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METHODOLOGIES ANALISYS FOR THE PRESSURE EVALUATION ON BIODIVERSITY USING THREE CASE STUDIES.

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"If all the insects were to disappear from the earth, within 50 years all life on earth would end. If all human beings disappeared from the earth, within 50 years all forms of life would flourish"

- Jonas Salk –

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METHODOLOGIES ANALISYS FOR THE PRESSURE EVALUATION ON BIODIVERSITY USING THREE CASE STUDIES

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METHODOLOGIES ANALISYS FOR THE PRESSURE EVALUATION ON BIODIVERSITY USING THREE CASE STUDIES

1. INTRODUCTION

Biodiversity describes the existing variety between living organisms and the ecologic complex they are part of. This includes both, the intra and inters specific diversity and the ecosystem's one. Although this is a list of species and natural processes, it is also the material manifesto of the triumph of life on earth. Indeed, it can be said that this is the picture of the incredible progress that organisms have made from the primary life forms to the brilliant and multiple human's intelligence events. Biodiversity studies need to refer to complex mechanisms that carried the man to the top dominion position on planet Earth. The knot between man and biodiversity is, in this case, the key of our development.

However, it is necessary to think about all the benefits that human being takes out from nature. Many things such as pure water, medications, and services like the fertility of croplands depend on certain conditions of biodiversity that must be conserved. As a proof of this, some studies tried to quantify the commercial value of the natural heritage with amazing results. The economic value of resources was estimated between 16 and 64 billion dollars. This amount represents around 7% of the world's GDP (Gross Domestic Product). Yet, this absolute value is not a quantification of biodiversity, which is decreasing constantly, causing the progressive lack of services, affecting human health and both planetary processes, natural and human.

As a matter of fact, official data released shows that in the last 40 years the natural species have decreased 40%. Moreover, the ones from internal aquatic systems had a loss of almost 50%. These decreasing rates are significant for mammals, birds, amphibians, the whole coral barrier community and most of the fishing species.

According to the 2011 IUCN's red list, more than 19.000 species are threatened[1]. Furthermore, the European Red List[2] shows that 23% of the amphibian, 19% of reptile, 13% of bird, and 37% of fish species are endangered today. In addition, the EU Biodiversity Action Plan states that for December 2008 the conservation state is unfavourable for half of the animal species. Now, on the aspect that regards to the invasive species, the European Agency points a fast and preoccupant growth. For sure, this will bring remarkable economic and ecologic consequences.

Biologic Diversity Convention's third edition of Global Biodiversity Outlook (GBO3)[3], brings the assessments about this topic, emphasising on how dependent is the human being from the ecosystem's services, and how the future of mankind is tied to the welfare of nature.

In order to act against biodiversity loss, the world leaders requested an initiative aiming to cut off this negative growth by 2010. Nonetheless, on 2010 this aim was not achieved, and

[1] The IUCN Red List of Threatened Species™ (Available online at: http://www.iucn.org)
[2] European Red List (Available online at: http://ec.europa.eu/environment/nature/conservation/species/redlist/)
[3] Pearce D., Moran D., The Economic value of biodiversity, IUCN, (First edition on 1994)

this issue loss has pushed United Nations to create new strategies that shall slow down this phenomenon for 2020.

Consequently, 2010 was named the International Biodiversity Year. Indeed, it is clear that biodiversity loss is a huge problem that must be solved while it continues to disappear year by year.

When someone tries to look for the causes of this loss, it becomes necessary to research on human activities, particularly on the degradation of natural habitats. In addition, the insertion of foreign species by commercial activities, the overexploitation of resources, the pollution and the climate change are factors that enhance the loss of biodiversity.

Consequences of this collective failure could be catastrophic for the whole mankind, if they are not solved in an express way. Biodiversity is, as a matter of fact, a basic wealth for all humans' survival and progress.

Since the last year, the Studio Fieschi developed a methodology to assess the impact caused by industrial plants on local biodiversity of different sites. Until now, the company has done three biodiversity Impact assessments using its own technique and the results have been good. However, the scope of constant improvement leads the Studio Fieschi to test and validate its own methodology to see which are the strong and the weak point of it.

This document is based on a work made by the Studio by request of an industrial company. The concern of this company is aligned with the nomination of 2010 as the international year of biodiversity. As a matter of fact, the Studio work was the quantification of the local biodiversity around the industrial plants owned by this company.

In order to get this information, the sensible areas around each industrial site were identified to mark them as protected spots and places where the biodiversity can be enhanced. Besides, if there was any case in which there were not sensible areas, the forests, woodlands or areas with no anthropic pressure were taken as the sensible spots for biodiversity enhancement.

As a result, using the Thesis document discussed last year by Valentina Sechi, three methodologies are going to be tested with three case studies that the company attended for the last year. This document presents a brief description of the company methodology and how will it be used for each one of the models that are going to be used. Then, a comparison between the case studies presented, followed by the results of each method application and their respective comparison.

In the end, this document is intended to be used as a solid base to any further update for the method, a basis for any change that can be done to it and a collaboration to improve the quality of the local ecosystems in which it is employed.

2. OBJECT AND SCOPE

2.1. Main objective

Validate the methodology used by the Company to evaluate the pressures on biodiversity by comparing the results obtained in three different industrial sites, after applying three different methodologies to evaluate the pressures on biodiversity.

2.2. Specific objectives

1. Apply three different methodologies to evaluate pressures on biodiversity.
2. Identify the qualitative and quantitative differences between the applied methodologies.
3. Compare the results obtained after using the different methodologies.
4. Determine the most important factors that affect each one of the methodologies.

3. METHODOLOGY

The present document follows the Thesis presented for the COREP course taught on 2009-2010, and elaborated by Valentina Sechi[4]. In that paper, three methodologies for evaluating pressures of human activities on biodiversity were described and analysed (GLOBIO3, IMPACT 2002+ and ReCipe2008). These methodologies are going to be used in this study to accomplish to objectives proposed in the previous chapter.

The logical process is composed by three main phases, which at the same time are divided in sub-processes. In first place there is the data acquisition phase, in which the information of each site is picked up and arranged to fit the models that are going to be tested. In second place the methodologies are going to be applied on each site, and finally the results are going to be compared.

As a first approach there is going to be a comparison between sites, and the results of different methodologies applied each one of them, Afterwards, these results will be compared in order to find the most relevant differences between them and to judge their suitability for use in the cases studied by the company.

The **figure 3.1** shows the logical process that has been followed in order to complete the study. The path followed goes from left to right. Each phase was identified with a name, as listed: "Data acquisition", "methodologies application" and "analysis and comparison".

---

[4] Sechi V., "Analisi delle metodologie di valutazione esistenti per determinazione della pressione antropica esercitata sulla Biodiversità". Master Tecniche per la progettazione e valutazione ambientale 2009/2010. COREP, Studio Maurizio Fieschi.

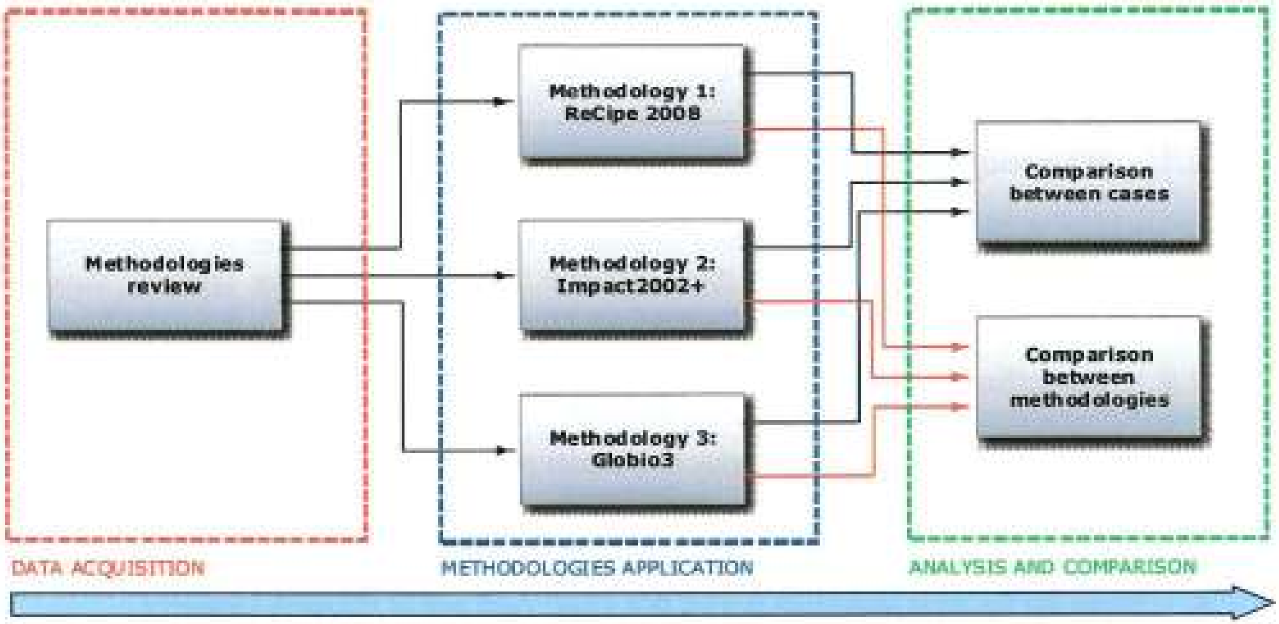

Figure 3.1. Methodology process explained by topics and their divisions.

As it was said before, the methodology for this study has its cornerstone in the three impact methodologies analysed by the previous thesis, produced by Valentina Sechi[5]. Here, those methodologies are summarized and explained to the reader in order to familiarize him with the techniques and theoretical base used.

For the studies done by the company, the methodologies have been limited to the impacts on biodiversity, keeping outside the impacts on climate change and human health. In the specific case of the GLOBIO3 methodology, no changes were needed because this one is aimed to determine the impacts on biodiversity directly. But, this doesn't happen with IMPACT 2002+ and ReCipe2008, which are Life Cycle Assessment methodologies. Thus, not all the impact categories and drivers presented are taken into account to determine the impact on biodiversity.

However, these methodologies are intended for the Life Cycle Assessment of practically every process or product. This is the reason why the methodologies have been adapted to suit the geographic cases studied in the present document, and the work that the company develops.

The first step for all the study consists in setting up the geographic boundaries of each case study. These limits will be named *influence zones*, and two of them are identified in the process.

IA (Influence Area): It is limited by a 5 km radius circumference, which centre is located on the specific site chosen. Inside this zone, naturalistic sensitive areas are

[5] Ibidem

identified, to consolidate the base for the calculation of each methodology pressure index.

PA (Pressure Area): This area is limited by the perimeter drawn for the points that are 5 km far away from the boundaries of the sensible areas identified on the state buffer. Inside the PA, the Pressures are calculated to get the base of each methodology index. The PA always includes the IA.

The *sensible areas* are identified as the areas that are protected by government laws like natural reserves, parks and forests. However, if there is any case where there are no protected areas, the ones occupied by forests and with no human intervention will be considered as *sensible areas*.

An example of these areas is shown in **figure 3.2**, where both of them are clearly identified.

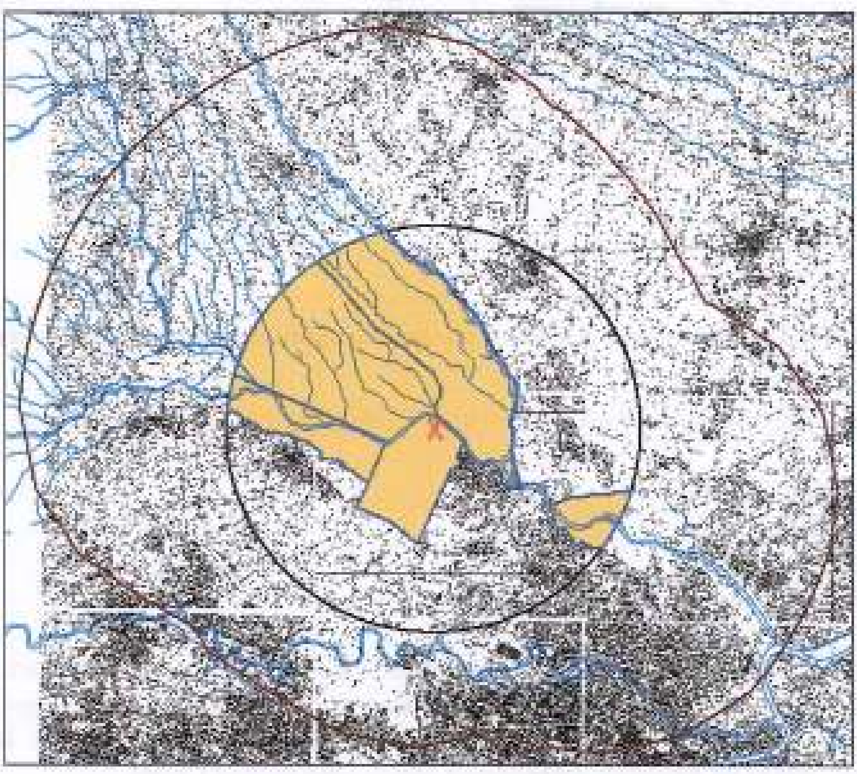

Figure 3.2. Area identification for case study A. Black perimeter identifies the Influence Area (IA), and red perimeter marks the Pressure Area (PA)

After setting the geographic boundaries, inside each methodology used in this document it is possible to identify four clear steps followed, named below:

1. Identifying Driving Forces
2. Specifying pressures.

3. Quantifying impacts.
4. Calculating biodiversity loss.

Figure 3.3 shows a synthetic process diagram.

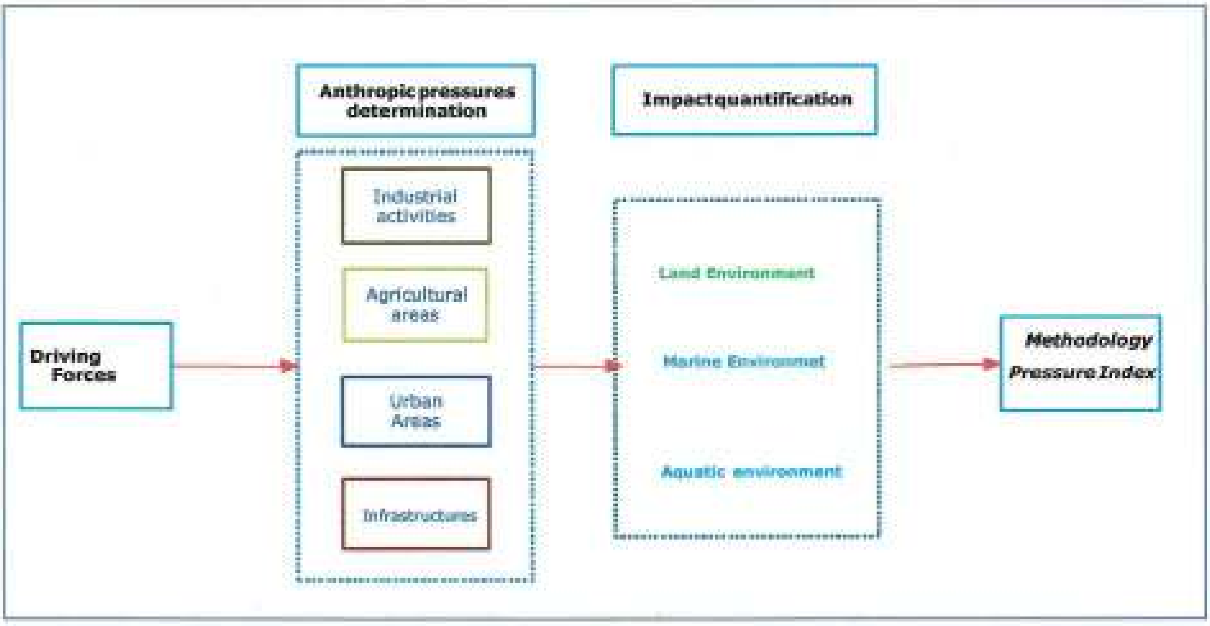

Figure 3.3. Summarized scheme of the steps to apply each one of the methodologies

Inside the Pressure Area, four categories of Driving Forces are identified.

1. Industrial activities
2. Agricultural areas
3. Urban areas
4. Infrastructures

Each one of these Driving Forces categories is divided in smaller categories depending on the type of activity that is developed inside this portion of terrain. In the agricultural Driving Force category, five sub categories are identified: Non irrigated arable land, Permanent irrigated land, Areas of pastures, Permanent grows and Mixed Crops.

The Urban areas are divided in Continuous and Discontinuous Urban fabric, and the infrastructure is divided in Railroads and Roads. On the other hand, the industrial activities are not divided into categories, because their pressures are calculated according to their own emissions, waste and type of industry. Furthermore, the infrastructure is considered as a Driving force with no land occupation factor in the methodologies used.

The **figure 3.4** shows an example of the Driving Forces identification inside the Pressure Area (PA), referred to the case study A. It is necessary to say that this identification is made with GIS software, in order to achieve more reliable results.

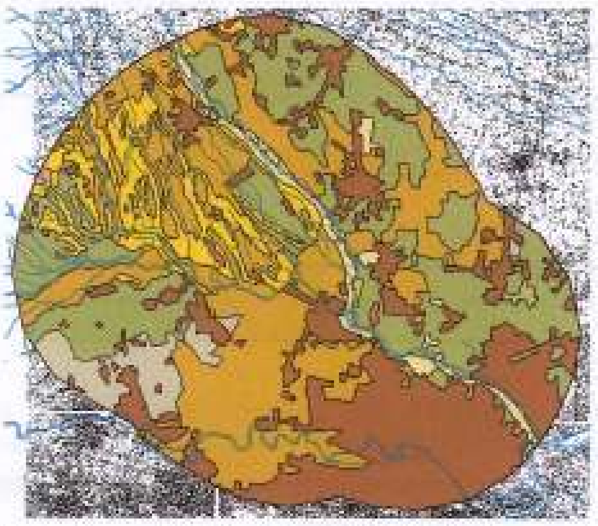

Figure 3.4. Example of Driving Forces individuation inside the PA (*Pressure Area*), inside case study A

After gathering the Driving Forces, pressures are assessed. Within IA, are considered pressures for:

1. Industrial activities
    - Land occupation.
2. Agricultural areas.
    - Land occupation according to the different categories of croplands.
3. Urban areas
    - Land occupation according to continuous or discontinuous residence density.
4. Infrastructure.
    - It is not taken into account in the issue of land occupation.

Within the PA are considered.

1. Industrial activities
    - Air, water and soil emissions potentially harmful for local biodiversity.
2. Agricultural areas.
    - Air and water emissions linked to the use of pesticides and fertilizers.
3. Urban areas
    - Air emissions linked to urban transportation, heating systems and small industrial activities.
4. Infrastructure.
    - Emissions caused by land vehicles on streets and railroads.

Table 3.1 summarizes the buffers that are considered to determine the pressures.

	Emissions	Land Use
Industrial Activities	PA	IA
Agricultural areas	PA	IA
Urban areas	PA	IA
Infrastructure	PA	-

Table 3.1. Reference used for the impact calculation relative to emissions and land use for the 4 used categories[6].

The land occupation also includes any changes through time. This means the changes from naturalized to anthropized land or vice versa. As a consequence, this factor will only be counted if there is a land use conversion after applying the methodology.

The basis of each methodology is going to be explained in the next sections, emphasizing on the use of these tools and without discussing the methodologies since it was done in previous documents. For the application, the LCA Software Package SimaPro 7.3 was used to analyse the data and run each one of the models following the specified methodologies.

3.1. ReCipe 2008

This is the methodology used currently by the company to evaluate the impacts on biodiversity caused by the different projects analysed. However, this is a LCA assessment methodology that considers every single impact on the environment. Thus, Recipe 2008 has been adapted in order to calculate exclusively the impacts on biodiversity. It was developed by RIVM, CML (*University of Leiden, Institute of Environmental Sciences, PRé Consultants, Radboud Universiteit Nijmegen e CE Delft*),

First of all, this methodology works classifying the anthropic pressures into different pre-defined categories. Each one of these pressures is well defined with a known unit so it can be easily quantified. This is called a *mid point* impact category.

After having all the *mid point* categories quantified, the next step is to take these values one step further so the damage to the environment can be expressed as a number. This is what the methodology itself calls an *end point* category. To make this understandable, the use of characterizing factors relates the *mid point* with the *end point* categories.

Of all the impact categories that the methodology takes into account, the present study will show just the degradation of the ecosystem around the sites. The aim of this is to quantify the potential biodiversity loss within the boundaries of the direct impact zone of each one of the analysed case studies. The methodology summary can be seen in **figure 3.5**.

