR52
	Poitou-Charentes	FR53
	Aquitaine	FR61
	Languedoc-Roussillon	FR81
	Provence-Alpes-Côte-d'Azur	FR82
	Corse	FR83
	Guadeloupe	FR91
	Guyane	FR93
IRELAND		
	Border, Midland and Western	IE01
	Southern and Eastern	IE02
ITALIA		
	Liguria	ITC3
	Veneto	ITD3
	Friuli-Venezia Giulia	ITD4
	Emilia-Romagna	ITD5
	Toscana	ITE1
	Marche	ITE3
	Lazio	ITE4
	Abruzzo	ITF1
	Molise	ITF2
	Campania	ITF3
	Puglia	ITF4
	Basilicata	ITF5
	Calabria	ITF6
	Sicilia	ITG1
	Sardegna	ITG2
NEDERLAND		
	Groningen	NL11
	Friesland	NL12
	Noord-Holland	NL32
	Zuid-Holland	NL33
	Zeeland	NL34
PORTUGAL		
	Norte	PT11
	Centro	PT16
	Lisboa e Vale do Tejo	PT17
	Alentejo	PT18
	Algarve	PT15
	Açores – Sao Miguel Is.	PT20
	Madeira	PT30
SUOMI/FINLAND		
	Lansi-Suomi	FI2
	Oulu-Suomi	FI4
	Etela-Suomi	FI1
	Ahvenanmaa-Åland	FI6
	Lappi	FI5
SVERIGE		
	Stockholm	SE01
	Östra Mellansverige	SE02
	Sydsverige	SE04
	Norra Mellansverige	SE06
	Mellersta Norrland	SE07
	Övre Norrland	SE08
	Smaland med öarna	SE09
	Vastsverige	SE0A
UNITED KINGDOM		
	North East	UKC
	North West	UKD
	Yorkshire & the Humber	UKE
	East Midlands	UKF
	East of England	UKH
	London	UKI
	South East	UKJ
	Southwest	UKK
	Wales	UKL
	Scotland	UKM
	Northern Ireland	UKN
CYPRUS		
	Kypros / Kibris	CY
ESTONIA		
	Eesti	EE
LITHUNIA		
	Lietuva	LT
LATVIA		
	Latvija	LV
MALTA		
	Region Malta	MT
POLAND		
	Pomorskie	PL0B
	Warminsko-Mazurskie	PL0E
	Zachodniopomorskie	PL0G
SLOVENIA		
	Slovenija	SI

Rating of European regions in terms of exposure to coastal erosion and flooding

It is assumed that the exposure of European regions to coastal erosion and flooding can derived by combining the above mentioned indicators in such a way that the combination considered

a) reflects the current and future pressure factors relating to coastal erosion and flooding

b) reflects the potential impact of coastal erosion and flooding to assets located in the coastal areas.

This leads to an approach that makes the priority of shoreline management depending on the extent to which threshold values for all indicators are exceeded or not, using "pressure scoring" and "impact scoring" as follows:

Table 2.2. Indicator-based methodology for rating European regions in terms of coastal erosion and flooding

METHODOLOGY FOR RATING EUROPEAN REGIONS IN TERMS OF COASTAL EROSION AND FLOODING			
Indicator	**0 point**	**1 point**	**2 points**
Pressure scoring			
1) Relative sea level rise (best estimate for the next 100 years)	*< 0 cm (per region)*	*Between 0 and 40cm (per region)*	*> 40 cm (per region)*
2) Shoreline evolution trend status	*Less than 20% of the shoreline is in erosion or in accretion (per region)*	*Between 20% and 60% of the shoreline is in erosion or in accretion (per region)*	*More than 60% of the shoreline is in erosion or in accretion (per region)*
3) Shoreline changes from stability to erosion or accretion between the 2 versions (CCEr and CEL)	*Less than 10% of the shoreline changes between the 2 versions (CCEr and CEL)*	*Between 10 and 30% of the shoreline have changed between the 2 versions (CCEr and CEL)*	*More than 30% of the shoreline have changed between the 2 versions (CCEr and CEL)*
4) Highest water level	*Less than 1,5 meters*	*Between 1,5 and 3 meters*	*More than 3 meters*
5) Coastal urbanization (in the 10 km land strip)	*Urban areas (in km2) have increased of less than 5% between 1975 and present*	*Urban areas (in km2) have increased of 5 to 10% between 1975 and present*	*Urban areas (in km2) have increased of more than 10% between 1975 and present*
6) Reduction of river sediment supply (ratio)	*Ratio between effective volume of river sediment discharged and theoretical volume (i.e. without dams) is superior to 80%*	*Ratio between 50 and 80%*	*Ratio is less than 50%*
7) Geological coastal type	*> 70% of "likely non erodable" segments*[1]	*"likely non erodable segments" between 40% and 70%*	*< 40% of "likely non erodable segments"*
8) Elevation	*< 5% of the region area lies below 5 meters*	*Between 5 and 10% of the region area lies below 5 meters*	*> 10% of the region area lies below 5 meters*
9) Engineered frontage (including protection structure)	*< 5% of engineered frontage along the regional coastline*	*Between 5% and 35% of engineered frontage along the regional coastline*	*> 35% of engineered frontage along the regional coastline*
Impact scoring			
10) Population living within the RICE	*< 5,000 inhabitants per region*	*Between 5,000 and 20,000 inhabitants per region*	*> 20,000 inhabitants per region*
11) Coastal urbanization (in the 10 km land strip)	*Urban areas (in km2) have increased of less than 5% between 1975 and present*	*Urban areas (in km2) have increased of 5 to 10% between 1975 and present*	*Urban areas (in km2) have increased of more than 10% between 1975 and present*
12) Urban and industrial living within the RICE	*< 10% of the land cover within the RICE is occupied by urban and industrial areas (per region)*	*Between 10% and 40% of the land cover within the RICE is occupied by urban and industrial areas (per region)*	*> 40% of the land cover within the RICE is occupied by urban and industrial areas (per region)*
13) Areas of high ecological value within the RICE	*< 5 % of areas of high ecological value within the RICE per region*	*Between 5% and 30% of areas of high ecological value within the RICE per region*	*> 30% of areas of high ecological value within the RICE per region*

[1] "likely non erodable" segments are defined in the Technical Document – Methodology for the Assessment of EUROSION Indicators "Chapter 4.7 – Geological Coastal Line"

Due to limitations in the data available, it is not possible to include at this point indicators on the responses – e.g. budget invested in coastline management – which help mitigate the potential impact of coastal erosion and flooding, and therefore to finetune the impact scoring.

The following chapters provide the methodology for the calculation of the RICE and the 8 indicators.

Rationale for the threshold values adopted

Establishment of threshold value in the above mentioned scoring system undeniably constitutes the major challenge faced by the project team. A pragmatic approach which consisted to consider chosen as follows:

- a low threshold value representing a level of concern about the expected future risk or impact of erosion and flooding
- a higher threshold value representing a level of considerable concern about the expected future risk or impact of erosion and flooding.

The threshold values finally adopted for each of the indicators reflected in table 2 rely on the following assumptions:

- Relative sea level rise best estimate for the next 100 years: it is assumed that when the relative sea level is expected to fall (due to land uplift) or remain close to zero during the next 100 years, this does not add to the risk of erosion or flooding; with a higher level of expected relative sea level rise risks will increase, especially for the real damaging events - storms and storm surges as far as life and property are concerned; a rise more than 40 cm over the next 100 years (corresponding to a doubling of the recent trend; also corresponding to about half the expected sea level rise) would be considered a considerable risk factor.
- Shoreline evolution: it is assumed that when the shoreline has not been eroding in 1985-1990 (former CORINE Costal erosion database) nor recently (according to the EUROSION database), this factor will not add to the risk of erosion or flooding; with a continued status erosion (both 1985-'90 and recently) concerns will increase; when there is erosion now and there was no erosion 10-15 years ago, there is an indication of a new phenomenon so this is to be considered a considerable risk factor.
- Highest water levels: In 1992, Delft Hydraulics and RIKZ conducted a study for the account of the Intergovernmental Panel on Climate Change (IPCC). This study recommened the adoption of 1,5 and 3 meters as respective thresholds to characterize low energy, medium energy and high energy coast.
- Coastal urbanisation: thresholds proposed for characterizing coastal urbanisation are best guess which will have to be carafully calibrated once the first results are available. An iterative process might be needed to fine-tune these thresholds and finally come with a more sensible figures.
- Reduction of sediment supply from rivers. River damming has sealed an outstanding proportion of European water catchments. In the worst cases, the volume of sediment supplied in 2002 represents less than 50% of what used to be the annual supply before the 1950's. In those cases, the impact on coastal erosion is undeniable. Between 50% and 80%, the impact of river sediment shortage on coastal processes is probable but has not necessarily been highlighted since not all the sediments drained by rivers participate to coastal sediment transport processes. Above 80%, dam sealing has probably not a significant impact on coastal erosion (with some exceptions).
- Geological coastal type: it is assumed that the presence of a hard rock substrate is considered least sensitive for erosion; a soft rock substrate would have an increased sensitivity for erosion; a sedimentary coast would be highly sensitive to both erosion and flooding.
- Elevation of nearshore coastal zone: it is assumed that when a coastal area is elevated above 5 m above mean sea level (the 5-meter-contour line is one of the layers of the EUROSION database) there would not be risk of flooding; a situation below 5 m would be a considerable risk factor. Limitations of the EUROSION database does not make it possible to further discriminate areas which are below 5 meters (for example, no discrimination of areas below 1 meter and above 1 meter is possible at this point).
- Density of engineered frontage (including protection structure): it is assumed that the presence of coastal protection structures is an indication of a past or present erosion problem or flood risk; as such

this would be a reason for concern, but only in a soft rock or sedimentary coast, where these structures would have knock-on effects on coastal sections downshore (i.e. in the direction of the longshore drift). The presence of a harbour or marina and its piers would considerably increase the physical sensitivity to erosion downshore, again - only in a soft rock or sedimentary coast.

- Population living within the RICE: it is assumed that when a regional population located within the radius of influence of coastal erosion and flooding exceeds 50,000 inhabitants per region, there would be a considerable potential impact of erosion or flooding. A population of over 200,000 inhabitants per region would correspond to a very high exposure. The thresholds 50,000 and 200,000 have been estabished by calibrating the values obtained after calculation of the population living within the RICE, so that there are approximately the same number of regions below, between and above the thresholds.

- Urban and industrial assets lying within the RICE: it is assumed that when the combined surface of urban and industrial assets located within the radius of influence of coastal erosion and flooding exceeds 40% of the total surface of this zone (the case encountered in highly industrialized and urbanized regions such as Zuid-Holland, or London for example), there would be a very high exposure to erosion or flooding on these economic assets. The thresholds 10% and 40% have been estabished by calibrating the values obtained after calculation of the urban and indutstrial assets lying within the RICE, so that there are approximately the same number of regions below, between and above the thresholds.

- Areas of high ecological value within the RICE: it is assumed that the presence of protected natural areas with regional or national designations in the radius of influence of coastal erosion and flooding (below the 5m plus contour line) would correspond to a moderate exposure to erosion or flooding on the environmental assets. The presence of a (candidate) Natura 2000 site (SPA, SAC) would correspond to a high potential impact.

  It should be noted that baseline information on indicator nr. 13 is subject to data restrictions from the Commission and EU Member States. However it is possible to use the CORINE Biotopes database (more ancient and less accurate than future Natura 2000 data) as a proxy for areas of high ecological value. It is however recommended that the assessment using Natura 2000 data is performed by national or local agencies in charge of assessing shoreline management priority.

In this way the EUROSION consortium is able to perform an assessment of seven indicators resulting into a number of “sensitivity points” in a scale from 0 up to max. 16 and a number of “impact points” in a scale from 0 up to 8.

