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Abstract

This Master thesis focuses on land management use in Europe. A model has been created to analyses the effects that different strategies of agricultural production have on the environment. In the model, four scenarios have been shaped to investigate land requirement and environmental impacts of different farming activities. The first scenario focuses on land used in Europe to feed livestock and the amount that could be freed by assuming lower meat consumption. In the second scenario, the land required for replacing 5.75 percent and 10 percent fossil fuels used in transportation with biofuels has been calculated. The third scenario examines organic cereal and livestock production in Europe and the land necessary for enlarging their production. Finally, the last scenario explores advantages and disadvantages of increasing yield of cereal production. From the analysis of the findings it emerges that many benefits could be gained by reducing meat consumption. A significant amount of arable land would be available and could used for mitigating the impacts of intensive agriculture on biodiversity and natural resources, as well as for producing organic products.

Appendixes: 2 printed and CD attached

Preface

This Master's thesis "Land use management in Europe: from cattle to grave" was produced in the 10th semester of the Environmental Management programme of Aalborg University in spring 2008.

The list of reference in the report is organized according to the Chicago Style. The reference is stated with the author's surname and the publication year.

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Eleonora Cogo

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List of Abbreviations

FAO: Food and Agriculture Organisation

IEA: International Energy Agency

WWF: World Wide Fund

1 INTRODUCTION

In the past centuries, the agricultural sector has played an influential role in all known civilisations; control over agricultural resources was heavily connected to the distribution of economic and political power. Furthermore, agriculture constituted the primary source of employment and income for most of the worldwide population in the past. Throughout the centuries, agricultural activity has witnessed crucial developments; practices have drastically changed thanks to innovations in the domains of biology, chemistry and machinery. Consequently, a large set of agricultural products became available at low prices. Agriculture became a global business instead of being confined to subsistence activities.

Back in the 1960s, the Green Revolution movement marked the shift to a modern agriculture. It promoted the increase of yields through the use of pesticides, fertilisers, monoculture, irrigation and mechanisation and the creation of new crop varieties. High yields were achieved, leading the cereal production to increase by more than 130 percent from 1960 to 2000 (FAOSTAT 2008). However, a strong dependence on fossil energy for the production of agricultural chemicals was fostered (Pimentel 1996). Furthermore, while the yield immensely grew, the harvested areas increased by only 4% (FAOSTAT 2008). Large yields were achieved through an intensification process and agricultur e could meet the food needs of most of the world population; yet a damaging contamination of the environment was the price paid for this achievement (Tildman 1998).

In spite of the encouraging results attributable to the 'Green Revolution'; 800 million people are still affected by under-nutrition worldwide, and this rate is increasing in low-income countries (FAO 2006). Whether food will be plentiful for everybody in the context of population growth is a major issue to consider. Simultaneously, a new phenomenon once restricted to industrial countries and now reaching affluent classes is unfolding worldwide: the increased prevalence of obesity. A rise of individual incomes and economic buying power has called for an increased demand for food as well as a shift in diet patterns. Growing incomes boost the demand for livestock products; the 'livestock revolution' is taking place (FAO 2006). Before the 1990s, animal products were mainly consumed in rich countries; in the last decade, many in developing nations have adopted what was once known as the western diet, resulting in an increase of total expected meat demand of 56 percent from 1997 to 2020 (FAO 2006).

Over the years, the livestock production in industrialised countries has undergone numerous changes such as the use of concentrate feed, the resort to advanced genetics and feeding systems, and new regulations regarding animal health protection and habitat (FAO 2006). Such changes were introduced to compensate for the rapid growth of demand. The production of meat became resource intensive, grazing was increasingly abandoned and grain-fed animals became the norm. Meat production in such conditions led to pollution and an intensive use of resources such as fossil fuels, water and land; making the livestock sector the largest user of agricultural land on earth and one of the biggest threats to resource availability and pollution.

1.1 LIVESTOCK AND THE ENVIRONMENT

Intensive production processes lead to a high output of agricultural products, but at high environmental costs. Ecosystems are affected by a heightened input of pesticides and other agro-chemical substances in farming. The major issues being pollution of water, soil degradation and reduction of biodiversity.

Many of the problems related to industrial agriculture are magnified when meat is the output. Food supply relies more on intensive resource exploitation when grain-fed animals are consumed instead of grain, since a significant amount of energy is lost in the conversion from grain to meat and therefore larger areas are required (Horrigan & al. 2002).

1.1.1 Land use and degradation

In terms of environmental costs and natural resources used, the production of food has one of the most significant impacts on land quality and quantity (Elferink & Nonhebel 2007). Currently, 40% of the land is used for food production; furthermore, an estimated 60% of arable land worldwide is used by livestock, which requires substantial amounts of feed crops (Nonhebel 2005).

Intensive exploitation of land has caused for many years the deterioration of the physical, chemical and biological properties of the soil, as well as a loss of natural vegetation. Among the many implications resulting from land degradation, the loss of biodiversity and the depletion of water resources are the most alarming features; these phenomena are caused by habitat destruction, pollution of aquifers, deforestation and alteration of the texture (FAO 2006).In addition to the loss of land due to degradation or erosion of the soils and desertification, the amount of land available per person is gradually decreasing as the world population grows (Horrigan & al. 2002).

According to the Food and Agriculture Organisation (FAO), meat production accounts for 70 percent of all agricultural land and 30 percent of the total land surface. In the Amazon, 70 percent of previously forested land is now occupied by pastures for cattle and most of the remaining part used to grow soybeans and other feed crops (Nierenberg 2006).

1.1.2 Pollution

Intensive animal farming creates both direct pollution, such as manure, and indirect pollution, attributed to the use of pesticides and other agro-chemical products used in feed production.

Waste produced by farm animals is a major issue, because of the high level of ammonia generated in the barn through the process of decomposition of urea and other nitrogenous compounds. The Industrial system generates vast amounts of manure which is partially used on cropland and pasture and partially collected and disposed of. Problems occur when the nitrogen use far exceeds the absorption capacity of crops (FAO 2006). Gaseous emissions of ammonia are also deeply problematic, especially when livestock is highly concentrated (Backus & al. 1998). Additionally, high levels of ammonia and nitrate are released through the intense use of fertilisers to grow animal feed, which pollute soil, water and air (FAO 2006). Since 1960, the worldwide rate of application of nitrogen fertilisers increased sevenfold, and today, crops are estimated to absorb only half to one third of the nitrogen used on farmland (Tilman 1998).

Worldwide use of pesticides is growing, especially in developing countries; Europe however, is still the leading consumer of pesticides (FAOSTAT 2008). Many pesticides applied to crops eventually reach ground and surface waters, where the residues remain for many years (Pimentel 1996). Another side effect of pesticide use is the destruction of natural predators and parasites; in some cases it leads to problematic pesticide resistance, plant pathogens and weeds (Pimentel 1996). The consumption of pesticides and fertilisers negatively transforms the environment and has harmful indirect effects on people and animal health. The main consequences of heavy pesticide use are human poisoning and illness. In addition to pesticide problems that affect humans, domestic animals are also prone to poisoning, as well as meat, milk and egg products (Pimentel 1996).

1.1.3 Water use and pollution

As the world demand for food has tripled over the last 50 years, so has the use of water for irrigation. Agriculture is the largest consumer of water, accounting for 70 percent of total freshwater use (FAO 2006).

Since the advent of powerful diesel and electrical driven pumps, water pumping capacity has increased in some cases beyond the capacity of recharge from rainfall, which inevitably led to water depletion (Brown 2005). Since approximately 1000 tons of water are required to produce one ton of grain, a close link between issues of food security and water accessibility exists (Brown 2005). To produce one kg of beef, ten times more water is required than to produce the same amount of grain (Goodland 1997). Furthermore, the livestock sector is the principal culprit for nitrogen and phosphorus emissions into freshwater resources, which are already contaminated by antibiotics and heavy metal (FAO 2006). In addition, rivers and streams are contaminated by the runoff of manure from feedlots. Livestock waste can also contaminate soil and groundwater with hormones and antibiotics used in factory farms (Nierenberg 2006).

Besides the problem of lack of water and pollution, another threat to water resources is water loss: 40 percent of water extracted for irrigation never reaches farmers' fields (Goodland 1997).

1.1.4 CLIMATE CHANGE

Climate change is understood as one of the main challenges the world is facing today. The agricultural sector is both a large contributor to and a victim of the effects of the climate change. Global warming could have serious effects on the agricultural production, such as increased temperature, droughts and more severe natural disasters like floods, which are factors leading to crop failures. Brown (2005) states that if the temperature were to rise by one degree Celsius during the growing season, the yield of wheat, rice, and corn would drop by 10 percent.

Agriculture is one of the main sources of greenhouse gas emissions, even surpassing the transportation sector; the livestock sector alone accounts for 18 percent of all greenhouse gas emissions (as measured in carbon dioxide equivalent) and nearly 80 percent of all emissions of the agricultural sector (FAO 2006). Emissions are mainly attributed to the use of fertilisers and manure storage. However, indirect sources of these emissions include fossil fuel to produce fertilisers used in feed production, land use changes, land degradation, production and transport of animal products, and deforestation (FAO 2006).

The three major greenhouse gases contributing to global warming are: carbon dioxide, methane and nitrous dioxide. Livestock accounts for 9 percent of global anthropogenic emissions of carbon dioxide, which is mainly released from fertilisers' production and fossil fuels. On a minor scale, transportation of feed and animals over long distances contributes to these emissions. Another important greenhouse gas is methane, which is about 21 times more effective than carbon dioxide in trapping heat, and remains in the atmosphere for 9 to 15 years. Methane is mainly released through enteric fermentation and manure which contribute to 80 percent of agricultural methane emissions and about 35–40 percent of the total anthropogenic methane emissions. Lastly, nitrous oxide is 320 times more powerful than carbon dioxide and has a significantly longer atmospheric lifetime. It is mainly emitted through fertiliser's use and manure.

1.1.5 BIODIVERSITY

The intensification of agricultural production and livestock activity has already jeopardized earth's biodiversity. A reduction of natural habitats providing land for pasture and feed crop production has been noted (FAO 2006). It has been estimated that about three-quarters of the genetic diversity of agricultural crops have been lost over the last century, and that hundreds of the 7000 animal breeds are threatened by extinction. Only twelve crops and fourteen animal species currently provide most of the world's food (FAO 2008b).

Extensive grazing has played a role in forest fragmentation and destruction; intensive systems have lead to habitat pollution (FAO 2006). Monocultures eroding biodiversity among plants and animals are another major threat (Horrigan & al. 2002). Reduced genetic diversity results in less adaptability to environmental challenges such as climate change or water scarcity, as well as less opportunities for growth of production in the agriculture sector. Therefore, the loss of biodiversity could become a serious threat to food security (FAO 2008b).

In the past 50 years agriculture has expanded in large proportions; however this has also meant a threat to its capacity of regenerating, like loss of biodiversity, soil degradation and water scarcity. In the future, further expansion of arable land and menaces from climate change could lead to loss of productivity and difficulties to ensure food security.

1.2 Production and Consumption

The world population nearly doubled in the last 40 years and is expected to reach nine billion by 2050 (UN 2006). Food demand is increasing both in quantity and type of diet; the future challenge for the planet concerns not only the projected three billion people to feed, but also the five billion people who want to diversify their diets and eat more grain intensive livestock products (Brown 2005).

There are significant differences in amounts of environmental resources used between meat-based diets and grain-based diets, and new trends like biofuels compete for land use. In order to quantify these developments, some figures about meat production and consumption, as well as biofuel use are presented in the following section.

1.2.1 Grain production for livestock

Meat consumption has increased fivefold since 1950 and, in the last decades, the most notable increase was observed in developing countries (FAO 2006).

For decades, grain production followed a similar growing trend to meat production, but it slowed down over the last years. Since grain consumption continued to grow in the meanwhile, the world grain stock dropped drastically (Brown 2005). In recent months several conflicts have originated over the drastic increase in grain, maize and other basic foods' prices. The poorest countries' cereal costs rose by 37 percent in 2006/2007 and are forecast to increase by 56 percent in 2007/2008 (FAO 2008). The reasons behind this surge are mainly attributed to oil prices; however, the issue of the effects of climate changes on agricultural production in the future is now being heavily discussed.

In 2002, 670 million tonnes of cereal were fed to livestock, which covered an area of 211 million hectares. This amount represents roughly one-third of the global cereal harvest. In addition, another 350 million tonnes of protein-rich processing by-products were used as feed; mainly brans, oilcakes and fishmeal (FAO 2006). Much of the growing demand for animal products is being met by large-scale industrial systems which rely on commercial breeds of livestock, such as pigs and chickens that have been bred to gain weight quickly on soybeans and corn. Factory farms are often crowded and confine animals in close quarters, in many cases they are forced to live within their waste (Nierenberg 2006).

Despite the large amount of land used for growing feed, farm animals utilise considerably more food calories than they produce in form of meat, since most of the energy and protein value is wasted in digestion and bodily maintenance (Brown 2005).

1.2.2 Meat consumption and consequences on human health

Until the 1980s, diets that included the daily consumption of milk and meat were largely a privilege of OECD countries, and of wealthy elite elsewhere. A growing rate of income determined a shift in demand towards animal products, which continues to increase. In developing countries, annual per capita consumption of meat has doubled since 1980, from 14 kg to 28 kg in 2002 (FAO 2006).

Meat products and dairy foods constitute the greatest percentage of the saturated fat intake, which contributes significantly to several health problems such as heart diseases, diabetes, hypertension and certain cancers. These illnesses have reached epidemic proportions (FAO 2006). In rich countries, the main causes of dead are associated with over-nutrition and excessive consumption of fat (Horrigan & al. 2002), but a rapid increase in diet-related chronic diseases is now also registered in developing countries (FAO 2006). In the last decades of the 20th century many countries experienced unprecedented increases in diseases associated with obesity, due to both inactivity and excessive intake of food (Blair & Sobal 2006). Worldwide, the number of overweight individuals (about 1 billion) has now surpassed the number of malnourished people (about 800 million) (FAO 2006). However, there are still large differences in meat consumption rates per capita around the world. Affluent societies are still the main meat consumers, while daily meat consumption remains an illusion in many poor countries, which register a deficit in proteins intake (FAO 2006).

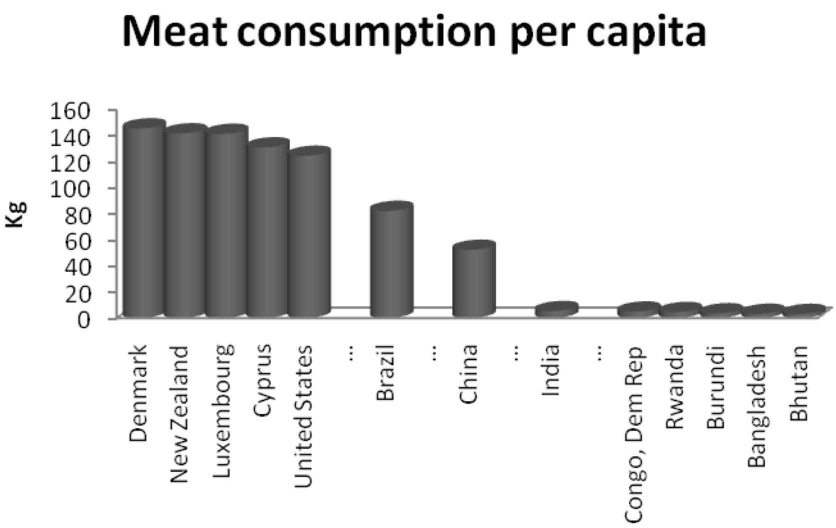

Figure 1.1: Consumption of meat by country (kg/capita/year) in 2002. Source (FAOSTAT 2008)

Denmark, New Zealand and Luxemburg, with over 140 kg a year per capita, have the highest meat consumption rate in the world. Conversely Burundi, Bangladesh and Bhutan, with less than 3 kg a year, hold the record on the low end (FAOSTAT 2008). (See table at in appendix A for meat consumption data in every country).

Additionally, the world egg production has doubled between 1990 and 2005, and is expected to reach 72 million tons by 2015 (FAO 2006). People in industrial countries eat about twice as many eggs as people in developing countries. While small farmers once produced eggs for local consumer markets, today large scale vertically integrated factory farming, with hens in small wire battery cages, has become the norm. This intensive industrial style has been implicated in the epidemic's spread of avian influenza (Carrus 2006).

1.2.3 Figures on production and consumption of biofuels

The energy sector is becoming another strong competitor to land use. Due to the foreseeable depletion of fossil fuel resources and increasing efforts to mitigate climate change, biomass and especially biofuels are being discussed as an alternative. Ethanol produced from sugar cane accounts for 40 percent of the fuel sold in Brazil. Worldwide, fuel ethanol production increased from 20 billion litres in 2000 to 40 billion litres in 2005, and is expected to reach 65 billion litres in 2010 (Berg 2004). If such predictions are accurate, the biofuel sector may well become a strong competitor to feed production (FAO 2006), as well as to nature conservation and urbanisation needs and for the demand of land and water resources (EEA 2006).

It is however foreseen that the "second generation" biofuels will rely on cellulosic biomass resource for energy production. In that case, biofuel will not be competing for land any longer (Rajagopal & al. 2007). According to the Intergovernmental Panel on Climate Change's (IPCC) fourth assessment report on climate change, second-generation biofuels are considered one of the key mitigation technologies for the transportation sector. However, they are only expected to be commercialised by 2030 (IPCC 2007).

Considering the growing need for the world population for agricultural land, whose surface is diminishing, all these factors will need to be considered when developing sustainable land management.