[6] Sechi V., "Analisi delle metodologie di valutazione esistenti per determinazione della pressione antropica esercitata sulla Biodiversità". Master Tecniche per la progettazione e valutazione ambientale 2009/2010. COREP, Studio Maurizio Fieschi

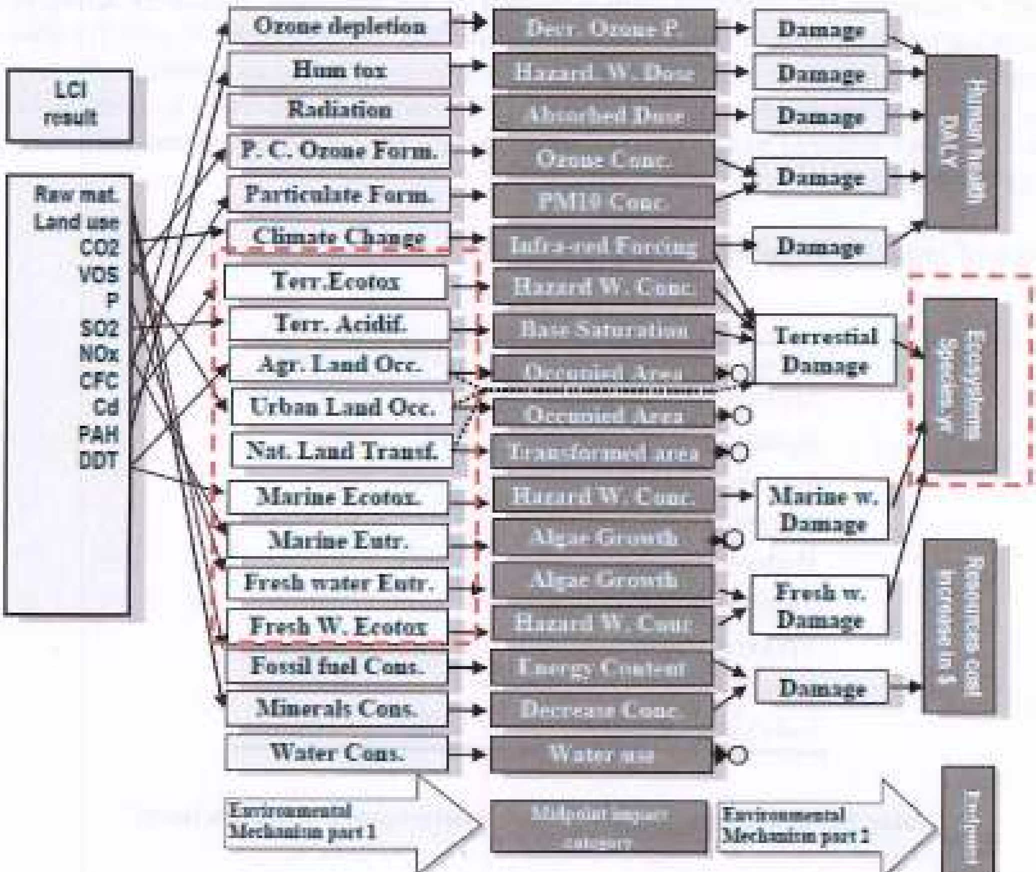

Figure 3.5. ReCipe 2008 methodology scheme.[7]

The chosen unit to quantify the impacts on the ecosystems is the PDF (Potentially Disappeared Fraction of Species), which helps to understand how many species will be lost and for how many years (PDF year).

The PDF values in each different environment are calculated according to the mean species density (SD), for each different system (terrestrial, fresh water and marine systems). Then, the result is a final unique factor that represents the damage on the ecosystem quality (*Ecosystem damage*). It is the result of the product between the species density and the sum of the PDF values found in the previous step.

Each human activity acts on the land with a pressure due to air, ground and water emissions, resources consumption or land use. Then, each anthropic pressure is referred to an impact category on which it is going to act. Most of the pressures are related to the biodiversity loss, expressed under the concept of Biodiversity Loss Potential (BLP).

[7] Goedkoop M.J., Heijungs R, Huijbregts M., De Schryver A.;Struijs J.,; Van Zelm R, ReCiPe 2008, A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation; 6 January 2009, http://www.lcia-recipe.net

The BLP measures the potential impact caused by the anthropic pressures acting in terms of the disappearance of specie over a determined period. For example, if a BLP value is 2,0 specie year, this would mean either that there are 2 species missing in a period of one year, or that there is just one specie missing in the lapse of 2 years. It is important to take into account that BLP is always referred to the IA (Influence Area), so it does not necessarily means that this specie is endangered.

The list of Impact Categories contributing to BLP is summarized in **table 3.2**.

Impact categories	Abbr.	Unit
Terrestrial Acidification	TA	BLP
Aquatic Eutrophication	FE	BLP
Terrestrial Toxicity	TET	BLP
Aquatic Toxicity	FET	BLP
Marine Toxicity	MET	BLP
Agricultural land occupation	ALO	BLP
Urban land occupation	ULO	BLP
Industrial land occupation	ILO	BLP
Land transformation	NLT	BLP

Table 3.2. Impact categories with their relative characterization factor[8]

The impact categories are aggregated through characterization factors.

To calculate the total anthropic pressures, each one of them is translated and quantified in single impact categories through the characterization factors that belong to each pressure and category. A pressure is able to affect one or more categories.

For each impact category the BLP is estimated under the formula.

$$BLP_{Ci} = \Sigma P_i \cdot Q_i$$

In which:

- BLP_{Ci}: Potential loss of specie of the impact category *i* in one year.
- P_i: Pressure *i*.
- Q_i: Characterization factor that links the pressure P_i with impact category *i*.

[8] Sechi V., "Analisi delle metodologie di valutazione esistenti per determinazione della pressione antropica esercitata sulla Biodiversità". Master Tecniche per la progettazione e valutazione ambientale 2009/2010. COREP, Studio Maurizio Fieschi

This count is made for all the identified anthropic pressures, P_i, which is aggregated in the single impact categories. In the end, the BLP value is extracted.

The BLP values are translated into the normalized API (Anthropic Pressure Index), adimensional.

The formula used to calculate the API is reported below:

$$ED = PDF_{terr}\ SD_{terr} + PDF_{fw}\ SD_{fw} + PDF_{mw}\ SD_{mw}$$

With:

- ED = *Ecosystem Damage* (PDF in specie·year)
- PDF_{terr} = Terrestrial system characterization factor in PDF $m^2 \cdot year$
- SD_{terr} = Species density for the terrestrial system, in specie/m^2
- PDF_{fw} = Aquatic system characterization factor in $m^2 \cdot year$
- SD_{fw} = Species density for the aquatic system in specie/m^2
- PDF_{mw}= Marine system characterization factor in $m^2 \cdot year$
- SD_{mw} = Species density for the marine system in specie/m^2

Specie density (SD)

The species density calculation is made considering the following factors:

- The total amount of species present in the area.
- Their distribution in the different systems (earth, water and marine)
- The surface and volume used

The ReCipe2008 model links the anthropic pressures due to emissions and land occupation with a limited number of impact categories (*midpoint*), connected with a damage category (*endpoint*). This is shown in **table 3.3**; it shows the midpoint categories and their measure units. Just below, **table 3.4** shows the characterization factors correspondent to each endpoint category for the *Ecosystem Quality* list.

Impact category	Abbr.	Unit	Indicator	Unit
Freshwater eutrophication	FE	kg (P to freshwater)	Phosphorus concentration	year kg /m^3
Marine eutrophication	ME	kg (N to freshwater)	Nitrogen concentration	year kg /m^3
Terrestrial ecotoxicity	TET	kg (14DCB to industrial soil)	Hazard-weighted concentration	$m^2 \cdot$year
Freshwater ecotoxicity	FET	kg (14DCB to freshwater)	Hazard-weighted concentration	$m^2 \cdot$year
Marine ecotoxicity	MET	kg (14-DCB7 to marine water)	Hazard-weighted concentration	$m^2 \cdot$year
Land occupation	LO	$m^2 \cdot$anno (urban land)	Occupation	$m^2 \cdot$year
Natural land transformation	NLT	m^2 (natural land)	Transformation	m^2
Climate change	CC	kg (CO2 to air)	Infra red radiation force	W·year·m^2
Terrestrial acidification	TA	kg (SO2 to air)	Base saturation	$m^2 \cdot$year

Table 3.3. Midpoint impact categories and indicators with their own measure units.[9]

[9] Sechi V., "Analisi delle metodologie di valutazione esistenti per determinazione della pressione antropica esercitata sulla Biodiversità". Master Tecniche per la progettazione e valutazione ambientale 2009/2010. COREP, Studio Maurizio Fieschi

Impact categories		Characterization factors	
Abbr.	Unit	Name	Abbr.
CC	kg (CO^2 to air)	Global warming potential	GWP
TA	kg (SO^2 to air)	Terrestrial acidification potential	TAP
FE	kg (P to freshwater)	Freshwater eutrophication potential	FEP
ME	kg (N to freshwater)	Marine eutrophication potential	MEP
TET	kg (14DCB*to industrial soil)	Terrestrial ecotoxicity potential	TETP
FET	kg (14DCB* to freshwater)	Freshwater ecotoxicity potential	FETP
MET	kg (14-DCB* to marine water)	Marine ecotoxicity potential	METP
LO	m^2/anno	Land occupation potential	ALOP
NLT	m^2/anno (natural land)	Natural land transformation potential	NLTP

Table 3.4. Midpoint and characterization factors corresponding to the *Ecosystem Quality*[10]

The conversion from midpoint to endpoint factors is made with a set of determined factors given by the literature found. Databases like ECOINVENT are taken into account, and other factors are estimated with mean data for each country or region that is studied. However these values are given initially by the methodology, so this document will not treat the way they are obtained.

3.2. IMPACT 2002+

The second applied methodology for this document is IMPACT 2002+. It is another Life Cycle Assessment (LCA) model, developed by the *Risk and Impact Modelling group* from the Michigan University, under the leadership of Prof. Olivier Jolliet.

It is characterized by the connection of each result of the Life-Cycle Inventory with a determinate impact on the environment. These impacts are represented in the *midpoint* categories as "kg of equivalent substance", for each impact category identified.

For the case studies shown in this document, the impact categories that are taken into account are: Terrestrial ecotoxicity, Freshwater eutrophication, Terrestrial and Aquatic acidification/nitrification, and Land occupation.

IMPACT 2002+ groups the categories and impacts that are alike inside each midpoint categories where some damage can be associated. **Figure 3.6** shows the schematic diagram of the midpoint categories and the damages that are associated for each one of the first mentioned.

Besides, this methodology provides three different units on each of its components to quantify the impacts caused on the environment. At the midpoint level the "kg of equivalent substance" is used to quantify the damage in common units for each category. Going on further, at the Damage Level, the "PDF·m2·yr" ("Potentially Disappeared Fraction of species per m2 per year") is the unit to "measure" the impacts on ecosystems. Finally, the unit used to normalize all the results is the "point", which are equal to "pers·yr". A "point" represents the average impact in a specific category "caused" by a person during one year in Europe.

[10] Ibidem

In the results presented for this methodology, the results are presented in "points". First of all because this is unit is the normalized one for IMPACT 2002+ and because the results obtained in "PDF·m2·yr" have a magnitude order way of around 10^7. Besides, the authors of the methodology recommend using the normalized results for comparisons between the different case studies.

Figure 3.6; shows the midpoint categories that are taken into account for the analysis. There are ten arrows that go from the midpoint categories to the "Ecosystem Damage" category. But, of these ten arrows there are six that are not taken into account inside the methodology that will be applied.

These six that are not taken into account are: Ozone layer depletion, Photochemical oxidation, Aquatic acidification and Eutrophication and acidification. In this particular case the lack of information in the methodology cause the omission of this data. Photochemical oxidation is known to have an impact on the growth of plants. However, currently no available studies were able to support calculations of the damage on ecosystem quality due to photochemical oxidation.

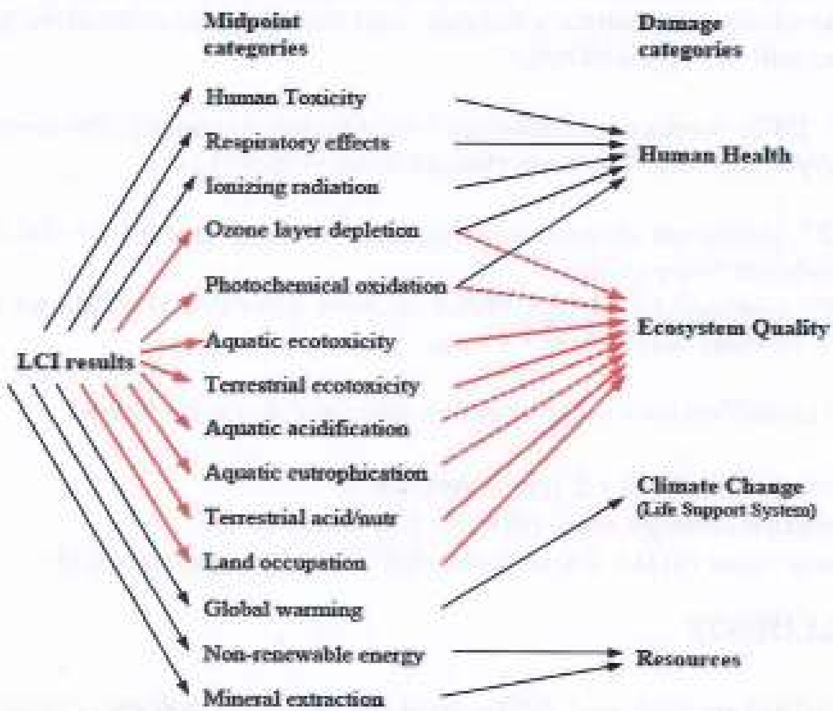

Figure 3.6. IMPACT 2002+ structure. From the LCI results, to the damage categories identified.[11]

The damage categories are represented as it is shown in **table 3.5**, where the factors are named one by one and the amount of equivalent substance is shown for each one of the cases.

[11] Humbert S., Margni M., Jolliet O., IMPACT 2002+ User Guide, Draft for Version 2.1, Industrial Ecology & Life Cycle systems Group, GECOS, Swiss Federal Institute of Technology Lausanne (EPFL), CH-1015 Lausanne, Switzerland

However, the only categories that are used in this document are the ones that are referred to the Ecosystem Quality damage category.

Midpoint category	*Midpoint reference*	*Damage unit*	*Normalized damage unit*
Aquatic ecotoxicity	kg Triethylene glycol- eq into water	PDF m^2·anno	point
Terrestrial ecotoxicity	kg Triethylene glycol- eq into soil	PDF m2·anno	point
Terrestrial acidification/nutrification	kg SO_2-eq into air	PDF m2·anno	point
Aquatic acidification	kg SO_2-eq into air	n/a*	n/a
Aquatic eutrophication	kg PO_4^{3-}- eq into water	n/a*	n/a
Land occupation Ecosystem quality	m^2 Organic arable land-eq year	PDF m2·anno	point

Table 3.5. Midpoint categories, references damage units and normalised damage units for Impact 2002+

The way how the results are presented in the methodology is almost the same as they are presented in the ReCipe2008 case. There are a number of factors that link the results of the Life Cycle Inventory with pattern substances and then they are normalized to a standard unit. However, this will be explained below.

IMPACT 2002+ works associating numerical factors to quantify the environmental impact of each anthropic pressure. The main characterization factors are:

1. CF^m (*Midpoint characterization factor* in kg_{eq}) that allows the evaluation of the *Midpoint Score* (SM).
2. DF^n (*normalized damage factor* in *point (pers year)*): It allows the evaluation of the *Damage Score* (SD).

The final quantification of the impacts is estimated as shown below:

- *Midpoint score* (SM) = Σ (*emissions*$_i$·$CF^m{}_i$)
- *Normalized Damage score* (SDN) = Σ (*emissions*$_i$ ·$DF^n{}_i$)
- *Damage score* (SD) = Σ (*emissions*$_i$·$DF^{DM}{}_i$) – Not recommended –

3.3. GLOBIO3

The GLOBIO3 methodology differs from the two methodologies presented previously. It is not a Life Cycle Assessment methodology, but it is a model that is based on cause-effect relationship between the pressures acting on biodiversity and their possible consequences in a determinate period. This methodology uses the software package IMAGE 2.4[12], which divides the terrain in squared cells and models through time the information related to the impact due to the Driving Forces.

[12] Image 2.4. Bouwman AF; Kram T; Klein Goldewijk K, *Integrated modeling of global environmental change. An overview of IMAGE 2.4*. Netherlands Environmental Assessment Agency (MNP), Bilthoven, October 2006

As a matter of fact, the main issue with this methodology is the availability of data that allows the knowledge of the current state of the environment. However, secondary information was used to estimate the main values of main biodiversity in the whole earth.

The unit of measure used by this methodology is the MSA (Main Specie Abundance), which is defined by the correlation between the drivers and the presence of native species in a determined cell in which the terrain was divided. In fact, this indicator expresses the relationship between the current status of biodiversity and a hypothetical original status.

Translating this information to a mathematical formula, it is notable that it is a result of a linear combination between the factors mentioned above. For each Driver there is a MSA obtained, and in the end the sum of each one of those MSA will build the gross MSA indicator. Particularly, the expression can be summarized as:

$$MSA_i = MSA_{LUi} \cdot MSA_{Ni} \cdot MSA_{Ii} \cdot MSA_{Fi} \cdot MSA_{Cci}$$

Where:

"i" is the cell where the calculus has been done.
MSA_i is the total value for the cell *i*
MSA_{LUi} *Land Cover/Land Use driver*,
MSA_{Ni}: is the abundance relative to the *Atmospheric N deposition driver*,
MSA_{Ii}: is the abundance relative to the *Infrastructure development driver*
MSA_{Fi}: is the abundance relative to the *Fragmentation driver*
MSA_{CCi}: is the abundance relative to the *Climate Change driver*

After calculating the MSA for each cell in the space studied, the methodology follows its path calculating the mean of the MSA values found. The final result will be a single value of MSA that can be used to express the biodiversity indicator as follows.

$$MSA_r = \sum MSA_i \cdot A_i / \sum A_i$$

Where:
MSA_r is the MSA of a determinate region,
MSA_i is the gross MSA value for the cell *i*
A_i The area of the cell *i*

However, this methodology presents a series of concerns that have to be considered when it will be applied.

In first place, it counts the primary vegetation observed as an environment with no human intervention, then, it considers the MSA as a good biodiversity indicator, and areas with different species density are considered with equal weight on the final calculations. As a consequence, environments with low biodiversity such a deserts and extreme environments, have the same value than environments such as rainforests or tropical ecosystems.

Furthermore, this methodology presents a wide scale of application. The data was managed to be used in a world/region scale. This means that the cells analysed have a considerable size and the methodology cannot be applied to regional or local environments.

Since the study presented is a type of local biodiversity, the methodology GLOBIO3 is not used to determine the anthropic pressures on biodiversity.

4. Sites. Case studies presented.

Three different industrial sites were used in order to analyse the described methodology. The sites were selected by the Company who ordered the study, and they present different land distributions and sites of naturalistic interest. The sites will be named with the letters A, B and C, respectively.

In this chapter, the sites will be described one by one. The different area types will be identified and other important information gathered from the data management will be shown. However, the data will be treated just in terms of areas and percentages, excluding the influence factors and their value.

4.1. Site A

The site A lays in the middle of an agricultural area, mainly non-irrigated and irrigated arable land, mixed crops and pastures. Inside the Influence Area (IA), there are a total of 6.389 ha of land which is used for agriculture, while in the Pressure Area (PA); the total agricultural land goes up to 15.676 ha.

However, there is also presence of an urbanized portion of land. Inside the (IA) there are 271 ha; while inside the PA there are 1.125 ha. The industrialized zones in the area surrounding the plant go up just to 259 ha inside the PA, and it is all concentrated inside the IA.

At the same time, the extension of the infrastructure inside the analysed zone goes up to 26 km for railroads, and to 449 km for streets and roads.

The summarized data containing site A, information is reported in **table4.1**.

Activity	Unit	Influence Area	Pressure Area
Agr. 1. Non-Irrigated arable land	ha	3.757	6.267
Agr. 2. Permanent irrigated land	ha	1.100	3.323
Agr. 3. Areas of pastures	ha	306	560
Agr. 4. Permanent grows	ha	0	105
Agr. 5. Mixed Crops.	ha	1.226	5.421
AGRICULTURAL LAND TOTAL	**ha**	**6.389**	**15.676**
Industry - industrial Areas	**ha**	**259**	**259**
Inf. 1. Railroads	km	-	26
Inf. 2. Roads	km	-	449
Urb. 1, Continuous urban fabric	ha	0	0
Urb. 2. Discontinuous urban fabric	ha	271	1.125
TOTAL URBAN AREA	**ha**	**271**	**1.125**
Non Influent Area	**ha**	**935**	**5.673**
TOTAL AREA	**ha**	**7.854**	**22.733**

Table 4.1. Area distribution summary for the site A

The total area of the Pressure Area (PA) is 22.733 ha. The land shape and land distributions are shown in **figure 4.1**. The red X points the approximate location of the analysed industrial site.

Figure 4.1. Land distribution for site A

The total sensible or non impacting area goes up to 5.673 ha, which represents the 24,95% of the Pressure Area (PA). Inside the Influence Area (IA), the non impacting portion goes up to 935 ha, which represents the 11,90% of this area. **Figure 4.2** and **figure 4.3** show the land occupation distribution in the Influence and Pressure areas respectively.

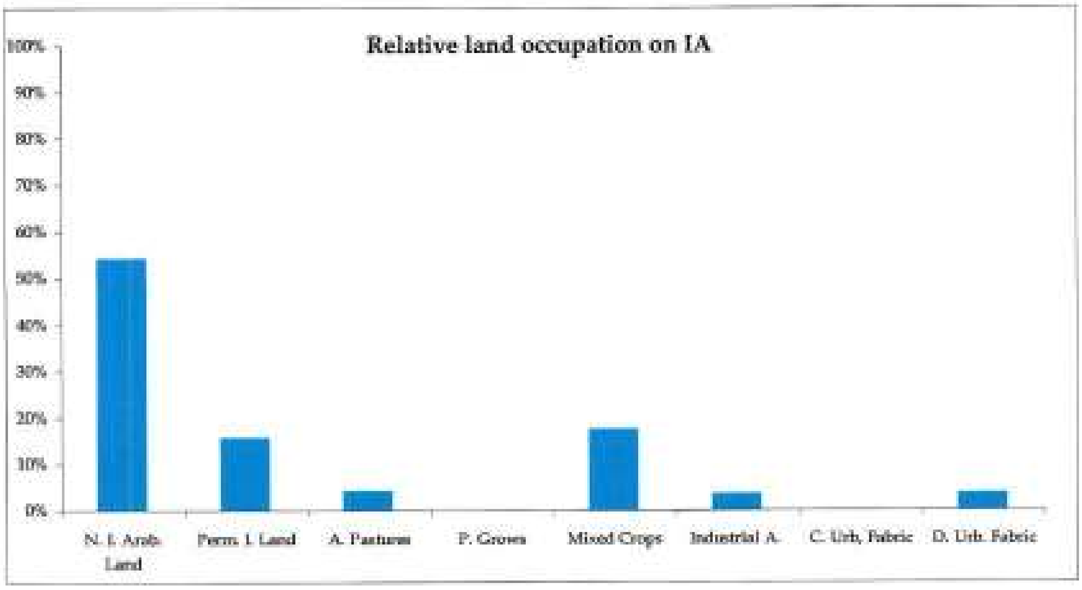

Figure 4.2. Land Occupation distribution inside the Influence Area for the case A.