3. RADIUS OF INFLUENCE OF COASTAL EROSION (RICE)

The EUROSION project found it convenient to introduce the concept of radius of influence of coastal erosion (RICE). The exposure of population, infrastructure and ecological valuable areas to the effects of erosion or flooding depends on their direct and surrounding physical location. In order to come to a first assessment of these exposed areas and their related level of risks, the quantity, quality and location have been determined.

The RICE concept is meant to provide a proxy of the terrestrial areas, which may potentially be subject to coastal erosion or flooding in the coming period of 100 years. To determine this radius a distinction between the two most important flooding and erosion parameters is made.

Erosion and flooding concerns

Taking Sea Level Rise, local effects of land subsidence and other relevant parameters such as tide, extreme storms, bathymetry, shape of the coastline into account the coastal areas lying below 5 meter above sea level are considered to belong to the radius of influence of coastal erosion (RICE).

RICE Definition

For the purpose of the project, the radius of influence of coastal erosion and flooding has been defined as all terrestrial areas located within 500 meters. This is an assumption based on the average observed erosion rates - EUROSION 60 case studies - and time scale - 100 years. From the shoreline, the radius of influence of coastal erosion and flooding (RICE) is defined as :

- all areas located within 500m from the coastline,
- extended to areas lying under 5 meter

3.1 RICE Delimitation

3.1.1 Sources

- EUROSION coastline
- EUROSION 5 meter line

Assumption : in order to compute statistic or geoprocessing, the RICE dataset must be a polygon, including the spatial area between the coastline (as a polyline) and the 5 meter line (polyline too). A manual delimitation intervention is needed to perform this in addtition to GIS geoprocesses.

3.1.2 Step by step methodology

Step 1.1. – Creation of buffer 1: areas located within 500 meters from the coastline (fig. 3.1)

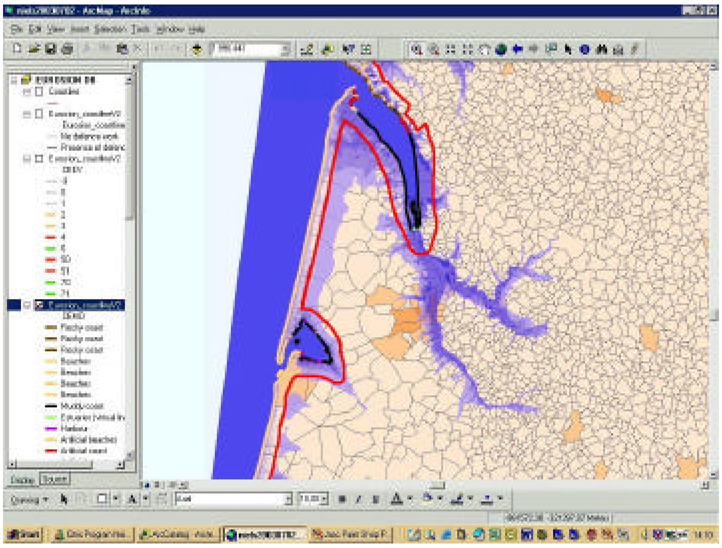


fig 3.1 – 500m from the coastline line (buffer 1)

Step 1.2. – Creation of buffer 2: areas lying under 5 meter (see figure 3.2),

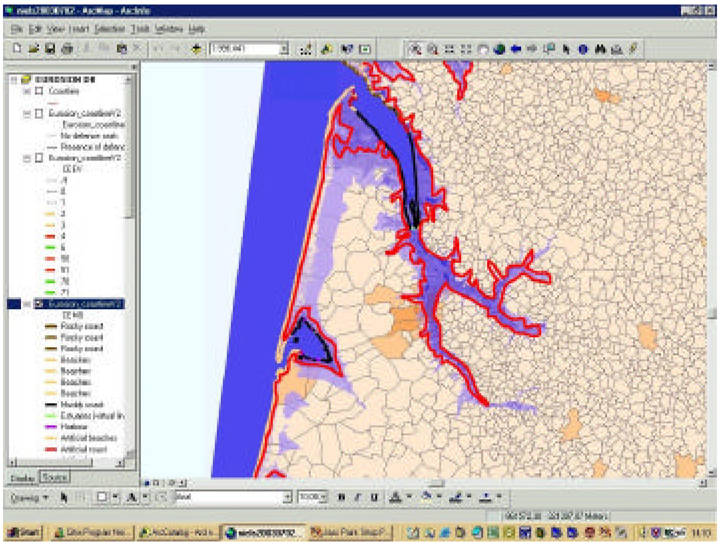


fig 3.2 – areas located below 5 meters (buffer 2)

Step 1.3. – combination of buffers 1 & 2 = buffer 3.

Buffer 3 is referred hereafter as the radius of influence of coastal erosion and flood (see figure 3.3)

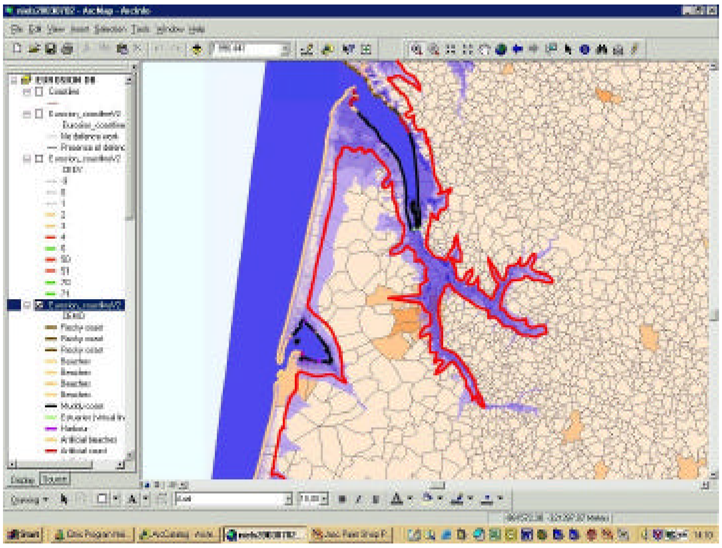


fig 3.3 – combination of buffer 1 and buffer 2 (=buffer 3)

The 'combination' terminology represents a non-GIS procedure that hides some operations mainly consisting in building a topological polygon from polylines data (EUROSION coastline, EUROSION 5 meter line, outer administrative limits of a region). Once this new built polygon represents the RICE and calculations are made possible especially with area.

3.2 Limitations and future recommendations

The distance value 500 m from the coastline is close to the max error distance estimated during EUROSION integration between two datasets from different sources (ex: GISCO, SABE or CLC90) and therefore must be considered as a 500 +/-300 m. Nevertheless when coherent sources are overlaid, the GIS computed distance 500m is considered as reliable.

For limitations on the EUROSION 5 meter line, please report **to §4.8.3.**

4. METHODOLOGY FOR ASSESSING THE SENSITIVITY INDICATORS

The methodology described hereunder aims at making the use of the various datasets produced and compiled in the framework of EUROSION project in order to assess the indicators which combination reflects the current and future "physical" sensitivity of the European coastal zones to coastal erosion and flooding.

4.1 Relative sea level rise (best estimate for the next 100 years)

This first indicator is aiming at rating each european region with respective impact of relative sea level rise (0, 1 or 2 points), using common sense thresholds of relative sea level rise (proposed a priori – Threshold1 = 0 mm/year, Threshold2 = 0,40 mm/year)

4.1.1 Sources

- Relative Sea level rise dataset from EUROSION database (Layer HDEURK100KV1). 237 points of interest located between 30 to 100 km from the coastline and giving an average value of the sea level evolution in a 200 x 200 km square around each point.
- GISCO NUTS polygon dataset NUEC1MV7 and associated tables.

4.1.2 Step by step methodology

As the Sea level rise value is not connected to a segment of the shoreline, its rating to the coastal region is not possible directly. This indication can be done graphically with the help of maps, gathering many regions where sea level rise data is available.

<u>Step1.</u> Open the dataset NUEC1MV7

- Display Regions using Symbology Tab,
- Choosing Categories and NURCGDL2 field.

<u>Step2.</u> Joining NUEC1MV7 polygon coverage with NUECATV7.inf attribute table using field NURGCDL2.

<u>Step3.</u> Display label of polygon coverage using NUECATV7.INF.NURGCM field

<u>Step4.</u> Add the layer Sea level rise

<u>Step5.</u> Display the Thresholds setting-up an ArcMap symbology :

- Using Quantities and field Sea_level_rise,

- Create 3 classes (0, 1, 2)

  - Sea_level_rise < Threshold1;
  - Threshold1 < Sea_level_rise < Threshold2;
  - Threshold2 < Sea_level_rise < max_value (given by the tool)

<u>Step6.</u> Rating of GISCO NUTS polygons

To populate GISCO NUTS polygons with closest Sea Level Rise value, the GIS tool allows to perform a *spatial join* between the two datasets as shown below.

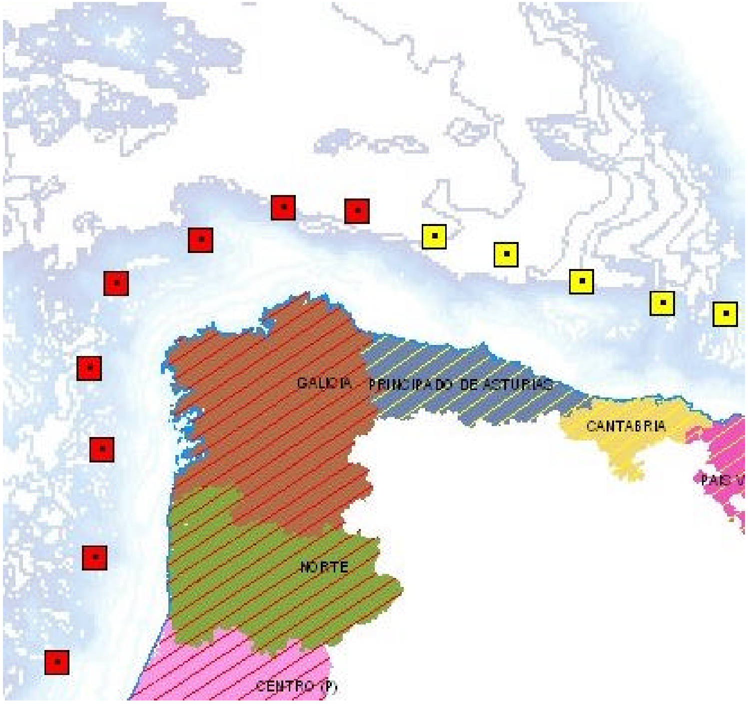


fig 4.1 – Sea Level Rise rating per region (red/yellow/green slashed)

4.1.3 Limitations and recommendations

Main limitations are related to the data calculations themselves [TRD1], especially considering the Mediterranean sea where "Sea level change in the Mediterranean was limited to 1 mm/year", those values are not really significant since they are mapped on the mean of global accelerated sea level rise value.

4.2 Shoreline evolution (shoreline erosion or accretion)

This indicator reflects shoreline evolution trend status which expresses the percentage of shoreline in erosion or accretion

4.2.1 Sources

- Coastal Erosion Layer CEEUBG100KV2 and the Evolution Trends attribute (CEEVV2)

4.2.2 Step by step methodology

Step 1. Extraction of non informed segments or segments out of nomenclature lines which will not be taken into account for the indicator.

Within GIS tool, selection of segments for which CEEVV2 differs from "1" (i.e. No information) or "0" (i.e. out of nomenclature).