2 Research Structure

This chapter specifies the structure of the thesis. The overall layout of the report as well as every part's content will be detailed. Subsequently the research questions will be illustrated, and the resulting investigations identified. In order to do so, a model based on four scenarios will be elaborated, each presenting a set of questions intended to break down the overall problem.

2.1 Thesis Outline

The thesis is divided into three parts: introduction and research questions, conceptual framework and methodology, analysis and conclusion.

Part I: Introduction and research questions

Chapter 1 - Introduction - provides an overview of the main impacts the livestock sector has on the environment due to the increased intensity of farming. The consequences include the increasing land use for crop farming, land degradation, pollution by fertilizers and agrochemicals, reduction of biodiversity and global warming. These issues are presented in relation to world increasing population and consumption of meat and biofuels.

This chapter - Research structure - presents the structure of the report and the research objectives, followed by detailed questions which intend to give a framework to investigate the sustainability of land management in Europe.

Part II: conceptual framework and methodology

Chapter 3 - Conceptual framework - details the conceptual framework applied to the research and analysis. It includes a description of the principal input and output flows in the intensive farming process and environmental impacts related. These concepts are incorporated into the presentation of theories which reconsider human consumption and use of natural resources in the light of Ecological Footprint, growing population and pressure on the ecosystem. A reformed agricultural system is proposed in opposition to the infinite economic growth model and the return to more sustainable agriculture.

The fourth chapter - Methodology - describes the scenarios and the methodology that were used during research. The scenarios are divided in four sections and are based on hypothetical situations within the context of meat consumption, use and production of biofuels, increased yield and organic farming. The assumptions and limitations made in the model are also discussed.

In Chapter 5 - Findings - the results obtained by the evaluation of the scenarios previously illustrated are commented and illustrated.

Part III: Analysis and conclusion

Chapter 6 – Result Analysis - focuses on the analysis of the results for each scenario and identifies which scenario would be most efficient in terms of land use, consumption of resources and environmental impact.

In light of the theories and the results obtained, chapter 7 - Discussion - discusses the propositions made in chapter 6. Here, the scope is expanded beyond Europe regarding imports and worldwide impacts on biodiversity.

The final chapter - Conclusion - presents a summary of the discussion on the findings with a critical reflection of the achievements.

2.2 RESEARCH QUESTIONS

For many years, Europe could afford high living standards; easy access to large quantity of goods and services was encouraged. However, new challenges such as solving the problems related to high pollution and climate change have become paramount. Along with other industrialised countries, Europe has a predominant role in meat consumption; consumption which necessitates an enormous use of land to feed animal production. A European citizen consumes an average of 87 kg of meat per year; this figure should be compared to a world average of 40 kg, which lowers to 28 kg in Asia and 13 kg in Africa (FAOSTAT 2008). Europe is also highly dependent on fossil fuels in the agriculture sector and industrial farming system. In 2003, European citizens emitted 8.3 metric tons of CO_2 per capita, double than the world average (IEA 2006). Livestock is a major contributor to those greenhouse gas emissions.

In the last years, an attempt to introduce processes of cleaner production has been promoted. This effort was encouraged to guarantee the same facilities and standards of living, but with a focus on reducing the pressure on the ecosystem. In Europe, environmental awareness is growing as shown for example by an increasing demand for organic food. Organic farming cultivates the land in a more ecological way, reaching lower yields; therefore, more land is required to produce the same amount of crops.

Furthermore, biofuels have been identified as a complement to fossil fuels and as a way of reducing CO_2 emissions. They are to help foster greater independence from traditional energy supply whilst maintaining the same means of transportation. However, they also require an extensive use of land and the resort to intensive agriculture practices for cultivating the plants. Furthermore, the EU commission in the last biofuel directive has set a goal of replacing 10 percent of fossil fuels used in transport with biofuels by 2020; however there is an ongoing discussion assessing the environmental risks and benefits of biofuels; whether or not this target should be maintained is now being questioned.

New dilemmas are coming to light with regard to the growth of the world population, and the limited resources and lands available. In the season 2006/2007, cereal stock and especially wheat decreased drastically. As a consequence of the sharp increase of cereal prices, some of the main producers reduced their exports of wheat, in order to avoid the internal inflation of cereal prices (FAO 2008a). The EU removed the 10 percent compulsory set-aside requirements for the 2008 cropping season, and cereal import duties were suspended subsequently (FAO 2008a).

Concern is expressed about future possible scenarios if cereal prices were to considerably rise; dangers of worsening weather condition destroying field crop are discussed and doubts about Europe's capacity to sustain itself on its own limited resources and energy supply without further compromising the environment are raised.

Taking into consideration the factors mentioned above, the problem formulation will be presented as followed:

Given the current trends of consumption in the EU:

Investigating alternative scenarios for agricultural production: which implications will these scenarios have on the environment?

The focus of this study will be on land management scenarios and the repercussions that alternative uses may have on production patterns, and the direct and indirect impact on the environment. Environment in this context means the natural habitat and how it will be affected by the exploitation of natural resources like soil and water, and the perpetuation of the introduction of chemical substances into the biosphere. Closer attention will be given to biodiversity and the sustainability in the long term.

In order to investigate these aspects, the attention will be directed to each of the four scenarios that have been chosen as key cases for agricultural management and its sustainability. The first two scenarios consider meat and biofuel consumption and their consequences on land and resource use. The second two scenarios instead organic and traditional intensive farming practices.

The following sub-questions expand on the main problem formulation above:

What are the environmental implications of meat consumption?

What consequences will increased production of biofuel have on land availability?

What are the advantages and disadvantages of organic farming?

What are the advantages and disadvantages of traditional intensive farming?

The competition over land is examined through the analysis of land occupied by livestock. Furthermore the effects of intensive farming are taken into account, considering increasing the yield in order to reduce land use in Europe, and assessing the effects in terms of land degradation, reduction of biodiversity and greenhouse gas emissions.

In order to answer the problem formulation and the sub-questions, the following research questions have been formulated:

1. Livestock scenario:

- How much land is used for feeding animals in traditional intensive farming?
- How much land would be used assuming lower meat consumption?
- What could be the environmental benefits of reducing the amount of land used?

2. Biofuel scenario:

- How much biofuel is consumed, produced and imported?
- How much land would be needed to increase biofuels production?

- How much land would be needed to completely replace the total fuel demand for transportation?

3. Organic scenario:

- What percentage of total agricultural production do organic cereals and livestock represent compared to traditional farming?
- How much land does organic production require in comparison to traditional intensive farming?
- How much land would be needed to convert the current traditional cereal and livestock production to an organic one?

4. Traditional intensive scenario:

- What is the yield of cereal production in EU countries?
- How much grain could be additionally produced by increasing the yield?
- What would be the environmental costs of such a yield increase?

Primarily, land distribution and use of arable land in Europe should be investigated; subsequently, these aspects should be examined also in relation to the scenarios: land use for feedingstuffs, land required for biofuel and organic production, land that can be made available by intensification of agricultural practices. Finally the emissions and dependence on fossil fuels should be examined in order to evaluate their environmental impact.

These questions intend to quantify the effects choices of agricultural techniques have on production capacities and the environment in terms of land used and environmental impacts, as they will reflect on long term sustainability.

Land use for meat production has been identified as determinant for the large impacts which it has on resources use and outputs, as presented in the introduction. Biofuel for transportation, although it has the advantage of replacing fossil fuel, requires large areas. It will be investigated whether enough land is available under current conditions. Organic and traditional intensive practices of agriculture are not understood as being mutually exclusive, but are investigated separately to assess the most sustainable forms.

This study further examines the degree of dependency of the EU on other countries in term of occupied land, and the extent of Europe's self sufficiency in food and fuel supply. However in the model of land use in Europe, imports will not be included, as additional land used. However, Europe will be regarded as an entity with a deficit in terms of land occupied and resources consumed towards other countries, without quantifying this deficit. Although the model refers only to the EU, the results will be discussed in broader perspectives: consumption of natural resources to maintain the European standard of living, ability of natural resources to regenerate, influence of consumer choices on the environment, such us biodiversity.

3 CONCEPTUAL FRAMEWORK

In this chapter the theoretical framework and the main concepts on which this research is based are presented, in order to offer a basis for the subsequent data analysis and discussion. First the main environmental impacts of livestock farming are described following a life cycle assessment (LCA), after which the discussion is broadened by taking into consideration the cost of western standards of living in the light of the ecological footprint model. Finally, on at more theoretical level, consumption, economical model of growth and impacts on the planet are presented with respect to the growing demand for food products.

3.1 WHAT IS THE COST OF MEAT CONSUMPTION?

In this part the main impacts of agricultural farming are presented. Special attention is given to the livestock sector, as it is excessively harmful for the environment. Although it will be attempted to differentiate between traditional and organic ways of farming, the presentation will focus on traditional intensive agriculture in order to give basic insight before proceeding to analysis.

3.1.1 INPUTS, OUTPUTS AND ENVIRONMENTAL IMPACTS OF INTENSIVE FARMING

The current system for agricultural production in Europe requires waste resources and causes several negative environmental effects. The principal inputs related to intensive farming are illustrated through a Screening Life Cycle Assessment (LCA), which provides a framework to assess the main environmental impacts of the agricultural process for livestock production. An inventory of the most relevant inputs and outputs is presented in connection with the consequent environmental impacts in order to evaluate the potential effects at each stage of the process (ISO 14044: 2006). A qualitative description of the production and the system will be carried out to learn more about the agricultural production system, and underline the most problematic issues. This description will be based on existing literature and databases only (Thrane and Schmidt 2006).

It will be used to point out the most affected resources (soil, water and air) at each stage of the farming process. The LCA method is suitable for tracing the environmental impacts of the livestock sector, since it takes into consideration the entire process from cradle to grave; possible improvements can then be derived from the results. However, two important aspects like land use and resource consumption, which are the core of this research, are not sufficiently included in the evaluation (Brentrup & al. 2004). Furthermore, since the area of investigation is quite large and each geographical region differs in management practices and use of resources, it is not possible to estimate precisely the different effects of intensive farming. Consequently, neither the analysis nor the assessment phases of the LCA are included.

The unit process focuses on field activities from crop production to consumption. During the entire process, the production of raw materials such as minerals, the use of fossil fuels and the application of seeds, farm inputs like fertilisers and agrochemicals are considered, as well as the recourse to machinery (Brentrup & al. 2004).

In this LCA, the system boundaries will be confined to the EU, excluding the effects of long distance transportation of imported goods. Biofuel is seen mainly as a competitor for land use as ethanol is mainly imported (IEA 2004) it has therefore been excluded from this description which intends to exemplify the environmental impacts of agriculture and livestock in Europe. In this presentation pigs and cattle will be the main point of reference, although poultry is later also included. However, a more detailed definition of the system boundaries will be offered in chapter 4 – methodology -.

In the figure below, the main inputs and outputs of farming activity are illustrated.

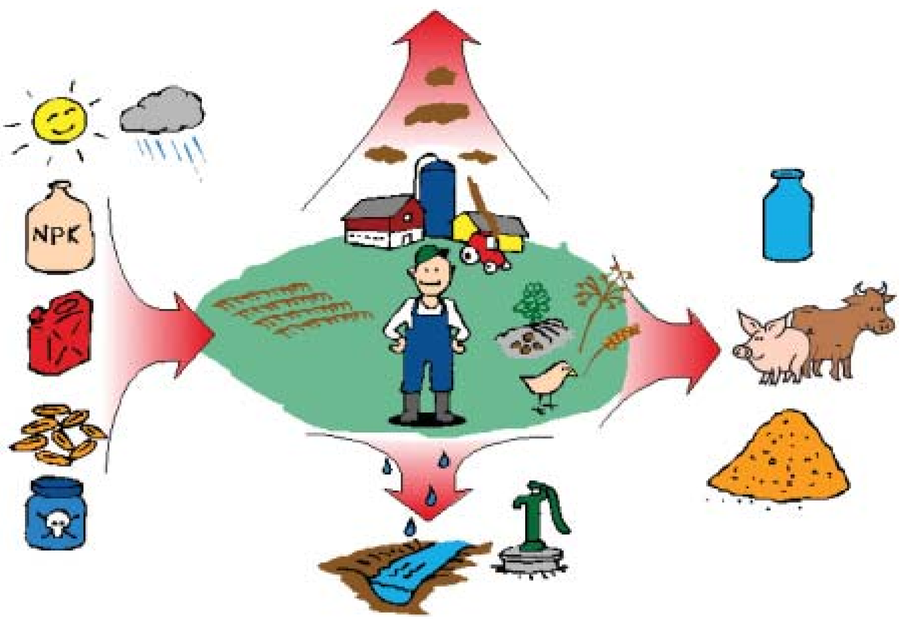

Figure 3.1: Farming activity affects yield and cause environmental impacts. Source: Elmquist 2005

As can be seen in the figure 3.1 the principal inputs in farming are seeds and chemical substances, which affect the biosphere (soil, water and air).

3.1.2 PROCESS DETAILS

In this part, the stages of production are described: from the production of feed ingredients to meat consumption. The processes in the chain include growing crops, conversion into feed, animal feeding and fattening. Finally, the livestock is slaughtered; parts of the carcass are processed into meat products and transported to the retailer for distribution to the final consumer (Zhu & van Ierland 2004). While pigs and poultry are mainly fed, cattle usually makes also use of pasture land. Feed ingredients for livestock include crops (wheat, maize, soybeans, cassava, etc) but also by-products from the food industry (oilseed cakes, molasses, potato peels, etc.). Furthermore, amino-acids, minerals and trace elements are added to the mixture of feed ingredients to balance the nutritive value (Elferink & Nonhebel 2007). For example a pig diet in Sweden is composed of 60 to 80 percent barley and wheat, while the rest consists of peas, rapeseed cakes, rapeseed meals, soybean meals and synthetic amnioacids (Eriksson & al. 2005).

There are many differences in levels of emission depending on the choices made during the farming process; for example, the use of machineries for operations or management systems to dispose of manure. Another source of emissions depends on strategies of crop cultivation like the added use of fertilisers or other agro-chemicals. In figure 3.2 the main inputs and outputs in the farming system are represented: these variables will be considered, while the description will be mainly qualitative.

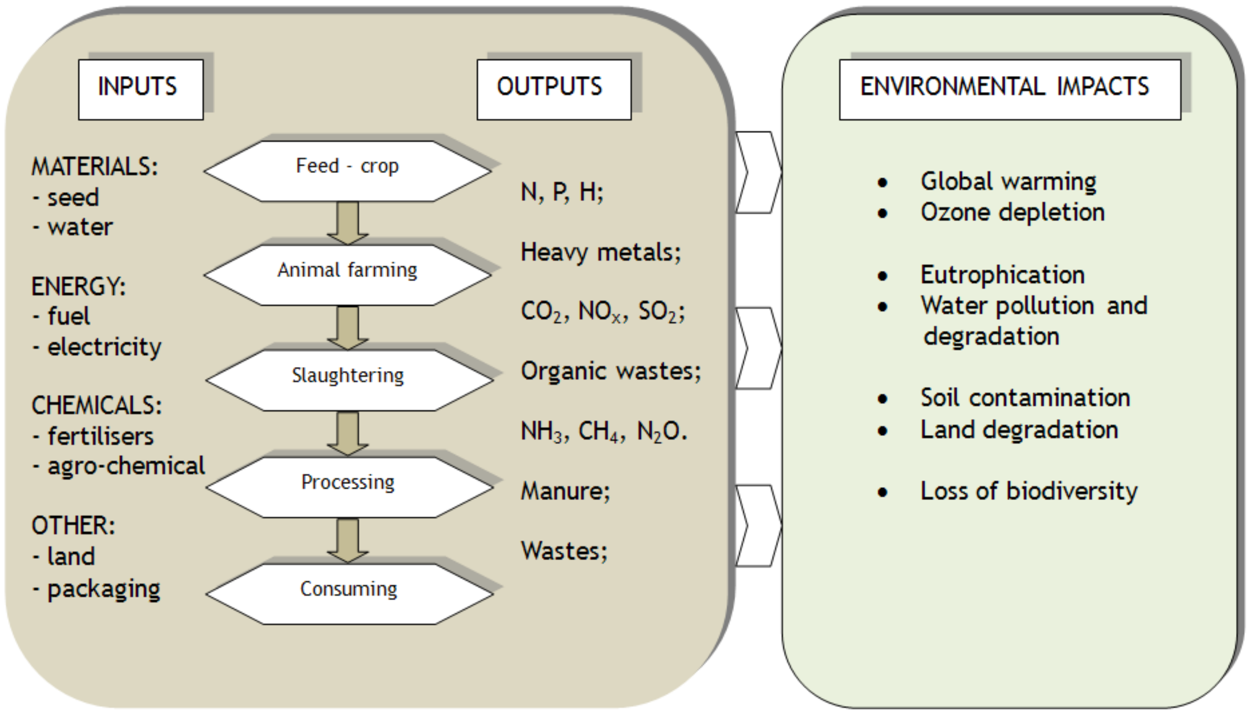

Figure 3.2: Categories of inputs and output of the process and related environmental impacts.

Field activities

As previously mentioned, the chain starts with the crops cultivation intended for animal feed production. The main inputs are composed of seeds and water. In addition, industrial farms utilise machinery for field work like soil preparation or spreading compost which consumes fossil fuels. Furthermore, to enhance yields and control pests, fertilisers are largely used along with agro-chemicals, such as insecticides and herbicides (Zhu & van Ierland 2004). Additionally, the operations of harvesting, drying and transportation of feed to the farm are carried out by machines requiring fuel. Therefore, the main inputs for feed production are land, water, energy, fossil fuels, fertilisers and pesticides (Eriksson & al. 2005, Zhu & van Ierland 2004).