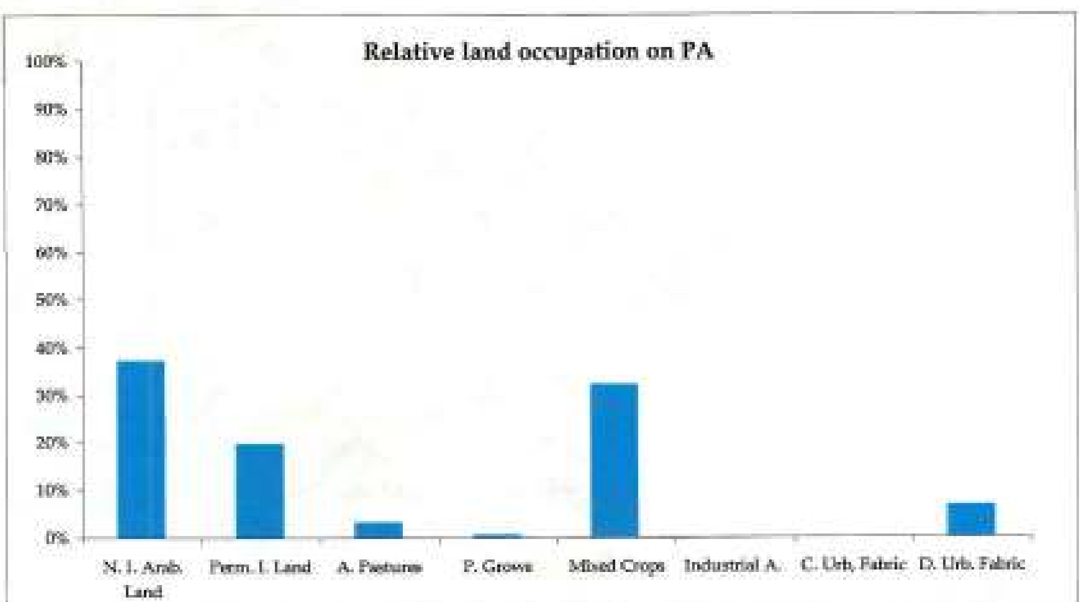

Figure 4.3. Land Occupation distribution inside the Pressure Area (PA) for the case A

The distribution of the industrial sites found inside the area of study is shown in the **table 4.2**. The "Activity description" column shows the IPPC definition of the industry from which the information was taken out. The Activity Code refers to the IPPC code form the 2008/1/EC

Directive of the European Parliament. Then, the third column marks if the values were taken directly from the industrial site (marked with an X), or the information available on databases was used. If the values were taken directly from the industries (primary data), they are shown in **table 4.3**, in which are summarized the emissions measured in situ.

Activity description	Site No.	Activity code*	Direct values	Production index	Unit
Plants for the pre-treatment (operations such as washing, bleaching, mercerisation) or dyeing of fibres or textiles where the treatment capacity exceeds 10 tonnes per day.	1	6.2		4500	ton
	2	6.2		10000	ton
	3	6.2		6000	ton
Installations for the disposal or recovery of hazardous waste.	4	5.1		42000	ton
	5	5.1		2000	ton
Surface treatment of substances using organic solvents	6	6.7	x		

* Activity code from: DIRECTIVE 2008/1/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

Table 4.2. Industrial activities identified in the study area of site A.

Substance	Unit	Amount
Air emissions		
Nitrogen Oxides	kg/y	29,00
Phosphorus total	kg/y	232,00
Water emissions		
Aluminium	kg/y	2,00
Nitrite	kg/y	752,00
Sulfate	kg/y	4763,00
Iron	kg/y	24,00
Zinc	kg/y	16,00
Boron	kg/y	10,00
Chloride	kg/y	2183,00
Fluoride	kg/y	2,00
Phosphorus total	kg/y	156,00

Table 4.3. Direct emissions values for case study A.

4.2. Site B

As the A site, there is a predominance of agricultural land. However, the urban land use is larger than in the previous case. As it is shown in **table 4.4**, the agricultural area total goes up to 4.478 ha in the IA, and 13.926 ha in the PA. Furthermore, the urban area total is 5.350 ha (counting continuous and discontinuous urban fabric).

Now, in the infrastructure topic the data is very similar to the one found in the site A (less than 500 km), moreover neither the A nor the B site have infrastructure inside the Influence Area (IA).

Activity	Unit	Influence Area	Pressure Area
Agr. 1. Non-Irrigated arable land	ha	2.694	7.803
Agr. 2. Permanent irrigated land	ha	0	0
Agr. 3. Areas of pastures	ha	1.063	2.322
Agr. 4. Permanent grows	ha	0	0
Agr. 5. Mixed Crops.	ha	991	3.801
AGRICULTURAL LAND TOTAL	**ha**	**4.748**	**13.926**
Industry - industrial Areas	**ha**	**501**	**501**
Inf. 1. Railroads	km	-	34
Inf. 2. Roads	km	-	459
Urb. 1, Continuous urban fabric	ha	0	903
Urb. 2. Discontinuous urban fabric	ha	1.249	4.447
TOTAL URBAN AREA	**ha**	**1.249**	**5.350**
Non Influent Area	**ha**	**1.356**	**5.517**
TOTAL AREA	**ha**	**7.854**	**25.294**

Table 4.4. Area distribution summary for site B

In **figure 4.4** below the area distribution of the site B is shown. The total area of the Pressure Area (PA) goes up to 25.294 ha.

In the other hand, the sensible or non impacting area identified inside the Pressure Area (PA) is 5.517 ha, which represents around the 21,81% of this sector. Inside the Influence Area (IA), the zero impact area is 1.356 ha, which represent the 17,27% of this land portion.

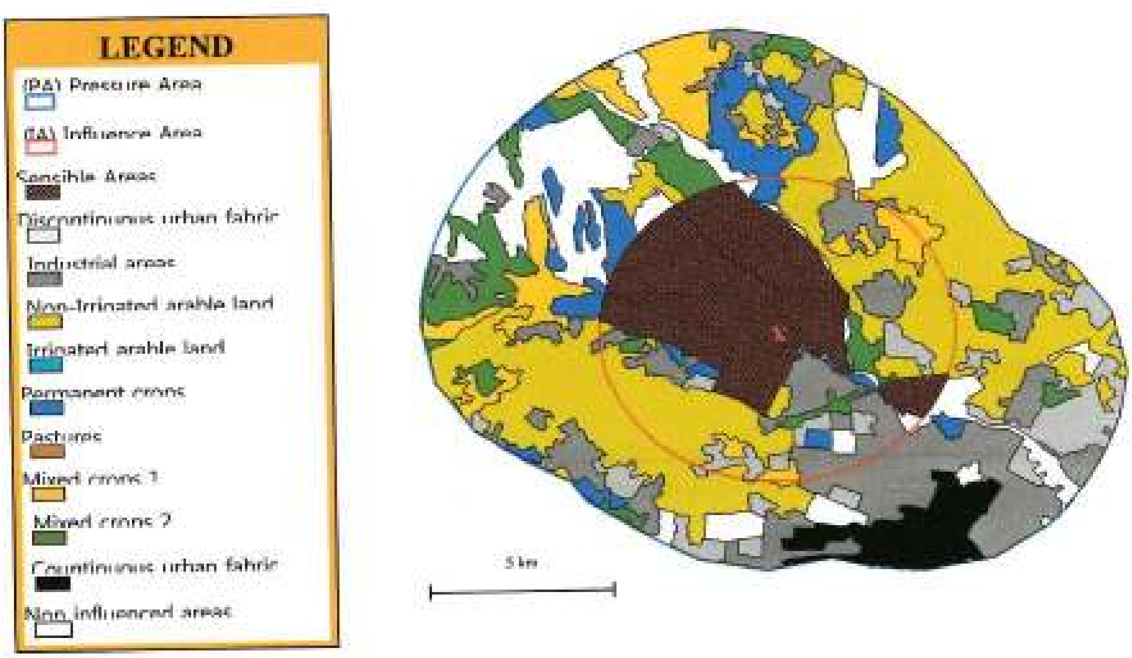

Figure 4.4. Land use distribution for site B

The land occupation distribution is shown in **figure 4.5** and **figure 4.6**, for the IA and the PA respectively. The comparison between the cases is shown in title "*4.4. Site comparison*".

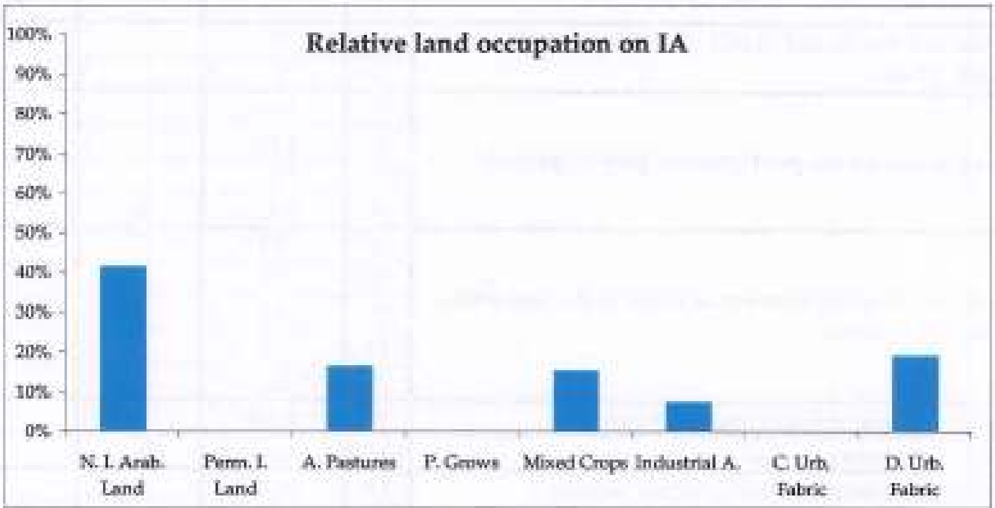

Figure 4.5. Land Occupation distribution inside the Influence Area (IA) for case B.

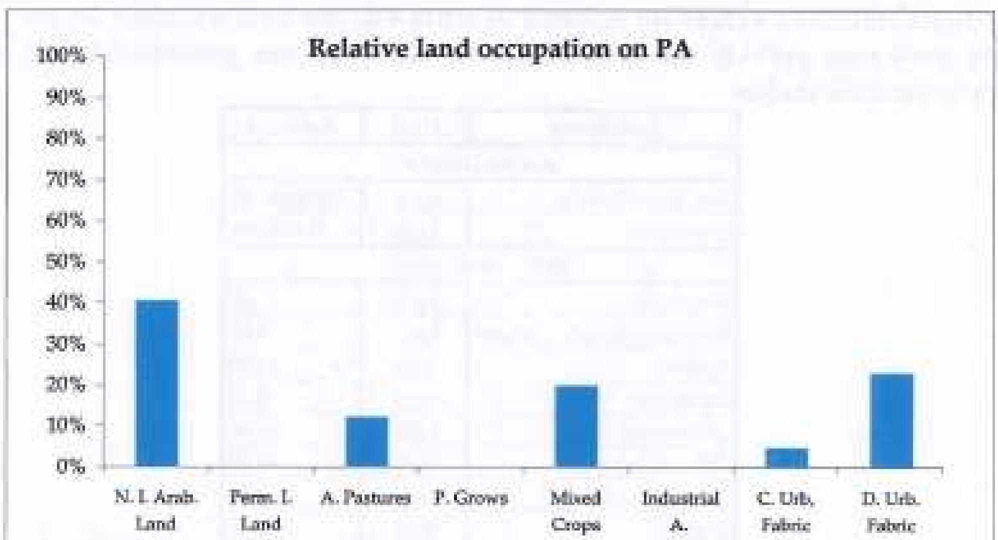

Figure 4.6. Land Occupation distribution inside the Pressure Area (PA) for case B.

Once again, the industrial activities for the study area were identified, giving as a result the values shown in **table 4.5**. The activities that are marked with an X in the "Direct Values" column are considered later in this section.

ACTIVITY DESCRIPTION	Site No.	Activity Code *	Direct Values	Production Index	Unit
Combustion installations thermal input over 50 MW	1	1.1	x	9.000.000.000	MJ
	2	1.1		12.600.000	MJ
Surface treatment of metals and plastic materials where the vats volume exceeds 30 m3.	3	2.6		97.920	ton
	4	2.6		374.400	ton
Chemical installations for the production of simple hydrocarbons	5	4.1.a		15.800	ton
	6	4.1.b		5.000	ton
	7	4.1.c		35.000	ton
	8	4.2.e	x		
Installations for the disposal/recovery of hazardous waste with a capacity exceeding 10 ton/d.	9	5.1		74.498	ton
	10	5.1		3.894	ton
	11	5.1		74.500	ton
	12	5.1		522	ton
	13	5.1		1.415	ton
Plants for the production of paper and cardboard	14	6.1.b		41.321	ton
Intensive rearing of poultry or pigs	15	6.6.b	x		
Surface treatment of substances using organic solvents (consumption over 150 kg/h)	16	6.7		470	ton
	17	6.7	x		

* Activity code from: DIRECTIVE 2008/1/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

Table 4.5. Industrial activities identified in the study area of site B.

The direct emissions values are reported in **table 4.6**, just as it was done for the case study A. These emissions provide the information for the pressures generated by the industrial activities in the case studies.

Substance	Unit	Amount
Air emissions		
Nitrogen Oxides	kg/y	256.000,00
Ammonia	kg/y	38.000,00
Water emissions		
Ammonia	kg/y	3,09
Anionic phosph. Esthers	kg/y	3,09
Arsenic	kg/y	15,70
Cadmium	kg/y	0,31
Chromium	kg/y	84,40
Chromium ion	kg/y	30,88
Chromium IV	kg/y	0,31
Copper	kg/y	6,18
Cyanide	kg/y	78,60
Iron	kg/y	0,31
Lead	kg/y	0,31
Manganese	kg/y	0,31
Mercury	kg/y	1,60
Nickel	kg/y	90,98
Nitrate	kg/y	379,76
Nitrite	kg/y	3,09
Sulfate	kg/y	7.749,11
Zinc	kg/y	30,88

Table 4.6. Direct emissions values for the case study B

4.3. Site C

The third site under analysis for this study is a site that again is mostly agricultural, but it has a considerable Urban Land occupation. In fact, it is superior to the proportion on the other two case studies. The gross agricultural portion total in the Pressure Area (PA) is 16.265 ha, and inside the Influence Area (IA) it occupies 3.965 ha. To illustrate the case study C **table 4.7** is shown below with a report summary.

Activity	Unit	Influence Area	Pressure Area
Agr. 1. Non-Irrigated arable land	ha	159	1.002
Agr. 2. Permanent irrigated land	ha	0	0
Agr. 3. Areas of pastures	ha	71	208
Agr. 4. Permanent grows	ha	0	0
Agr. 5. Mixed Crops.	ha	3.735	15.056
AGRICULTURAL LAND TOTAL	ha	3.965	16.266
Industry - industrial Areas	ha	327	327
Inf. 1. Railroads	km	-	25
Inf. 2. Roads	km	-	689
Urb. 1, Continuous urban fabric	ha	0	0
Urb. 2. Discontinuous urban fabric	ha	2.260	2.637
TOTAL URBAN AREA	ha	2.260	2.637
Non Influent Area	ha	1.302	7.264
TOTAL AREA	ha	7.854	26.494

Table 4.7. Area distribution summary for case C

The land distribution is shown also in **figures 4.7** and **figure 4.8**. This, together with the cartographic information completes the description of the Land Occupation for the case C.

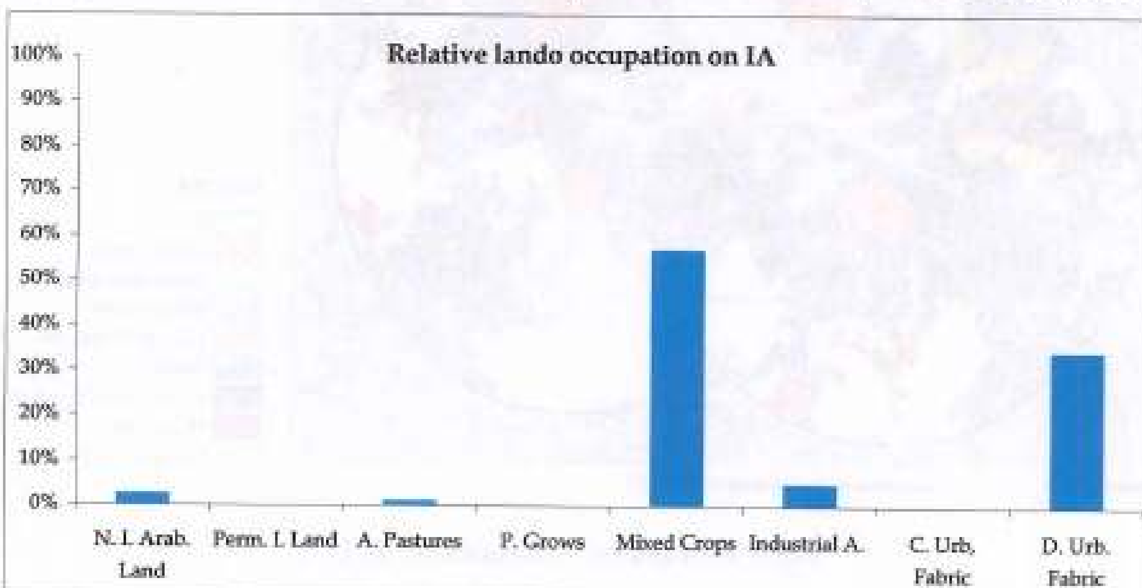

Figure 4.7. Land Occupation distribution within the Influence Area (IA) for the case C.

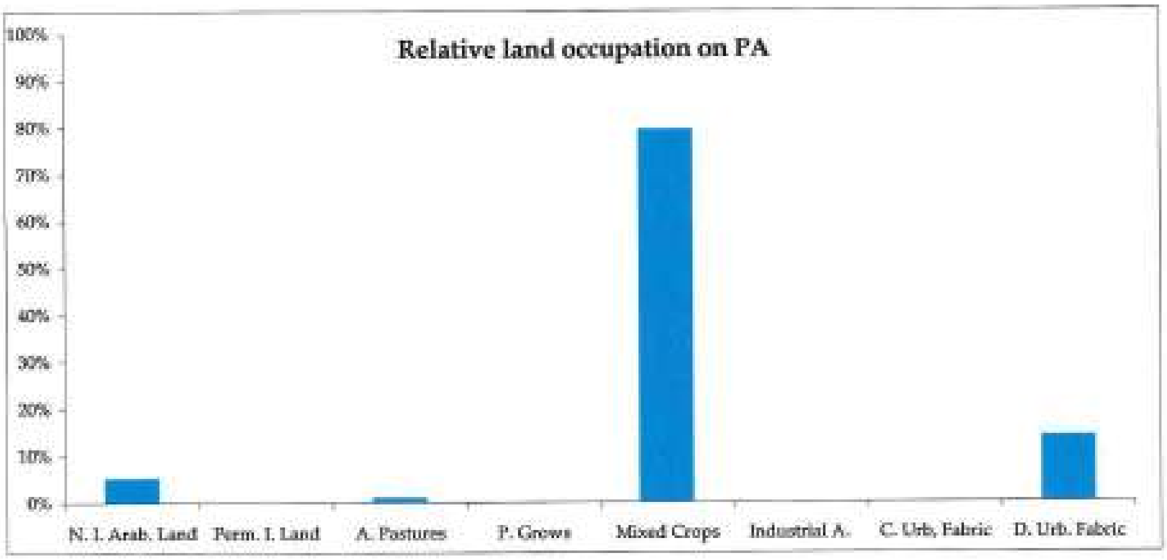

Figure 4.8. Land Occupation distribution within the Pressure Area (PA) for the case C.

As in the previous cases, the land distribution scheme is shown in **figure 4.9**.