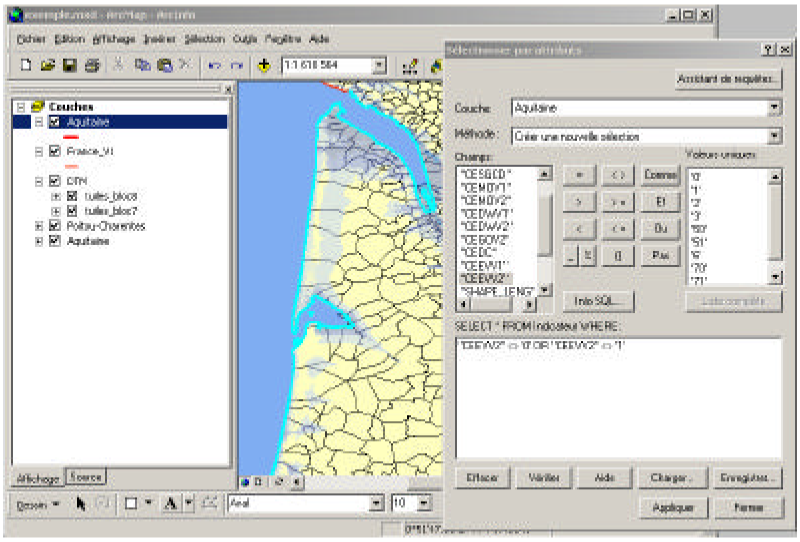


fig 4.2 – Selected segments (highlighted in cyan)

Step 2. Assessment of the considered length of coast (L1a) by GIS statistical tool.

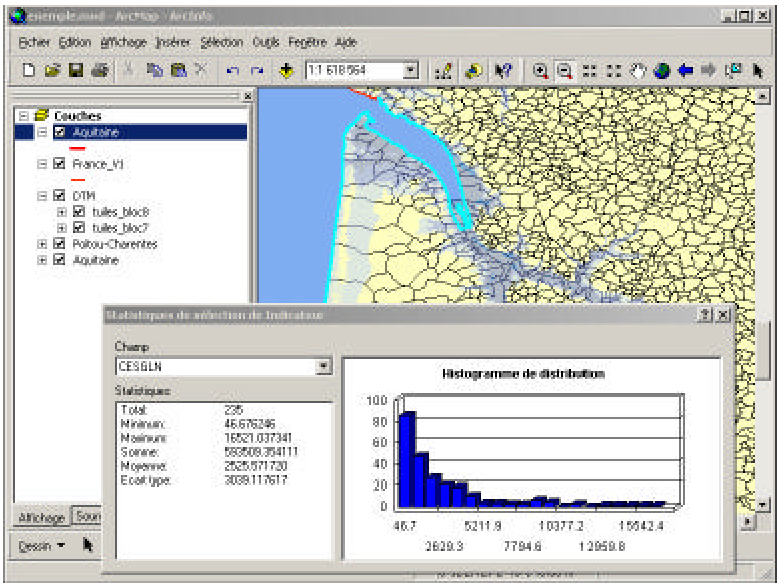


fig 4.3 – Example of FR61 – Aquitaine: considered length L1a equal to 593509 m

Step 3. Identification of segments in erosion or in accretion.

Within GIS tool, the selection is based on evolutionary trend with:

Code CEEVV2 not equal to " 2" (*i.e.* Stable – evolution almost not perceptible at human scale)

and

CEEVV2 not equal to '3' (*i.e.* Generally stable – small "occasional" variations around a stable position – evolutionary trend is uncertain)

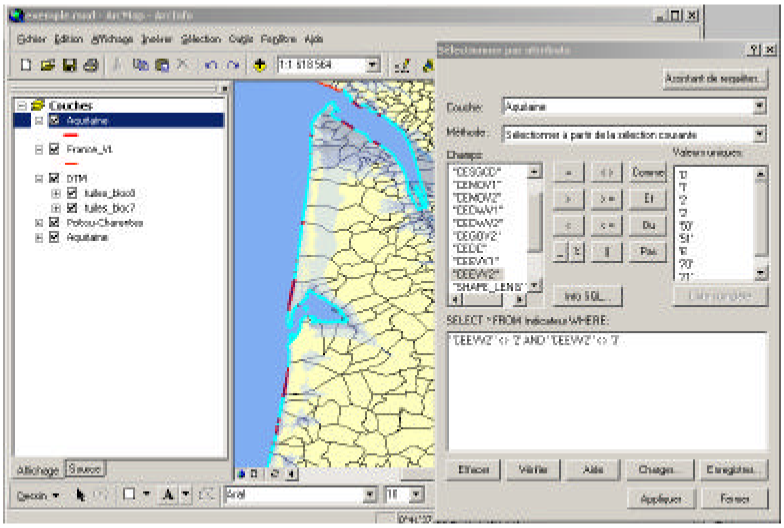


fig 4.4 – FR61-Aquitaine : segments in erosion or in accretion

Step 4. Defining length of coasts in erosion or in accretion (L2a) with GIS statistical tool (same method as in step 1) and calculation of percentage from L1a.

Within FR61-Aquitaine example, L2a = 487394 m and L1a = 593509 m.

Therefore 82% of the coast for this region appear as in erosion or accretion.

Step 5. Rating of region coast for erosion or accretion with the 2 thresholds initially defined, according to Table 2.2.

FR61-Aquitaine coast is rated with 2 points.

4.2.3 Limitations and recommendations

The rate of change assessed for this indicator may have two possible sources we can not differentiate :

- an improvement of the knowledge with a better accuracy in evolutionary trend assessment.
- a physical change in the evolutionary trend on a sector.

The changes from accretion in CCEr (version 1) to erosion in CEL (version 2) are not taken into account. Moreover, in CEL (V2) priority has been given on evolutionary trend to the last 15 years where data were available but if not the case, CCEr (V1) value has been maintained.

Anyway proposed thresholds need to be tested on real cases in order to be representative at European level.

4.3 Shoreline evolution (change of erosion patterns)

This indicator reflects Shoreline change which expresses the changes from a stable trend assessed in the CORINE Coastal Erosion database (CCEr-V1) to erosion or accretion in the present Coastal Erosion Layer (CEL-V2). This second indicator will be valuable only for regions covered by both databases.

4.3.1 Sources

- Coastal Erosion Layer CEEUBG100KV2. Evolution Trends attribute CEEVV2 and evolution trend attribute CEEVV1 (reported from CORINE Coastal Erosion database)

4.3.2 Step by step methodology

Step 1. Extraction of non informed segments or segments out of nomenclature in both databases.

Within GIS tool, selection of segments with evolution trend codes CEMEVV2 and CEMEVV1 not equal to “1” (i.e. No information) nor “0” (i.e. out of nomenclature).

Step 2. Assessment of the considered length of coast (L1b) by GIS statistical tool.

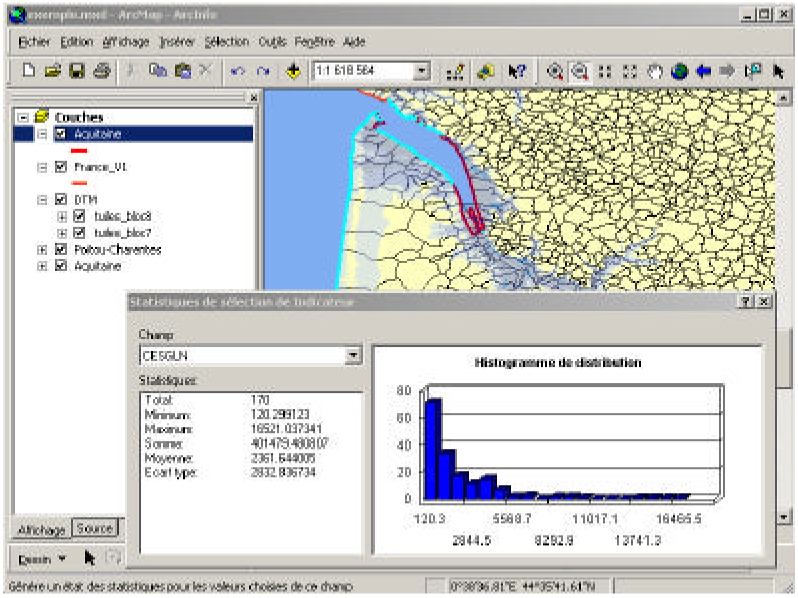


fig 4.5 – FR61-Aquitaine : considered length L1b is equal to 401479 m.

The difference with the L1a value (593509 m) must be underlined.

Step 3. Identification of segments which have changed from stable in CCEr (version 1) to erosion or accretion in Coastal Erosion Layer (version 2).

The selection is based on evolutionary trend with the following request:

CEEVV1 equal to “ 2” (i.e. Stable – evolution almost not perceptible at human scale)

or

CEEVV1 equal to “3” (i.e. Generally stable – small “occasional” variations around a stable position – evolutionary trend is uncertain)

and

CEEVV2 not equal to “ 2” or CEEVV2 not equal to “3”

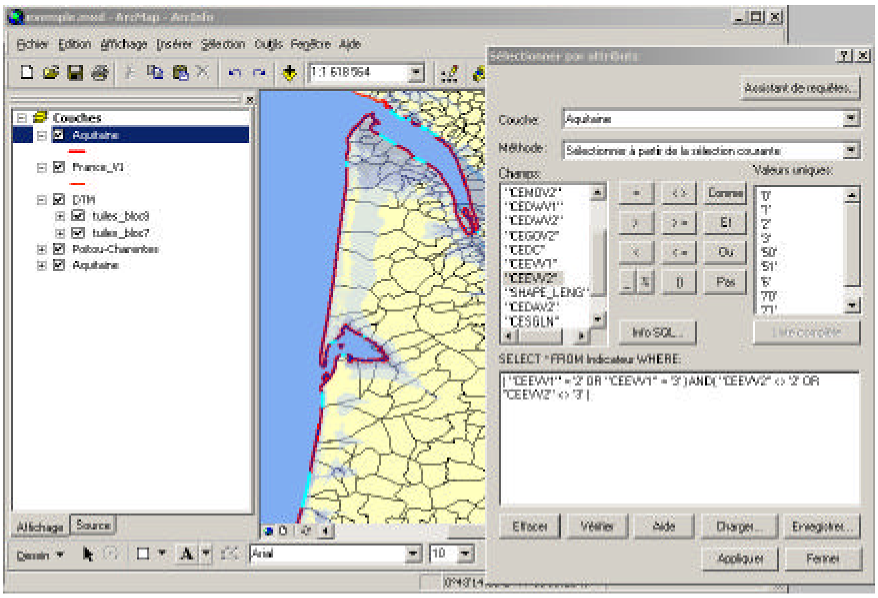


fig 4.6 – segments which have changed from stable in CCEr (version 1) to erosion or accretion in Coastal Erosion Layer (version 2)

Step 4. Defining length of coasts with changes to erosion or accretion (L2b) with ArcGis statistical tool (same method as in step 1) and calculation of percentage from L1b.

With FR61-Aquitaine example, L2b = 68391 m and L1b = 401479 m

Therefore 17% of the coast for this region appear to have changed from a stability assessment in CCEr (V1) to erosion or accretion in CEL (V2).

Step 5. Rating of region coast for change to erosion or accretion with the 2 thresholds initially defined, according to Table 2.2.

FR61-Aquitaine coast is rated with 1 point.

4.4 Highest water level (surge level)

A storm surge is defined as "an unusually high stand of sea level produced by strong storm winds blowing water shoreward and by the ocean surface rising in response to low atmospheric pressure." A surge as such may not be a threat to the assets located along the coastline. However, a surge, even moderate, coinciding with high tide may potentially lead to acute erosion and finally in coastal flooding. This is what happened in 1953 in the North Sea.