Among the outputs there is air emission resulting from the use of fossil fuels and agrochemicals dispersed on the crops (Narayanaswamy & al. 2003). Nitrogen (N), phosphorus (P), heavy metals, carbon dioxide (CO_2), nitrogen oxide (NO_x), sulphur dioxide (SO_2) and organic waste are released during the operations (Zhu & van Ierland 2004). The presence and amount of substances in the environment, as previously mentioned, depend on the type of practices and the choice of feed ingredients. For example, soymeal has the highest impact of all categories (Eriksson & al. 2005), while dairy farms in some regions make predominant use of permanent grassland (Haas & al. 2000). Also, the amount of fertilisers used varies from region to region (Zhu & van Ierland 2004).

Farm activities

The second stage takes into account the activities in animal farming. As to intensive farming, animals are mainly raised in the barn and are grain-fed. To maintain the animals, electricity is consumed, as well as water and other products to keep the barn orderly. The main waste product at this stage of the process is manure, which is also a valuable fertiliser for plant production (Haas & al. 2000). Manure is usually spread in farm land, while the surplus is stored and disposed off. Plants absorb part of the nitrogen from the fertilisers and the manure, but the rest is emitted to soil, water and air (Zhu & van Ierland 2004).

Ammonia (NH_3) emissions are also released by the manure production; furthermore the digestive process of animals and the manure management system release methane (CH4) and NO_x. Additionally CO_2, NO_x and SO_2 emissions result from energy use. Finally, P and nitrates are emitted into soil and water because of manure and fertiliser use (Zhu & van Ierland 2004, Narayanaswamy & al. 2003).

Water and energy are also required for the slaughtering process, which emits CO_2, NO_x, SO_2 and wastes. Emissions due to use of fossil fuel combustion are: CO_2, carbon monoxide (CO), NO_x, SO_2 and volatile Organic chemicals (VOC). Among the emissions due to electricity use there are: CO_2, CO, NO_x and SO_2 (Narayanaswamy & al. 2003).

Delivered to consumer

Finally, meat products are packed and distributed to the final consumers trough retailers. Preparation of meat product requires energy, water and packaging, which emits CO_2, NO_x, SO_2 and wastes (Zhu & van Ierland 2004).

In order to reach the consumers in good condition, meat is transported and stored in refrigeration systems which also require energy and fossil fuels; therefore, the outputs of this stage are also related to CO_2, NO_x, SO_2 emissions and wastes.

Impact categories

The most common impact categories mostly recognised in LCA studies regarding crop production and animal farming are: depletion of abiotic resources, land use, climate change, human toxicity, eco-toxicity, acidification, eutrophication (Brentrup & al. 2004; van der Werf & al. 2005; Eriksson & al. 2005). However, as Haas & al. (2000) point out, agricultural LCA differs from classical LCA, where land use, waste and photo-oxidants are the impact categories considered essential; biodiversity, wildlife habitats and landscape are identified as key agro-environmental issues.

Table 3.4 lists characteristic farming issues as well as typical impact categories from traditional LCA.

Impact category	Environmental indicator
Global warming	CO_2, CH_4, N_2O emissions
Resource consumption **energy** **minerals**	Use of primary energy Use of fertilisers
Soil strain **Grassland of other ecosystems** **(eutrophication and acidification)**	Accumulation of heavy metals NH_2, NO_x, SO_2 emissions
Water quality	Use of fertilisers. Nitrate
Human and eco-toxicity	Application of herbicides and antibiotics. NH_4
Biodiversity	Grassland, hedges and field margins, grazing animals. Ammonia releases
Animal welfare	Housing system and conditions, herd management

Table 3.4: Inspired by Haas &al.2000

Emissions of greenhouse gases like CO_2, CH_4 and N_2O (nitrous oxide) lead to an unnatural warming of the Earth's surface, a phenomenon known as global warming which in turn caused climate change (Brentrup & al. 2004). This is a problem at a global scale, while the other main impacts associated to farming are mainly having consequences at a regional or local scale.

Resource consumption refers to the use of sources of energy such as fossil fuels, and minerals as fertilisers. Besides causing depletion of the abiotic resources, these substances are decreasing in availability (Brentrup & al. 2004). Eutrophication and land use are the most important impact categories in production and delivery of feed (van der Werf & al. 2005). Acidification is mainly caused by air emissions of SO_2, NO_x and NH_3 (ammonia), which are released during the use of organic and mineral fertilisers in arable crop production. Water includes both ground water and surface water. One main source of contamination is use of fertilisers based on N and P (Haas &al.2000). Human toxicity, as the word implies, includes effects on humans, while eco-toxicity refers to effects on ecosystems. Potential toxic emissions are released by application of herbicides, antibiotics and inorganic air pollutants like $NH_{3,}$ SO_2, NO_x and heavy metals (Brentrup & al. 2004; Haas &al.2000). Environmental indicators regarding biodiversity status regard grassland, as well as number of species or date of first cut, but also hedges & field margins, like density, diversity, state and care (Haas &al.2000). Finally, animal welfare depends on the conditions on which the animals are settled in the housing system or herd, like lightness, spacing, grazing season, care etc. (Haas &al.2000).

Assessing the whole chain process, Eriksson & al. (2005) conclude that feed production, considering energy use and emissions from production of feed and cereals, contributes more to the environmental impact of the system than animal husbandry, intended as manure emissions, electricity and energy use. While this conclusion is valid for the global warming potential and eutrophication categories; the opposite is true for acidification.

Organic farming

An LCA study about dairy production at farm level in Sweden “Life cycle assessment of milk production - a comparison of conventional and organic farming” focused especially on the feeding system differences between organic and conventional strategies. The following divergences were noticed between the two systems: the use of primary energy is higher in the conventional system; the result depends on the difference in feeding strategy (higher input of concentrate feed in conventional milk production, and the use of synthetic fertilisers in conventional production). The total use of crude oil was slightly higher in the conventional system. On the contrary the use of diesel was more prominent in the organic system due to larger use of tractor diesel at the farm level, larger fodder production and lower yields on the organic farming (Cederberg & Mattsson 2000).

The area of farmland necessary for production of one functional unit of milk was 30% higher in the organic system. The organic system has a much greater dependence on grassland for producing silage, hay and pasture. In organic farming, a high proportion of the ruminants’ intake must be rough fodder. Smaller land use in the conventional system is explained by higher yield and the choice of concentrated feed; milk production per hectare is more than twice as high with conventional farming compared to organic farming. Furthermore, the traditional system has a higher animal density, which results from the use of imported feed and fertilisers (Cederberg & Mattsson 2000).

However, the Swedish study (Kumm 2000) “Sustainability of organic meat production under Swedish conditions” suggests that organic production can be more sustainable than conventional production for beef, but not for pork. Kumm (2000) concludes that meat production has surprisingly positive effects on the environment, since grazing is important for biodiversity, and pasture and grass improve its fertility, while the same land cultivated with cereals would lead to soil deterioration. Therefore, organic meat production based on natural pastures, by-products and feed produced without fertilisers and pesticides can be more sustainable than traditional meat production based on potential human food and chemical inputs. The main difference between beef and pork results from the fact that organic beef production is more sustainable in terms of soil conservation, nature conservation and independence on chemicals.

As it has been shown in the first part, many impacts with consequences at the local and global scale occur, although much depend on the management choices and strategies of the farms in terms of feed choices. In the next section, a broader view on the effect will be presented, as well as the role of political intervention.

3.2 LIMITS TO GROWTH

As seen in the previous paragraphs, many of the environmental impacts and especially the intensity of their effects on the ecosystem, depend on the choices on farming methods. These choices will affect the final results in terms of yield, but they may also affect the future capacity for the environment to regenerate. Therefore, this part attempts an evaluation of the Earth’ status through an Ecological Footprint; future actions to meet food demand in line with the planet is capacity to endure will be then delineated.

3.2.1 THE ERA OF GROWTH

In regard to Earth’s capacity to sustain human population, Brown (2005) refers to the last half century as “the era of growth”. World population grew more in the last 50 years than in the previous 4 million years and world economy increased sevenfold in the same period. However, as the economy grows, the demand on the Earth also increases, in some cases exceeding the planet’s natural capacities to regenerate.

In the case of food economy, the capacity of producing food increased drastically in the last half a century, due to the abundance of cheap oil and modern mechanised agriculture techniques. However, water use has tripled, the demand for seafood increased fivefold, the amount of fossil fuels burnt have increased carbon dioxide emissions, but the capacity of nature to absorb emissions and replenish resources remained the same (Brown 2005). Large amounts of food are thrown away as well. According to the WRAP (2008) "Food Waste" report, in the United Kingdom, 30 percent of the food bought is thrown away. In the case of meat the percentage diminishes to 4.2 percent. For years, scientists have issued warnings about the un-sustainability of these trends and stated that Earth was not capable of supporting infinite economic growth (Arrow & al. 1995).

Already in the early 70s, a group of scientists of the Massachusetts Institute of Technology (MIT) simulated Earth capacity of sustain exponential growth with limited resources. They predicted that if consumption and population continued to increase at this rate, the carrying capacity limit of the Earth would be reached within a century (Meadows & al. 1972). The results were then published in the book "Limits to Growth". Although the extrapolations made there have since been refined, the main assumption on which their research is based is still current and of extraordinary importance: Earth is infinite neither as resource "tank", nor as garbage "dump".

In spite of these warnings, subordinating the environment to economic growth has been the norm. It is assumed that an empirical relation between per capita income and some measure of environmental quality exists: the richer the societies become; the more ecologically aware they are (Arrow & al. 1995). Although some trends may indicate a correlation between economic growth and some improvements in environmental indicators, this assumption may not be true in all circumstances and therefore it is not generally applicable. As a matter of fact the environmental resources on which all economical activities are based, are finite. Therefore, the capacity of regenerating these resources may irreversibly reduce in the future. This implies that there are limits to the carrying capacity of the planet (Arrow & al. 1995).

The question of responsibility for the situation could then be raised. In order to address the issues of accountability and to understand to what extend the planet's resources have been depleted, the condition of the Earth will be evaluated below.

3.2.2 STATE OF THE EARTH

Ten years ago, the World Wide Fund (WWF) began to diagnose of the 'health state' of the planet, presenting the results in the 'Living Planet' reports. The 2006 edition stated that the Earth capacity of biological regeneration was exceeded by 25 percent (WWF 2006). The report presented the state of global biodiversity and pressures on the biosphere due to human consumption of natural resources. Two indicators were used: the Living Planet index and the Ecological Footprint. The first one reflects the health of the planet's ecosystem while the second illustrates the extent of human demand on these ecosystems (WWF 2006).

Table 3.5 shows the three indicators for several areas:

Ecological demand and supply in selected countries, 2003.

	Total Ecological Footprint (billion hectares)	Per capita Ecological Footprint (hectares/person)	Biocapacity (hectares/person)
World	14.073	2.2	1.8
USA	2.819	9.6	4.7
China	2.152	1.6	0.8
India	802	0.8	0.4
Russian Federation	631	4.4	6.9
Japan	556	4.4	0.7
Brazil	383	2.1	9.9
Germany	375	4.5	1.7
France	339	5.6	1.6
United Kingdom	333	5.6	1.6
Mexico	265	2.6	1.7
Canada	240	7.6	14.5
Italy	239	4.2	1.0
Denmark	31	5.8	3.5

Table 3.5: Samples of Ecological Footprint and biocapacity

The Earth's biocapacity is the amount of biologically productive area available to meet the needs of humanity, such as croplands, pasture lands, forests and fisheries. By 2003, the Ecological Footprint has exceeded Earth's biocapacity by about 25 percent; this meant that the regenerative capacity could not keep up with human demand any longer and resources were turned into waste faster than nature could turn waste back into resources. The Planet Index shows a rapid and continuous loss of biodiversity: vertebrate species have declined by about one third since 1970 and Ecological Footprint has more than tripled since 1961. In 2003, global Ecological Footprint was 14.1 billion hectares[1], or 2.2 global hectares per capita, while the total biocapacity area was only 11.2 billion hectares.

The footprint of a country is calculated from the area required to meet people's consumption from:

- Cropland - Needed for food, animal feeds, fibres and oils.
- Grassland and pasture - Needed for grazing for livestock, hides, wool and milk, as well as fishing grounds for fish and seafood.
- Forests - needed for wood, wood fibre, pulp, and fuel wood.

It also includes the space required for infrastructure, and the area required to absorb CO2 released when fossil fuels are burned, minus the amount absorbed by oceans (WWF 2006). Resources consumed by people and ecological services come from all over the world, so the footprints are calculated as the sum of all these factors. The consumption of goods and services is then calculated per capita, making an average between all inhabitants. A country deficit is calculated as its biocapacity per capita minus the ecological footprint per capita.

The EU has a large deficit per capita of 2.6 global hectares, second only to the USA with a deficit of 3.7 hectares. The EU is therefore using over twice its own biocapacity.

For decades, resources have been used inconsiderately, the current situation demands a radical change in the relations with the ecosystems, their capability of renewing resources is weakened and current practice not sustainable. Therefore, it is important to quickly redefine the relation between societies and ecosystems; the capability and technical knowledge exists, however it needs to be accompanied by political means. These changes will not be easy; however, they need to be carried out to guarantee a future to the next generations.

[1] The Ecological Footprint and biocapacity are both measured in units of global hectares, a hectare normalised to the average productivity of all bioproductive hectares on Earth (Kitzes & al. 2007). Therefore when referring to Ecological Footprint hectares, another unit of reference is used; this should not be confused with hectares, the unit of area.

3.2.3 WHAT WILL BE THE NEXT ERA?

In order to guarantee environmental sustainability, the natural capital should remain intact according to Goodland (1997). Contrary to this agriculture has degraded more of this capital and caused more extinction of species than any other sectors. However, agricultural production needs to be increased to guarantee food supply for the growing world population.

Goodland (1997) indentifies only three possible options for increasing food production: extensification, intensification and a decrease of the production of grain-feed meat. Extensification refers to an expansion of the cultivated areas. The uncultivated area is unfortunately limited and most of it is marginal land. In fact, opposing problem is occurring worldwide; erosion and abandonment of land. During the last 50 years about one third of the world is arable land has been lost by erosion and continues to vanish at a rate of 10 million hectares per year (Goodland 1997). If the as of now untouched land, such as remaining wildlands, and tropical forests would be converted into agricultural land, much biodiversity will be lost. Therefore, according to Goodland, the expansion of cultivated land is going to impose greater environmental costs than food benefits. The second option is to increase food production by intensifying existing cultivated areas. As in the Green Revolution, this approach will require more fertilisers and water, but both are becoming scarce resources. Fossil fuels have become too expensive and water is limited. Furthermore cereals yields have slowed considerably in the last decades, while overgrazing and soil erosion are increasing and reducing the availability of cropland. However while there is a restricted availability of irrigated land, much could be done by improving irrigation efficiency, since 40 percent of water set aside for irrigation never reaches the farms, and agriculture is estimated to use 70 percent of all water sources (Goodland 1997; FAO 2006). The third choice consists in redirecting feed grains to people instead of livestock; this measure alone would increase availability of food without any further intensification of production. Formerly, farm animals used to graze and to be fed with farm wastes; they were used for traction and provided valuable manure. Today, animals are consuming more grain than humans (Goodland 1997). Furthermore, nations used to be basically self-sufficient in food production until the 1960s, while today only a few countries are (Goodland 1997).

It can be argued that diets should be simplified and grass-fed animals should be preferred to the grain-fed ones, this obliging people to obtain their food from lower parts of the food (Goodland 1997). Although moving up the food chain by eating meat has been considered as a positive consequence of economic development, this assumption should be reconsidered in light of limits to this development.

4 METHODOLOGY

This chapter provides a description of the methodology applied to the research model in order to answer the research questions presented in chapter 2 – research structure. Within the methodology, the system applied as well its limitations are explained, along with the data collection method and the data preparation for each scenario.

4.1 SYSTEM DESCRIPTION

Agricultural practices around the world differ in terms of choice of crops and livestock to produce. This thesis focuses on land management in Europe, and four specific cases in regard to:

- land use and environmental impacts of the livestock sector;
- land use for biofuel production;
- land necessary for compensating lower yield;
- side effects of traditional intensive farming as well as organic agriculture.

4.1.1 DELIMITATIONS

Farming is a global business as seeds, chemicals, crops, and other resources are nowadays widely imported and exported around the globe; however, this investigation will be limited to Europe.

Europe - or EU 27 - is defined as the 27 member countries of the European Union: Belgium, Luxemburg, Netherlands, France, Italy, Germany, Denmark, Ireland, United Kingdom, Greece, Portugal, Spain, Austria, Finland, Sweden, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria and Romania (EU 2007). However, data which refers to the period before the year 2007 do not include Bulgaria and Romania which became members of the EU only in 2007. Countries which belong to the European continent but are not members of the EU have not been included. Limited data was available on these countries, and although they may be joining in the future, and may have a significant influence in crops production, the assumptions made refer mainly to current consumption patterns and current land availability. Also, overseas countries that are part of the EU but are not in the geographical territory, such as Canary Islands, Guadalupe or French Guiana have not been included.

The calculation of environmental impacts and land use is therefore limited to the European territory for the data elaboration and analysis; although it is acknowledged that import of agricultural goods has consequences for the environment and biodiversity of other countries. Regarding livestock, only 3 species will be considered: cattle, pigs and poultry. As elaborated in the following chapter, they represent about 90 percent of the meat production and consumption in Europe. Regarding biofuels, high hope arise for second generation biofuels. However, only first generation biofuels will be considered since they are currently being commercialised and have significant impacts on demand. Many other sectors could have been taken into consideration, but livestock and biofuel have been chosen for their significant impact in terms of land use and especially for the controversy they fuel; since they occupy land which could otherwise be used for food production. As seen in the screening LCA, the most significant impacts occur in the first stage, during the crop cultivation for preparing animal feed. Therefore the analysis of the meat scenario will focus mainly on this part, although impacts in the farm will also be considered. Since cereals are the main ingredient cultivated for feed production (Elferink & Nonhebel 2007), it has been used as a reference in the calculation of organic and traditional intensive agriculture. Furthermore, cereals are also significant in terms of occupied land in Europe.