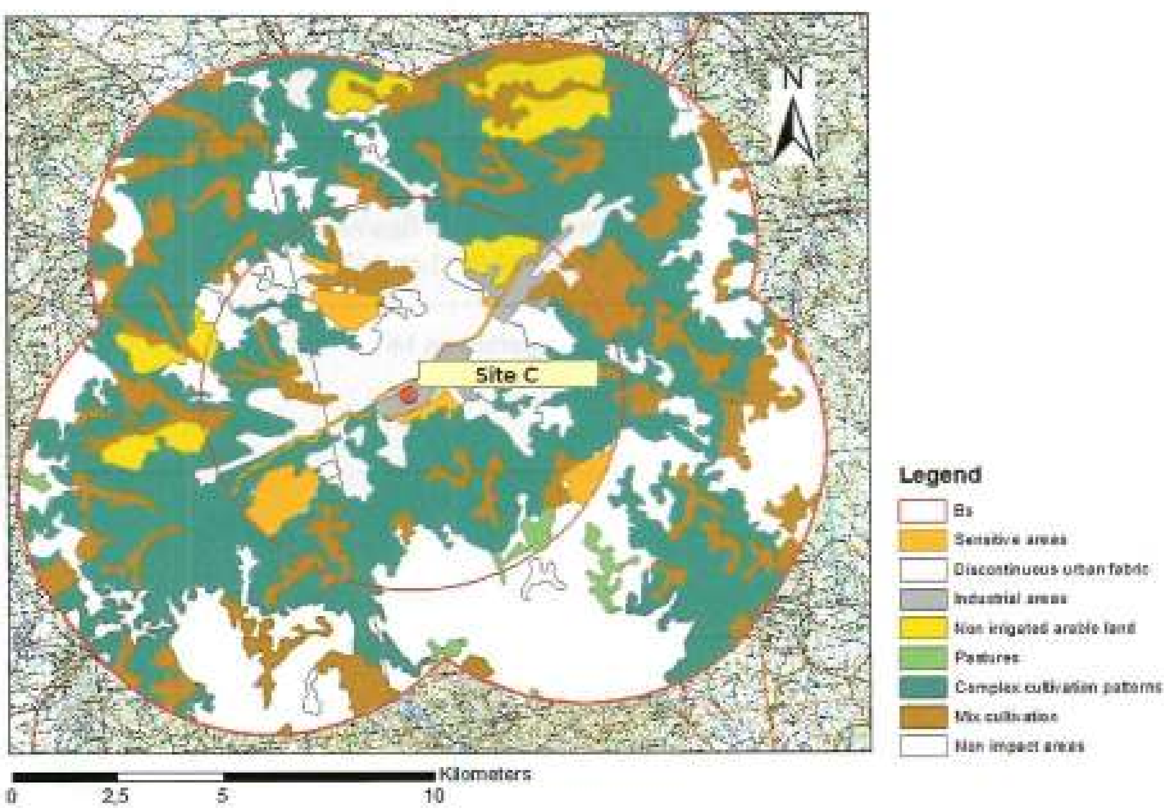

Figure 4.9. Land use distribution for site C.

The area of the sensible areas considered inside the IA is 1.302 ha, it represents the 16,58% of the total IA. Besides, inside the PA there are 7.264 ha, which is the 27,42% of the total area.

To complete the description of the site C, it is necessary to consider the industrial occupation and the emissions for this study area. **Table 4.8** shows the distribution of the industrial sites found and their respective emissions.

Site	Site No.	Activity code*	Direct Values	Production Index	Unit
Plants for the pre-treatment of fibres or textiles where the treatment capacity exceeds 10 tonnes per day.	1	6.2	x	-	-
	2	6.2		4.020	ton
Installations for the surface treatment of substances using organic solvents	3	6.7	x	-	-

* Activity code from: DIRECTIVE 2008/1/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

Table 4.8. Industrial activities identified in the study area of site C.

The direct values emissions are reported in **table 4.9**, these values correspond to the primary information gathered from the industries within the Pressure Area of this case study.

Substance	Unit	Amount
Air emissions		
Nitrogen oxides	kg/y	215.000,00
NO2	kg/y	129.333,00
Phosphates	kg/y	5.310,00
Sulfur oxides	kg/y	273.000,00
VOC as C	kg/y	41.986,00
Water emissions		
Cadmium	kg/y	0,45
Chromium	kg/y	0,09
Lead	kg/y	0,90
Nickel	kg/y	7,20
Phenol	kg/y	0,15
Phosphates	kg/y	36,00
Phosphorous	kg/y	0,36
Zinc	kg/y	5,70

Table 4.9. Direct emissions values for the case study C

Unlike site A, this site is very close to an urban area. It will be seen in the comparison that this is a very important factor for the land distribution, and then for the quantification of the pressures in the results comparison chapter.

4.4. Site comparison

As a first analysis, this section will show the main similarities and differences between each one of the case studies. As a summary, the relative values concerning to the total areas for each use are shown in **table 4.10**. The Pressure Area (PA) is considered for this analysis.

Case	PA (ha)	Influent Area			NON-INFLUENT AREA (ha)
		AGRICULTURE (ha)	INDUSTRIAL (ha)	URBAN (ha)	
Site A	22.833	15.676	259	1.125	5.773
Site B	25.294	13.926	501	5.350	5.517
Site C	26.494	16.266	327	2.637	7.264

Table 4.10. Main areas comparison between the 3 case studies, in hectares (ha)

The site that has more agricultural area is site C, while the one that has more industrial areas and more urban coverage is site B. Moreover it is interesting to observe the amount of land that is occupied and affect the environment and specifically biodiversity. In this study, this area is larger in site B, followed by site C and in last place, site A.

However, these absolute values are transformed to values referred to the total area of each case study. The results are shown in **table 4.11**. This data is referred to the gross Pressure Area of each case.

Case	PA (ha)	AGRICULTURE	INDUSTRIAL	URBAN	INFLUENT AREA
Site A	22.833	68,66%	1,13%	4,93%	74,72%
Site B	25.294	55,06%	1,98%	21,15%	78,19%
Site C	26.494	61,40%	1,23%	9,95%	72,58%

Table 4.11. Relative occupation values for each site, inside the PA

In order to make a qualitative interpretation, this data was set up to fill **figure 4.10**, shown below.

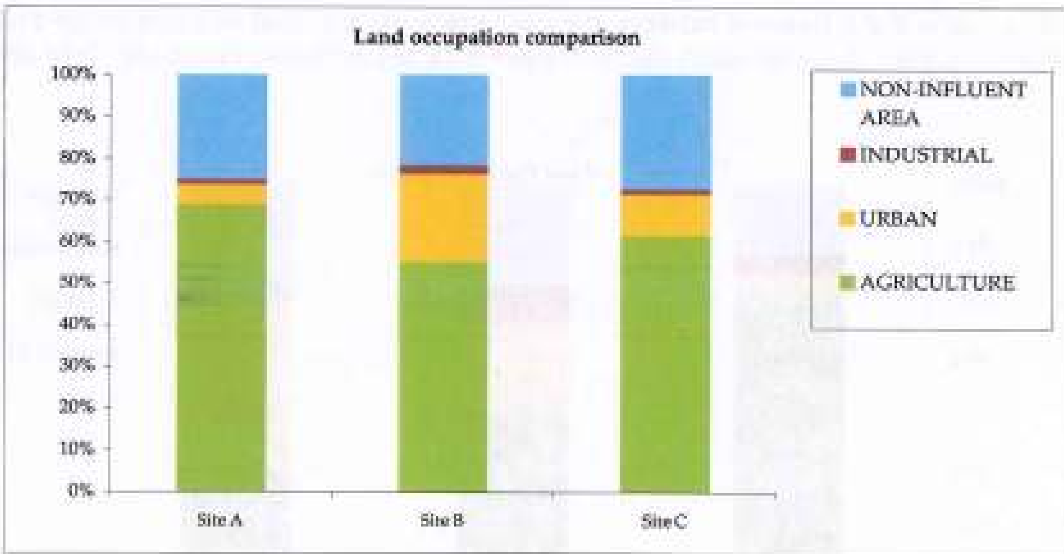

Figure 4.10. Comparison between the land occupation of the three case studies inside the PA

To complete the comparison it is necessary to consider the analysis of the case studies just inside the Influence Area (IA), the closest to the sensible zones considered and the one that is affected by the land use factors.

The amount of occupied area inside the (IA) is reported in absolute values in **table 4.12**. The total area is the same for the three case studies, according to the methodology.

Values reported in ha				
Case	AGRICULTURE	INDUSTRIAL	URBAN	NON-INFLUENT AREA
Site A	6.389	259	271	935
Site B	4.748	501	1.249	1.356
Site C	3.965	327	2.260	1.302

Table 4.12. Absolute area occupation inside each one of the Influence Area.

Using the values on **table 4.12**, and using 7.854 ha, which is the total area of the IA, it is possible to build **table 4.13**, with the relative values of land occupation.

Case	AGRICULTURE	INDUSTRIAL	URBAN	NON-INFLUENT AREA
Site A	81,35%	3,30%	3,45%	11,90%
Site B	60,45%	6,38%	15,90%	17,27%
Site C	50,48%	4,16%	28,78%	16,58%

Table 4.13. Relative land occupation values for the case studies inside the Influence Area (IA)

Once again, the difference between the case studies is reported as a composed histogram, in order to identify the differences easily. **Figure 4.11** below shows the result of the analysis.

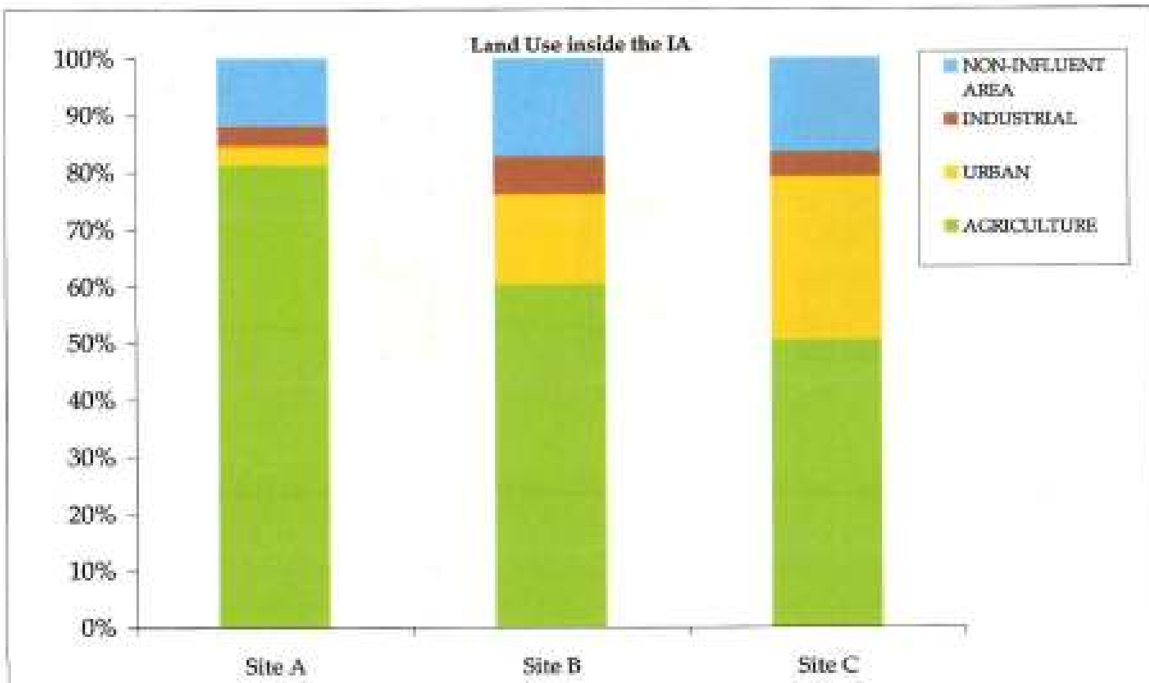

Figure 4.11. Land Use inside the IA, given in relative values.

As it is shown in the figure above, the land use inside the Influence Area is quite different for the different case studies. In effect, the site A has a predominant agricultural surrounding, site B has a considerable amount of urban surrounding and site C has even more land used for urban occupation.

5. RESULTS

This section shows the anthropic pressure results for each site using each methodology. In first place, it shows the ReCipe 2008 results, because this is the actual methodology used by the company for the case studies. Then, the results given by the other methodology are shown.

The analysis performed takes under consideration the area distribution given in chapter 4. In that section the different activities and distributions were shown.

5.1. Results for ReCipe 2008 methodology

As ReCipe 2008 is the methodology chosen by the company to elaborate the studies nowadays, the results are shown in first place. In the end of the section the results for each case will be compared too with the scope of giving the reader an idea of how the values obtained are different for each one of the cases.

5.1.1. Site A

As it was seen before, this site is the one with less Urban Land Occupation, it also has the second bigger agricultural area and has the smaller industrial occupation of the sites selected to make the comparison.

In first place, **table 5.1**, shows the values obtained after applying the methodology to each category considered. All values are expressed in PDF (Potentially Disappeared Fraction of species), specie·year.

Driving Force	Terrestrial acidification	Freshwater eutrophication	Terrestrial ecotoxicity	Freshwater ecotoxicity	Agricultural land occupation	Industrial land occupation	Urban land occupation	Total for category
Agriculture	9,856E-03	1,745E-04	1,933E-02	9,465E-05	1,151E+00	0,000E+00	0,000E+00	**1,180E+00**
Industrial	6,435E-07	6,942E-06	4,602E-04	3,998E-08	0,000E+00	5,005E-02	0,000E+00	**5,052E-02**
Infrastructure	1,189E-03	0,000E+00	2,784E-04	8,477E-08	0,000E+00	0,000E+00	0,000E+00	**1,467E-03**
Urban	6,341E-03	0,000E+00	4,328E-03	2,776E-06	0,000E+00	0,000E+00	5,230E-02	**6,297E-02**
Total	**1,739E-02**	**1,815E-04**	**2,439E-02**	**9,755E-05**	**1,151E+00**	**5,005E-02**	**5,230E-02**	**1,295E+00**

Table 5.1. PDF results for case study A. All values expressed in PDF specie·year

However, it is convenient to express the absolute values as a percentage to get an idea of the contribution of each Impact Category and/or Driving Force. This transformation is shown in **table 5.2**.

Driving Force	Terrestrial acidification	Freshwater eutrophication	Terrestrial ecotoxicity	Freshwater ecotoxicity	Agricultural land occupation	Industrial land occupation	Urban land occupation	Total for category
Agriculture	0,76%	0,01%	1,49%	0,01%	88,85%	0,00%	0,00%	**91,12%**
Industrial	0,00%	0,00%	0,04%	0,00%	0,00%	3,86%	0,00%	**3,90%**
Infrastructure	0,09%	0,00%	0,02%	0,00%	0,00%	0,00%	0,00%	**0,11%**
Urban	0,49%	0,00%	0,33%	0,00%	0,00%	0,00%	4,04%	**4,86%**
Total	**1,34%**	**0,01%**	**1,88%**	**0,01%**	**88,85%**	**3,86%**	**4,04%**	**100,00%**

Table 5.2. Relative results for the case study A. The total impact is considered as 100%.

With the results of the table, two graphics can be built. The contribution for each Driving Force, in **figure 5.1** and the contribution for each Impact Category in **figure 5.2**.

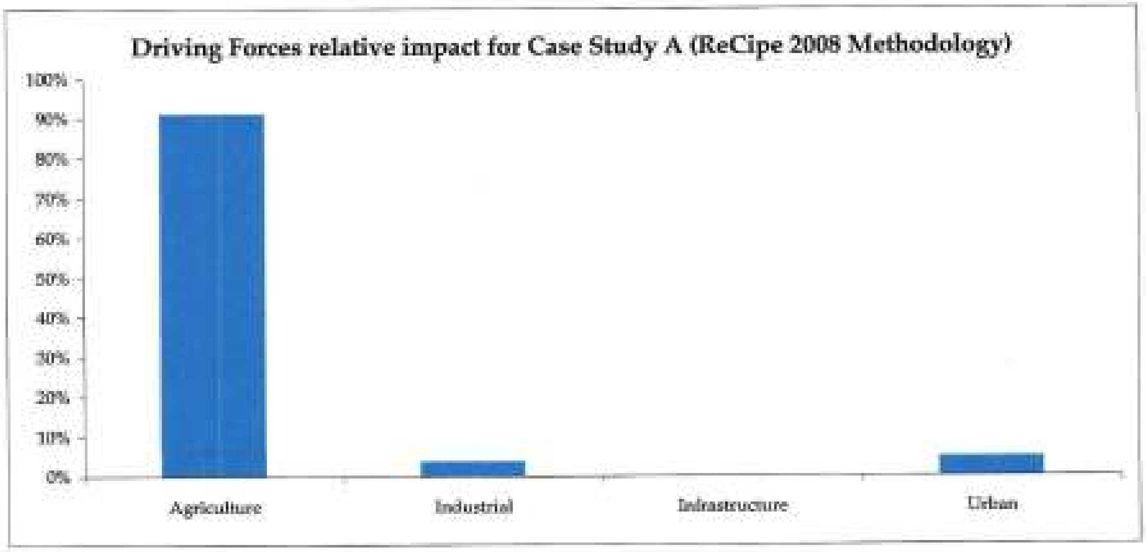

Figure 5.1. Driving Forces relative impact for Case Study A

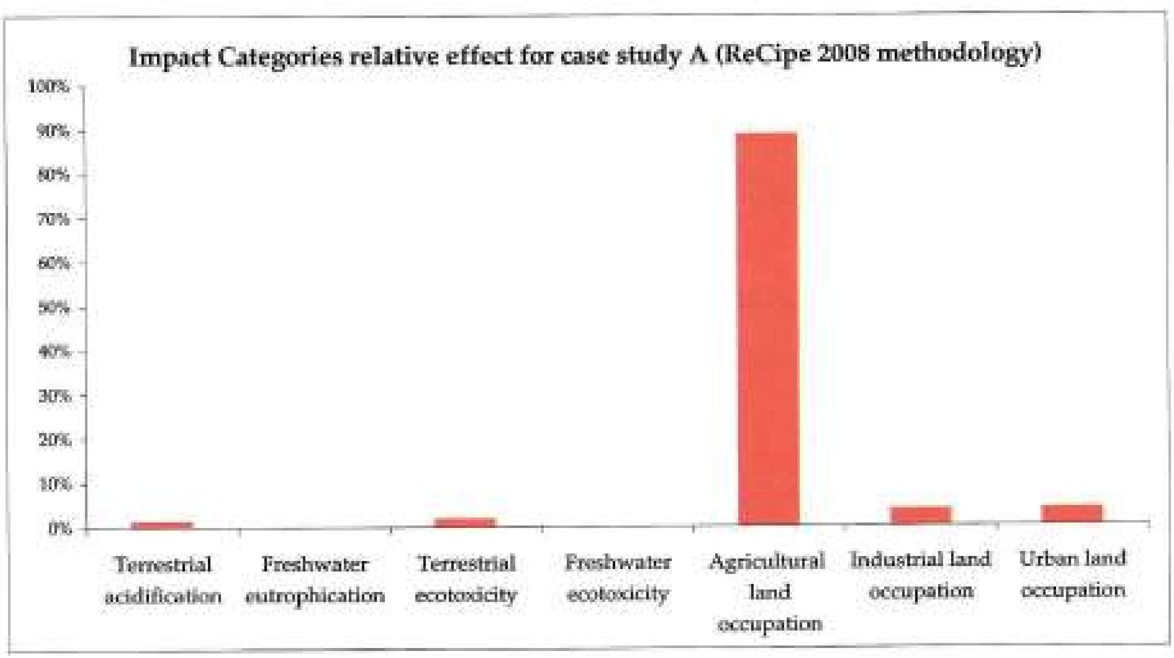

Figure 5.2. Impact categories relative effect for case study A

5.1.2. Site B

For the case study B the same results are presented as in case A. This site is characterized by having the biggest industrial area, but also the biggest non influent area on the field. **Table 5.3** and **table 5.4** show the result of the calculations for the impact on biodiversity.

Driving Force	Terrestrial acidification	Freshwater eutrophication	Terrestrial ecotoxicity	Freshwater ecotoxicity	Agricultural land occupation	Industrial land occupation	Urban land occupation	Total for each Driving Force
Agriculture	1,556E-04	1,629E-02	5,874E-05	7,088E-06	8,071E-01	0,000E+00	0,000E+00	8,237E-01
Industrial	1,232E-06	1,744E-03	4,570E-07	2,006E-06	0,000E+00	9,662E-02	0,000E+00	9,837E-02
Infrastructure	0,000E+00	1,566E-02	3,518E-06	1,538E-05	0,000E+00	0,000E+00	0,000E+00	1,568E-02
Urban	0,000E+00	5,159E-02	3,309E-05	2,679E-08	0,000E+00	0,000E+00	2,410E-01	2,926E-01
Total	1,568E-04	8,528E-02	9,580E-05	2,450E-05	8,071E-01	9,662E-02	2,410E-01	1,230E+00

Table 5.3. PDF results for case study B. All values expressed in PDF specie•year

Driving Force	Terrestrial acidification	Freshwater eutrophication	Terrestrial ecotoxicity	Freshwater ecotoxicity	Agricultural land occupation	Industrial land occupation	Urban land occupation	Total for each Driving Force
Agriculture	0,01%	1,32%	0,00%	0,00%	65,61%	0,00%	0,00%	66,95%
Industrial	0,00%	0,14%	0,00%	0,00%	0,00%	7,85%	0,00%	8,00%
Infrastructure	0,00%	1,27%	0,00%	0,00%	0,00%	0,00%	0,00%	1,27%
Urban	0,00%	4,19%	0,00%	0,00%	0,00%	0,00%	19,59%	23,78%
Total	0,01%	6,93%	0,01%	0,00%	65,61%	7,85%	19,59%	100,00%

Table 5.4. Relative results for the case study B. The total impact is considered as 100%.

With the relative values established, the impact graphics can be built. They show the impacts by Driving Force, **figure 5.3**, and the effects by impact category, **figure 5.4**.