4.4.1 Sources

- Tidal regime Layer HDEURK100KV1 from EUROSION database
- Shoreline geometry Layer : CLEUER100KV1 from EUROSION database
- Bathymetry Layer : BTEUGO100KV1 from EUROSION database

4.4.2 Step by step methodology

Background information

Schematically, the exposure of coastline segments to surges depends on various factors:

- the tidal regime,
- the fetch, i.e. the extent of water upfront the coastline
- the bathymetry,
- the wind set-up, i.e. the elevation of water level due to the wind stress over the sea surface, and being locally defined by the following equation:

$$\frac{\partial \eta}{\partial X} = \frac{C_D \rho_A W_{10}^2}{\rho g h(X)}$$

(derived from the "wind stress" formula by Wu, 1980)

where,

η is the variation of water level due to wind stress (wind set-up)

X is the cross-shore distance from the shoreline over which the wind blows

$C_D = (0.8+0.065W_{10})\times10^{-3}$ is the drag coefficient (for W>1)

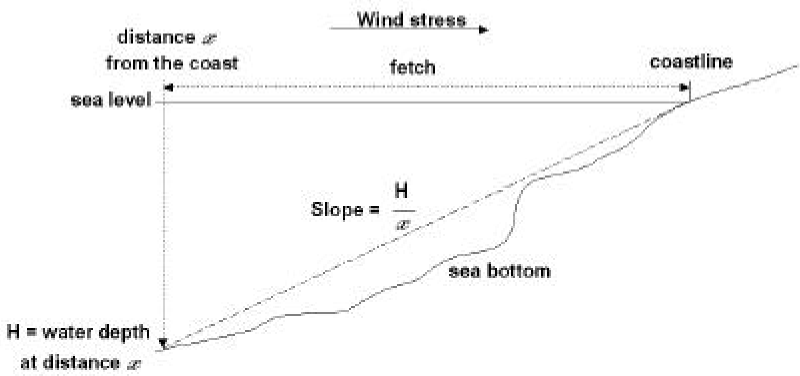
W_{10} is the wind speed 10 meters above the sea surface

ρ_A = 1.293 kg.m^{-3} is the air density (if needed, it may be converted as a function of latitude)

$\rho = 1025\ kg.m^{-3}$ is the sea water density

$g = 9.8\ ms^{-2}$ is the gravitation coefficient

$h(x)$ is the water depth at distance x from the shoreline. In the present situation, the water depth can be approximated as a linear function with a constant slope (see picture).



Assuming that the wind constantly blows towards the coast over a distance equal to the fetch, then the wind set up can be estimated by integrating the previous equation as follows:

$$\eta = \int_{x=\text{fetch}}^{x=5\ (\text{"near" shoreline})} \frac{\partial \eta}{\partial x}\, dx = \frac{C_D \rho_A W_{10}^2}{\rho g} \int_{x=\text{fetch}}^{x=5} \frac{dx}{h(x)} = \frac{C_D \rho_A W_{10}^2}{\rho g} \times \frac{-\text{fetch} * [\ln(5) - \ln(x=\text{fetch})]}{h(\text{fetch})}$$

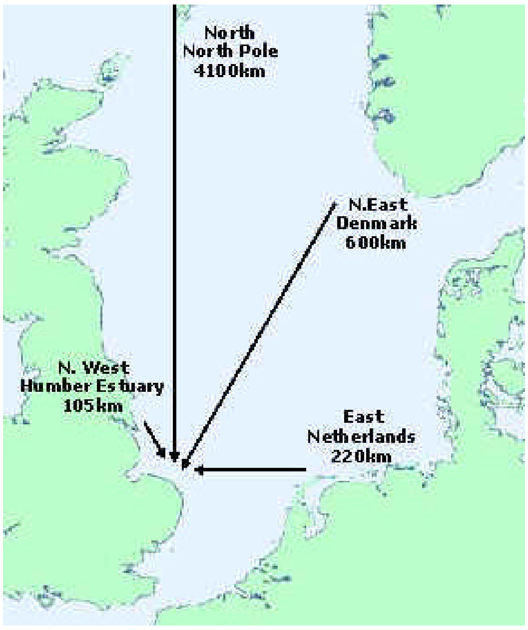
(Note 1: An adapted version of this formula was also used by Delft Hydraulics in Global Vulnerability Assessment, p. 21)

Methodology

To estimate exposure of the European coastline to storm surge, the previous formula can be combined with the EUROSION database as follows:

<u>Step 1.</u> For each point featured by the layer “wind and wave regime” (237 locations), 8 values of fetches can be derived (one fetch value per direction). The fetch values can be stored in a separate layer.

NB: directions oriented off-shore are assigned to “zero”.



Example of fetch calculation for North Norfolk (source: http://www.jfk.herts.sch.uk/class/geography/ks5/north_norfolk/marine_processes.htm)

Step 2. For each of the 237 points, 8 bathymetric values *h* are derived from the layer "bathymetry" (bathymetry at the distance x=fetch from the shoreline in each specific direction).

Step 3. For each of the 237 locations, and for each direction, the above mentioned formula is calculated using the values of Step 1, Step 2, and the wind speed which is exceeded 1% of the time (most extreme conditions observed in the past 18 years).

Step 4. The highest of the 8 values calculated for each location is stored. Other values are discarded.

Step 5. To each of the values calculated above, the mean tidal range (coming from the "tidal range" layer) is added.

Step 6. The 237 values are grouped into 3 classes (*the same used by Delft Hydraulics in "Global Vulnerability Assessment", p.21*) for a classification:

(i) low exposure (surge level < 1,5 meter) -> 0 point

(ii) moderate exposure (3 meters < surge level < 1,5 meter) -> 1 point

(iii) high exposure (3 meters < surge level) -> 2 points

4.5 Coastal urbanisation rate

This indicator reflects the rate of urban growth within a coastal region

4.5.1 Sources

- Layers LC**COI100kV1 and LC**CH100kV1 relating to Land Cover Changes (e.g. LCPLCOI100kV1 and LCPLCH100kV1 for Poland PL) and their attributes LCCHCDL2V1 and LCCHCDL2V2 and AREA.

4.5.2 Step by step methodology

Step 1. Extraction of urban areas in 1975 at the level of a specific region.

Within GIS tool, selection from LCPLCOI100kV1 polygons for which LCCHCDL2V1 is “11” (i.e. urban fabric)

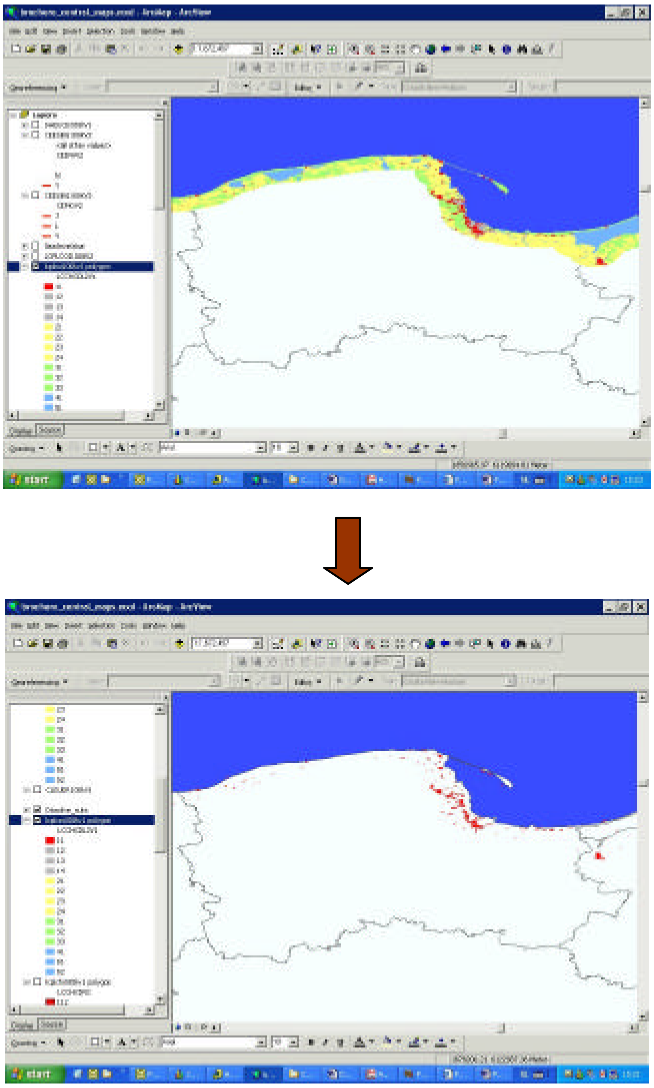


fig – Extraction of urban areas in 1875 in a polish region

With the GIS tools, clip the selected polygons which are within the polygon region (NUTS2)

Step 2. Calculation of the total area covered by urban polygons at the level of a specific region.

Within GIS tool, open the attribute table of the layer containing the polygons selected as a result of Step 1, and summarize the attribute AREA. The result is called URBANAREA1975

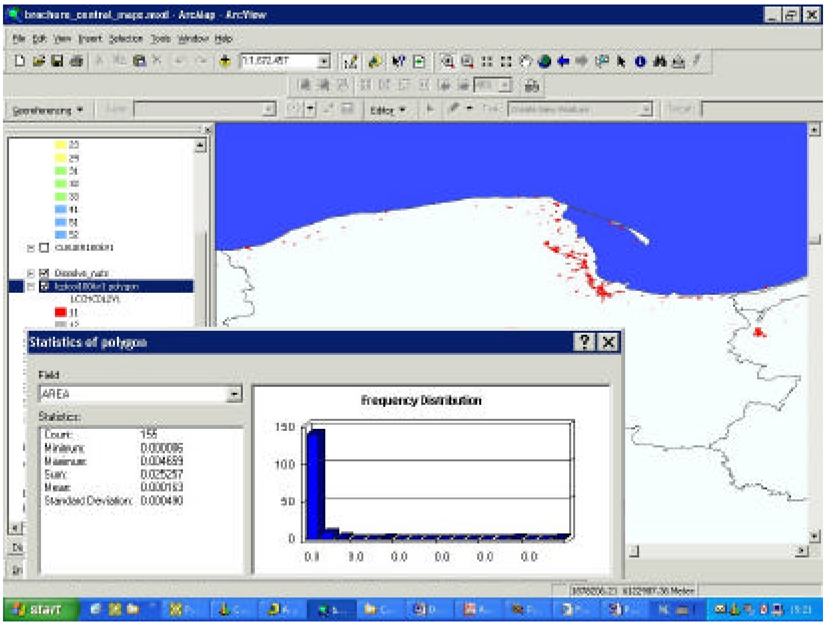


fig – Calculation of total areas covered with urban areas

Step 3. Extraction of polygons which are urban areas in 1990 (V2) and not urban in 1975 (V1) at the level of a specific region.

Within GIS tool, selection from LCPLCH100kV1polygons for which LCCHCDL2V2 is “11” (i.e. urban fabric)

Ex.

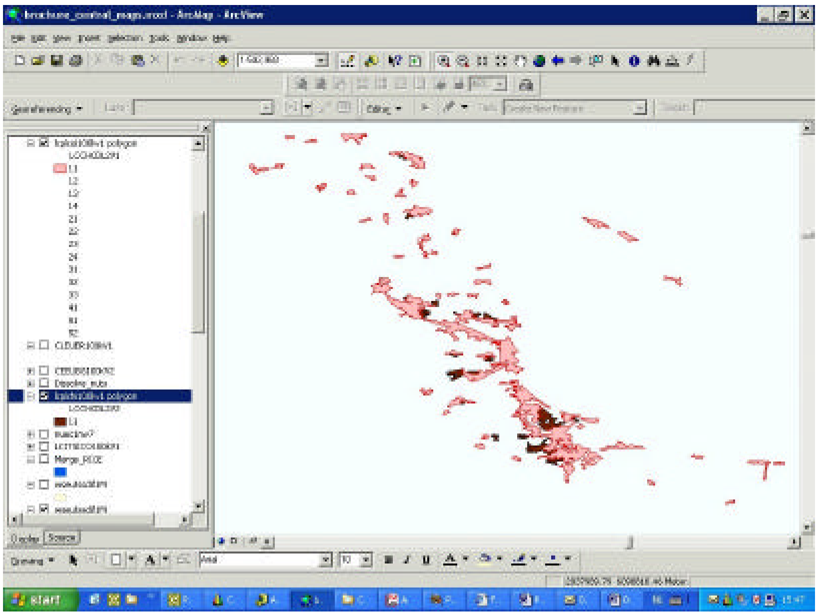


fig – Extraction of new urban areas (in 1990). Zoom on the city of Gdank. New urban areas appear in dark red, while already existing urban polygons are in light red.