Nowadays, potentials of bio-engineering and genetically modified organisms (GMO) in agriculture are widely discussed; it is argued that these could help to reduce plant diseases and increase the production (FAO 2003). However they have not been included in the model because of the uncertain results and potential risks still addressed, and most of all due to their limited availability in the EU (Loureiro 2003).

European agriculture varies in yield depending on the type of soil and climate. In Northern Europe, due to the short length of the growing season and geological conditions, the area available for agriculture is fairly limited. The areas along the Atlantic coast and the Alpine countries are characterised by wet conditions which favour permanent pastures, but lower yield and quality for several arable areas. The most productive region, in terms of soil and climate is the great European plain which includes Southeast England, France, Germany and western Poland. Similarly, good conditions are found in Hungary. The continental conditions of Eastern Europe are less favourable: little precipitations and large variations in the annual temperature cycle reduce the choice of crops. The Mediterranean regions are favoured by a relatively warm climate and a long growing season, but are strongly affected by dry conditions which implicate relatively low cereal yields in Southern Europe (Ericsson & Nilsson 2006).

It should be noted that the results from these calculations are mere approximations intended to derive general correlations and trends. The inaccuracies result from data from different years being compared (e.g. some data referred to 2002 other to 2004) on the one hand, and the unavailability of certain data on the other. A more detailed description about data collection is offered in paragraph 4.1.3.

4.1.2 Scenarios description

The four scenarios have been chosen to model ecological impacts of agricultural intensive use and land occupation. As the various activities within agricultural intensive practices have already been presented, the results from hypothetical changes in the current scenarios' patterns will now be investigated. First of all, the principal land uses in Europe will be delineated focusing on land occupied by arable land. Then, the questions applied to the four scenarios will be answered.

The first scenario intents to answer the first sub-question: "What are the environmental implications of meat consumption?" In order to answer to this question, the species of livestock are evaluated to determine the current land requirement for cattle, pigs and poultry. Meat production in Europe is then compared with meat consumption by EU inhabitants and the land required to satisfy this demand is calculated. Subsequently, hypothetical scenarios are presented to demonstrate how much land could be saved by reducing meat consumption, and used for other purposes, such as the production of biomass for energy use. Finally, the advantages and disadvantages of reducing the land occupied are discussed.

The second sub-question refers to biofuel production and consumption for the transportation sector. The biofuel scenario refers only to the EU 15: Belgium, Luxemburg, Netherlands, France, Italy, Germany, Denmark, Ireland, United Kingdom, Greece, Portugal, Spain, Austria, Finland and Sweden, since the data refers to the year 2000 when the other 10 countries just joined the EU. Firstly, data about production and consumption in the EU 15 are presented. Thereafter, the amount of land necessary to replace 5.75 percent, 10 percent or 100 percent of fossil fuel with biofuel is calculated. The last two scenarios refer to advantages and disadvantage of organic farming and traditional intensive farming in the EU 27. First of all the status of organic and intensive farming is presented in terms of percentage of total land production for cereals and livestock, as well as yield of cereals in the 27 countries member of the EU. Subsequently, the following hypothetical scenarios are calculated:

- land necessary to switch the current production of livestock and cereals to organic;
- land that could be available by increasing the yield of cereals production in countries with lower yield.

The required and available land is then compared with the other uses like land occupied by livestock and land available for biofuels or re-naturalisation.

4.1.3 Data collection and preparation

The estimation of land use and farm production are based on data from FAOSTAT and Eurostat: FAOSTAT (2008) is a database of worldwide statistics on agricultural and food production, consumption, trade and resources of the FAO, while Eurostat offers harmonised statistics about EU member states. These statistics have been combined with a variety of other sources, extracted principally from the publications discussed in chapter 5 – Findings -.

Many simplifications have been applied through the modelling, leading to less accurate results for the following reasons: not all data is from the same year (the oldest one refers to the year 2000) and certain data about specific countries were missing.

However, it has been assumed that the variations from one year to the other were insignificant and missing data has been extrapolated (from previous years or other data) in order to offer a more accurate result. In the presentation of the findings in chapter 5, such missing data is always clearly marked. In table 4.1, a brief specification of data sources, year and procedures for preparation of the model value is shown. After the evaluation and where possible, the data will be converted in terms of land used per country.

Variable and parameter	Principal data source	Reference year	Comment on data preparation and model values
Population	FAOSTAT	2006	
Land use	FAOSTAT	2005-2006	Land area refers to total land area excluding area under major water bodies like rivers and lakes. Arable land refers to land under temporary crops. Permanent crops are sown or planted once, and then occupy the land for one year and need to be replanted after each harvest. Forest refers to land under natural or planted stands of trees, whether productive or not.
Arable land uses	Eurostat	2006-2007	
Meat production	FAOSTAT	2002	Meat production is from both commercial and farm slaughtering. Data are given in terms of dressed carcass weight, excluding offal and slaughter fats.
Meat consumption	FAOSTAT - Eurostat	2002-2004	FAOSTAT: meat consumption refers to the total meat retained in country and comprises horsemeat, poultry, and meat from all other domestic or wild animals.
Feeding stuff sold	Eurostat	2006	
Fish consumption	FAOSTAT	2002	Total food supply from fishery products is defined as the quantity of both freshwater and marine fish, seafood and derived products available for human consumption. All parts of the fish are included.
Protein consumption	Eurostat	2001-2003	Includes data about eggs, milk, cheese and dried pulses.
Feeding stuff	Eurostat		
Biofuels	EurObservER	2002:2004	
Biofuel yield, production and consumption	IEA	2000	
Cereals production	Eurostat	2006	
Livestock units	Eurostat	2006	
Organic cereals	Eurostat	2006	
Organic livestock	Eurostat	2006	
Fertilisers	Eurostat	2001	Total volume of nitrogen (N), phosphate (P_2O_5) and potash (K_2O).
Pesticides	Eurostat	2001	Total volume of pesticides is the sum of fungicides, herbicides, insecticides and other pesticides.
GHG emissions	UNEP	2004	Emissions of N_2O and CH_4 from the agricultural sector include emissions from: Arable Land (fertiliser use); Animal waste management; Savannah burning; Agricultural waste; Crop production; Animal waste (deposited on soil - N_2O); Atmospheric deposition; Leaching and Run-off. The emissions from deforestation, vegetation fires and deforestation post burn effects are not included.

Table 4.1: Source and specifications for the data used in the model

An estimation of land use per country in the same cases is not possible due to the lack of per country data, which may have been available for the EU 15 but not for the 27 EU countries. The delineation of the scenarios has been challenging in many cases because of limited data availability, limitations in the format of existing data and the need to make assumptions about relationships and processes involved in the farming process.

The analysis will take the methodological issues previously mentioned into consideration, especially the collection of current and precise data for every member of the EU. Consequently, the harmonisations of the results will somewhat be imprecise. However, the results obtained are still valid when deriving trends for Europe.

4.2 METHOD

This paragraph details the method applied to answer the scenario through calculations. The most significant steps and the assumptions made are explained in detail. Land is considered as the functional unit and in order to put it into perspective, it is also expressed in terms of the amount of other goods it can produce. This consists in very important approximations, since each country has particular characteristics and different productivity rates, although an average will be assumed for Europe. It has been decided in this thesis to adopt this specific method to allow results to be compared more easily, especially in regard to political choices. It is important to acknowledge the limits to these results as they might not reflect the current empirical situation in the EU. As always the case with system modelling, many other variables that could have potentially been considered have been left out or simplified.

Before starting with the presentation of the results for the four scenarios, land use in Europe is illustrated. The distribution of land devoted to agriculture, forestry or other uses as well at the population density are depicted.

4.2.1 MEAT SCENARIO

This scenario intents to investigate the amount of land occupied by livestock as a consequence of meat consumption in Europe. Pig and poultry production systems depend to a large extent on concentrated feed imported from outside the farm (Van der Werf & al. 2005). The calculations about land use for producing meat are based on a research article made by Elferink & Nonhebel (2007) about livestock in the Netherlands.

According to their study, the sum of all the feed ingredients gives the land required to produce 1 kg of beef, chicken and pork; respectively 29.0 m^2/kg, 7.7 m^2/kg and 10.3 m^2/kg. There are many differences in the feeding system, both in species diet and feed ingredients. However the study makes an average feed composition for livestock species, both for feed crops and by products, considering specific yields of ingredients produced in the Netherlands and abroad; as well as the dressing factor[2]. Also, waste-streams have been considered in the balance of nutrition value. Within the feed crops which represent the livestock feed there are: wheat, barley, maize, soybeans, rapeseed, cassava and pea. According to Elferink & Nonhebel (2007), beef cattle consume large amounts of by-products, but almost no crops or waste-streams. Pigs consume nearly everything but rapeseed, while broilers essentially eat feed grains and waste streams.

As mentioned earlier, the feeding system varies a lot from country to country, especially in regard to the yield of production. Therefore, equating the Dutch feeding system to the whole of Europe is an approximation; especially as some countries make larger use of pasture or have lower yields. However, Brown (2005), while describing livestock requirements in terms of resources, assumes a proportional rate of feed for the 3 species: 7 kg of grain for each kg of beef, 3.5 kg for the same amount of pork and 2 kg for chicken. Although imported, feeding stuffs are an essential part of livestock diet in Europe; this value has been neglected in the calculations as there were no specific data available about imports for each country and within the European countries. However, the main purpose is to calculate the quantity of land dedicated to livestock. Pasture land will not be included in the calculation, since it is not possible to quantify the amount of pasture land actually used by livestock.

Data about total meat consumption were available for each country, but the specific amount of beef; pork and chicken consumed were available only for certain countries. Therefore, the average meat consumption of the countries available has been calculated and applied to countries without available data; the total amount of land necessary for livestock is the result. The same percentages have been kept for calculating the reduced consumption cases.

[2] The dressing factor represents the consumable fraction of each animal, or the part that is suitable for human consumption. Pigs are the most efficient with a dressing factor of 0.81, followed by chicken with a dressing factor of 0.75, while beef cattle have the lowest dressing factor, 0.59 (Elferink & Nonhebel 2007).

4.2.2 Biofuel scenario

The issue of biofuel is currently being debated in the light of the recent grain prices' increase and land use "conflicts" between grains and biofuels. Using the data from 2000, the land required for replacing 5.75 percent and 10 percent fossil fuels by biofuels will be calculated, in order to understand if these goals could feasibly be achieved.

Biofuels produced in Europe are made of wheat (50 percent), beet (30 percent), barley (20 percent) for ethanol, while rape (70 percent) and sunflower (30 percent) are employed for biodiesel production (IEA 2006). However the varieties produced vary from country to country within the EU. As will be shown it the next chapter, much more biodiesel than ethanol is produced, while the calculation assumes an equal production of ethanol and biodiesel. Ethanol has a yield (in litres per hectare) 6 times higher than biofuel; therefore, calculations could have been made also in regard to a higher production of ethanol; however this consideration has been excluded, since Europe produces mainly biodiesel (IEA 2006).

The yield and fuel consumptions rate have been considered similar to those of the year 2000, although there have been developments in this sector and new biofuels are seemingly more efficient. This factor can raise the risk of incertitude. In the meanwhile, the consumption of fuels has risen as well, so it has been assumed this increment as a way to compensate lower yields.

4.2.3 Organic scenario

The purpose of organic agriculture is ideal to produce good crop varieties with a minimal impact on ecological factors such as soil fertility (Mäder 2002). However organic farming is problematic as it requires larger areas to produce the same amount of crops compared to intensive farming.

Data available about organic farming is limited to areas of cereals production and units of livestock. Therefore, many approximations have been applied to this case and the calculations made refer mainly to literature information. Another problem occurring in this case is the difficulty to identify the cause of low yield. This can be caused by a reduced use of agrochemicals and by inefficiency or unfavourable climate conditions.

4.2.4 Traditional intensive farming scenario

In order to compare advantages and disadvantages of traditional intensive farming the amount of spare land that could be saved by increasing the yield of cereals production in countries with lower yield has been calculated. As a term of comparison, the average yield in the EU 15 has been chosen, as the choice of the highest yield available would have been unrealistic.

Unfortunately, it is difficult to delimitate a quantitative relation between intensive practices and the use of chemicals and water. Therefore, a more qualitative approach has been deemed most appropriate, presenting the emissions in the agriculture sector. Limited calculations about organic farming and gas emissions have been performed since these depend on the type of farming and species grown. Therefore, the analysis will be limited to representative data sample and a qualitative discussion rather that quantitative. Studies on organic agricultural practise often return contradictory results. Therefore, only the common understanding will be presented.

The main underlying assumptions which will inform the calculations of the different scenarios have been presented. It is acknowledged that the results to be detailed in the following chapter will be approximate and their accuracy leave room for improvement. However, these results are used in order to provide an overarching picture to frame the discussion of political choices in terms of agricultural land uses and management in Europe.

5 FINDINGS

In this chapter, the outcome of the scenarios presented in chapter 2 is shown in order to offer elements of evaluation in the analysis and discussion. The method explained in chapter 4 and the data presented will be used for the calculations regarding land use. The results will then be outlined mainly through graphs. In the appendix, all data used and the calculation made are available.

5.1 LAND USE

The main focus of this project is land distribution in Europe and its uses. Figure 5.1 and Figure 5.2, represent the mainland uses in Europe.

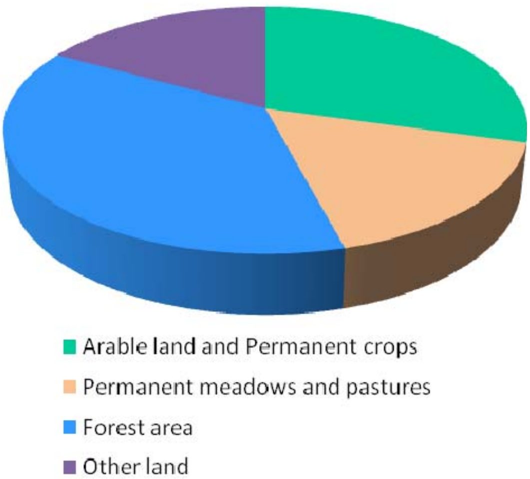

Figure 5.1: Land use in the EU. Year 2005. Source: FAOSTAT

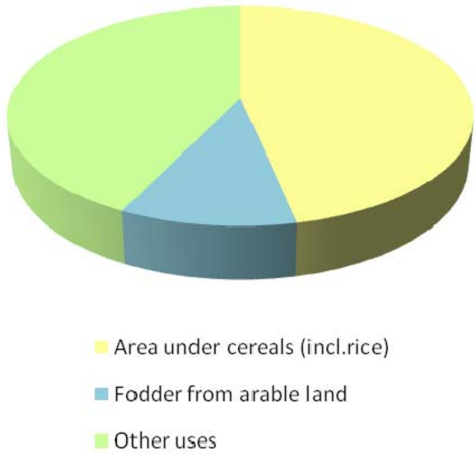

Figure 5.2: Land use of arable land. Year 2006, 2007. Source: Eurostat

Note: In figure 5.1, data about permanent meadows and pastures in Malta is not available. Other land is calculated as the difference to total land available.

In figure 5.2, data about area used for cereals production in Malta, fodder in Ireland, France, Malta and United Kingdom are missing. Data about area under cereals is from 2006, while fodder is from 2007. Other uses are calculated as the difference between arable land and the other two uses.

As show in figure 5.1, the area used for agricultural practices (arable land and pastures) occupies 46 percent of the total land available. Out of arable land and permanent crops, 47 percent is dedicated to cereal crops (figure 5.2).

In order to offer a visual idea about the land distribution in the different countries, in figure 5.3 it is provided the subdivision in arable, pasture, forest and other uses, for each state.

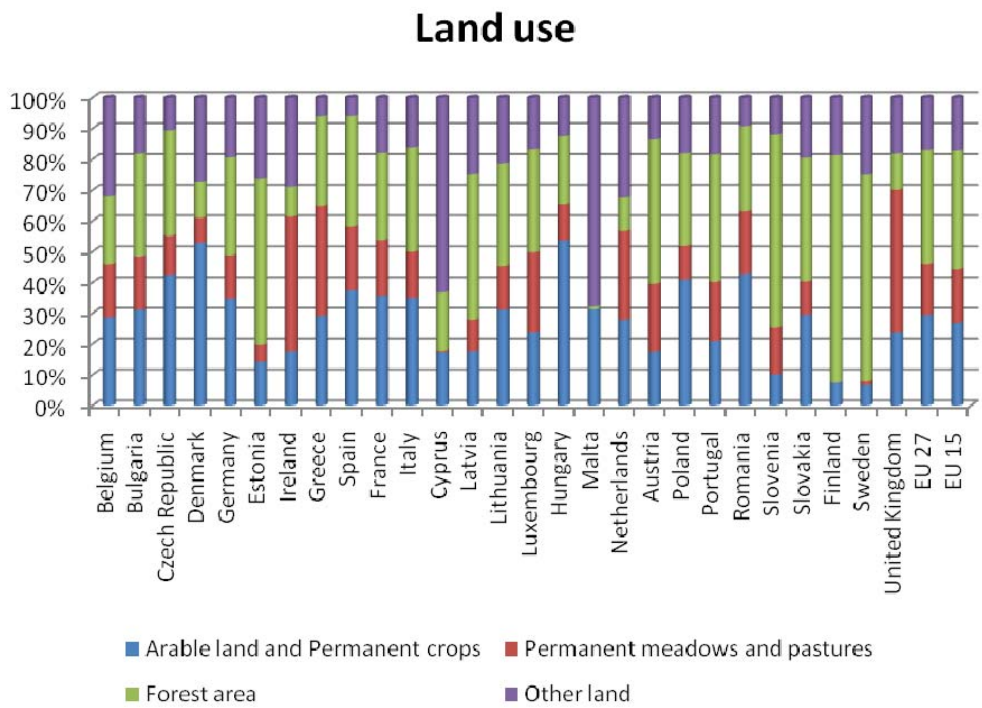

Figure 5.3: Percentages of total available land in each European country. Year 2005. Source: FAOSTAT

Note: Data about permanent meadows and pastures in Malta is not available.