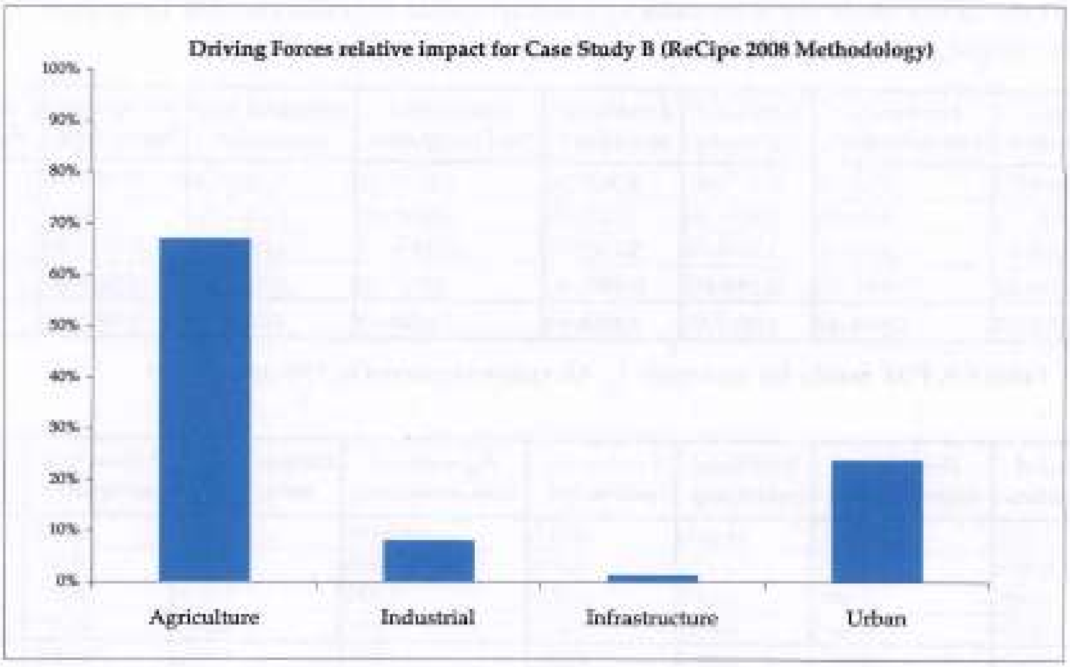

Figure 5.3. Driving Forces relative impact for Case Study B

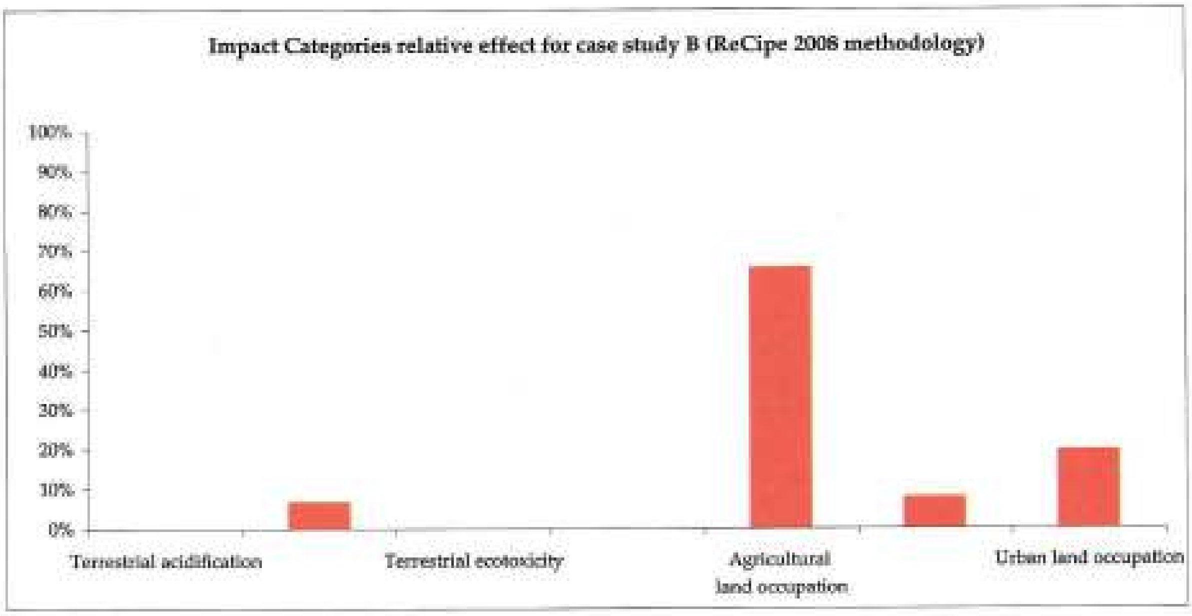

Figure 5.4. Impact categories relative effect for case study B

5.1.3. Site C

The results for site C are shown as absolute values in **table 5.5** and in relative values in **table 5.6**. These tables show the total values of impact either for each Driving force than for each impact category.

Driving Force	Terrestrial acidification	Freshwater eutrophication	Terrestrial ecotoxicity	Freshwater ecotoxicity	Agricultural land occupation	Industrial land occupation	Urban land occupation	Total for each driving force
Agricultural	1,505E-02	1,596E-04	1,607E-01	3,067E-04	7,032E-01	0,000E+00	0,000E+00	8,794E-01
Industrial	7,368E-03	0,000E+00	5,902E-03	1,132E-06	0,000E+00	6,320E-02	0,000E+00	7,647E-02
Infrastructure	9,538E-03	0,000E+00	2,349E-02	5,274E-06	0,000E+00	0,000E+00	0,000E+00	3,303E-02
Urban	1,487E-02	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00	4,362E-01	4,511E-01
Total	**4,682E-02**	**1,596E-04**	**1,901E-01**	**3,132E-04**	**7,032E-01**	**6,320E-02**	**4,362E-01**	**1,440E+00**

Table 5.5. PDF results for case study C. All values expressed in PDF specie·year

Driving Force	Terrestrial acidification	Freshwater eutrophication	Terrestrial ecotoxicity	Freshwater ecotoxicity	Agricultural land occupation	Industrial land occupation	Urban land occupation	Total by driving force
Agricultural	1,04%	0,01%	11,16%	0,02%	48,83%	0,00%	0,00%	61,07%
Industrial	0,51%	0,00%	0,41%	0,00%	0,00%	4,39%	0,00%	5,31%
Infrastructure	0,66%	0,00%	1,63%	0,00%	0,00%	0,00%	0,00%	2,29%
Urban	1,03%	0,00%	0,00%	0,00%	0,00%	0,00%	30,29%	31,32%
Total	**3,25%**	**0,01%**	**13,20%**	**0,02%**	**48,83%**	**4,39%**	**30,29%**	**100,00%**

Table 5.6. Relative results for the case study C. The total impact is considered as 100%

Using the data in **table 5.6** the **figure 5.5** and **figure 5.6**, that show the distribution of the impact on biodiversity for the Driving Forces and the impact categories.

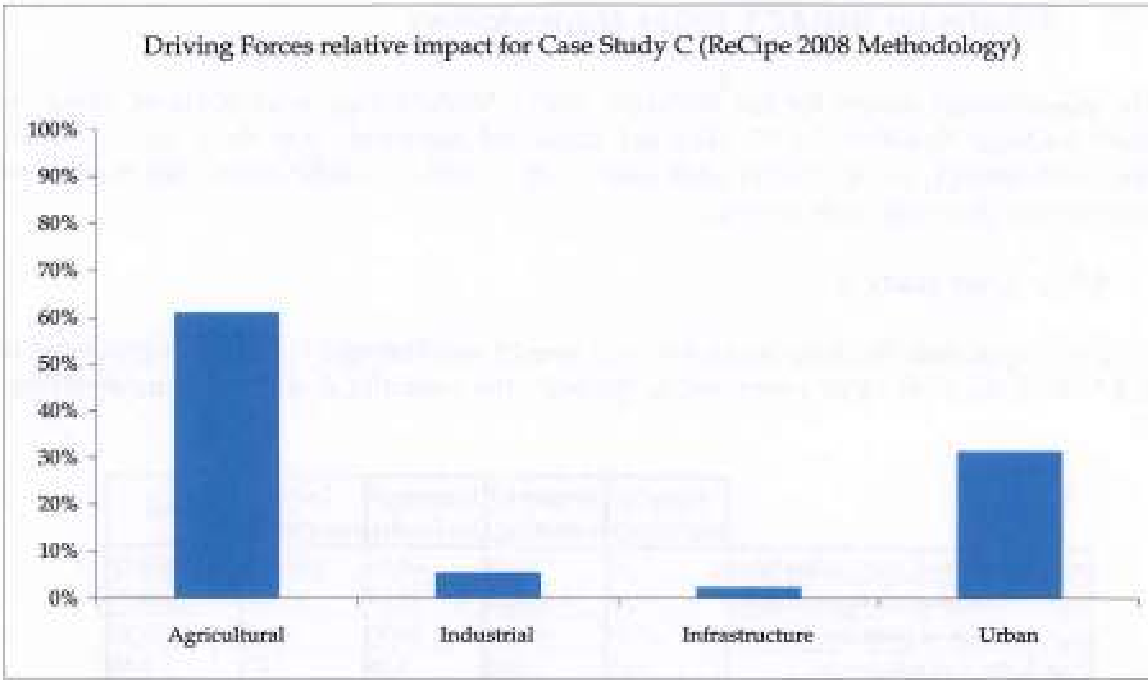

Figure 5.5. Driving Forces relative impact for Case Study C

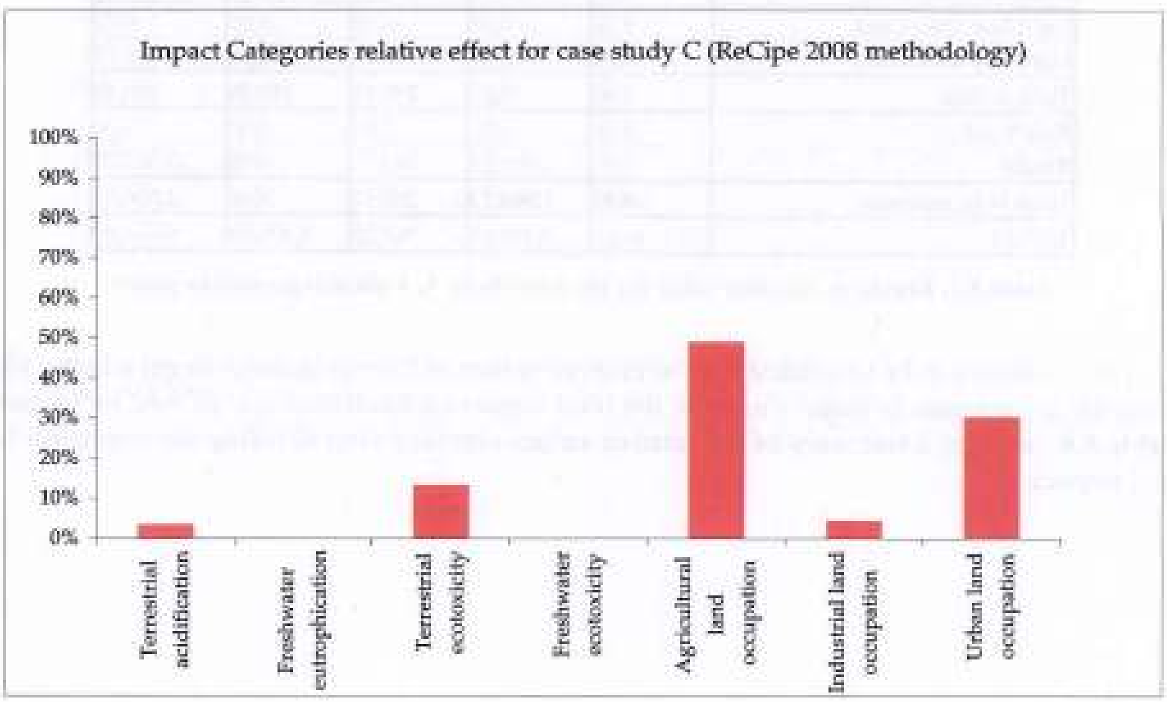

Figure 5.6. Impact categories relative effect for case study C

5.2. Results for IMPACT 2002+ Methodology

The experimental results for the IMPACT 2002+ Methodology were obtained using the Software package SimaPro 7.3.™ They are presented separately and then, just as in the ReCipe methodology, compared for each case study in order to differentiate the results and get information about the methodology.

5.2.1. Case study A

As a first approach, the total result for each Impact and Damage Category is presented in **table 5.7**, with the total value expressed in "points", the normalized unit of the methodology used.

	Aquatic ecotoxicity	Terrestrial ecotoxicity	Terrestrial acid/nutri	Land occupation	Total
Agr. 1. Non-Irrigated arable land	1,65	738,35	69,78	3.154,05	3.963,83
Agr. 2. Permanent irrigated land	3,89	1.310,22	32,69	923,07	2.269,87
Agr. 3. Areas of pastures	0,98	164,12	26,35	0,00	191,45
Agr. 4. Permanent grows	0,01	3,09	3,76	0,00	6,86
Agr. 5. Mixed Crops.	4,49	1.131,31	140,96	0,00	1.276,76
Total Agriculture	**11,02**	**3.347,09**	**273,55**	**4.077,12**	**7.708,78**
Industrial Activities	**0,00**	**0,00**	**0,00**	**159,01**	**159,01**
Land Use Urb. Cont.	0,00	0,00	0,00	0,00	0,00
Land Use Urb. Disc.	0,00	0,07	239,14	189,89	429,10
Total Urban	**0,00**	**0,07**	**239,14**	**189,89**	**429,10**
Rail Roads	0,00	0,22	2,83	0,00	3,06
Roads	5,51	1.068,51	249,73	0,00	1.323,75
Total Infrastructure	**5,51**	**1.068,73**	**252,57**	**0,00**	**1.326,81**
TOTAL	**16,53**	**4.415,89**	**765,25**	**4.426,02**	**9.623,69**

Table 5.7. Results in absolute value for the case study A. Values expressed in points

These values can be translated now to relative values of impact in order to get a better idea when the comparison is made. For now, the total impact on biodiversity is of 9.623,69 points. **Table 5.8**, presents a summary of the relative values obtained after dividing the results for the total impact.

	Aquatic ecotoxicity	Terrestrial ecotoxicity	Terrestrial acid/nutri	Land occupation	Total
Agr. 1. Non-Irrigated arable land	0,02%	7,67%	0,73%	32,77%	41,19%
Agr. 2. Permanent irrigated land	0,04%	13,61%	0,34%	9,59%	23,59%
Agr. 3. Areas of pastures	0,01%	1,71%	0,27%	0,00%	1,99%
Agr. 4. Permanent grows	0,00%	0,03%	0,04%	0,00%	0,07%
Agr. 5. Mixed Crops.	0,05%	11,76%	1,46%	0,00%	13,27%
Total Agriculture	0,11%	34,78%	2,84%	42,37%	80,10%
Industrial Activities	0,00%	0,00%	0,00%	1,65%	1,65%
Land Use Urb. Cont.	0,00%	0,00%	0,00%	0,00%	0,00%
Land Use Urb. Disc.	0,00%	0,00%	2,48%	1,97%	4,46%
Total Urban	0,00%	0,00%	2,48%	1,97%	4,46%
Rail Roads	0,00%	0,00%	0,03%	0,00%	0,03%
Roads	0,06%	11,10%	2,59%	0,00%	13,76%
Total Infrastructure	0,06%	11,11%	2,62%	0,00%	13,79%
TOTAL	0,17%	45,89%	7,95%	45,99%	100,00%

Table 5.8. Relative results for case study A. IMPACT 2002+ methodology

The first graph that can be obtained from the values in previous tables is the impact for each damage category, shown below in **figure 5.7**.

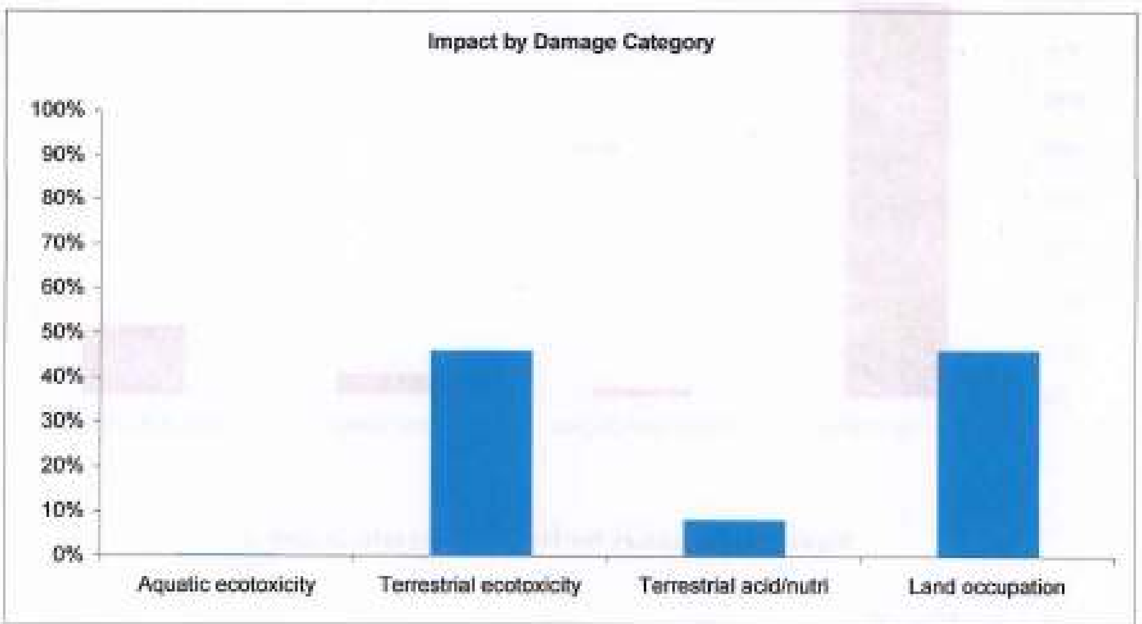

Figure 5.7. Damage Categories relative contribution with Impact 2002+, case study A

If the solution is presented from another side, the contribution of each Impact Category is represented in **figure 5.8**.

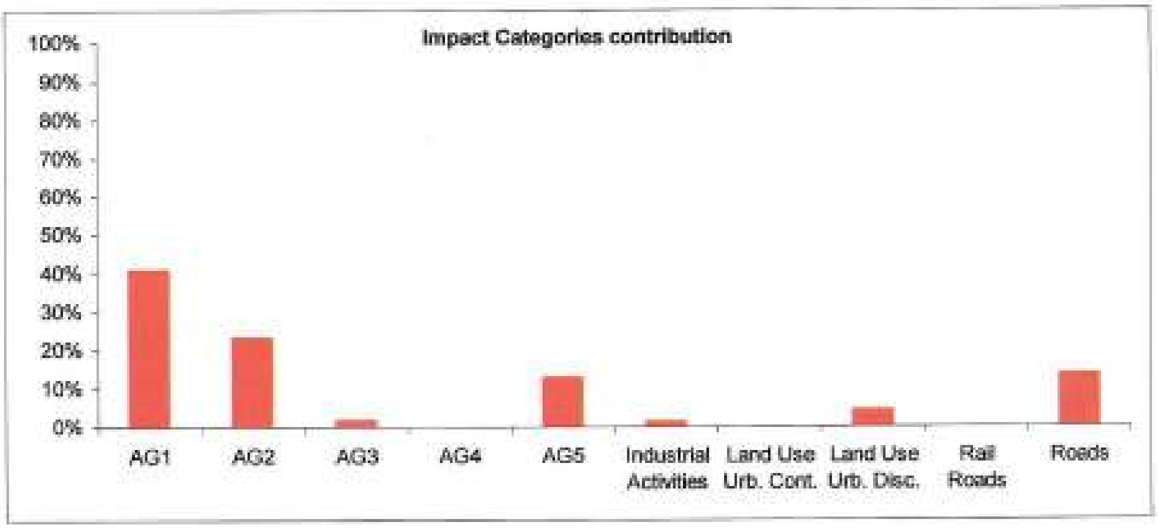

Figure 5.8. Impact Categories contribution in relative values, case study A

Grouping the total values by category, **figure 5.9**, is obtained.

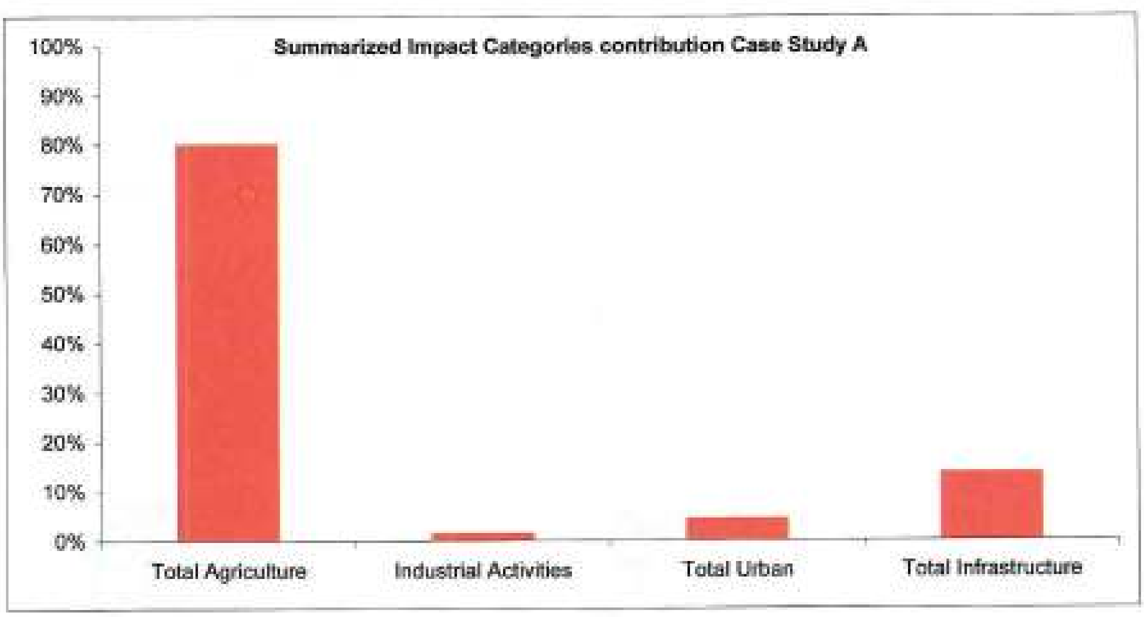

Figure 5.9. Summary for Impact Categories in case A

5.2.2. Case B

The results for case study B are presented in **table 5.9**, as absolute values and then in **table 5.10** as relative values. For case study B the data was set in the same order as in case study A so it can be compared with the other two models.