Step 4. Calculation of the total area covered by new urban polygons at the level of a specific region.

Within GIS tool, open the attribute table of the layer containing the polygons selected as a result of Step 3, and summarize the attribute AREA. The result is called NEWURBANAREA1990

Step 5. Calculation of urbanization rate, URBANRATE, at the level of a specific region.

The urbanization rate is given by the formula:

$$URBANRATE = \frac{URBANAREA1975 + NEWURBANAREA2000}{URBANAREA1975} x100$$

Step 6. Rating of urbanisation rate using the 2 thresholds initially defined, according to Table 2.2.

4.6 Reduction of river sediment supply

This indicator aims to assess the susceptibility of the coast to erosion, through the reduction of sediments available protecting the shoreline from erosion and breaking waves. The project observed a huge variety of catchment scale and corresponding data. The impacts at the level of the region, regarding sediment flows from river catchment origins requires delineation of coastal sediment cells. Therefore this indicator has not been incorporated in the sensitivity analysis.

4.7 Geological coastal type

This indicator aims to asses the susceptibility of the coast to erosion, through its geological characteristics.

4.7.1 Sources

- Coastal Erosion Layer: CEEUBG100KV2. Geomorphological attribute (CEMOV2) and geological attribute (CEGOV2)

4.7.2 Step by step methodology

Step 1. Extraction of non informed segments or non natural shore lines which will not be taken into account for the indicator

Within GIS tool, selection of all coastline segments whose geological code CEMOV2 differs from "C00" (i.e. No information) or "D00" (i.e. out of nomenclature).

Step 2. Assessment of the considered length of coast (L1) by GIS statistical tool.

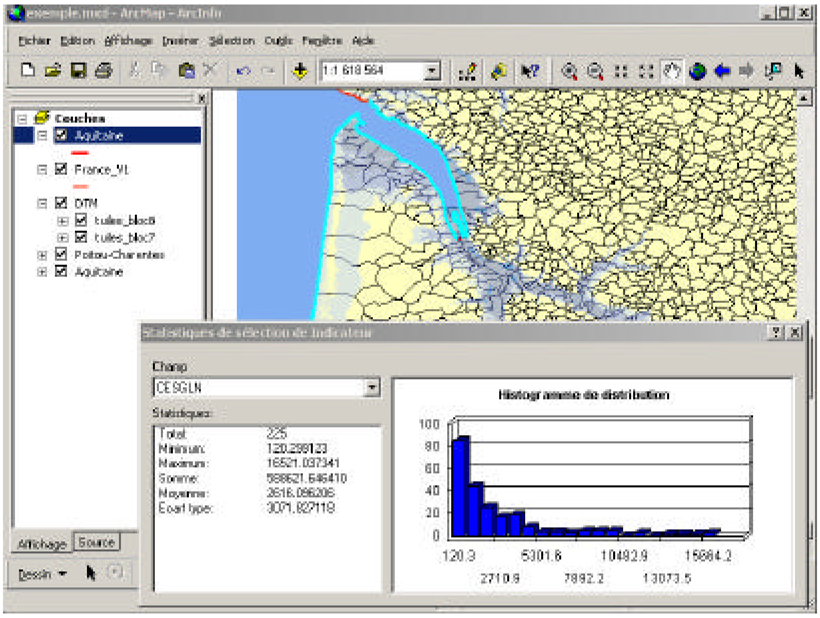


fig 4.7 – Step 2 selected segments (highlighted in cyan),

for FR61-Aquitaine, considered length L1 equal to 588621 m.

Step 3 Identification of "likely non erodable segments" i.e. substratum, adding muddy coasts (mostly subject to aggradation, in difference with other non cohesive sediments).

The selection is based on geomorphology and geology within the following request:

CEMOV2 = " N" (i.e. Very narrow and vegetated strands – ponds or lake shore type)

or

CEMOV2 = "G" (*i.e.* Strands of muddy sediments : "wadden" and intertidal marshes with "slikkes ansd shorres")

or

CEGOV2 code beginning with "A" (*i.e.* all substratum formations)

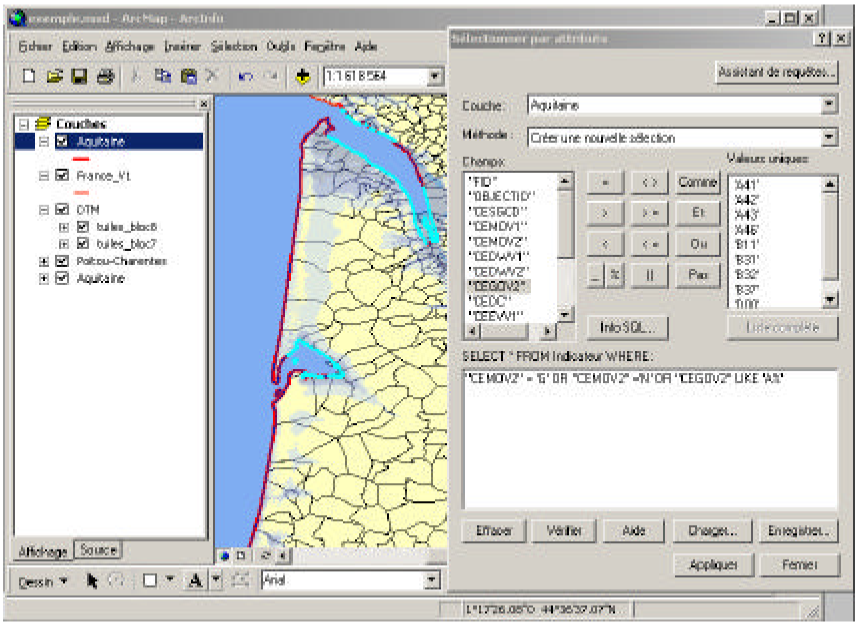


fig 4.8 – Step 3 selected segments (highlighted in cyan)

<u>Step 4</u> : Defining length of coasts of "likely non erodable" segments (L2) with GIS statistical tool and calculation of percentage from L1

With FR61-Aquitaine example L2 = 207972 m and L1 = 588621 m

Therefrom 35% of the coast for this region appear "likely non erodable"

<u>Step 5</u> Rating of region coast for geological erodability with the 2 thresholds initially defined, according to Table 2.2.

FR61-Aquitaine coast is rated with 2 points.

4.7.3 Limitations and recommendations

It must be underlined that some substratum formations may be altered or weathered and react as erodable (e.g. "A22" – Ashes and stone fragments, "A45" – Evaporites or "A46" – "Flysch" and interbeded series). They are not been taken into account in our calculation. In the same way, some muddy coast may also be on erosion.

4.8 Elevation

This indicator shall reveal regions under the influence of flooding due to presence of coastal lowlands (even below mean sea level). The calculation of such indicator needs accurate data on elevation such as Digital Elevation Models near the shoreline landwards up to the 5 meter altimetric line (see limitations).

4.8.1 Sources

- EUROSION Coastline (layer CLEUER100KV1)
- EUROSION 5 meter line and/or DTM Layer (layers DEEUINMPV1 or DEEUMP100Knm)
- Administrative Regions boundaries (from GISCO)

4.8.2 Step by step methodology

For each region listed in Table 2.1

Step1. Creation of a Coastline to 5 meter buffer (=>buffer1)

Step2. Creation of the corresponding administrative region buffer (=> buffer2)

Step3. Overlay and Clipping of buffer1 and buffer2 (=> RICE)

Step4. Calculate the ratio between Area of RICE and Area of buffer2, that is to say the percentage of area lying under 5 meters compared to the region area.

Final step. Rating of each region according to the rules mentioned in Table 2.2

4.8.3 Limitations and recommendations

- About 5 meter contour line

The contour line has been extracted from Digital Elevation Models with vertical accuracy inherent Height Reference System. Therefore every Digital Elevation Model or contour line has been vertically adjusted according to the EVRF2000[2] realization.

The extraction of the 10 meter line from Digital Elevation Models leads to vertical 5 meters RMSE[3]. Thus the worst case corresponds to 5 meters and ensure the study not underestimating the surface.

Nevertheless, those indications have to be considered as relative regarding the scale of representation (1:100,000). Actually the error mapped at this scale consists in a sub pixel mislocation of the contour line: as the pixel size is about 100 meters, with the smallest slopes (Mont Saint-Michel) the error of placement due to non consideration of European zero altitude definition revealed a planimetric shift of 50m for the "5 meter" contour line, that is to say half a pixel). Mapping with better scales such as 1:25,000 should lead to a fairly visible worst placement of the line.

- About administrative regions surfaces

Region values are mainly issued from GISCO Communes dataset (NUTS2 level except for DE and UK - NUTS1). The GIS tool was used to calculate surfaces from polygons. Comparison checking was made with SABE dataset on available regions (not communes) as well as with exogen internet sources (www.quid.fr amongst others) that revealed an average error of less than 1% for the GISCO dataset.

- About RICE creation

From its buffer constitution, the surface of the RICE polygon was slightly over-evaluated: the 500 m buffer is systematically symmetric on both sides of the coastline and thus cover an area (500 m wide) in the sea. For the calculation and to minimise this sie-effect (independent of the region and only

[2] [TRD 3] European Vertical Reference Frame 2000: For Western European countries the common height reference system were referring to the (NAP) Normaal Amsterdam Peils for defining the altitude zero whereas Baltic and Eastern countries referred to the Kronstadt tidegauge. Within this new realization the same System is applied for all those countries (except Bulgaria). Differences between EVRF2000 zero level and the zero levels of countries national height systems in Europe are well documented (within centimetric accuracy). Adjustments for each datasets (under or over elevation) have been made accordingly.

[3] Root Mean Square Error

increasing in proportion to the coast length), it has been subtracted the value of the coast length x 500 m, globally excluding the sea part of the RICE.

Main remaining source of RICE's surface over estimation comes out from the water bodies. Actually as the RICE is built from the altimetric 5 m line, it takes into account all water bodies (lakes) lying landwards near the coast. Whereas Arcachon basin is definitively part of the sea, wide estuaries, rivers or lakes such as 'pond of Berre' are located inside the local RICE. From our point of view, water bodies should be consider case by case (pond of Thau vs pond of Berre) regarding influence of coastal erosion or flooding.

4.9 Engineereed frontage (including protection structures)

4.9.1 Sources

- Coastal Erosion Layer: CEEUBG100KV2. Geomorphological attribute (CEMOV2) and presence of defence works attribute (CEDWV2)

4.9.2 Step by step methodology

<u>Step 1</u>. Assessment of the length of coast (L0) by GIS statistical tool.