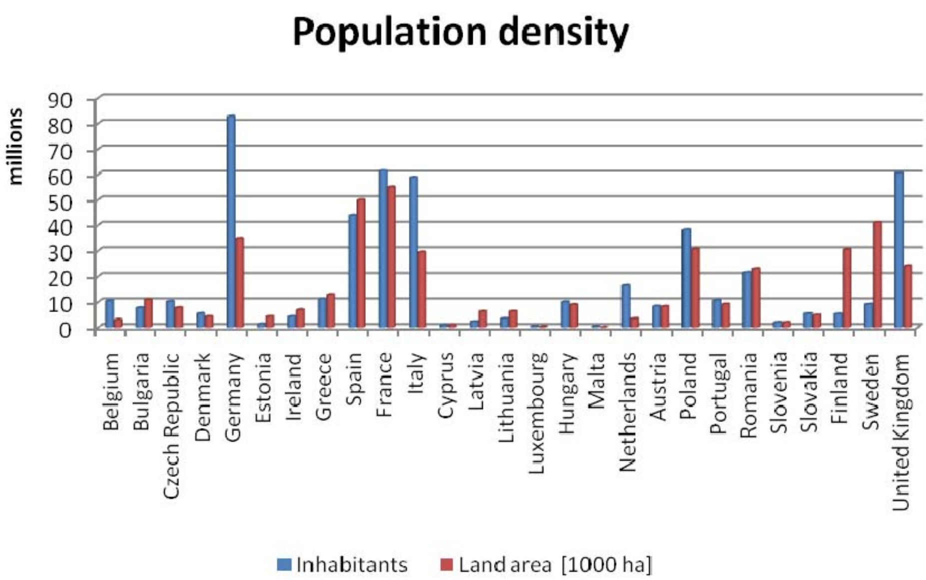

Figure 5.4: Total land available and population. Year 2006, 2005. Source: FAOSTAT

Note: Data about inhabitants is from year 2006, while population refers to the year 2005.

As can be seen in figure 5.3, Germany, Spain, France and Sweden have the largest areas available, although in Sweden and Finland the arable land is quite limited, since most part of the country is covered by forests. In order to show the relation between human consumptions and land available, in figure 5.4 are represented inhabitants and total land area available.

Europe has nearly 500 million inhabitants, which amounts to one hectare per person. However, population density varies a lot form country to country: The Netherlands, Belgium, Luxembourg, Germany and Italy have a high density of population, while Finland and Sweden have a low population density.

After this general presentation of the general caracteristics of the model, the focus will move to the spesific scenarios.

5.2 LIVESTOCK SCENARIO

In this section, the meat consumption rate is shown in relation to the land used to produce feeds for livestock. Subsequently, the land required for producing meat, assuming a lower consumption rate, will be presented. In 2002, 44 million tons of meat was produced in Europe, principally from cattle, pigs and poultry. In figure 5.5, the percentage of meat produced in each country is presented. The rest of the meat includes: bird, buffalo, duck, game, goat, goose, guinea fowl, horse, rabbit, sheep and turkey meat. Since all these categories of meat represent less than 10% of the total meat produced in Europe, the calculation of the total meat consumed is based on cattle, pigs and poultry only.

Animal farms are supplied with feed ingredients of different origins. According to the European trade statistics of 2004, nearly 33 millions tons of feeding stuffs were imported from outside EU15, principally from Argentina and Brazil (EU 2008). This amount represent 36 percent of the total preparation used for animal feeds in the EU15 (France, Greece and Netherland are excluded from the total amount).

As seen in figure 5.2, cereal crops occupy nearly half of the arable land in Europe. In 2006, 267 million tons of cereals (including rice) were produced. In the EU 27, the main producers were France (62 million tons), Germany (43 million tons) and Poland (22 million tons). In 2006, EU27 imported four million tons of cereals and exported 12 million tons. About 60% of these cereals (including imports) were used as feedingstuff (Eurostat 2002).

The calculation made for estimating the land occupied by livestock will not be based on feedingstuff consumption, but on a model estimation showing the land requirement for meat production of cattle, pigs and poultry.

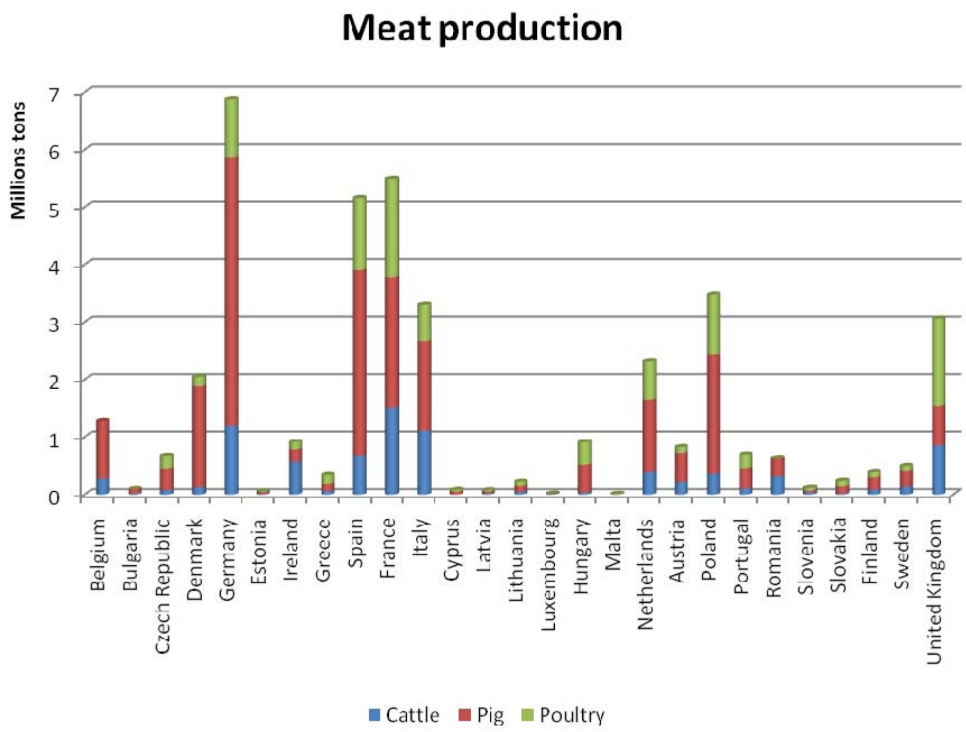

Figure 5.5: Beef, pork and chicken production per country. Year 2006. Source: Eurostat

Note: Data about poultry production in Belgium, Bulgaria and Romania are not available.

5.2.1 Land used for animal feeding

The amount of land occupied for cultivating feed crops has been calculated based on assumptions made in the Elferink & Nonhebel (2007) article. Namely, the land required to produce 1 kg of chicken, beef and pork is estimated as respectively 7,7 m^2/kg, 29,0 m^2/kg and 10,3 m^2/kg. Based on this assumption, the land occupied by the livestock sector in each country has been calculated, as show in Figure 5.6. As mentioned in chapter 4, the amount of land shown does not represent the actual land occupied for growing feed in Europe, but it is based on the assumption of equal feed composition and consumption for all the states while neglecting imports.

In certain countries, like The Netherlands, Ireland and Malta, the land required for feeding animals would exceed the available arable land. Figure 5.7 shows the proportion between cereals consumed by humans and cereals consumed by farm animals in Europe. In average, 2.6 times more cereals are consumed by livestock than humans.

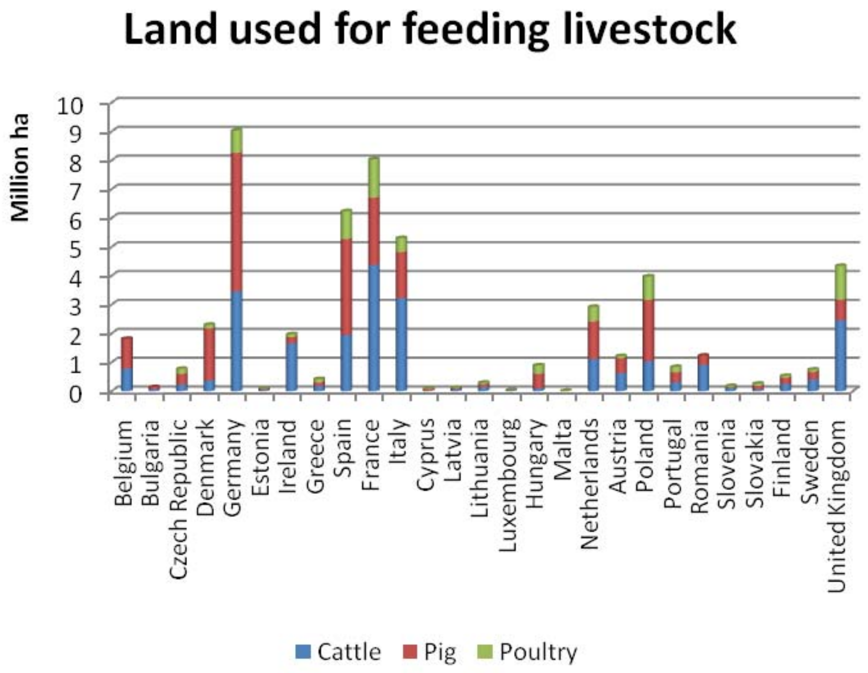

Figure 5.6: Land used for feeding cattle, pigs and poultry.

Note: Data about poultry production in Belgium, Bulgaria and Romania are not available.

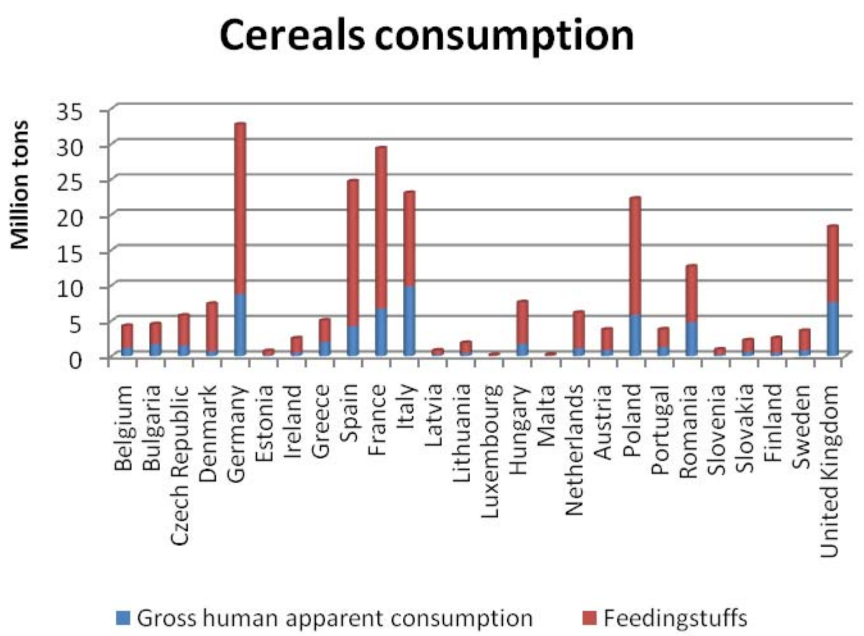

Figure 5.7: Cereals consumption, excluding rice. Year 2002. Source: Eurostat

Note: Data about cereal consumption in Cyprus is not available.

5.2.2 LAND USED ASSUMING A LOWER MEAT CONSUMPTION

As can be seen in figure 5.8, meat consumption varies considerably within the EU 27 countries: Denmark, Luxembourg and Cyprus have the highest meat consumption rate per capita, which is also among the highest in the world, while Latvia, Lithuania and Romania have the lowest meat consumption per capita, below 150 g per day. The average meat consumption per capita is around 240g per day, while the human requirement for protein it has been estimated to be 55g per day for adult men and 45g for women (Bender 1992). Gilland (2002) suggests 40g of animal protein per capita and day as sufficient. However, since meat consumption in Europe is considerably higher than that, more realistic scenarios of 70g to 100g meat consumption per day have been considered here for the calculation of land demand.

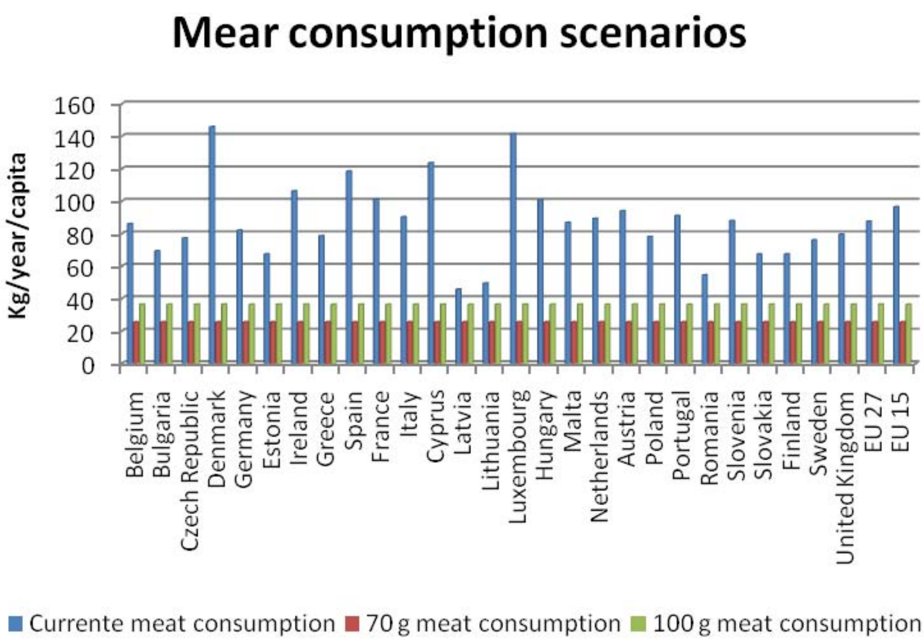

Figure 5.8: Meat consumption per capita. Year 2002. Source: Eurostat

Before exploring the land required for reduced meat consumption scenarios, some considerations should be made about the advantages and disadvantages of eating different amounts of meat. As mentioned in the previous chapters, excessive meat consumption favours cholesterol and heart diseases. Furthermore, meat is only one of many sources of food proteins. In figure 5.9, the other sources of common protein intake are displayed.

As mentioned in paragraph 3.2.1, 4.2 percent of the meat bought in the UK is thrown away, when using our model to extrapolate this waste to the whole of Europe, this costs nearly 2.5 million hectares of arable land.

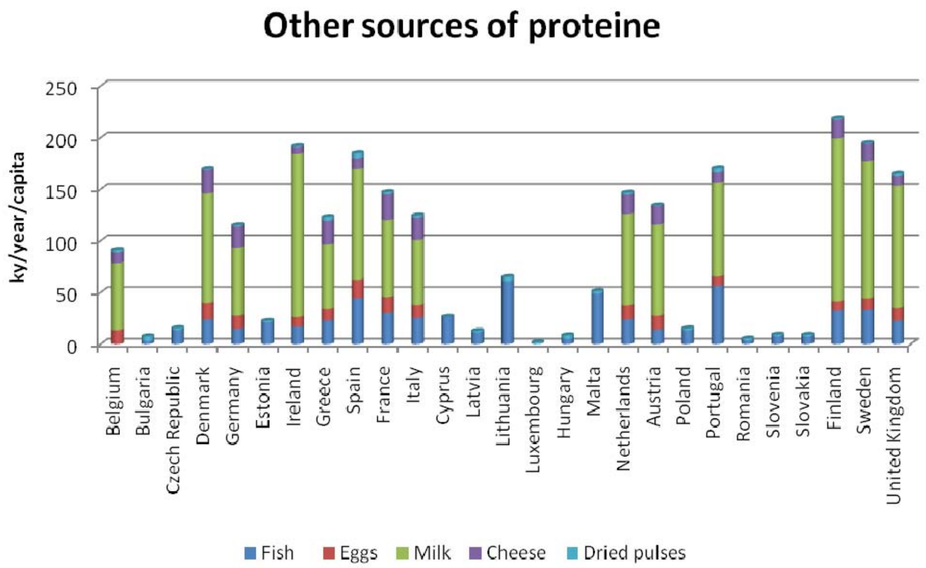

Figure: 5.9: Protein intake through consumption of fish, eggs, milk, cheese and dried pulses. Year: 2001, 2002, 2003. Source: FAOSTAT, Eurostat

Note: Fish consumption data are from FAOSTAT, year 2002. The fish consumption for Belgium and Luxemburg is missing. Eggs (2003), milk (2003), cheese (2003) and dried pulses (2001) consumption data are from Eurostat. Eggs, milk and cheese consumption are available only for EU15 beside Luxemburg. Dried pulses consumption for Cyprus is not available.