	Aquatic ecotoxicity	Terrestrial ecotoxicity	Terrestrial acid/nutri	Land occupation	Total
Agr. 1. Non-Irrigated arable land	2,050	919,216	86,879	2.261,576	3.269,72
Agr. 2. Permanent irrigated land	0,000	0,000	0,000	0,000	0,00
Agr. 3. Areas of pastures	0,406	68,143	10,942	2.261,576	2.341,07
Agr. 4. Permanent grows	0,000	0,000	0,000	0,000	0,00
Agr. 5. Mixed Crops.	3,148	793,274	98,838	0,000	895,26
Total Agriculture	**5,60**	**1.780,63**	**196,66**	**4.523,15**	**6.506,05**
Industrial Activities	**61,809**	**186,825**	**175,841**	306,977	**731,45**
Land Use Urb. Cont.	0,001	0,591	1.979,561	0,000	1.980,15
Land Use Urb. Disc.	0,001	0,282	945,603	874,971	1.820,86
Total Urban	**0,00**	**0,87**	**2.925,16**	**874,97**	**3.801,01**
Rail Roads	0,003	0,288	3,690	0,00	3,98
Roads	5,641	1.093,533	255,583	0,00	1.354,76
Total Infrastructure	**5,64**	**1.093,82**	**259,27**	**0,00**	**1.358,74**
TOTAL	**73,06**	**3.062,15**	**3.556,94**	**5.705,10**	**12.397,25**

Table 5.9. Results in absolute value for the case study B. Values expressed in points

	Aquatic ecotoxicity	Terrestrial ecotoxicity	Terrestrial acid/nutri	Land occupation	Total
Agr. 1. Non-Irrigated arable land	0,02%	7,41%	0,70%	18,24%	26,37%
Agr. 2. Permanent irrigated land	0,00%	0,00%	0,00%	0,00%	0,00%
Agr. 3. Areas of pastures	0,00%	0,55%	0,09%	18,24%	18,88%
Agr. 4. Permanent grows	0,00%	0,00%	0,00%	0,00%	0,00%
Agr. 5. Mixed Crops.	0,03%	6,40%	0,80%	0,00%	7,22%
Total Agriculture	**0,05%**	**14,36%**	**1,59%**	**36,49%**	**52,48%**
Industrial Activities	**0,50%**	**1,51%**	**1,42%**	**2,48%**	**5,90%**
Land Use Urb. Cont.	0,00%	0,00%	15,97%	0,00%	15,97%
Land Use Urb. Disc.	0,00%	0,00%	7,63%	7,06%	14,69%
Total Urban	**0,00%**	**0,01%**	**23,60%**	**7,06%**	**30,66%**
Rail Roads	0,00%	0,00%	0,03%	0,00%	0,03%
Roads	0,05%	8,82%	2,06%	0,00%	10,93%
Total Infrastructure	**0,05%**	**8,82%**	**2,09%**	**0,00%**	**10,96%**
TOTAL	**0,59%**	**24,70%**	**28,69%**	**46,02%**	**100,00%**

Table 5.10. Relative results for case study B. IMPACT 2002+ methodology

The impact for each Damage Category is shown in **figure 5.10.**

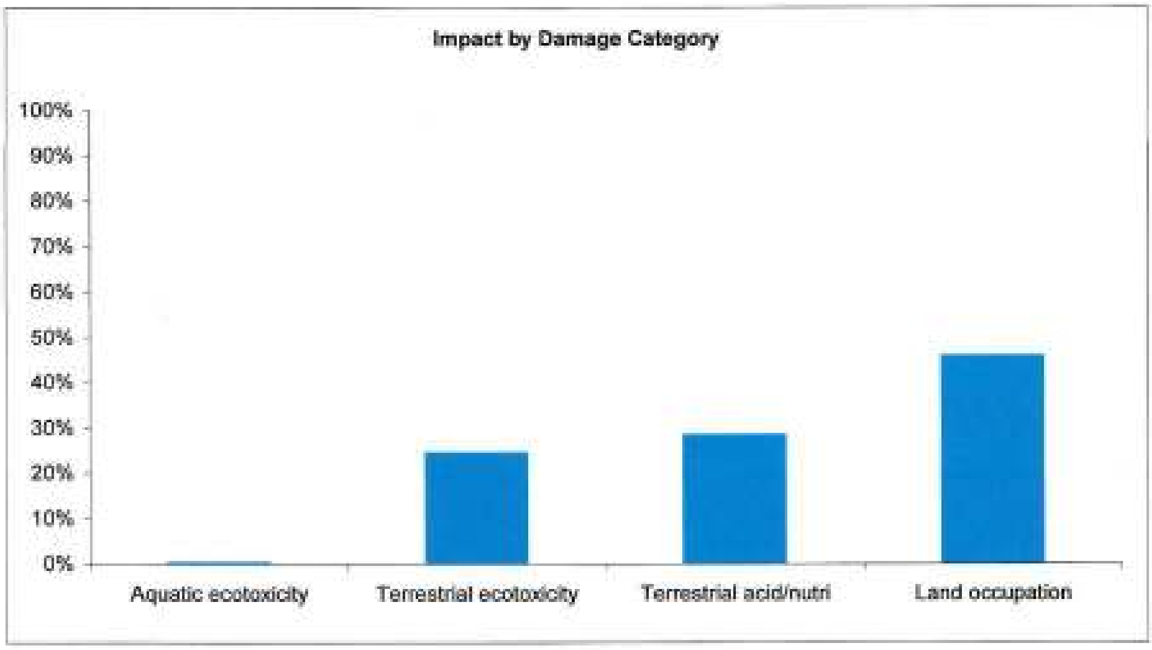

Figure 5.10. Damage Categories relative contribution with Impact 2002+, case study B

Then, each impact category contribution is shown in **figure 5.11**, and the summarized version in **figure 5.12**.

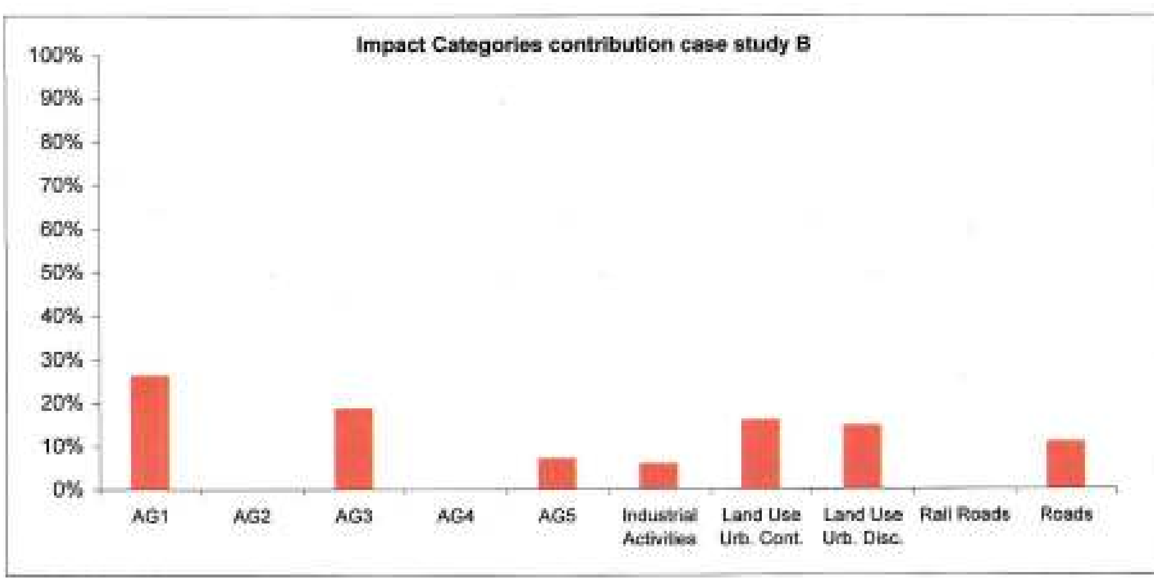

Figure 5.11. Impact Categories contribution in relative values, case study B

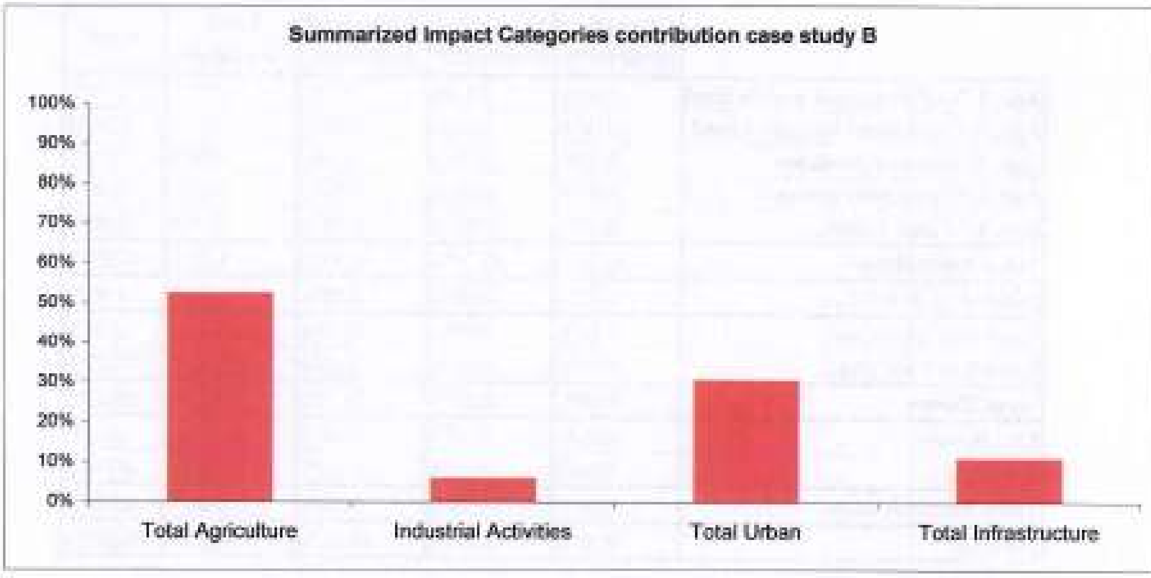

Figure 5.12. Summary for Impact Categories in case B

5.2.3. Case C

Results for case study C, using the IMPACT 2002+ Methodology are presented in the same way that for the two previous cases. First, **table 5.11**, and **table 5.12** show the absolute and relative results applying the methodology and then **figure 5.13**, and **figure 5.14** show the impact either for each Damage Category than for each Impact Category. Finally, **figure 5.15** shows the summarized version for each one of the impact categories.

	Aquatic ecotoxicity	Terrestrial ecotoxicity	Terrestrial acid/nutri	Land occupation	Total
Agr. 1. Non-Irrigated arable land	0,263	118,041	11,157	133,481	262,94
Agr. 2. Permanent irrigated land	0,000	0,000	0,000	0,000	0,00
Agr. 3. Areas of pastures	0,364	60,974	9,791	0,000	71,13
Agr. 4. Permanent grows	0,000	0,000	0,000	0,000	0,00
Agr. 5. Mixed Crops.	12,468	3.142,110	391,492	0,000	3.546,07
Total Agriculture	13,09	3.321,12	412,44	133,48	3.880,14
Industrial Activities	1,869	0,000	0,000	200,516	202,39
Land Use Urb. Cont.	0,000	0,000	0,000	0,000	0,00
Land Use Urb. Disc.	0,000	0,167	560,687	1.583,808	2.144,66
Total Urban	0,00	0,17	560,69	1.583,81	2.144,66
Rail Roads	0,002	0,210	2,695	0,00	2,91
Roads	8,294	3.682,447	554,406	0,00	4.245,15
Total Infrastructure	8,30	3.682,66	557,10	0,00	4.248,05
TOTAL	23,26	7.003,95	1.530,23	1.917,80	10.475,24

Table 5.11. Results in absolute value for the case study C. Values expressed in points

	Aquatic ecotoxicity	Terrestrial ecotoxicity	Terrestrial acid/nutri	Land occupation	Total
Agr. 1. Non-Irrigated arable land	0,00%	1,13%	0,11%	1,27%	2,51%
Agr. 2. Permanent irrigated land	0,00%	0,00%	0,00%	0,00%	0,00%
Agr. 3. Areas of pastures	0,00%	0,58%	0,09%	0,00%	0,68%
Agr. 4. Permanent grows	0,00%	0,00%	0,00%	0,00%	0,00%
Agr. 5. Mixed Crops.	0,12%	30,00%	3,74%	0,00%	33,85%
Total Agriculture	**0,13%**	**31,70%**	**3,94%**	**1,27%**	**37,04%**
Industrial Activities	**0,02%**	**0,00%**	**0,00%**	**1,91%**	**1,93%**
Land Use Urb. Cont.	0,00%	0,00%	0,00%	0,00%	0,00%
Land Use Urb. Disc.	0,00%	0,00%	5,35%	15,12%	20,47%
Total Urban	**0,00%**	**0,00%**	**5,35%**	**15,12%**	**20,47%**
Rail Roads	0,00%	0,00%	0,03%	0,00%	0,03%
Roads	0,08%	35,15%	5,29%	0,00%	40,53%
Total Infrastructure	**0,08%**	**35,16%**	**5,32%**	**0,00%**	**40,55%**
TOTAL	**0,22%**	**66,86%**	**14,61%**	**18,31%**	**100,00%**

Table 5.12. Relative results for case study C. IMPACT 2002+ methodology

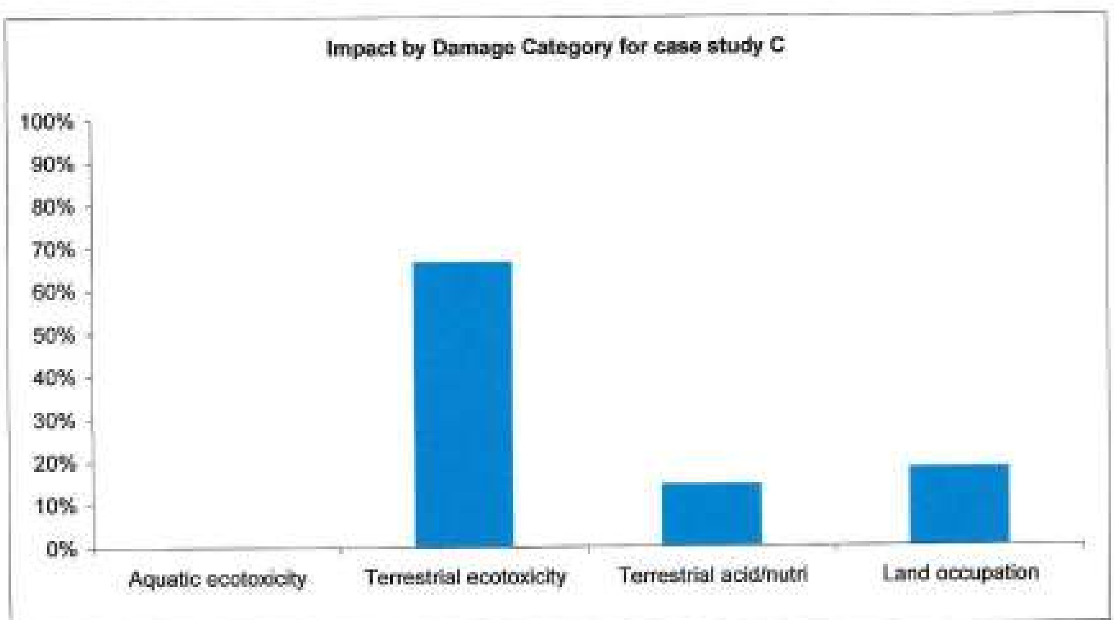

Figure 5.13. Damage Categories relative contribution with Impact 2002+, case study C

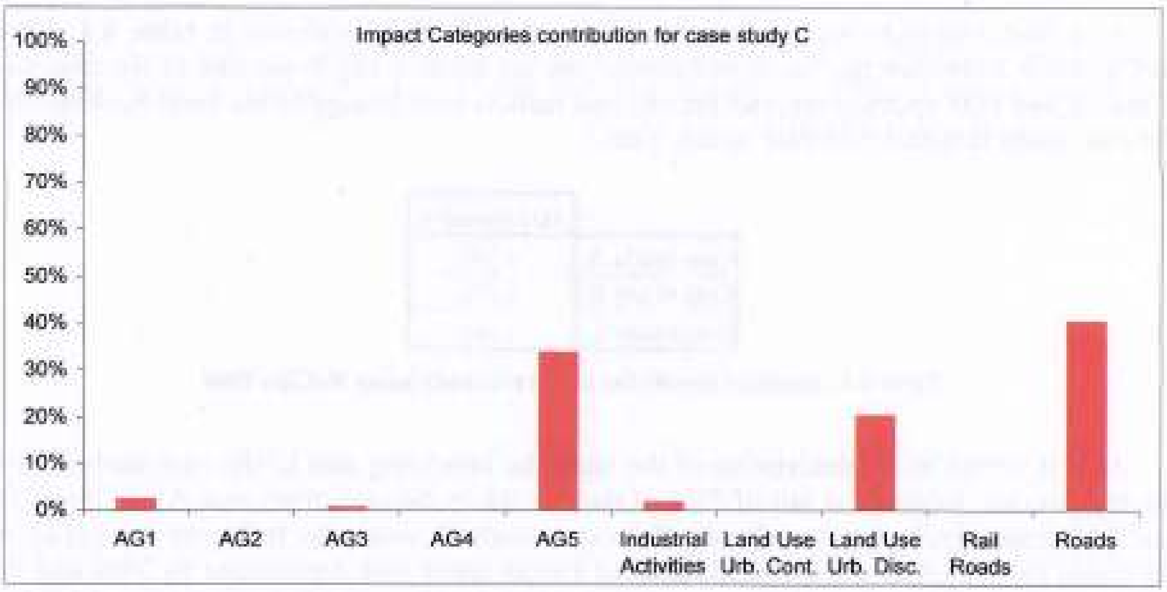

Figure 5.14. Impact Categories contribution in relative values, case study C

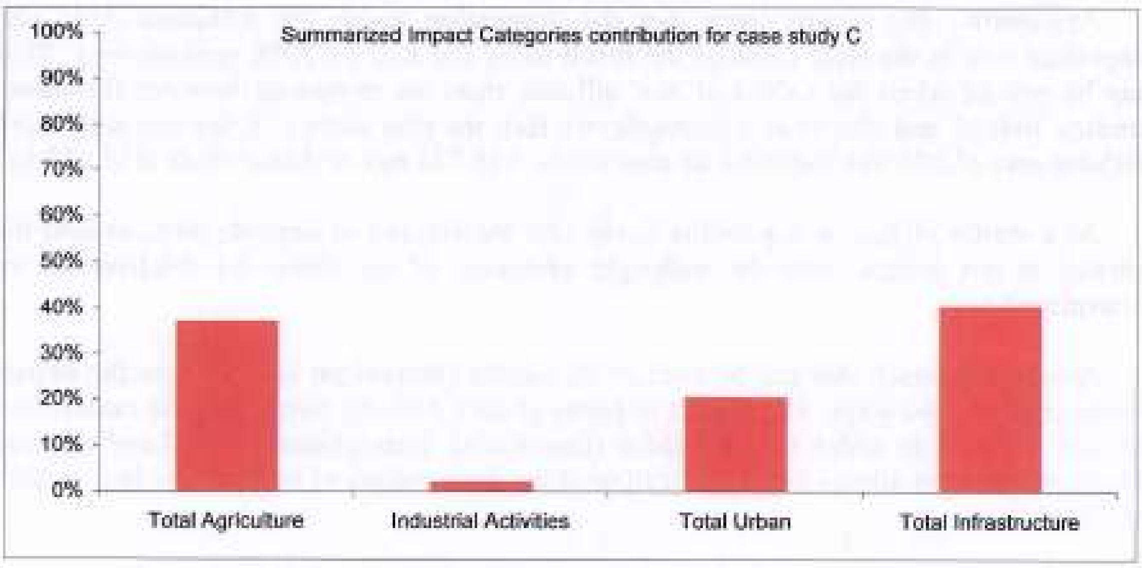

Figure 5.15. Summary for Impact Categories in case C

6. *ANALISYS*

This chapter has the same structure as Chapter Five. In first place, the ReCipe 2008 results are compared between the sites, then each IMPACT 2002+ applied to each case study, and finally the comparison between methodologies is shown to describe the differences between them and the reasons for the difference between methodologies.

6.1. ReCipe 2008 results comparison

As a first approach, the total results are compared. As it is shown in **table 6.1**, for the ReCipe2008 methodology, the most harmful site for biodiversity is the one of the case study C with 1,440 PDF specie·year, and the site that inflicts less damage to the local biodiversity is the case study B with 1,230 PDF specie·year.

	PDF specie·y
Case Study A	1,295
Case Study B	1,230
Case Study C	1,440

Table 6.1. Absolute results for each case study using ReCipe 2008

As it is shown in the description of the sites, the impacting area of the case study C is not the biggest one, indeed it is just of 73% of the PA, while the ones from case A and B are 75% and 78% respectively. On the other hand for case study C, inside the Influence Area (IA), it is clear that the land use is distributed between Urban fabric and Agriculture by 29% and 50% respectively, while in the other cases there is a predominance of the agricultural land use inside the Influence Area circle.

Apparently, this results show that the occupation inside the Influence Area play an important role in the final value of the result using the ReCipe 2008 methodology. This fact can be proved when the values of non influent areas are compared between the three case studies. Indeed, and almost as a contradictory fact, the case study C is the one with more non influent area (7.624 ha), followed by case study A (5.773 ha), and case study B (5.517 ha).

As a matter of fact, it is possible to say that the amount of sensible areas around the site studied is not related with the anthropic pressures or the threat for biodiversity in that determined zone.