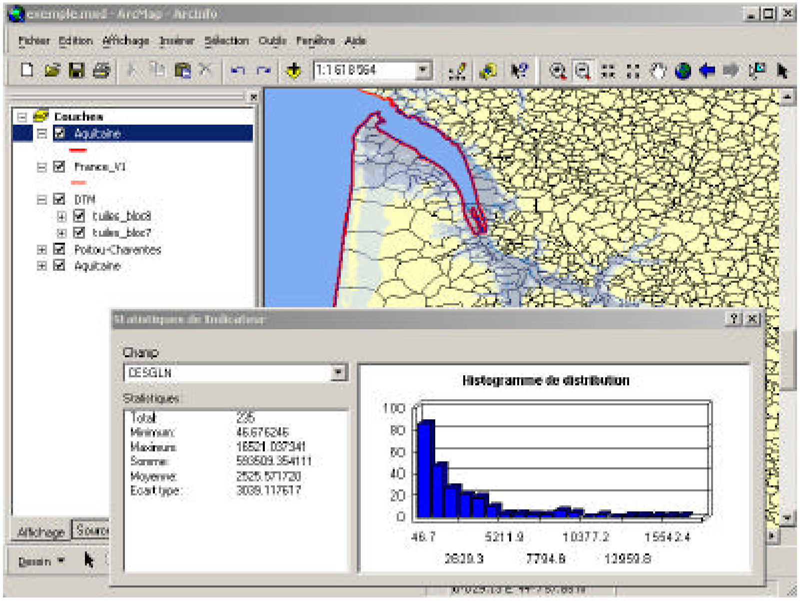


fig 4.9 – for FR61-Aquitaine, total length of coast (L0) is equal to 593509 m.

<u>Step 2</u>. Selection of segments being protected from erosion (or aggradation).

The selection is based on geomorphology and presence of defence works within the following request:

CEMOV2 = " K" (i.e. Artificial beaches)

or

CEMOV2 = 'Y' (i.e. Artificial shoreline or shoreline with longitudinal protection works)

or

CEMOV2 = " J" (i.e. Harbour Area)

or

CEMOV2 = " L" (i.e. Coastal embankments for construction purposes)

or

CEDWV2 = "Y" (i.e. presence of defence works)

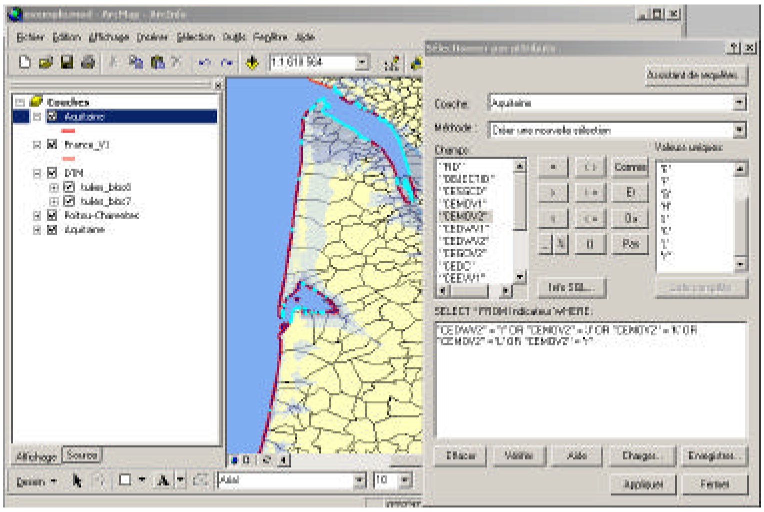


fig 4.10 – selected segments.

Step 4 Defining length of coasts engineered frontage segments (L3) with ArcGis statistical tool and calculation of percentage from L0

With FR61-Aquitaine example, L3 = 212064 m and L0 = 593509 m

Therefrom 36% of the coast for this region appear as an engineered frontage.

Step 5 Rating of region coast for engineered frontage with the 2 thresholds initially defined, according to Table 2.2.

FR61-Aquitaine coast is rated with 2 points.

4.9.3 Limitations and recommendations

For this indicator, it is assumed that harbor facilities are built up as protection against erosion or aggradation. This is clearly not valuable in any case. By this way, the project gives the coastline segments the highest score, following the precautionary principle.

5. METHODOLOGY FOR ASSESSING THE IMPACT INDICATORS

The methodology described hereunder aims at making the use of the various datasets produced and compiled in the framework of EUROSION project in order to assess the indicators which combination reflects the potential impact of coastal erosion and flooding to population, urban, industrial and natural areas.

This methodology will mention the RICE definition described in Chapter 3, and its calculation in Chapter 4.8.

5.1 Population living within the RICE

Population data only exist at the level of administrative boundaries (principally municipalities). It is however possible to fine-tune the geographical distribution of population by correlating land cover data with population known at the administrative level. Following preliminary JRC studies mentioned in EEA report [REF2], we assume that CORINE Land Cover data furnish useful georeferenced information allowing the exercise of population disagreggation, with assumptions made in [TRD2]. Nuances evoked in [REF2] shall be reinforced by our littoral limited study where it is predictable (for historical and economical reasons) that built-up areas host most of the population while agricultural areas and natural areas will only host a far smaller proportion. Important attention is paid for the final methodological assessment of the population density.

According to [TRD2] population disagreggation based on land cover data is made within the following two steps approach:

- Deriving from CORINE Land Cover an estimation of the Population Density for each coastal commune.
- Estimating the Population living within the RICE from the estimated Population Density.

5.1.1 Sources

- GISCO population database from Eurostat (Census 1991) and ancillary data for missing population.
- RICE (graphic results from chapter 4.8)
- CORINE Land Cover 90 database

5.1.2 Step by step methodology

STEP 1: ESTIMATION OF THE POPULATION DENSITY OF COASTAL COMMUNES FROM CLC POLYGONS.

Step 1.1. Selection of municipalities included in one specific (coastal) region in Europe. This extraction is referred hereafter as the $S_{1,NUTS\ code}$ selection (e.g. $S_{1,\ NUTS\text{-}FR61}$ for Aquitaine). NUTS code are given in the table 2.1.

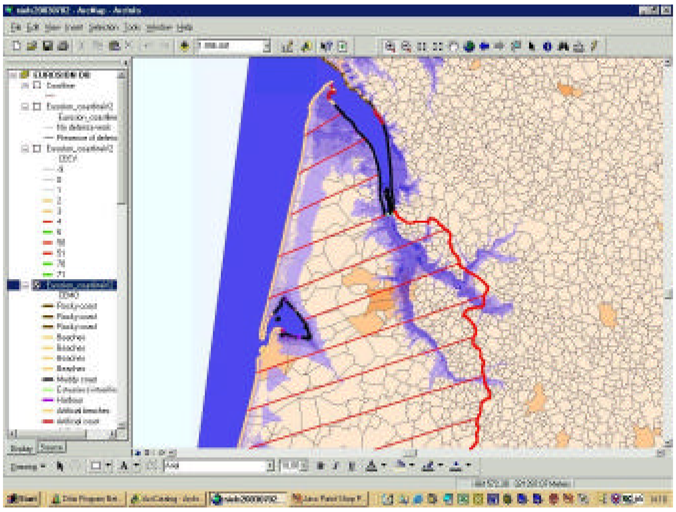


Fig 5.1 - Selection $S_{1,\ NUTS\text{-}FR61}$

Step 1.2. For each $S_{1,NUTS\ code}$ selection, extraction and selection of municipalities entirely or partly included within the radius of influence of coastal erosion and flooding (RICE). This extraction is referred hereafter as the $S_{2,NUTS\ code}$ selection.

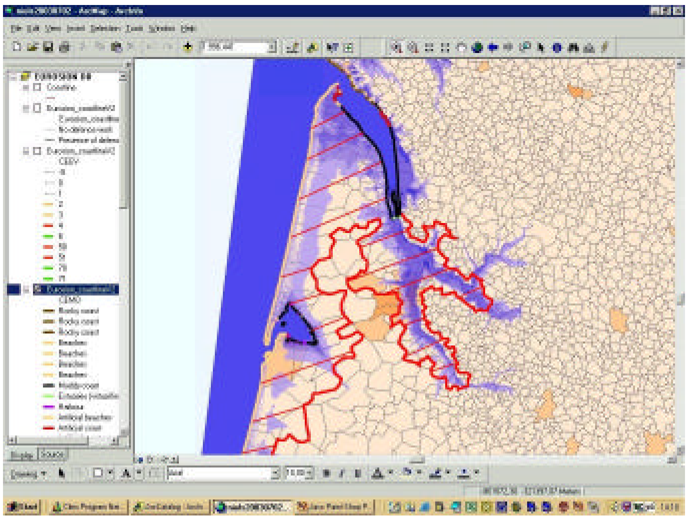


Fig 5.2 - Selection $S_{2,\ NUTS\text{-}FR61}$

Step 1.3. Calculation of the total population living in the municipalities of the $S_{2,NUTS\ code}$ selection (=$P_{2,NUTS\ code}$). This is done by adding the demographic data known for all municipalities of the $S_{2,NUTS\ code}$ selection (GISCO Communes population related attribute)

Step 1.4. Merging the boundaries of the municipalities $S_{2,\text{NUTS code}}$ selection. This is referred hereafter as the "merged" $MS_{2,\text{NUTS code}}$ selection.

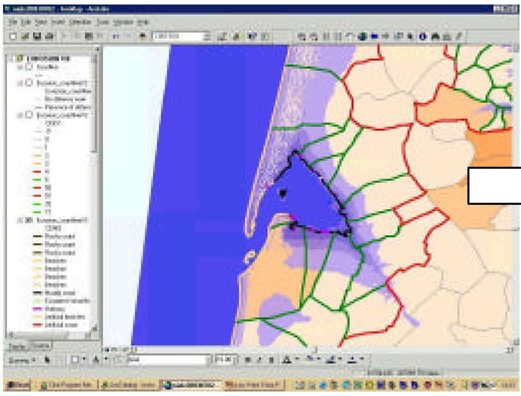


Fig 5.3 – Zoom of $S_{2,\text{NUTS-FR61}}$ selection

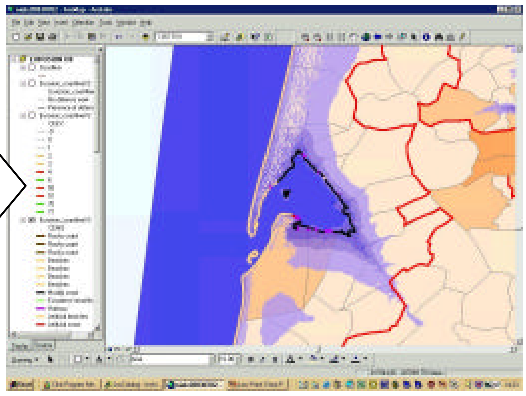


Fig 5.4 – "Merged" $MS_{2,\text{NUTS-FR61}}$ selection

Step 1.5. Overlaying of CLC Land Cover polygons with the merged $MS_{2,\text{NUTS code}}$ selection extracted from previous step. This overlay is referred hereafter as the $LC_{2,\text{NUTS code}}$ selection.

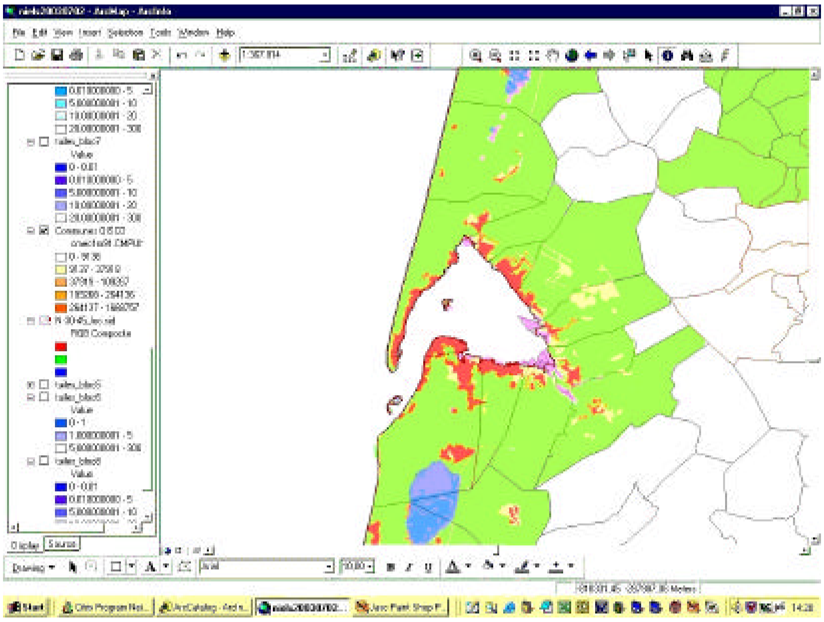


Fig 5.5 – Zoom of $LC_{2,\text{NUTS-FR61}}$ selection

Step 1.6. Calculation of the total area covered by CLC polygons (at level 1) of Class 1, Class 2 and Class 3 only (the more expected to host population) for each $LC_{2,\text{NUTS code}}$ selection.