The difference between meat consumed and meat produced was 1.5 million tons in 2002 (FAOSTAT 2008), which is less the four percent and since this quantity varies slightly form year to year, import and export of meat have been considered as negligible.

Data about beef, pork and chicken consumption is available only for Denmark, Germany, Greece, Spain, France, Italy, Austria, Portugal, Finland and United Kingdom. Based on the meat consumption in these countries, an average consumption of 20.5 percent beef, 45 percent pork, 23.5 percent chicken and 11 percent of other meat has been estimated for the remaining countries. The percentage for other meat was distributed to the other categories, obtaining: 23 percent beef, 50 percent pork and 27 percent chicken as a European average. Based on these relations, between the meat categories, the land required for meat production has been calculated. The 70g meat consumption scenario would reduce the land occupied for growing crops by 42 million hectares, which corresponds approximately to the total area of Sweden. If the consumption would be reduced to 100 grams, the area released would correspond to 35 million hectares, which is about 8 times the area of Denmark. Since poultry is the most efficient species in terms of feed conversion into meat, it has been calculated that the land required for producing only chicken to meet the demand of 2002, would require 45 percent less land than currently used for livestock.

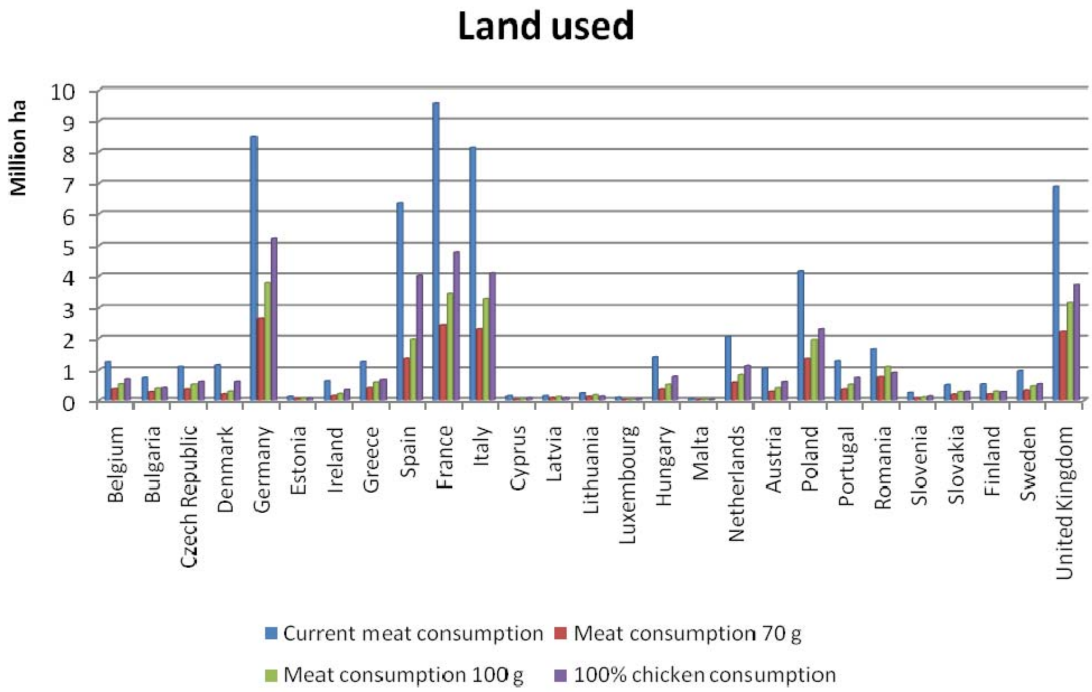

Figure 5.10: Land used in different scenarios of meat consumption.

Note: Data for poultry production in Belgium, Bulgaria and Romania are not available for the scenarios 'actual meat consumption', '70 g meat consumption' and '100 g meat consumption'.

As can be seen in figure 5.10, the proportions between the first three scenarios are similar, since it has been supposed a comparative consumption of beef, pork and chicken for large part of the countries. The last scenario, 100 percent chicken consumption, usually uses more land than the 70 g and 100 g scenarios. However, the relations change with Latvia, Lithuania and Romania having a lower percentage of land gained for the 100 percent chicken scenario than for the 100 g meat consumption scenario. Countries with a low per capita consumption understandably benefit less from reducing meat consumption On the other hand; countries with high meat consumption can regain more land by considerably reducing their meat consumption, compared to moving to more efficient species like chicken.

5.2.3 Environmental benefits of reducing the surface of land used

The most significant advantage of reducing meat consumption is the liberation of large parts of the land occupied by feed crop cultivation. Under these circumstances, the benefit would be multiple. First of all, by reducing meat production, all the threats related to traditional intensive farming would diminish; for example, inputs of fertilisers, agro-chemicals, water, energy use and the resulting outputs and impacts on the environment would be reduced. Another important factor, that the reduction of meat implies, is the availability of arable areas, which could be used for other purposes, depending on necessities and circumstances. For example, part of the area could be naturalised for conservation of biodiversity and increased absorption of CO_2, or it could be used for other purposes such as energy crops production or organic farming. Details for these alternate uses are given below, but many other options for the use of regained land exist;

5.3 Biofuel Scenario

Biofuels have been identified as an alternative energy supplier to fossil fuels, but they need to be cultivated and thus require arable land. A first target of replacing 5.75 percent fossil fuel for the transport sector with biofuel was set by European commission for 2010. Lately, a new goal of 10 percent was set by 2020. In this section, the land necessary to supply 5.75 percent, 10 percent and total fossil fuels demand has been calculated. Since the data on fuel demand used for the calculation are from the year 2000, only EU15 countries will be considered.

5.3.1 Biofuel consumed, produced and imported

In 2000, EU15 countries produced 0.3 billion litres of ethanol and 0.7 billion litres of biodiesel, which represented respectively 0.2 percent and 0.5 percent of relevant transport fuels. The total consumption of gasoline and diesel were equally large: 144.2 billion litres for the first and 146 billion litres for the second (IEA 2006).

Table 5.11 shows that the EU is mainly producing biodiesel, which in large parts is obtained from rapeseed: The EU is actually the world leader in biodiesel production. Even so, large amounts of ethanol are imported. The biggest exporter of ethanol to the EU is Pakistan, followed by Brazil and Guatemala (USDA 2005). Biodiesel accounted for nearly 80 percent of EU biofuel production. Germany alone produced over half of the total biodiesel in the EU. France and Italy are also important biodiesel producers, while Spain is leading ethanol production in Europe, as seen in table 5.11.

Country	Biodiesel			Ethanol			Total		
	2002	**2003**	**2004**	**2002**	**2003**	**2004**	**2002**	**2003**	**2004**
Germany	141	224	324	0	0	7	141	224	330
France	114	112	109	30	27	34	145	139	143
Italy	66	85	100	0	0	0	66	85	100
Spain	0	2	4	59	53	65	59	55	69
Denmark	3	13	22	0	0	0	3	13	22
Czech Republic	22	22	19	2	0	0	23	22	19
Austria	8	10	18	0	0	0	8	10	18
Sweden	0	0	0	17	17	17	17	18	18
Poland	0	0	0	22	20	12	22	20	12
United Kingdom	1	3	3	0	0	0	1	3	3
Slovak Republic	0	0	5	0	0	0	0	0	5
Lithuania	0	0	2	0	0	0	0	0	2
Intervention Stocks[3]	0	0	0	0	23	29	0	23	29
Total	355	470	604	130	141	164	484	612	768

Figure 5.11: Biofuel production in million gallons. Source: USDA 2007b

Between 2004 and 2005, biofuel production increased by 65.8 percent while biodiesel continued to be the preferred biofuel covering 81.5 percent of total production (EurObserv'ER 2006).

5.3.2 Land required for increased biofuel production

Assuming data referring to production in the year 2000, the land required for producing 5.75 and 10 percent biofuels in the EU15 has been calculated. The average biofuel yield for ethanol is 2790 litres per hectare and 1239 litres per hectare for biodiesel. In 2000, 0.3 billion litres of ethanol and 0.7 billion litres of biodiesel were produced, which occupied respectively 108 thousand hectares for producing ethanol and 569 thousand hectares for

[3] Under the CAP, the EU is obligated to purchase, at intervention prices, many qualifying crops offered by farmers and traders who are unable to sell at a higher price on the private market (USDA 2007b)

producing biodiesel. This represents 0.13 percent and 0.67 percent of total arable area in EU 15 countries.

	Ethanol	Biodiesel	Ethanol	Biodiesel	Ethanol	Biodiesel	Ethanol	Biodiesel
% total fuel consumption	0.2 %	0.5 %	5.75 %		10 %		100 %	
Biofuel production [billion litres]	0.3	0.7	8.3	8.4	14.4	14.6	144.2	146.0
Land required [1000 ha]	107	569	2972	6826	5169	11870	51685	118699
% arable land	0.1 %	0.7 %	3.5 %	8.1 %	6.2 %	14.2 %	61.7 %	141.6 %
% cereals land	0.3 %	1.6 %	8.4 %	19.3 %	14.6 %	33.5 %	145.8 %	334.9 %

Figure 5.12: Land required for different scenarios of biofuel consumption in EU 15.

Assuming a stable consumption of gasoline and diesel, the land required to produce 5.75 percent of biofuel would be approximately one billion hectares which corresponds to 12 percent the total arable land in EU 15. The land occupied for producing 10 percent biofuel would increase to 20 percent of the total arable land. In table 5.12, the percentages of land occupied by ethanol and biodiesel production have been listed and compared to the amount of land used for cereal production, with which bioenergy competes. In the model, an equal production of ethanol and biofuel were assumed, aven though biofuel production is higher. Assuming that all fossil fuel consumption is from diesel and the biofuel is produced only as biodiesel, the land required for producing 5.75 percent biodiesel would rise to 16 percent of all arable land, while 10 percent biodiesel would require 28 percent arable land. This is due to the lower yield that biodiesel presents in comparison to ethanol.

5.3.3 Land required for total replacement of transportation fuel demand

Biofuel is usually mixed with gasoline or diesel and represents only a small part of total fuel use. However, petroleum prices are expected to continuously rise, resulting in economic pressure to considerably reduce the use of fossil fuels in transportation. Therefore, a last scenario, which substitutes all gasoline and diesel consumption with biofuels, has been designed.

As shown in table 5.12, the arable land required for replacing all fossil fuels for the transportation sector would be twice the total arable land currently available in the EU 15, which corresponds to nearly 5 times the arable land used for cereal production.

Comparing the amount of land required for biofuel production and land available by reducing meat consumption in the EU 15, it is clear that the first two goals of 5.75 and 10 percent could easily be achieved by all scenarios for meat consumption reduction. In fact, the land available by reducing meat consumption is higher in the EU 15 than in the EU 27, since western countries consume more meat.

5.4 Organic farming scenario

Organic farming is considered a more sustainable form of agriculture because it avoids the use of chemicals and provides a cage- and barnless environment for the livestock. However, it requires large amounts of cultivated area due to the lower yield. In this section, the current state of organic cereals and livestock will be presented and the additional land required to switch to organic farming will be described.

5.4.1 Organic cereals and livestock compared to traditional farming

As can be seen in figure 5.13, every country except for Greece has a larger percentage of organic cattle than organic pigs. This difference can be explained with the amount of cattle used for producing organic milk and dairy products, which are also included in the figure. Figure 5.14 shows the percentage of the area used for organic cereal cultivation out of the total arable land. Austria and Latvia hold the record for most organic production of both cattle and cereal.

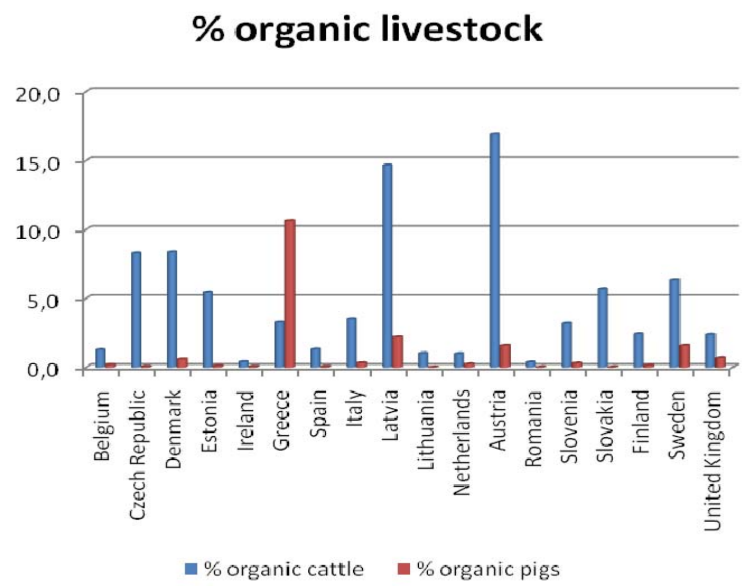

Figure: 5.13: Percentage of unit of organic cattle and pigs. Year 2006. Source: Eurostat

Note: Data for organic pigs in Bulgaria is not available. Data for organic cattle and pigs in Bulgaria, Germany, France, Cyprus, Luxemburg, Hungary, Malta, Poland and Portugal are not available.

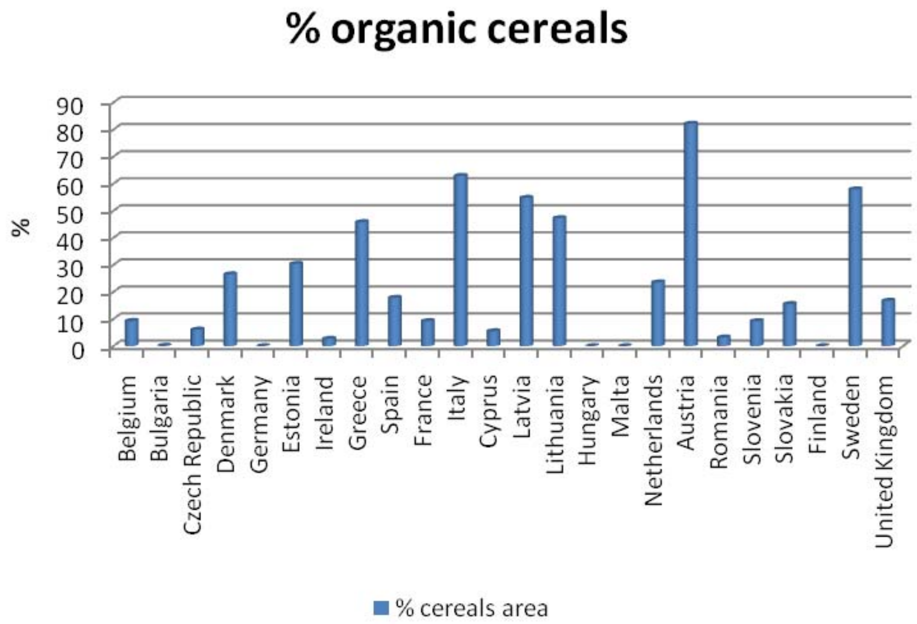

Figure 5.14: percentage of organic cereal area on total arable land. Year 2006. Source: Eurostat

Note: Data for cereals area in Germany, Hungary and Finland is not available

5.4.2 LAND REQUIREMENTS FOR ORGANIC PRODUCTION AND TRADITIONAL FARMING

According to Mäder & al. (2000), crop yield in organic production is 20 percent lower compared to traditional intensive agriculture in Central Europe, although the inputs of fertilizers and energy are reduced by 34 to 54 percent and pesticides input is reduced by 97 percent. They also found that cereal crop yields under organic management are 70 percent of those with conventional management systems.

Kumm (2002) investigated the land area required for organic meat production under Swedish circumstances. They concluded that conventional pork production is more efficient than the organic variant because here pigs are fed only with grain and have a high efficiency rate when converting feed into meat. On the contrary organic pork requires outdoor space and organic feed, which has one-third lower yield than conventional grain. Therefore, organic pigs necessitate nearly twice as much land per kilogram of meat than the traditionally reared ones. In the case of organic beef production, the differences between land requirements are smaller as, according to the authors, conventional cattle already have a ruminant-based diet, which is then enlarged in organic systems. Organic beef production requires approximately 10 percent more land than conventional ones (Kumm 2002). Considering also the impacts on biodiversity, use of pesticides and energy, GHG gases and production cost, Kumm (2002) argues that in case of shortage of arable land for food supply, conventional pork would be the most sustainable alternative. Another sustainable alternative would be organic meat production mainly based on by-products and natural pastures which do not require arable land.

Next, the amount of land that would be required for organic farming is calculated.

5.4.3 LAND REQUIRED TO SWITCH TRADITIONAL CEREALS AND LIVESTOCK PRODUCTION INTO ORGANIC

Figure 5.15 shows the amount of land required to switch cereal crop production to an organic one according under different scenarios.

The first column shows the land currently occupied by cereal crops production. The second category (30 percent less) represents the land required to produce the same amount of grain as in the traditional scenario, but with a 30 percent lower yield. Finally the last scenario imposes the organic production only on countries that already have a yield higher or equal to Sweden, in order to spare countries that already have a low yield.