Another approach that can be used in the results comparison is to analyse the impacts on biodiversity in two ways. The impact in terms of each Driving Force, and the impact in terms of each category in which this is divided (Ecotoxicity, Eutrophication and Land occupation). This segmentation allows the identification of the main causes of biodiversity loss in the areas analysed.

The **table 6.2**, shows the Driving Forces impact contribution for each one of the cases. For all of them is clear that the impact due to agriculture is clearly important. In fact, for the three cases it represents more than half of the total value. Moreover, in the three case studies, the second most important Driving Force is the Urban Land (grouping emissions and land occupation), then the industry and finally the infrastructure impact.

SUMMARY TABLE FOR DRIVING FORCES				
	Agriculture	Industrial	Infrastructure	Urban
Case A	91,124%	3,900%	0,113%	4,862%
Case B	80,042%	4,828%	0,770%	14,361%
Case C	61,070%	5,311%	2,296%	31,323%

Table 6.2. Driving Forces comparison for the ReCipe 2008 methodology

However, this data alone is not useful at all because it does not take into account the land distribution for each case study. As a consequence, **table 6.3**, shows a combination between the distribution of the impact according to the Driving Force and the land distribution presented in the fourth chapter (**table 4.11**, section 4.4).

		Driving Force Impact in %	Occupied portion of PA %	Influent area
Case study A	**Agriculture**	91,2%	68,7%	74,7%
	Industrial	3,9%	1,1%	
	Urban	4,8%	54,9%	
Case Study B	**Agriculture**	80,0%	55,1%	78,2%
	Industrial	4,8%	2,0%	
	Urban	14,4%	21,2%	
Case Study C	**Agriculture**	61,1%	61,4%	72,6%
	Industrial	5,3%	1,2%	
	Urban	31,3%	10,0%	

Table 6.3. Comparison between land occupation (PA) and impact given the Driving Forces

In case study C, it is shown that the impact due to agriculture represents 61% of the total impact, while in case A (which has 68,7% of agricultural area), the impact due to this Driving Force goes over 90%. This difference is explainable for the different agriculture types in the case studies. Indeed, this difference is seen in **table 6.4**, which shows the direct comparison between the different areas in each case study.

	Case Study A		Case Study B		Case Study C	
	Influence Area (IA)	Pressure Area (PA)	Influence Area (IA)	Pressure Area (PA)	Influence Area (IA)	Pressure Area (PA)
Agr. 1. Non-Irrigated arable land	3.757	6.267	2.694	7.803	159	1.002
Agr. 2. Permanent irrigated land	1.100	3.323	0	0	0	0
Agr. 3. Areas of pastures	306	560	1.063	2.322	71	208
Agr. 4. Permanent grows	0	105	0	0	0	0
Agr. 5. Mixed Crops.	1.226	5.421	991	3.801	3.735	15.056
AGRICULTURAL LAND TOTAL	**6.389**	**15.676**	**4.748**	**13926**	**3.965**	**16.266**
Industry - industrial Areas	**259**	**259**	**501**	**501**	**327**	**327**
Inf. 1. Railroads	-	26	-	34	-	25
Inf. 2. Roads	-	449	-	459	-	689
Urb. 1, Continuous urban fabric	0	0	0	903	0	0
Urb. 2. Discontinuous urban fabric	271	1.125	1.249	4.447	2.260	2.637
TOTAL URBAN AREA	**271**	**1125**	**1249**	**5350**	**2.260**	**2.637**
TOTAL AREA	**6.919**	**16.801**	**6.498**	**19.276**	**6.552**	**18.903**
All values reported in hectares (ha)						

Table 6.4. Direct area comparison between the three case studies (ReCipe 2008)

Another issue that can be analysed is the Urban Occupation and the impact due to this Driving Force. In case study B the Urban occupation is 21%, but its total impact (counting emissions and land occupation), represents 14,32% of the total impact. In the other hand, in case C, the urban occupation is 10% of the total area, but its impact goes over 30% of the total.

These results are crucial because they show that even if the values obtained after applying the methodology are close for the three case studies, they differ widely because their causes are different in each case. For instance, in case A is almost all given by the impact of agriculture; for case B is a mix between agriculture and urban impact, and for case C happens the same thing but with a different mix of contributions.

The result of this comparison is shown in **figure 6.1**, which is a contribution diagram for each one of the case studies analysed in this document.

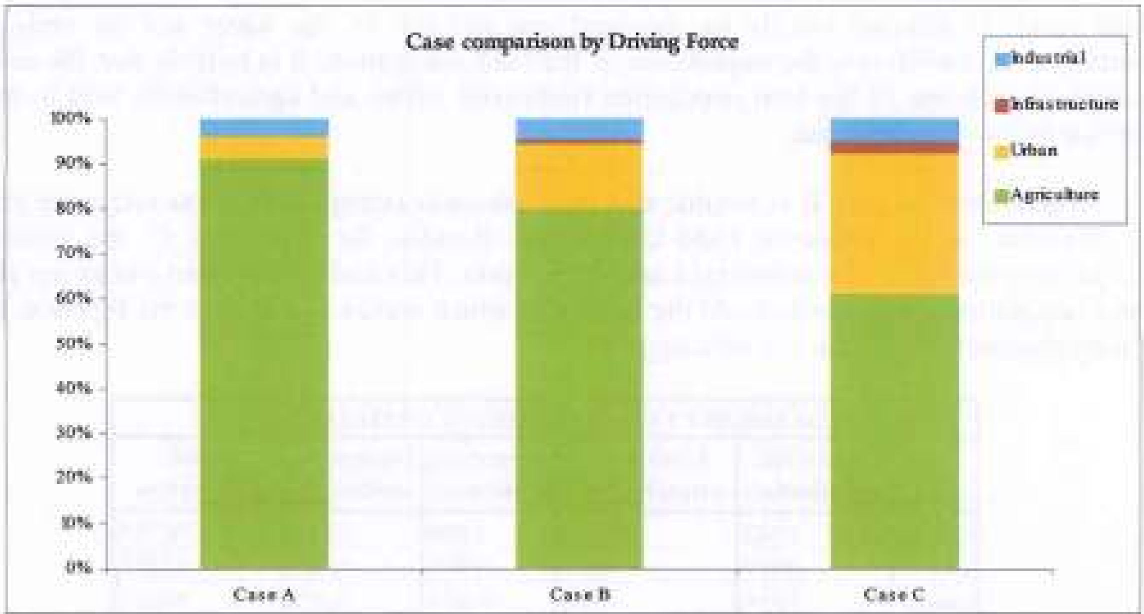

Figure 6.1. Contribution of each Driving Force for each case study analysed

It is clear that at least for the ReCipe 2008 methodology, and for the 3 case studies shown, the impact due to the industries is not the more representative because in any of the cases it exceeds the 6% of the total contribution. However it is notable that even if the occupation proportion is similar, the impacts are very different. Thus, it is strong evidence that the industrial processes can vary drastically with the emissions variation for each site.

In second place, the impact categories classification is shown in order to understand which part of the environment is more damaged for the process that are made inside the study area of each one of the cases. **Table 6.5**, shows the distribution of each one of these effects due to Impact Categories.

SUMMARY TABLE FOR IMPACT CATEGORIES							
	Terrestrial acidification	Freshwater eutrophication	Terrestrial ecotoxicity	Freshwater ecotoxicity	Agricultural land occupation	Industrial land occupation	Urban land occupation
Case A	1,34%	0,01%	1,88%	0,01%	88,85%	3,86%	4,04%
Case B	0,01%	6,92%	0,01%	0,00%	65,61%	7,84%	19,58%
Case C	3,25%	0,01%	13,20%	0,02%	48,83%	4,39%	30,29%

Table 6.5. Impact Categories comparison for the three case studies with the ReCipe 2008 methodology

After analysing the table is clear that the Agricultural Land Occupation (ALO) is the most important factor despite the place or the type of growth in the area. However it is important to observe that the Urban Land Occupation also weights in an important way for the case studies B and C.

Now, given that the Agriculture is the most important Driving Force that contributes to the final index, and that the ALO is the most important Impact Category, it is clear that the final result is affected mostly by the land use and not by the water and air emissions. Furthermore, confirming the importance of the land occupation, it is notable that the relative values of each one of the land occupation (industrial, urban and agricultural), tend to be the highest values for each case.

Nevertheless, in case B is notable that the freshwater eutrophication has relevance almost as important as the Industrial Land Occupation. Besides, for case study C, the Terrestrial Ecotoxicity overtakes the Industrial Land Occupation. This leads the initiative to group all the land occupation categories to build the **table 6.6**, which serves as a base to the **figure 6.2** that shows the relevance of the impact categories.

SUMMARY TABLE FOR IMPACT CATEGORIES					
	Terrestrial acidification	**Freshwater eutrophication**	**Terrestrial ecotoxicity**	**Freshwater ecotoxicity**	**Land Occupation**
Case A	1,34%	0,01%	1,88%	0,01%	96,75%
Case B	0,01%	6,93%	0,01%	0,00%	93,05%
Case C	3,25%	0,01%	13,20%	0,02%	83,51%

Table 6.6. Impact Category summary table. Aggregated land occupation

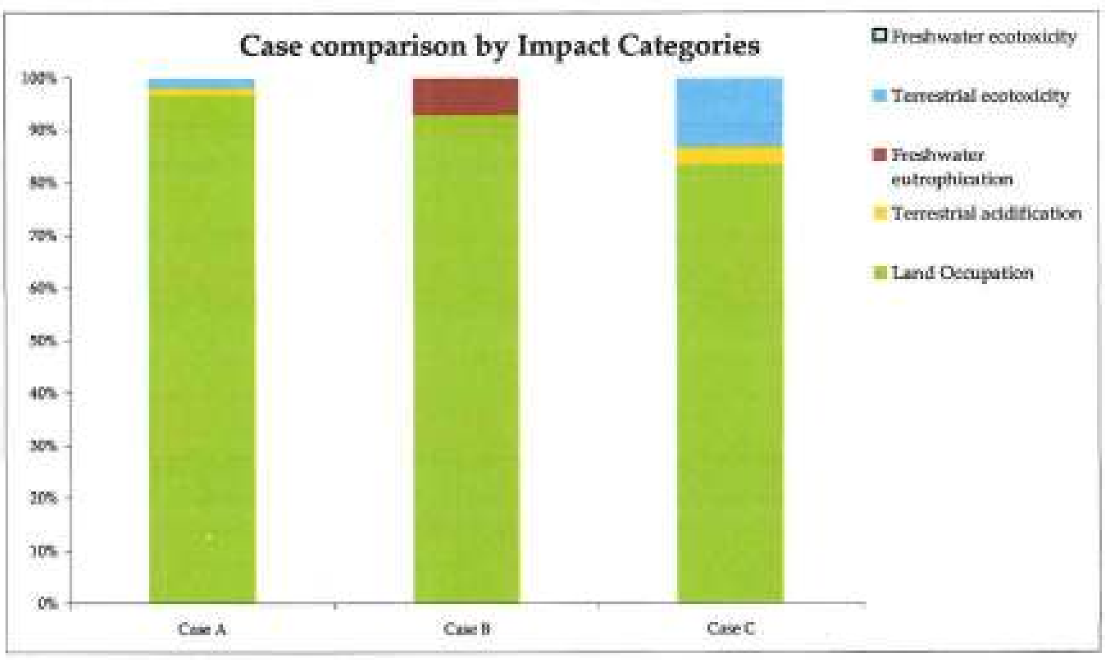

Figure 6.2. Contribution graphic for the Impact Categories effects

As it is seen in the figure, there are four main Impact Categories that are more important than the others. In first place, the land occupation, far behind, Terrestrial ecotoxicity and acidification, and last but not least the freshwater eutrophication.

6.2. Impact 2002+ results comparison

The IMPACT 2002+ results show a different panorama than the ones presented for ReCipe 2008. Indeed, the absolute results show that the most harmful case for biodiversity is not case study C, but case study B. These results are shown in **table 6.7**. In fact, it is interesting the fact that the results vary for the two methodologies. For the IMPACT 2002+, the most harmful case study would be case B, followed by case C, and the less harmful case is A.

	Points
Case Study A	9.623,69
Case Study B	12.397,25
Case Study C	10.475,24

Table 6.7. Absolute results for each case study using IMPACT 2002+

Studying the case study B is clear that this is the site that has more influent area in relative values than the other two sites. 78% for case B, 75% for the case study A, and 73% for the site C. All the values are referred to the Pressure Area, presenting the complete surface of each one of the case studies.

As a consequence, it is possible to say that at least for the three case studies presented, the amount of influent area is important for the IMPACT 2002+ methodology, and as the land occupation grows, the pressure index will grow too.

The results for the application of the IMPACT 2002+ methodology are presented in two comparative tables (**table 6.8** and **table 6.9**), leading to the construction of two contribution graphics that show the contrast between the three different case studies analysed in this document.

	Aquatic ecotoxicity	Terrestrial ecotoxicity	Terrestrial acid/nutri	Land occupation
Case Study A	0,17%	45,89%	7,95%	45,99%
Case Study B	0,59%	24,70%	28,69%	46,02%
Case Study C	0,22%	66,86%	14,61%	18,31%

Table 6.8. Comparison between the relative impacts of each midpoint category (IMPACT 2002+)

	Total Agriculture	Industrial Activities	Total Urban	Total Infrastructure
Case Study A	80,10%	1,65%	4,46%	13,79%
Case Study B	52,48%	5,90%	30,66%	10,96%
Case Study C	37,04%	1,93%	20,47%	40,55%

Table 6.9. Comparison between Impact Categories contribution (IMPACT 2002+)

Figure 6.3 shows the comparison between the Impact Categories impact on each case study. As it can be proved the distribution gives less weight to the land occupation category, contrary to what is shown in the ReCipe2008 methodology application.

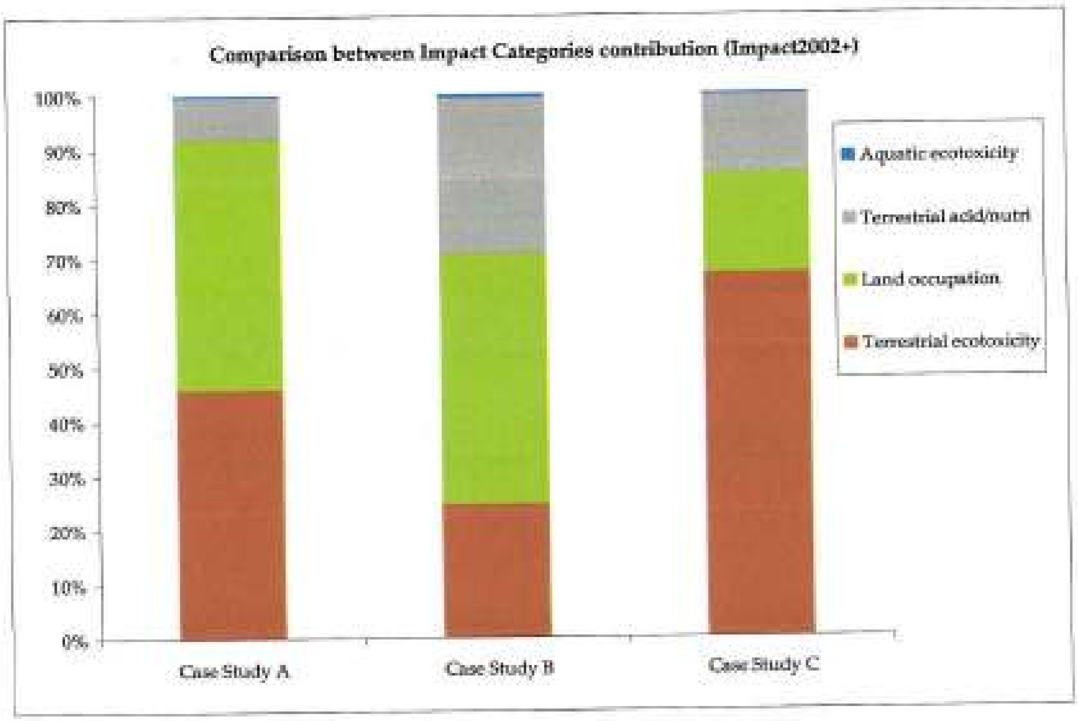

Figure 6.3. Impact category comparison, IMPACT 2002+ methodology

When the data is analysed from the perspective of the Midpoint Categories, the **figure 6.4**, serves as a simple comparison, taking into account all the four factors that the methodology takes into account.

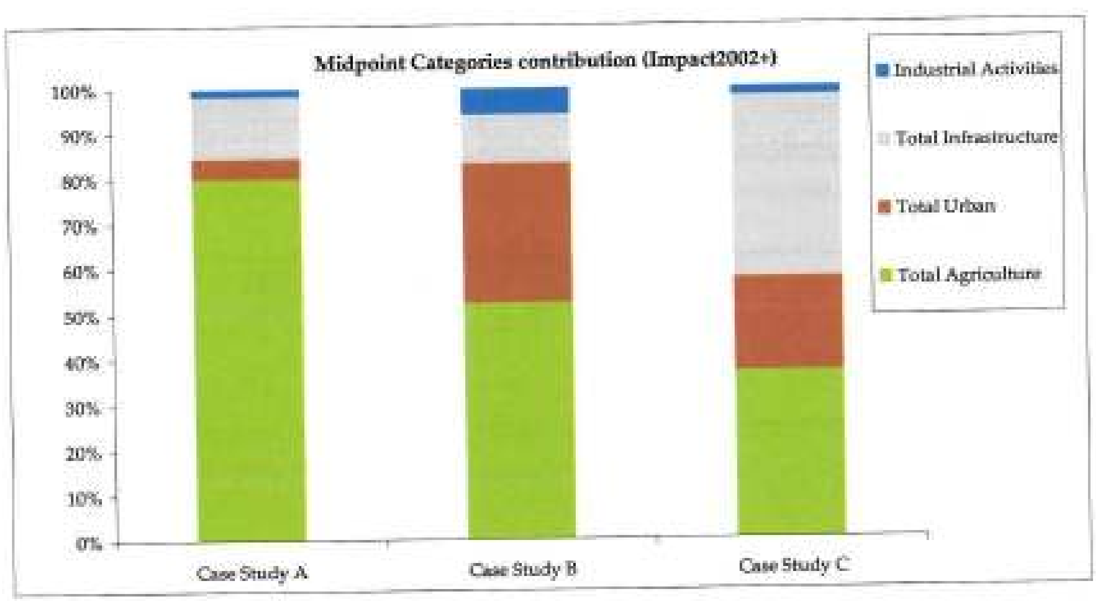

Figure 6.4. Midpoint Categories comparison using IMPACT 2002+

The comparison between the area occupied by each midpoint and its relative impact using the described methodology can be made again in this case, giving as a result the data shown in **table 6.10** below.

		Driving Force Impact on %	Portion of land occupied %	Influent area
Case study A	Agriculture	80,1%	68,7%	74,7%
	Industrial	1,7%	1,1%	
	Urban	4,5%	4,9%	
	Infrastructure (km)	13,8%	475	
Case Study B	Agriculture	52,5%	55,1%	78,2%
	Industrial	5,9%	2,0%	
	Urban	30,7%	21,2%	
	Infrastructure (km)	11,0%	493	
Case Study C	Agriculture	37,0%	61,4%	72,6%
	Industrial	1,9%	1,2%	
	Urban	20,5%	10,0%	
	Infrastructure (km)	40,55%	714	

Table 6.10. Direct area comparison between the three case studies (IMPACT 2002+)

The table above shows clearly that at least for the agricultural case, the impact goes up while the occupation does too. In fact, if there is a considerable portion of land occupied with agriculture, as in case A (68,7%), there is a considerable impact due to this Driving Force (80,1%).

Furthermore, the amount of infrastructure inside the area of study seems to have a relevant meaning. This will be proved when the methodologies are compared head to head. For now, it can be seen that the case with more gross infrastructure, which is case study C, has a 40,55% influence due to this Driving Force. Indeed, in this case study the infrastructure overwhelms the agriculture in contribution to the total value of the pressure index. The case should be revised carefully since it is the only one in which this kind of result happen even counting the ReCipe 2008 results.

However, in cases like the Industrial contribution to the index, it is not clear how it contributes to the final value. This happens again, because the contribution of this specific Driving Force is determined by the emissions of the different sites of the studied area, and in the cases presented, the emissions are quite different.

6.3. Methodology comparison

Firstly, it is interesting to analyse the main results of the methodologies used for the case studies. In the case of the ReCipe 2008 methodology, the most harmful case study for biodiversity is C, followed by case A and the less harmful is case B. On the other hand, for the IMPACT 2002+ methodology, the most harmful case study for biodiversity is case B, followed by case C and the last in this order is case A. **Table 6.11** shows the absolute results for each one of the methodology.

	ReCipe 2008 (BLP)	IMPACT 2002+ (Points)
Case Study A	1,295	9.623,690
Case Study B	1,230	12.397,250
Case Study C	1,440	10.475,240

Table 6.11. Comparison between methodology results

Going on with the comparison, and highlighting the differences in the results, it is interesting to observe the contribution on each Driving Force to the total result. Indeed, this relative values are quite different between both methodologies. **Table 6.12** shows the difference between each Driving Force considered for the study.

	Total Agriculture		Industrial Activities		Total Urban		Total Infrastructure	
	ReCipe2008	IMPACT 2002+	ReCipe2008	IMPACT 2002+	ReCipe2008	IMPACT 2002+	ReCipe2008	IMPACT 2002+
Case Study A	91,20%	80,10%	3,90%	1,65%	4,86%	4,46%	0,11%	13,79%
Case Study B	80,04%	52,48%	4,83%	5,90%	14,36%	30,65%	0,77%	10,96%
Case Study C	61,07%	37,04%	5,31%	1,93%	31,32%	20,47%	2,30%	40,55%

Table 6.12. Comparative values between Driving Forces for each methodology

As another interesting issue, these contributions to the index values can be compared again with the land occupation described in chapter four. **Table 6.13** shows a summary of the information given in tables 6.3 and 6.10.