This leads to the 3 following values:

CLC "Class 1" polygons total area = $U_{2,\text{ NUTS code}}$ (Urbanised areas)

CLC "Class 2" polygons total area = $A_{2,\text{ NUTS code}}$ (Agricultural areas)

CLC "Class 3" polygons total area = $N_{2,\text{ NUTS code}}$ (Natural and semi areas)

Step 1.7. Estimate of population specific densities for CLC90 Class 1, Class 2 and Class 3 polygons.

Assuming that, as a proxy, population distribution is mainly living in urban areas (for 70%), in agricultural area (for 20%) and in natural or semi-natural areas (for the 10% remaining), neglecting the water bodies where too few people are living:

- **Density of "Urban" polygons**, *i.e.* urbanized areas are expected to host 70% of the total population:

  $$DU_{2,\text{ NUTS code}} = 0.70 * P_{2,\text{NUTS code}} / U_{2,\text{ NUTS code}}$$

- **Density of "Agricultural" polygons**, *i.e.* agriculture areas are expected to host 20% of the total population:

$$DA_{2,\ NUTS\ code} = 0.20 * P_{2,NUTS\ code} / A_{2,\ NUTS\ code}$$

- **Density of "Natural" polygons**, *i.e.* natural and semi-natural areas are expected to host 10% of the total population:

$$DN_{2,\ NUTS\ code} = 0.10 * P_{2,NUTS\ code} / N_{2,\ NUTS\ code}$$

Step 1.7bis. Estimate of population specific location for CLC90 Class 1, Class 2 and Class 3 polygons with CLC90 disagreggation methodology.

Table 7: % of population in each CLC90 class with the suggested disaggregation method [TDR2]

	BE	DE	DK	ES	FR	GR	IE	IT	NL	PT	UK	All
Urban dense	5,7	2,5	10,1	54,1	13,2	33,2	8,4	23,8	85,3	18,3	16,1	21,9
Urban discontinuous	86,4	80	67,4	18,2	64,6	33,9	50,2	50,2	2,6	40,6	71,8	56,5
Indust. Commerc.	0,6	0,6	0,3	0,6	0,8	0,3	0,4	0,7	0,4	0,4	0,3	0,6
Transport	0,1	0,1	0,1	0,1	0,1	0,1	0,2	0,1	0,1	0	0,1	0,1
Green urban	0,1	0,1	0,2	0	0,1	0	0,2	0	0,1	0	0,2	0,1
Arable non irrigated	2,4	8,1	16,5	6,2	7,1	4,4	4,1	7,9	3,1	6,1	4,8	6,7
Arable irrigated	0	0	0	2,2	0	2,7	0	0,5	0	0,1	0	0,4
Rice	0	0	0	0,1	0	0	0	0,2	0	0,3	0	0,1
Permanent crops	0,1	0,5	0	4,8	1,6	7,2	0	4,3	0,1	7,2	0	2,1
Pasture	0,7	2,2	0,2	0,3	2,5	0	28,9	0,3	3,7	0	5,1	2,4
Arable & perm. Crops	0	0	0	0,4	0	0,2	0	1,3	0	10	0	0,6
Complex	3,1	3,4	2,9	6,3	6,7	8,5	2,1	5,6	3,8	5,7	0,8	4,7
Agric. & natural veg.	0,4	0,4	1,4	1,3	0,8	2,3	3	1,6	0,3	3,7	0,1	0,9
Agroforestry	0	0	0	0,5	0	0,2	0	0	0	0,4	0	0,1
Forest	0,5	2,2	0,8	2,7	2	3,1	1,3	2,8	0,4	5,8	0,4	2,1
Natural vegetation	0	0	0,1	2	0,3	4	1,3	0,6	0,1	1,3	0,4	0,7
% URBAN CLASSES	***92,9***	***83,3***	***78,1***	***73***	***78,8***	***67,5***	***59,4***	***74,8***	***88,5***	***59,3***	***88,5***	
% AGRICULTURAL CLASSES	***6,7***	***14,6***	***21***	***22,1***	***18,7***	***25,5***	***38,1***	***21,7***	***11***	***33,5***	***10,8***	
% NATURAL CLASSES	***0,5***	***2,2***	***0,9***	***4,7***	***2,3***	***7,1***	***2,6***	***3,4***	***0,5***	***7,1***	***0,8***	

Beyond this proxy, these coefficients (70%, 20% and 10%) have been advantageously replaced by other weights issued from a method of disagreggation of CORINE Land Cover 1990 data, evaluated and described in the referenced document [TDR2] Table 7. Those weights match, country by country, the percentage of distribution for each class of CORINE Land Cover 1990.

Thus for each region (defined by a NUTS Code) belonging to a given country, the three main densities of population are defined as following:

- **Density of "Urban" polygons for each NUTS Code:**

$$DU_{2,\ NUTS\ code} = \%URBAN\ CLASSES_{NUTSCode} * P_{2,NUTS\ code} / U_{2,\ NUTS\ code}$$

- **Density of "Agricultural" polygons:**

$$DA_{2,\ NUTS\ code} = \%AGRICULTURAL\ CLASSES_{NUTSCode} * P_{2,NUTS\ code} / A_{2,\ NUTS\ code}$$

- **Density of "Natural" polygons**, *i.e.* natural and semi-natural areas are expected to host 10% of the total population:

$$DN_{2,\ NUTS\ code} = \%NATURAL\ CLASSES_{NUTSCode} * P_{2,NUTS\ code} / N_{2,\ NUTS\ code}$$

For a given region, the total population $P_{2,\text{NUTS code}}$ can be estimated as

$$P_{2,\text{NUTS code}} = (U_{2,\text{NUTS code}} * DU_{2,\text{NUTS code}}) + (A_{2,\text{NUTS code}} * DA_{2,\text{NUTS code}}) + (N_{2,\text{NUTS code}} * DN_{2,\text{NUTS code}})$$

Within Selection2, the total population $P_{2,\text{NUTS code}}$ can be estimated as

$$P_{2,\text{NUTS code}} = (U_{2,\text{NUTS code}} * DU_{2,\text{NUTS code}}) + (A_{2,\text{NUTS code}} * DA_{2,\text{NUTS code}}) + (N_{2,\text{NUTS code}} * DN_{2,\text{NUTS code}})$$

Giving

$$DU_{2,\text{NUTS code}} = P_{2,\text{NUTS code}} / ((U_{2,\text{NUTS code}}) + (A_{2,\text{NUTS code}}/4) + (N_{2,\text{NUTS code}}/8))$$

Then by deduction,

$$DA_{2,\text{NUTS code}} = DU_{2,\text{NUTS code}} / 4$$

$$DN_{2,\text{NUTS code}} = DU_{2,\text{NUTS code}} / 8$$

STEP 2: ESTIMATION OF THE POPULATION WITHIN THE RICE, GIVEN THE PREVIOUS WEIGHTED ESTIMATED POPULATION DENSITY.

Once Population Density have been estimated for CLC90 polygons corresponding to coastal communes, the effective RICE area is used to determine the estimated population living within the RICE, result of the 'combination' on one side of the CLC coastal polygons areas clipped on the RICE area, and on the other side of the estimated population densities – results of Step 1.

Step 2.1. Overlaying and Clipping of land cover polygons with the radius of influence of coastal erosion and flooding (RICE). This overlay is referred hereafter as the $LC_{3,NUTS\ code}$ selection.

Step 2.2. Calculation of the total area covered by polygons of Class 1, Class 2 and Class 3 (the more expected to host population) for each $LC_{3,NUTS\ code}$ selection. Those polygons are effectively included in the RICE. This leads to the 3 following values:

“Class 1” polygons total area = $U_{3,\ NUTS\ code}$ (Urbanised areas)

“Class 2” polygons total area = $A_{3,\ NUTS\ code}$ (Agricultural areas)

“Class 3” polygons total area = $N_{3,\ NUTS\ code}$ (Natural and semi-natural areas)

Step 2.3. Estimating the population living within the radius of influence of coastal erosion and flooding (=$P_{3,NUTS\ code}$) using the following formula:

$$P_{3,NUTS\ code} = (U_{3,\ NUTS\ code} * DU_{2,\ NUTS\ code}) + (A_{3,\ NUTS\ code} * DA_{2,\ NUTS\ code}) + (N_{3,\ NUTS\ code} * DN_{2,\ NUTS\ code})$$

Final step. Rating of each region according to the rules mentioned in Table 2.2.

5.1.3 Limitations and recommendations

- *Prolegomena* : GISCO ‘Census 91’ Population data set covers the EU of 1991.
- The limitation to Urban, Agricultural and Natural or semi-natural classes revealed very few surplus which correspond to the tiny proportion of people living within the RICE in places mapped as Water bodies in CORINE Land Cover 1990 database.
- *About Step 1.3* : preliminary work has been made that consist in joining GISCO commune dataset *cmec1M91* with population dataset *puec1M91* using CMRGCD attribute; then exporting this result in order to obtain a GISCO communes dataset with population figures inside.
- *About Step 1.6* : In order to reallocate population density to land cover polygon, the density of population along the coast must be assessed first.

  1 – Intersect GISCO communes and population dataset (*cmec1M91* previously prepared) with RICE. Result dataset is named *[nurgcdl2]_RICE_cm*. It contains for each region, the communes that intersect the RICE, extracted using the select by location tool in ArcMap: *Select * FROM cmec1M91 that intersect [nurgcdl2]_RICE.*

  A visual check and a manually suppression is performed at the external limit of each region to remove communes selected by the intersection operation but which do not really belong to that region (actually the RICE juts out of 500 m and the operation automatically selects communes from the neighbouring region!)

  2 – Clip CORINE Land Cover 1990 with the result from the previous step. The result datasets are named *[NURGCDL2]_clip_cm_CLC*.

  Those datasets are then dissolved (aggregated) using the *LCCDL1* attribute of CORINE Land Cover 1990 to obtain the total area of Corine level 1 classes (1 for artificial surfaces, 2 for Agricultural area, 3 for forest and semi-natural area; Wetlands and water bodies - code 4 and 5 - are not taken into account). The resulting datasets are named *[NURGCDL2]_clip_cm_CLC_dissolved*.

3 – Clip CORINE Land Cover 1990 with RICE dataset to obtain the surface of the 3 classes (1-2-3) of CLC90 into the RICE area. Resulting datasets are named: *[NURGCDL2]_clip_RICE_CLC*. These datasets are also aggregated using the LCCDL1 attribute of CORINE Land Cover 1990 to obtain the total area per CLC class 1. Resulting datasets are named *[NURGCDL2]_clip_RICE_CLC_dissolved.*

5.2 Coastal urbanisation

To be completed

5.3 Urban and industrial areas located within the RICE

Within the CORINE Land Cover database, urban and industrial polygons are part of the Class 1, namely Artificial Surfaces. Using RICE polygons makes it possible to determine the percentage of urban and industrial area located in the RICE, per region, and than rate each region.