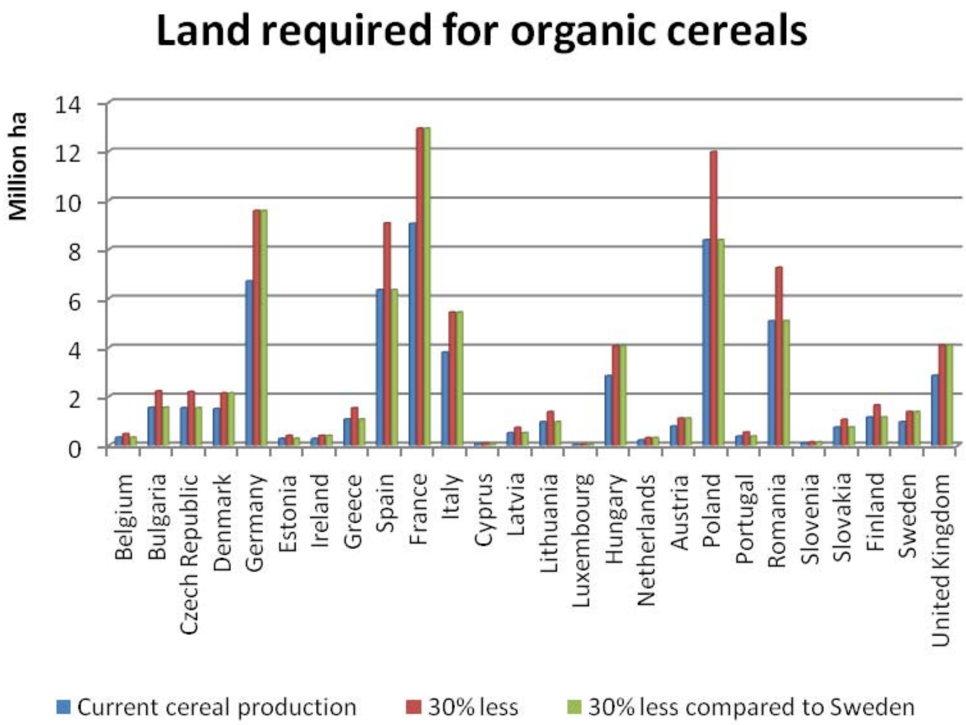

Figure 5.15: Land required for different scenarios of organic cereal production.

Note: Data for Malta is not available in each category.

For the livestock sector, land used in organic farms has been calculated only for cattle (figure 5.16). Poultry were excluded in this analysis due to the lack of data on meat production per unit, while pigs have been considered inadequate due to the considerations made above. The analysis thus shows that the additional land required for producing organic beef in the EU 27, is insignificant compared to the land saved by reducing meat consumption.

	Traditional farming	**Additional land required with organic cattle**
Total meat consumption	6.0	2.9
70 g meat consumption	1.8	0.8
100 g meat consumption	2.5	1.0

Figure 5.16: Land required for producing organic beef in the EU 27 in Million ha.

5.5 TRADITIONAL INTENSIVE AGRICULTURE SCENARIO

Here, it will be shown that cereal yield varies considerably within the EU. The area that could be regained by increasing the yield of low yield countries will be calculated as well as the advantages and disadvantages thereof.

5.5.1 CEREAL YIELD IN EU COUNTRIES

Cereal yield has been calculated as the production divided by the area occupied by the crops. As can be seen in figure 5.17, there is a significant difference among the 26 countries: Estonia and Latvia require nearly four times the amount of land that Belgium and Nederland use for producing the same quantity of cereals.

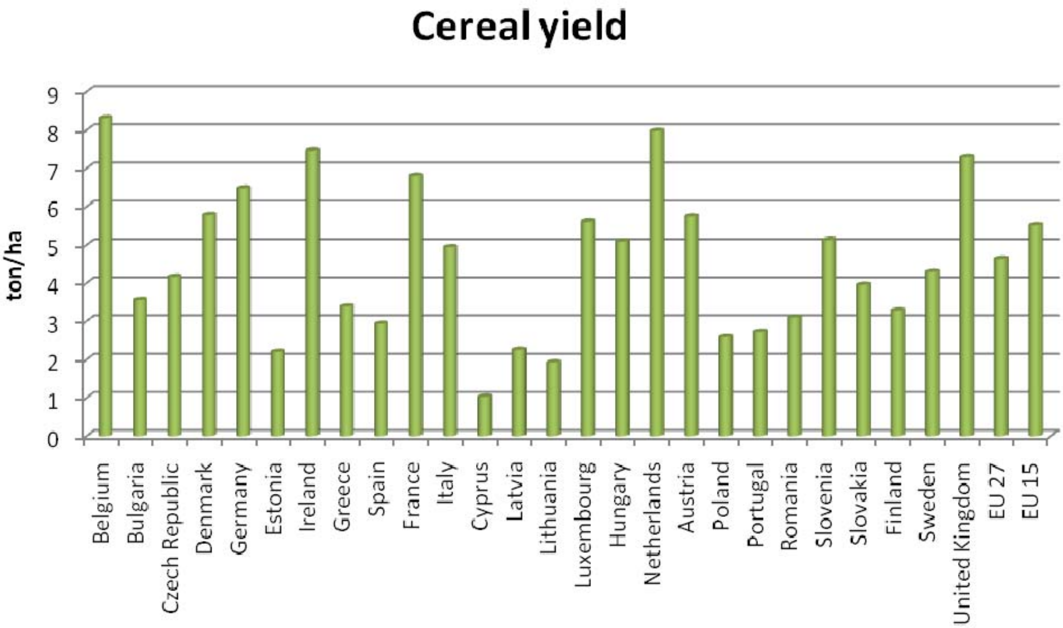

Figure 5.17: cereal yield in 2006.

Note: Data about Malta is not available.

Because of these substantial differences, the land that could be regained by increasing the production yield of low yield countries has been calculated.

5.5.2 Grain additionally produced by increasing the yield

If the countries with lower yield would increase their level of cereal production to the average EU15, it would be possible to produce additional 77 million tons of cereals, which corresponds to nearly 29% of the actual cereal production in the EU 27.

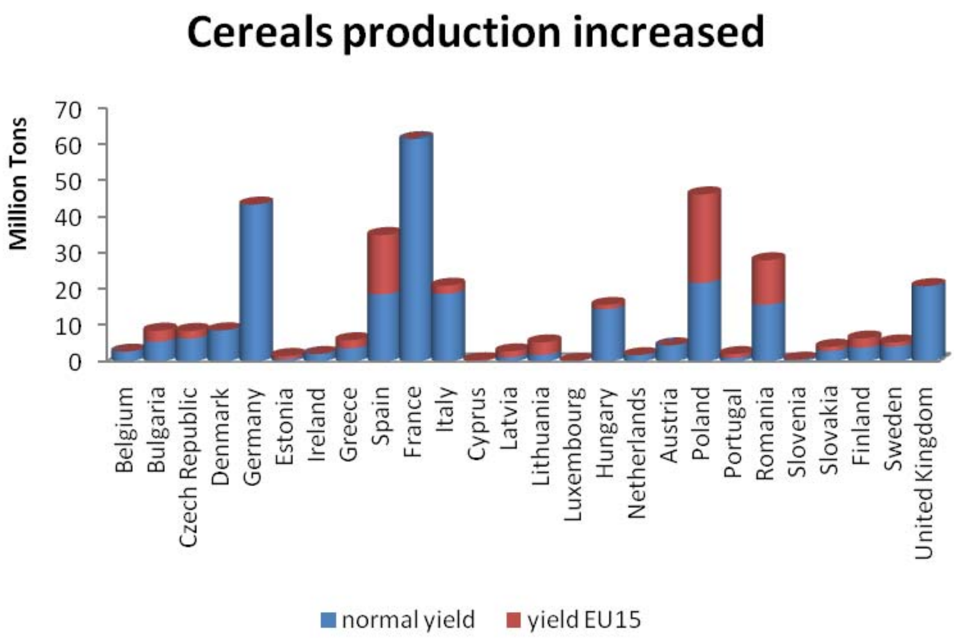

Figure: 5.18: Comparison between normal yield and yield increased to EU 15 average.

Note: Data about Malta is not available.

In figure 5.18, the red bars represent the additional cereal production assuming a higher yield. Thanks to this increased yield, total cereal production could be increased by 29 percent as described above or the arable land could be reduced by 13 million hectares. This land could in turn be used to produce 26 billion litres of biofuel (assuming to use 50 percent for ethanol and 50 percent for biodiesel), or 16 billion litres of ethanol per year.

5.5.3 Environmental costs

Before presenting the environmental costs of such a yield increase, two graphs that show the pesticide and fertiliser use in Europe are presented.

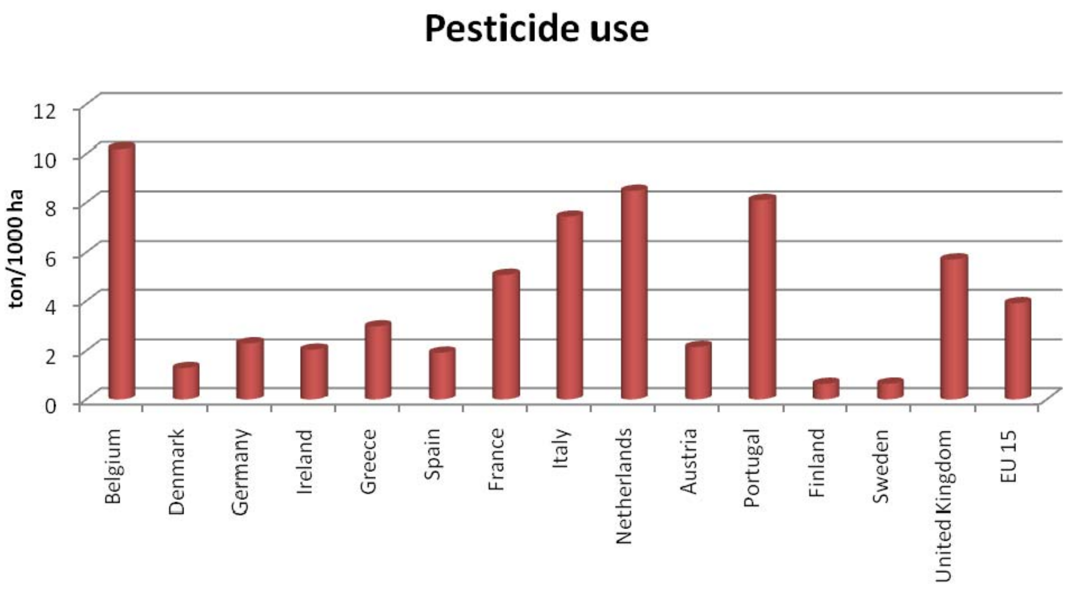

Figure 5.19: Total sale of pesticides in EU15. Year: 2001 Source: Eurostat

Note: Data refers only to EU15 countries. Data for Luxemburg is not available.

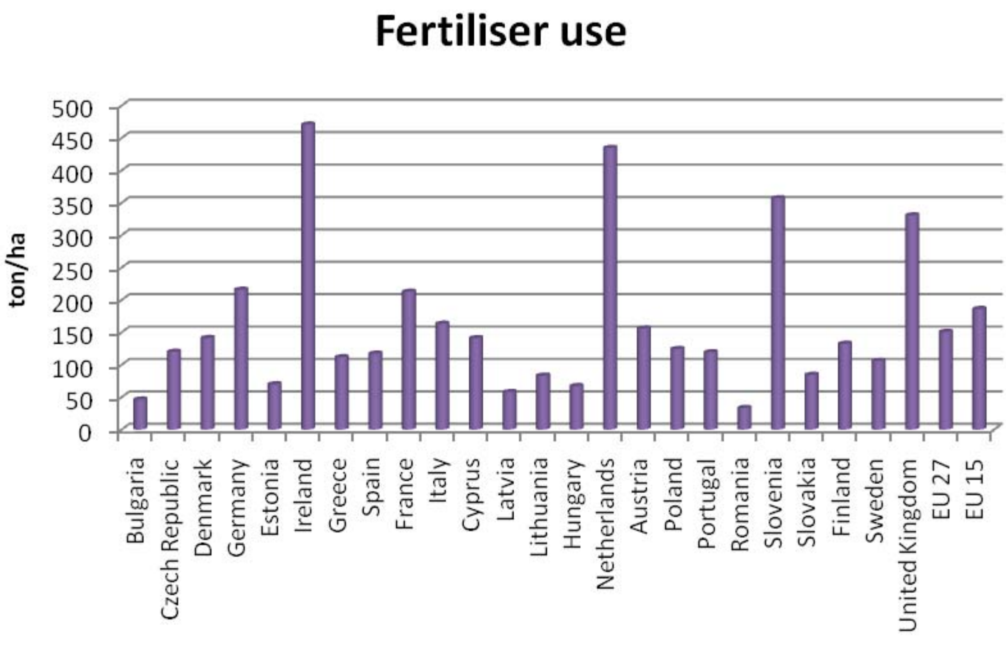

Figure 5.20: Quantity of commercial fertiliser utilised in agriculture. Year: 2001 Source: Eurostat

Note: Data about Belgium, Luxemburg and Malta are not available.

In figure 5.19 the intensity use of pesticides is shown. Belgium and Netherlands have the highest use and also the highest yield in cereals production. However, Portugal and Italy have also a high intensity use of pesticides, but their yield is under EU15 average. This difference could also be due the unfavourable climate. In order to expand on the relation between production yield and pesticide use, the data from Eastern Europe should also be considered. Unfortunately, such data is not available at this time.

Figure 5.20 shows that countries with high fertiliser use like Ireland, the Netherlands and the United Kingdom also have the highest yield in cereals production. With the exception of Slovenia, all the countries that joined the EU after 2000 have a low consumption of fertilisers and generally also lower yields.

In figure 5.21 the GHGs emissions from agriculture are expressed in CO_2 equivalents. Figure 5.22 shows the GHGs emissions divided by the arable land. The graph demonstrates an interrelation between fertiliser use and GHGs intensity. Ireland, the Netherlands, Slovenia and the United Kingdom have the highest fertiliser use per hectare and the same trend is registered in GHGs emissions per ha. This interrelation cannot be ascertained for Luxemburg as its data is missing in figure 5.20.

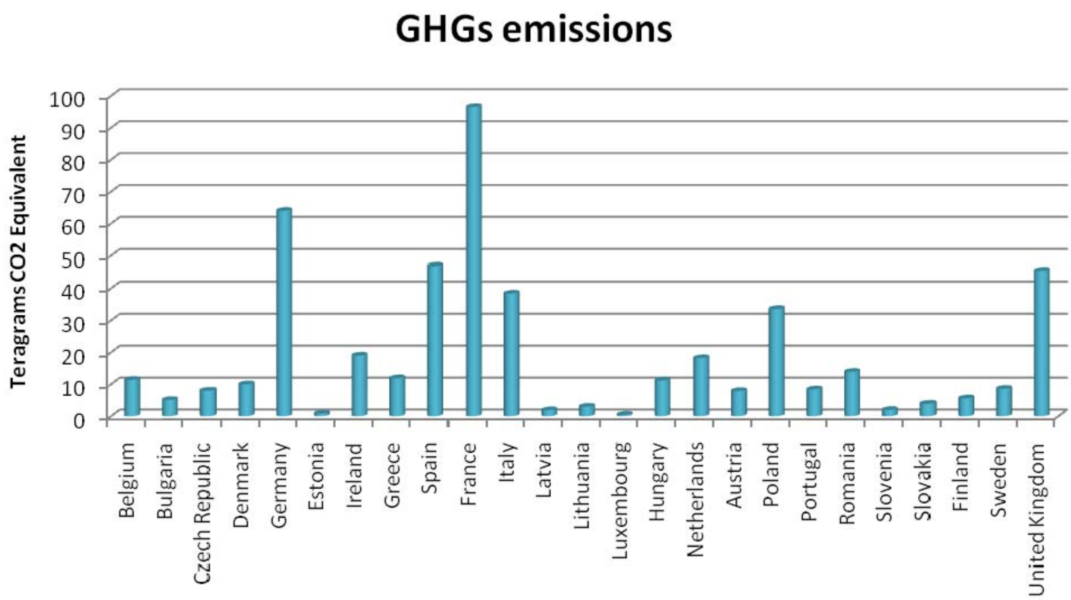

Figure 5.21: GHGs emissions from agriculture. Year 2004 Source UNEP

Note: Data about GHGs emissions for Malta is missing.

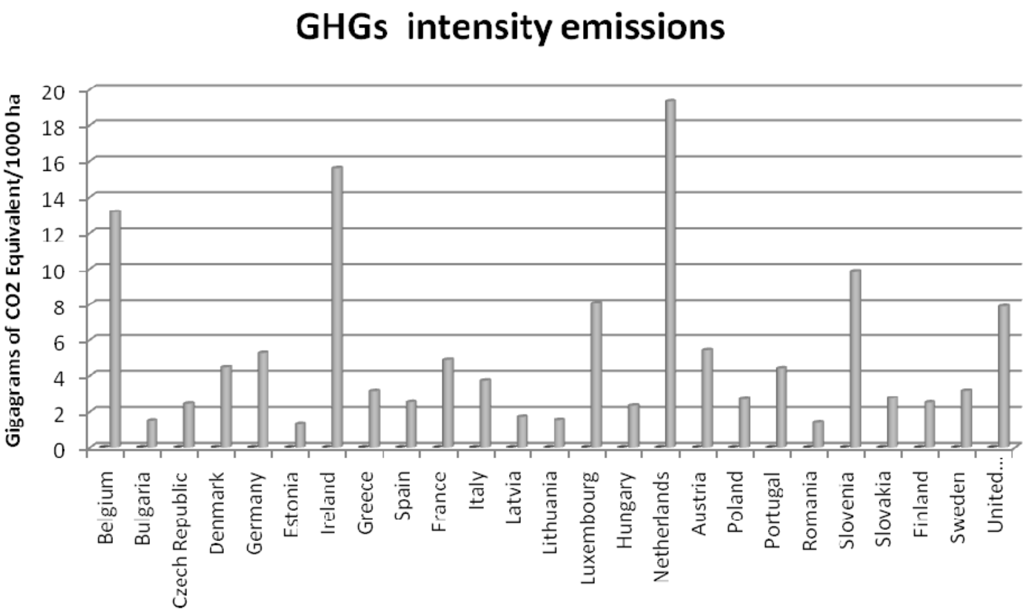

Figure 5.22: GHGs emissions per arable land

Note: Data about Cyprus and Malta are not available.