		Portion of land occupied %	DF Values for IMPACT 2002+	DF Value for ReCipe 2008	Non influent area
Case study A	Agriculture	68,7%	80,1%	91,2%	74,7%
	Industrial	1,1%	1,7%	3,9%	
	Urban	4,9%	4,5%	4,8%	
	Infrastructure (km)	475	13,8%	0,11%	
Case Study B	Agriculture	55,1%	52,5%	80,0%	78,2%
	Industrial	2,0%	5,9%	4,8%	
	Urban	21,2%	30,7%	14,4%	
	Infrastructure (km)	493	11,0%	1,27%	
Case Study C	Agriculture	61,4%	37,0%	61,1%	72,6%
	Industrial	1,2%	1,9%	5,3%	
	Urban	10,0%	20,5%	31,3%	
	Infrastructure (km)	714	40,6%	2,3%	

Table 6.13. Summarized comparison between driving forces and land occupation

As shown in the table above, for case A and B the most important Driving Force that contributes to the final value of the index is the agriculture, using both methodologies.

However, for case C the most determinant is the Infrastructure, when using IMPACT 2002+. In fact, it is interesting to observe that the impact of the Infrastructure changes considerably in all the case studies between both methodologies. From a 0,11% in case A using ReCipe 2008, it goes up to 13,8% when using the IMPACT 2002+ methodology. It means, about one hundred times the first value. This situation does not change for the other case studies, indeed, for case B the contribution of Infrastructure goes up almost ten times between methodologies, while in case C this relation is almost 20 times.

Besides, it is interesting the fact that the methodology IMPACT 2002+ seems to reduce the relevance of the contribution that has the agriculture in all the cases. As a matter of fact, for case A there is a reduction of 10%, in case B it goes almost to 28% and finally for case C it goes to 24,1%.

The graphic comparison between the case studies is shown in **figure 6.5**, for case A, **figure 6.6**, for case B, and **figure 6.7**, for case study C.

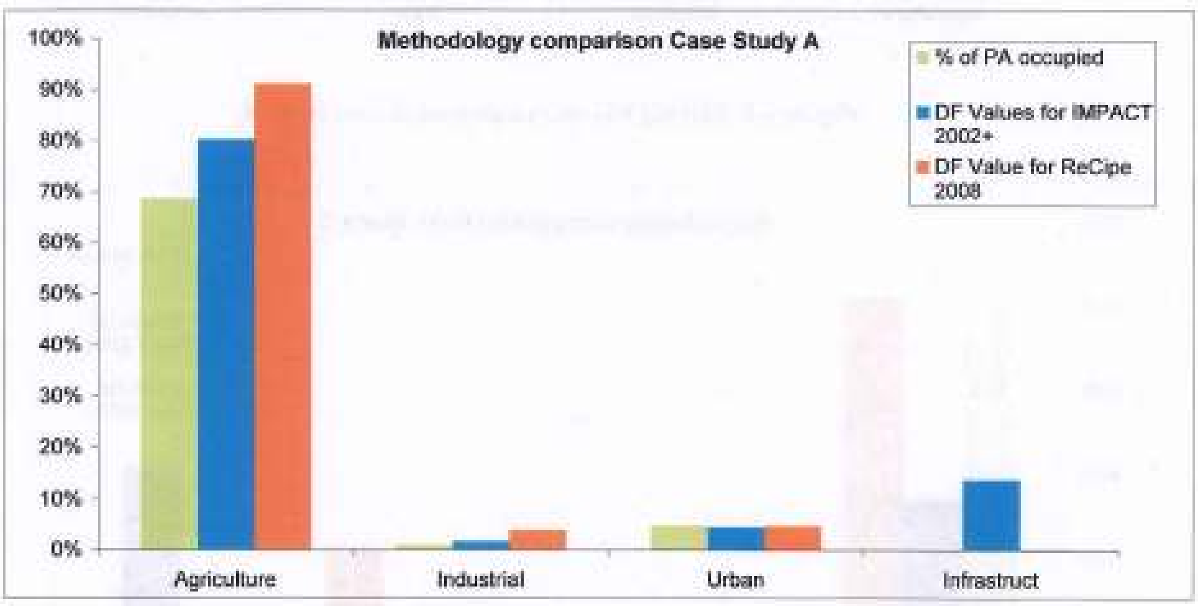

Figure 6.5. Driving forces comparison for case study A

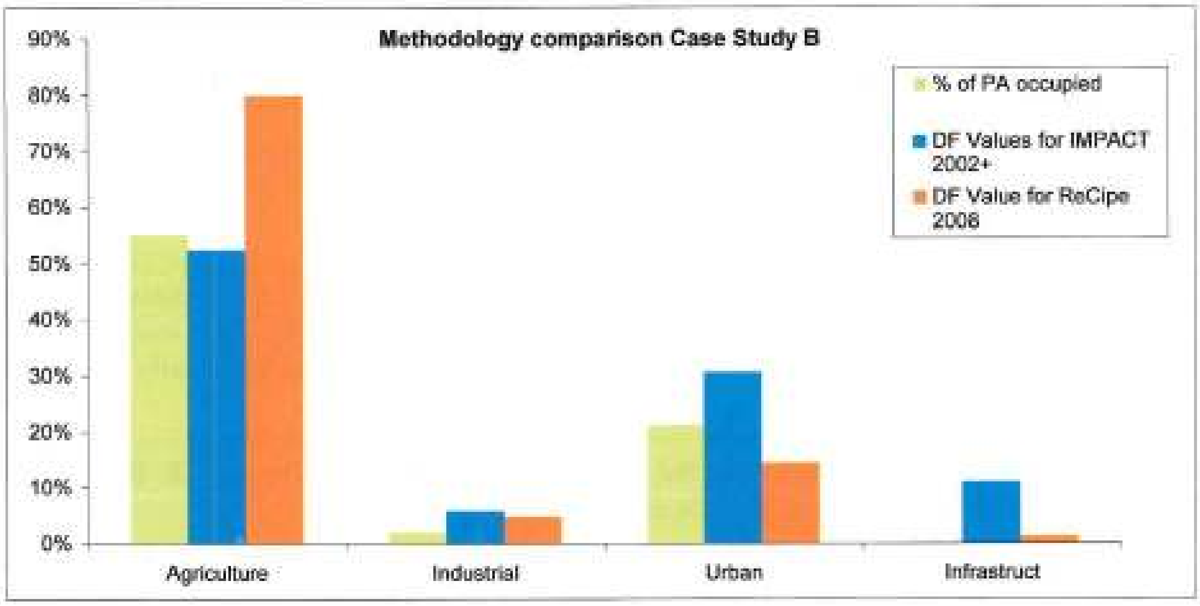

Figure 6.6. Driving Forces comparison in case study B

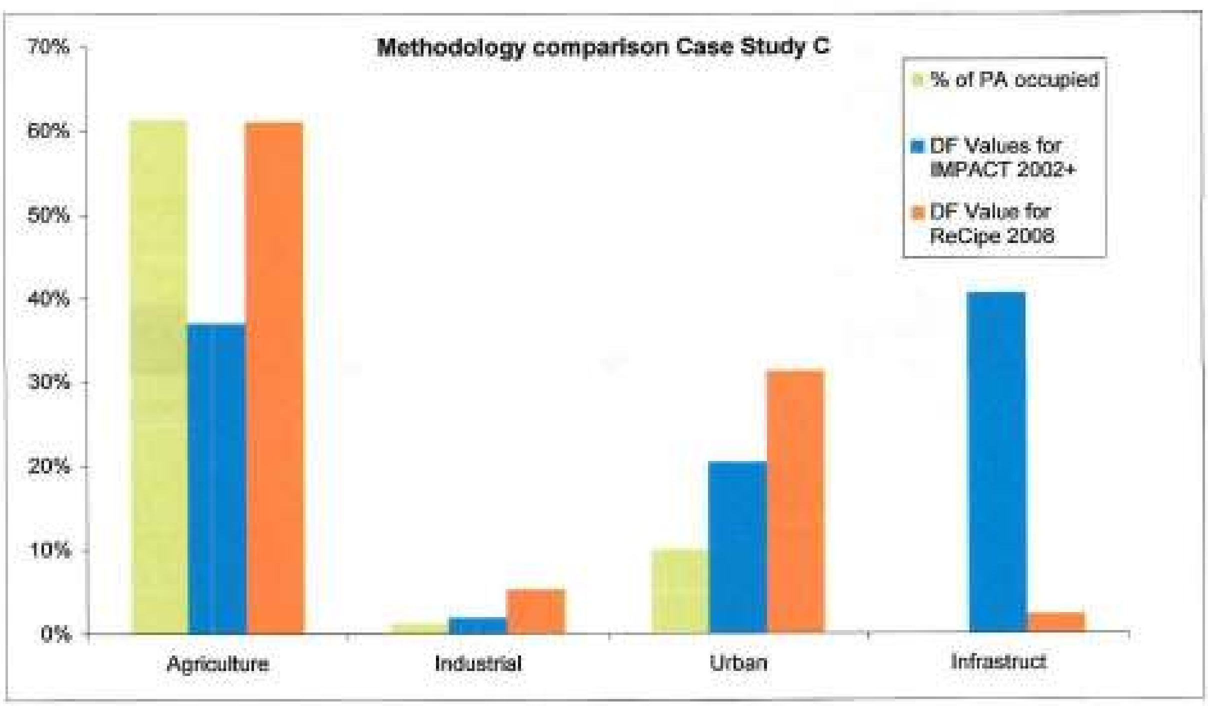

Figure 6.7. Driving Forces comparison for case study C

On the other hand, the Driving Force relative to the industrial activities changes less than the categories mentioned before. The maximum change observed is the case study C in which a change of 3,38% is observed. Now, the industrial Driving Force contribution can be understood as the most variable one. However, this variation can be explained as the industrial emissions for each case study are substantially different. Thus, the industrial contribution comparison in the case A shows that when running the ReCipe methodology, the result is bigger than the one obtained when running the IMPACT 2002+ methodology.

It is clear that the IMPACT 2002+ methodology gives more relevance to the presence of Agriculture, Urban areas and Infrastructure, while the ReCipe 2008 focuses its method in the Agricultural Driving Force. Indeed, for the three case studies the contribution of this Driving Force is always superior to 50%, while in the other categories there is just one time that go over the 20%.

Another interesting comparison is the weight attribution of the Impact Categories. Since the categories vary from one methodology to another, those are grouped into pressures and land occupation. This means that with this comparison the reader is able to recognize the weight of the land occupation against the one from the pressures generated on biodiversity. **Table 6.14** shows the relative results for each one of the methodologies used in each one of both cases.

	Land Occupation		Pressures	
	ReCipe2008	IMPACT2002+	ReCipe2008	IMPACT2002+
Case Study A	96,75%	45,99%	3,25%	54,01%
Case Study B	93,05%	46,02%	6,95%	53,98%
Case Study C	83,51%	18,31%	16,49%	81,69%

Table 6.14. Comparison between impact categories in each methodology

The first impression of the table above is that the ReCipe methodology gives absolute relevance to the land occupation factor, while for IMPACT 2002+, there is a more balanced distribution. Indeed, every result given by ReCipe 2008 shows more than 80% of influence in the Land Occupation category. Instead, the IMPACT 2002+ methodology shows that in general pressures (emissions), are more important than the land use.

In fact, for the table results in case C there is a contribution of 81,69% due to pressures, then, case study A shows a pressure contribution of 54,01% and finally, for case study B the emissions contribution is of 53,98%. As a general rule the pressures are more important for the IMPACT 2002+ methodology than for the ReCipe 2008.

Figure 6.8 shows the comparison between the values shown in the table above. Clearly, the results shown by the IMPACT 2002+ methodology are way more balanced than the ones showed by ReCipe 2008. The green bars show the results for the methodology used by the company (ReCipe 2008), and the blue bars show the results obtained by IMPACT 2002+. Besides, the dotted bars show the results for land occupation, while striped bars show the gross results for the pressures.

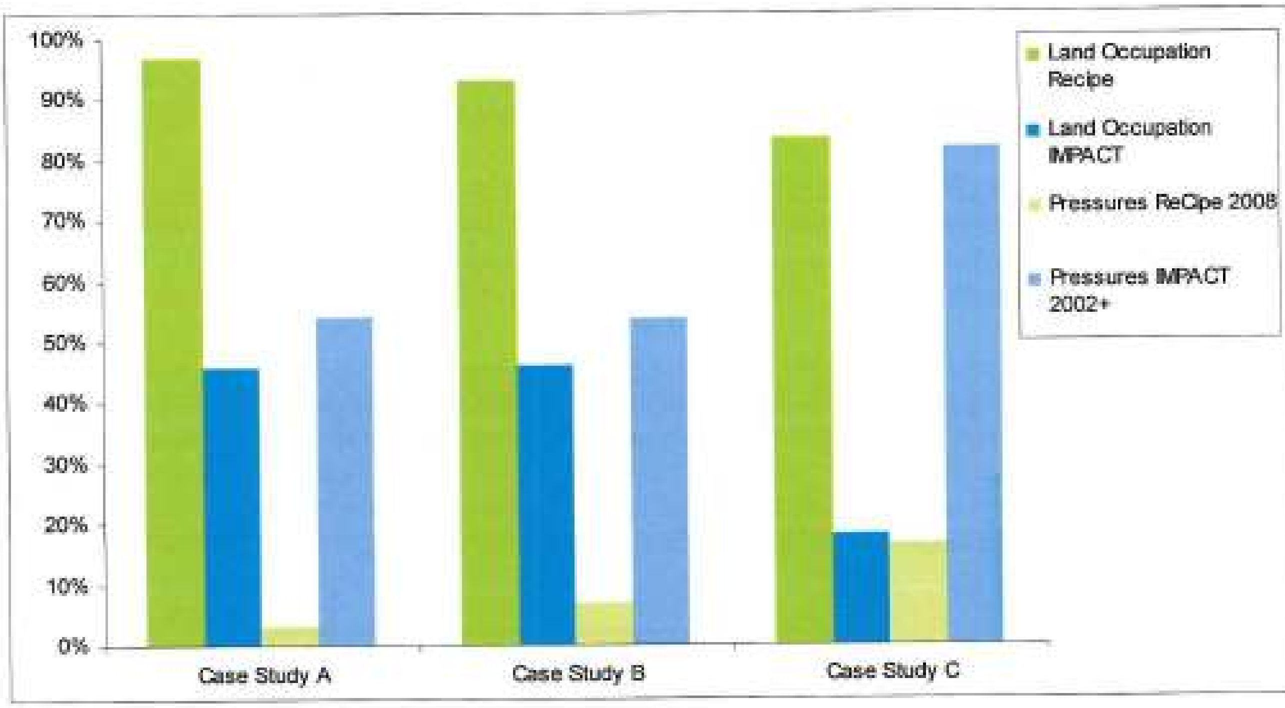

Figure 6.8. Gross comparison between both methodologies. Land Occupation and Pressures considered

7. CONCLUSIONS

The validation of the methodology used by Studio Fieschi for the evaluation of anthropic pressures on the different sites using the three methodologies selected (GLOBIO3, IMPACT 2002+ and ReCipe 2008), lead to the following statements that should be taken into account for further investigation and to complement the works done.

As a first approach, the methodology GLOBIO3 is not applicable to the work done by the company since it is a methodology that has already taken into account all the pressures and works in a frame that is too big to the scale needed for the regional biodiversity. Moreover, this methodology has already a calculation of the biodiversity quality in each zone where it was applied. It means that in the end it also quantified the anthropic pressure on each environment.

When talking about the results for the methodology used by the company (ReCipe 2008), it can be said that the land occupation category has the most important role in the total value of the index thrown by the methodology. This is an important issue when talking about reducing the pressures on biodiversity because changing the land use inside an area of around 20.000 ha is a matter that requires the collaboration of authorities, policies and government plans that can go according to the results of the studies done.

The initial results show that the most harmful case study is case C, followed by case A and finally case B. Despite the distribution, and taking into account just the first look of the sites, these results make sense. Since case C is the most urbanized one, it is reasonable that this is the site with more impact on local biodiversity. However, this is not true at all, because the most anthropized environment is the one from case B (less area with no impact on the environment), and it is the less harmful for the environment in terms of BLP.

Furthermore, the ReCipe 2008 methodology gives a lot of relevance to the agricultural and urban Driving Forces. As a matter of fact, the results show that more than 50% of the total value in the three case studies is due to the agricultural land use. This is also an interesting point. Despite the difficulties in changing the activities, probably changing the agriculture type or just controlling it can reduce substantially the value of the anthropic pressures using this methodology.

On the other hand, it is clearly visible that the impact due to industries or infrastructure is not that representative when using the ReCipe 2008 methodology. In fact, given the contribution of the industrial activities to the total value of the pressure index (Case A: 3,90%, Case B: 4,83%, Case C: 5,81%), it is clear that slow improvements on the quality of the industries won't change in a visible way the values of the index through time.

The issue of the infrastructure can be explained easily by the fact that it is not considered as an activity that occupies land, but as an activity that just generate pressures in the environment. More clearly, if the methodology assigns higher values to the land occupation, and the infrastructure is considered as a zero area activity, it won't weight in the final value in a representative way. The solution to this issue can be the assignation of an area to each km of infrastructure and considering its space occupation.

Now, the benefits shown by ReCipe 2008 can be summarized as follows: It takes into account more factors than the other methodology that was applied. In fact, it has associated valued to the categories that IMPACT 2002+ does not (aquatic eutrophication and acidification). Second, it is the most recent of the methodologies tried. This can be seen as a vantage or a disadvantage at the same time, because there might be some values that need to be recalibrated in order to get more satisfying results.

For the specific case of the company and the results on the three different case studies, the team expected higher values from the case study C than for the other case studies because of the regional conditions and of the type of industries found in the place of study. ReCipe 2008 was able to give these results after applying the methodology; however the final difference was not as high as the evaluation team expected.

On what refers to the IMPACT 2002+ methodology, or the confrontation methodology, the results showed some interesting issues. First of all, this is a methodology that is still under development and improving. It does not have any values for the aquatic acidification or eutrophication, which makes it (in a certain sense), an incomplete methodology for cases in which the presence of freshwater or sea represent an important portion of the place that is studied. Although the three case studies had freshwater represented by rivers, this methodology was applied, and the results are a good point of comparison between IMPACT 2002+ and ReCipe 2008.

The results of the application of IMPACT 2002+ were substantially different from the ones obtained when applying the first methodology. The most harmful case study in biodiversity terms was case B, followed by case C, and as the less harmful was case A. This discrepancy between both models can be explained with the land occupation consideration, and the relevance of categories that ReCipe may not take into account in a complete way.

As a first difference, the land occupation factors vary in a substantial way. This can be proved with the impact due to the different driving forces. While on the ReCipe 2008 methodology the land occupation represented always more than 80% of the total index, in the IMPACT 2002+ this same value never went over 50% of the gross impact. Instead, this last methodology always took into account as more harmful the pressures generated by the emissions of each Driving Force.

For instance, in the case of Infrastructure, the IMPACT 2002+ model gave more relevance to this driving force. In fact, it was able to put it as the second most relevant Driving Force in the case study A, and as the most relevant in the case study C. This clearly shows that if there is any improvement in transportation, the final value of the IMPACT 2002+ index will be touched in a sensible way.

However, not all the emissions that can be controlled easily have a considerable weight in the IMPACT 2002+ model. The case of the industrial Driving Force is a clear example. The higher relative value that the Industrial activity had in the three case studies is represented by case study B, where it took 5,90% of the total value, while in case A and case C it took 1,65% and 1,93% respectively.

The difference between these values is explainable because of the amount of industrial emissions in the areas. While case A and C had less emission values than case B, and fewer industries in their terrains, they got a minor value in the contribution of this activity to their gross pressure index.

The IMPACT 2002+ methodology also has substantial benefits. As it was shown in the comparative figure of the Impact Categories using this methodology (figure 6.4), the percentage of contribution of each category varies depending on the case, and it does it more sensibly than with the contribution analysis of the ReCipe 2008 methodology (figure 6.2), where the graph is clearly dominated by the land occupation issue.

Concluding, the ReCipe 2008 methodology is valid for the evaluation of human pressures on biodiversity. However, it is an index strongly affected by land occupation; therefore great changes on it require changes on land use around the analysed site. On the other hand, the IMPACT 2002+ model is built on a base that give the emissions more relevance (or at least equal relevance), to the land occupation issue, so it can be modified through time more easily than the ReCipe model.

Table 7.1 shows the summary of the methodologies, and the conclusions that this study took into account.

Issue	ReCipe 2008	IMPACT 2002+
Model used	LCA models	
Information Used	Emissions, Emission factors and Land Occupation Indexes	
Units	BLP (PDF specie year)	Points, normalized from PDF specie m2 year
Omitted issues	None	Aquatic acidification and Aquatic Eutrophication
Main Driving Force	In the three case studies agriculture is the main driving force	For case study A and B, agriculture is the main Driving force. Instead for case study C Infrastructure takes the main place
Main Impact category	For all the case studies the Land Occupation category overwhelms the other categories	Case A and case C have a relevant contribution of Terrestrial Ecotoxicity, case B is controlled by land occupation. However the categories have a more even distribution
Improvement of the biodiversity conditions	Enhance the natural potential of land is the main corrective action to be taken with this methodology	Reduce pressures by controlling emissions can have a great impact on reducing the pressures on biodiversity
Methodology limitations	Only applicable in tempered regions. The meaning of the Ecosystem Damage indicator can be uncertain due to its heterogeneity	The Ecosystem Quality is currently underestimated due to the lack of categories (Aquatic eutrophication and acidification)

Table 7.1. Conclusions summary

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