5.3.1 Sources

- RICE (graphic results from chapter 4.8)
- CORINE Land Cover 90 Level 1 - Class 1 : Artificial Surfaces

5.3.2 Step by step methodology

Step 1. Display CORINE Land Cover Class 1 and the RICE polygon for the region

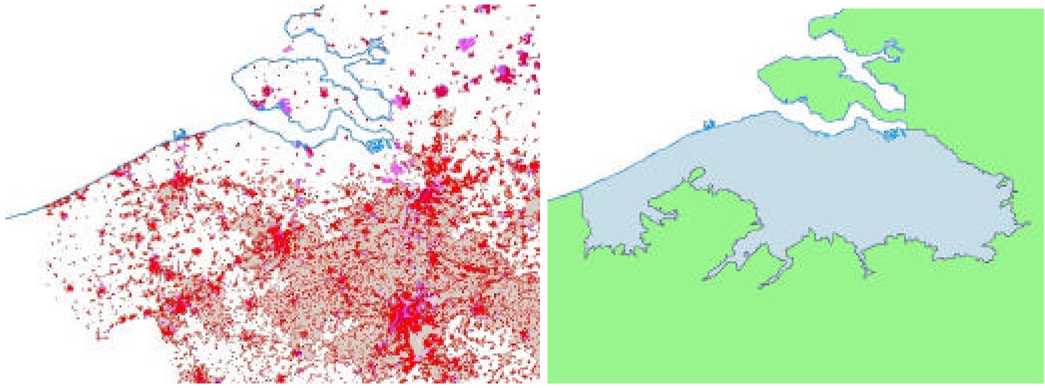


Fig 5.6 – BE-Vlaams CLC90 Artificial Surfaces (left) – Belgium RICE (right)

Step 2. Overlay and clipping of both data sets => Artificial Surfaces Polygons clipped

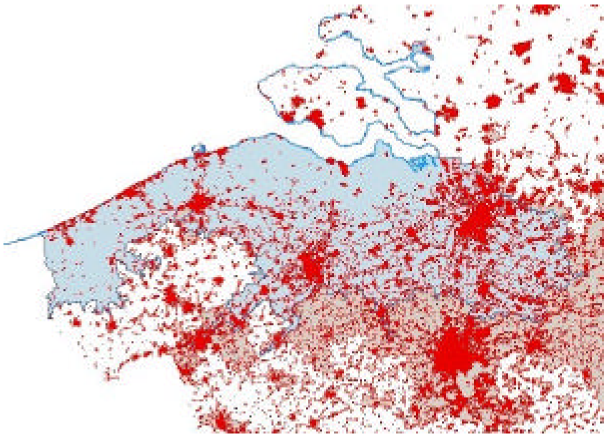


Fig 5.7 – BE-Vlaams Overlay of Artificial Surfaces and RICE

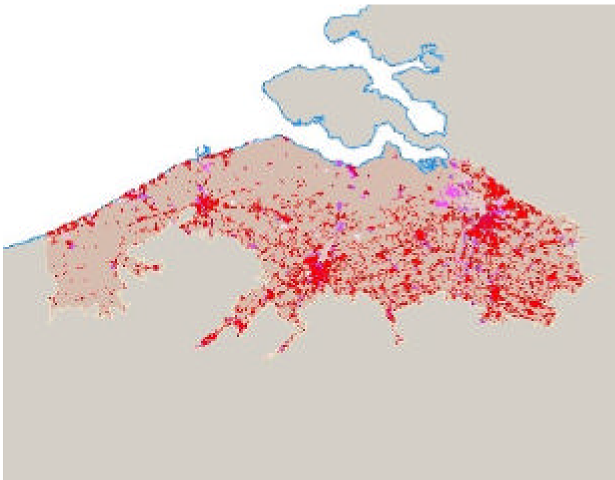


Fig 5.8 – BE-Vlaams Clipping of Artificial Surfaces and RICE

Step 3. Calculation of the Ratio **R** defined as:

$$\mathbf{R} = \frac{\textbf{Total area of Artificial Surfaces polygons clipped}}{\textbf{Total area of the RICE}}$$

Final step. Rating of each region according to the rules mentioned in Table 2.2

5.3.3 Limitations and recommendations

No more limitations than those associated to RICE establishment, and CLC known reliability and coverage.

5.4 Areas of high ecological value within the RICE

For the reason of our actual too small coverage of validated Natura2000 data which could led to not significant results, the rating of areas of high ecological value within the RICE is ensured by using CORINE BIOTOPES database.

Assumptions and limitations are to be made according to CORINE BIOTOPES characteristics.

5.4.1 Sources

- RICE (graphic results from chapter 4.8)
- CORINE Biotopes database as integrated in layer **DAEUCB100kV1** from EUROSION database

5.4.2 Step by step methodology

Step 1. Creation of a subset (referred as CB10m hereinafter) from CORINE Biotopes data set, and based on the populated field 'alt_min'.

Query : Select * from CORINE BIOTOPES where 'alt_min' <= 10.

Step 2. Overlay of CB10m and RICE.

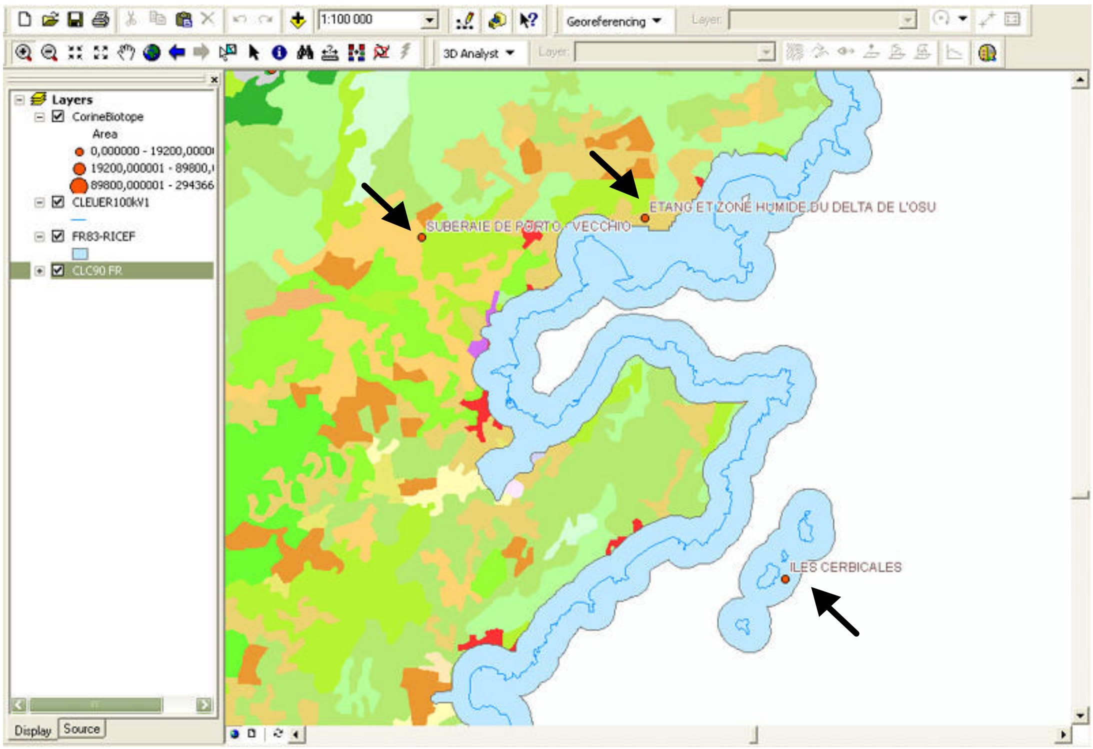


Fig 5.9 – FR83 Corse – Overlay of CORINE Biotopes (Red dots) and RICE (light blue)

Step 3. Spatial Joining between CB10m and RICE graphical region to be able then to calculate for each RICE surfaces.

Step 4. Selection of the CORINE BIOTOPES sites within the RICE.

CORINE Biotopes database records do not contain the geographical extent of the site, but refers its name, its 'centroid' georeferenced point (longitude, latitude) point, its altitudes (minimum, maximum and mean), its area… amongst other fields. The selection is made manually with the two following criteria:

- For points located within the RICE area, check the minimum, maximum and altitude values to discriminate realistic sites to be selected.
- For excluded points lying near the outer limit of the RICE area check the exact position, especially if minimum and maximum altitudes are likely to match with the one searched.

Resulting selection set is referred hereinafter as **CB_{RICE}**

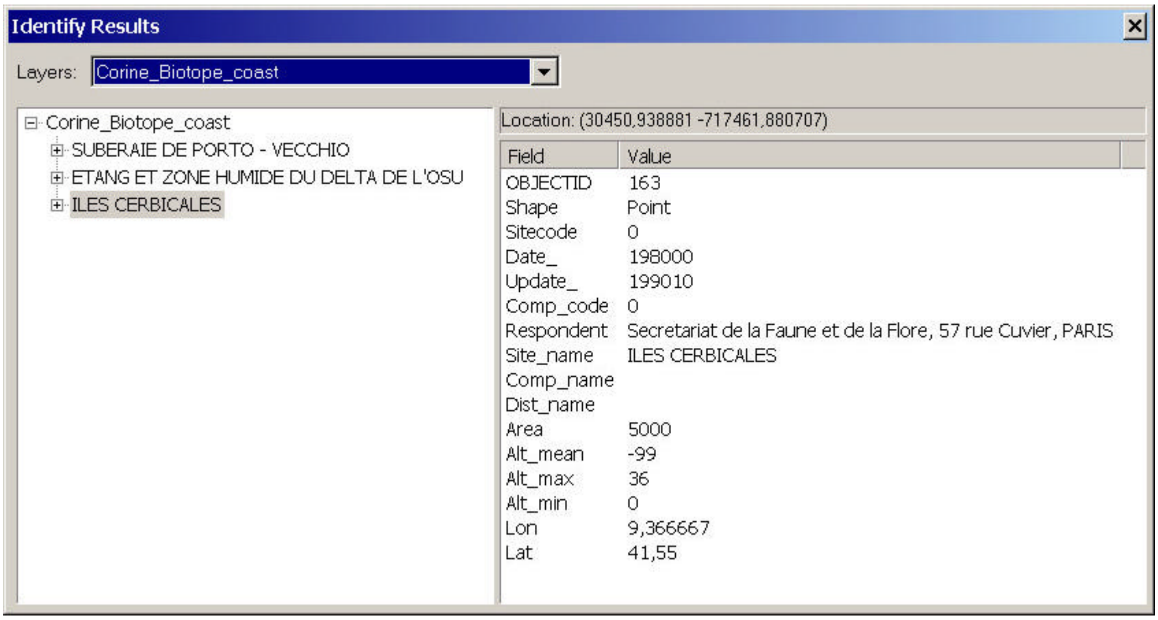


Fig 5.10 – FR83 Corse – Subset of selection CB_{FR83}

<u>Step 5</u>. Calculation of the total area covered by CB_{RICE}.

Result is referred hereinafter by **$AreaCB_{RICE}$** and obtained by using 'summarizing' function on Area attribute.

<u>Step 6</u>. Calculate the ratio **$RCB_{NUTS\ Code}$** = **$AreaCB_{RICE}$ / $AreaRICE_{NUTS\ Code}$**

<u>Final step</u>. Rating of each region according to the rules mentioned in Table 2.2

5.4.3 Limitations and recommendations

With no exact knowledge or whether the CORINE Biotopes site is also going over the sea or crossing an adjacent region, the **$AreaCB_{RICE}$** is likely to be over estimated. Nevertheless thresholds have been adjusted according to first results.

CORINE Biotopes database coverage:

- EU 15 (except Austria and **Sweden**)
- CEEC 13 (except **Cyprus**, **Malta**, **Slovenia** and Turkey)

NATURA2000

January 2004: contacts are established between Natura2000 Desk Officer and EUROSION, so as to make indicators on Natura2000 made by Natura2000 official sub contractor.

March 2004: transfer of RICE polygons files and EUROSION methodology to Natura2000 sub contractor Katholic University of Leuven which is intended to produce this indicator for the DGEnv.