Although it is difficult to design a relation between farming practices and vulnerability of the ecosystem, many studies agree on the benefits of less intensive agricultural systems. Kumm (2002) affirms that organic beef, raised on grass, emits 40 percent less GHGs and consumes 85 percent less energy. Van Elsen (2000) argues that organic agriculture has positive effects on the diversity of arable fields and grassland; a higher number of wild species can be found in an organic field. Although it is difficult to quantify biodiversity, most scientific studies conclude that intensive farming practices constitute a threat to biodiversity.

5.6 Scenario Synthesis

Bearing in mind all the considerations made in the previous chapters and the results obtained about land use reduction, three combined scenarios will be proposed with the intent of combining the previous scenarios in such a way as to take advantage of all their individual strengths.

5.6.1 First Combined Scenario

	EU 27	EU 15
Meat consumption (70 g)	42.6	38.6
Biofuel 10%		-17.0
Organic cereals	-24.6	-15.2
Organic cattle (70 g)	-0.9	-0.7
TOTAL	17.1	5.7

Figure 5.23: million ha gained for the first combined scenario. Negative values indicate additional land requirements

The first combined scenario from table 5.22 is based on the assumption of reducing meat consumption to 70g per day, replacing 10 percent fossil fuels for transportation in the EU15 with biofuel and rendering all cereal and cattle production organic. As can be noticed, for the EU27 there is a larger margin of spare arable land at the end because the biofuel consumption was not included.

5.6.2 Second Combined Scenario

	EU 27	EU 15
Meat consumption (100g)	35.1	32.7
Biofuel 5.75%		-9.8
Organic cereals	-24.6	-15.2
Organic cattle (100g)	-1.2	-1.0
TOTAL	9.2	6.7

Table 5.24: million ha gained for the second combined scenario. Negative values indicate additional land requirements

The second combined scenario from table 5.24 is based on the assumption that meat consumption is reduced to 100g per day, 5.75 percent of fuel demand is met by biofuel, as well as organic cereal and beef production. As in the first final scenario, the spare arable land at the end is different in EU 27 than in EU 15, but in this case the difference is less noticeable because only 5.75 percent biofuel was set.

5.6.3 Third Combined Scenario

	EU 27	EU 15
Meat consumption (100 g)	35.1	32.7
Biofuel 10%		-17.0
Organic cereals	-24.6	-15.2
Organic cattle (100 g)	-1.2	-1.0
TOTAL	9.2	**-0.5**

Figure 5.25: million ha gained for the third combined scenario.
Negative values indicate additional land requirements

The third combined scenario (figure 5.25) is based on a daily meat consumption of 100g , a biofuel production of 10 percent of total fuel demand, as well as organic cattle and cereal production. In this case, the EU 15 would not be able to satisfy all the demand.

5.6.4 Regarding yield increase

The option to increase yield has not been taken into consideration, because it regards only the EU 27, which already have a higher amount of arable land in all three final scenarios than the EU 15. However, as shown in paragraph 5.5.2, if yield would be increased to the EU 15 average, an additional 13 million hectares of land would be available for the EU 27. Even though this may appear as contradictory to the choice of preferring organic cultivations and farming, the spare land obtained could be employed for purposes such as extending marginal areas around cultivated fields to favour biodiversity, plantation of new forests and crop rotation.

Many options could favour biodiversity and reduce impacts on the environment. However, the choice will in large part depend on the condition of the arable land in question and the climate.

6 RESULT ANALYSIS

A number of environmental impacts correlate with arable land use, such as soil degradation and erosion, as well as other indirect effects such as loss of biodiversity and depletion of water resources. These aspects, as well as the demand for land, are important factors to consider when evaluating agriculture land use and management.

The arable land in Europe is cannot be expanded much further due to geographic limitations; over 50% of the total land is already occupied by agriculture and, with the exception of the Nordic countries, forest area is limited. Only a small percentage of available land could be turned into agriculture without compromising the natural ecosystem, since most of it is already in use; further deforestations would additionally reduce the remaining biodiversity and the natural capacity to absorb carbon dioxide. In the previous chapter, the patterns of land demand in Europe were shown from livestock to the biofuel sector. Furthermore, the consequences of different strategies for land management were estimated, in order to understand the effects the choices of land use have in terms of pollution, biodiversity reduction or regained land. One aspect among others was detailed in the comparison of agriculture intensification and expansion of organic agriculture.

Although many generalisations were made in the model, it was possible to derive the necessary characteristics of European land use and relate it to consumption patterns. The attention was at first focused on the consequences of decreasing the consumption of meat to free large amounts of land that would then be available for other purposes. Subsequently, biofuels were taken into consideration in order to evaluate how much land they would require to comply with the goals set by the European Commission regarding the replacement of fossil fuels in the transportation sector. It was challenging to draw quantitative conclusions due to the many simplifications and delimitations applied to the model's parameters. In this chapter, an attempt will be made to draw a more extensive analysis of the results presented in the previous chapter – Findings -. Finally, the evaluation of the results will be confronted to the theoretical framework detailed in chapter 3 – Conceptual framework -.

6.1 FIRST SCENARIO: LIVESTOCK

After North Americans, Europeans are the largest meat consumers in the world (Earthtrends 2008) and meat is mainly produced with intensive farming practices.

Nearly half of the arable land in Europe is used for the production of cereals. Together, cereals and fodder from crop cover nearly 60 percent of the arable land. A major part of the grain produced is then dedicated to livestock and an additional 33 percent of feedingstuffs for farm animals are imported, mainly from Argentina and Brazil (Eurostat 2008). Of all the preparations used for farm animal feeding, 40 percent is dedicated to pigs, while the rest is mainly divided into cattle and poultry. Notably, cattle have the lowest feed conversion efficiency, and in addition to feedings, cattle make also use of pastures, hereby becoming the species with the highest demand for land. In addition to land occupation, the livestock sector is directly and indirectly responsible for a large strain on the environment; harmful impacts resulting from livestock farming are pollution of water and air, soil degradation and loss of biodiversity. Furthermore, the livestock sector and especially cattle are responsible for 18 percent of greenhouse gas emissions that cause global warming; this contribution is larger than those for cars, planes and other forms of transportation put together (FAO 2006).

As seen in the previous chapter, European citizens consume an average of three to four times more meat than the healthy amount required. The consumption of fish, which is the second highest in the world (FAOSTAT 2008), and dairy products are not even considered here. An abuse in meat consumption, besides creating many environmental hazards, favours cholesterol and other health risks like heart diseases due to a high intake of saturated fat (Bender 1992). The issue of meat consumption is therefore not only related to the external environment but also to our personal wellbeing. However, these meat consumption values do not represent the actual meat intake for every person, since a percentage is thrown away before the preparation, for example if it has expired. This meat has still been produced and therefore has contributed to resource depletion and to the overall amount of waste, which in turn needs to be disposed of using even more resources. Besides meat and fish, protein sources can originate from other animal sources such as eggs, dairy products and legumes. These goods, as well as fish and fishery products which represent an additional 6% of protein consumption per day (FAOSTAT 2008), have not been considered in the model. This information on alternate protein intake sources have been proposed to underline the fact that a meat consumption of 70 or 100g a day, while considerably altering people's eating habits, would not affect their protein intake as it can be compensated by other sources.

In any case, the advantages of a reduced meat consumption in terms of reducing land use and depletion of natural resources would be enormous: by reducing meat consumption to 100g a day it would be possible to put 28 percent of the arable land in Europe to other uses, which would increase to 39 percent if only EU 15 would be taken into consideration. By further reducing meat consumption to 70 g per capita, the amount of land available would rise to 35 percent of total arable land in EU 27. As explained in the methodology chapter, this percentage do not represent the actual land employed for meat production in Europe, since 30 percent of the feed ingredients for preparing feed animals are actually imported. It is still interesting to notice how much land could be freed by assuming a more sustainable consumption.

In fact, the livestock sector is one of the most polluting, and a reduction of meat would consequently reduce the amount of land occupied and the level of GHG emissions, without any harm for the environment. In combination with reducing meat consumption, diets should be improved by moving down the food chain, namely direct consumption of grain. As shown in figure 5.8, assuming the same rate of meat consumption, but switching completely towards poultry, would already bring a noticeable reduction of occupied land, especially in countries with a high meat consumption rate per capita. Assuming an entire meat diet based on chicken is of course not realistic, yet it is important to notice that meat consumption should be accompanied by a change in diet down the food chain. Indeed, directly eating the grains rather than consuming them indirectly through the meat would constitute a healthier alternative for humans as well as a more sustainable one for the environment.

6.2 Second scenario: biofuels

A reduction of meat consumption could lead to a significant amount of freed arable land. It could then be argued that the regained land should be used to produce energy crops, since they constitute a less polluting alternative to fossil fuels.

Looking at the results in chapter 5.3, it can be seen that substituting 5.75 percent of fossil fuels with biofuel would necessitate the use of a further 12 percent of arable land in the EU 15. This percentage would increase to 20 percent if the goal of 10 percent biofuel is to be reached. Assuming that biofuel could constitute the total fuel consumption for transportation is therefore practically impossible. However, the first step of 5.75 percent biofuel could feasibly be reached by reducing meat consumption to 100g per day and capita. Similarly to feed ingredients, biofuel would depend largely on imports if meat consumption were not reduced, since there is little additional arable land available in Europe. The construction of such additional arable land would cause increasing pressure on the ecosystems and a loss of biodiversity in other countries. Even if biofuel were to be produced in Europe, it would occupy the space of the other crops that consequently would need to be imported; the environmental impacts would thus be exported to other countries. Wherever these biofuels will be produced, if a reduction of meat consumption is not occurring; the environmental costs will soar.

As mentioned in the methodology chapter, the data used for calculating biofuel use of land are not current and biofuel production in Europe has increased substantially in the last 8 years. Therefore, this prediction could be improved by taking into account both increased fuel consumption for transportation (Eurostat 2008) and higher yields in biofuel production. Anyway it should also be considered that the calculation made applied for the same percentage of biofuels out of gasoline and biodiesel consumption in 2000. In reality the EU 15 is mainly a producer of biodiesel, while ethanol is principally imported. Furthermore, biodiesel has a much lower yield than ethanol, this means that in fact the prediction about land use are quite optimistic; if the current trends of biodiesel and ethanol production were to continue, the land demand would be much higher. However, the question remains whether it is better to produce ethanol in Europe with low yield or import it from other countries with lower demand of land for the same production of biofuel.

6.3 Third scenario: organic farming

The production of organic products increased considerably over the last years, especially in the dairy sector (Eurostat 2008). Therefore, the option of turning more grain production into organic cultivation has been considered. Organic products are deemed healthier for the people and the environment, because of the lack or reduced application of chemicals. On the other side there are criticisms expressed towards organic farming, since a larger amount of land is required for producing the same amount of feed and more inputs have to be applied in order to obtain the same amount of products. Consequently, organic production is rather inappropriate in a situation of shortage of land available. As mentioned for biofuels, if the production of organic products increases, the use of land in Europe and consequently outside of Europe might also rise, causing additional intensive exploitation of resources as new areas have to be deforested and turned into arable land. However, as shown in section 5.4.2 – Grain additionally produced by increasing the yield -, the land freed by increasing cereal production is equal to a third of the total area occupied by cereal production in EU 27, while the land required for producing organic cattle is negligible in comparison; if all cattle would move to pasture land combined with by-products feed, there would be no need for additional arable land. It should be noted that these considerations are applicable only if meat consumption is reduced.

The question of the connection between organic production and a reduction of GHG emission remains open. However, if organic cultivation were to be achieved by further deforestation, GHG emissions are likely to increase. A similar conclusion for organic farming as for biofuel production can be drawn; if an increasing production of organic livestock and cereals is accompanied by a reduction in meat consumption and a change in diet, the final result is likely going to be positive, both for the people as they reduce their exposure to chemicals, and for the environment since it will be subjected to less stress.

6.4 Fourth scenario: yield increase

The possibility of increasing the yield has also been taken into account. The idea originated in the comparison of the cereal yield in Europe. It emerged that there is a significant difference among the 27 countries: in Belgium, 8.3 tons of cereals are produced out of one hectare of land, while in Lithuania only two tons of cereals are produced in the same amount of land. Such differences between the countries can result from different uses of fertilizers and agro-chemical, as well as different land management practices; but climate and water availability also play a significant role in yields. However, these are only general considerations since the data available permitted to draw relatively few interrelations between the previously mentioned factors and yield.

From the calculations in paragraph 5.5 it emerged that if the countries with a lower yield could produce at the same levels as the EU 15 average (for example Luxemburg, Hungary and Slovenia), nearly 13 million hectares could be devoted to other uses; this percentage corresponds to 10% of the arable land in Europe. It should be noted that this amount of land corresponds to only one third of the land that could be obtained by reducing the meat consumption to 100 g per day and capita. However, it was shown that the amount of land obtained by increasing the yield could be sufficient to abundantly cover the demand of 5.75 percent biofuel for the EU 15 countries. On the other hand, most of the available land is situated in the part of Europe that recently joined the EU, making it more appropriate to use this land for growing biofuels crops in order to supply the future demand of those countries.

On the downside, intensifying agricultural practices with increasing use of fertilisers and agrochemical will lead to soil degradation and water depletion, where water resources are already scarce. As seen in chapter three - conceptual framework -, more environmental impacts related to the livestock sector occur in the cultivation of the feed, than in the farm. By comparing fertiliser use and GHG emissions from agriculture, a clear correlation was noticed: an intensive use of fertilisers corresponds to higher emissions per area cultivated. These results clearly suggest the necessity to switch to less intensive cultivations of feed as well as a reduction in meat consumption. It remains open what the connection between GHG emissions and intensity of livestock is. Such a connection depends on many variables, such as the climate and the capability of the environment to reintegrate the pollution and the gas emissions, as well as the capability of farmers for disposing of manure and avoid contamination in the soil and water. Overall, one could comment that yields should be increased by implementing better land management and new practices in order to optimise the use of land and resources. If a decrease of pollution and loss of biodiversity is desired, it would be contradictory to increase the use of fertilizers and pesticides for a yield increase.

Considering the facts mentioned above, it can be concluded that the most promising option consists of a gradual reduction of meat consumption, while simultaneously increasing efficiency in low yield countries through the introduction of better land management practices. As shown in the combined scenarios of chapter 5.6, by combining a meat consumption reduced to 70g a day per capita, with an increased production of biofuels and a conversion of cereal and cattle production into organic practices, would free a considerable amount of arable area for other purposes. The available land could then be used to reduce imports from other countries, which in turn would reduce long distance transportation and emissions. Furthermore, a significant part of the land regained could be devoted to organic or ecologically friendly farming practices, as well as to renaturalisation projects.

7 DISCUSSION

In this section, the issues identified in the analysis will be discussed in a European and global context. Additionally, suggestions for possible solutions, which can be implemented through changes in individual behavior or political actions, will be proposed.

7.1 EUROPEAN ISSUES OUTSIDE OF EUROPE

Europe represents a peculiar case in comparison to the rest of the world: it has a high population density and high standards of living which are also reflected in the heavy meat consumption. However, limited land resources are available. After Asia and Central America, Europe is the most densely populated area in the world, but compared to other densely populated areas, it has higher meat consumption (WRI 2008). As seen in the Planet Report (WWF 2006), the EU has an Ecological Footprint (EF) of 4.8 hectares per capita, while other regions have all lower Footprints (Asia-Pacific region: 1.3 hectares; Middle East and Central Asia: 2,2 hectares; Latin America and the Caribbean: 2 hectares). As a consequence this lifestyle, the European need for natural resources far exceeds the amount available within their borders, and even those are depleted faster than they can regenerate.

Although European meat consumption stabilised over the last years, Europeans remain the second highest meat consumers in the world. At the same time, many emerging nations are increasing their meat consumption. Even though a basic level of meat consumption – especially in developing countries - is medically recommended, “the only reasons to eat high up in the food chain are weaker, namely fashion, taught taste and status” (Goodland 1997). This behaviour can also be observed in emerging countries and the upper classes of poor countries, who emulate western habits as a sign of status. In the southern hemisphere, livestock volume, as well as the meat consumption, is increasing fast. These trends, along with a continued population increase, are projected to continue in the next decades.

While during the Green Revolution, a stunning growth of production in agriculture has been possible thanks to large availability of cheap oil and water resources, today oil prices are soaring due to the diminishing oil resources, making agricultural production more expensive. This can have disastrous consequences, as seen in the grain price rockets over the last years. In light of these events, a policy of self-sufficiency for Europe in the next decades appears as a sensible solution. Rising prices on a global level may reflect negatively on the imports of crops to Europe, as producing countries might chose to limit their grain exports in order to avoid internal inflation.

Therefore, in addition to the environmental consequences mentioned previously, which result from an intensive exploitation of resources and high consumption standards, economic and political pressures can also render a more sustainable agriculture along with a reduced meat consumption more attractive.

Many studies have analysed the competition for land between biofuels and food. Some argue that not only high oil prices, the growing amount of feed moved to livestock and climatic changes, are responsible for the current increase in grain price, but land used by biofuel production as well. Assessing the level of responsibility for everyone involved is not challenging and further investigations might be necessary to precisely address responsibilities on these issues. However, it could be argued that in such a dire situation it is risky to expand biofuel production without accompanying it with a decrease of meat consumption. As long as the risks for biodiversity and food supply are that come with biofuel production are not evaluated, their production should be at least limited to the current level. In fact the earth is not infinite, neither is its capacity to regenerate. If resources are depleted in a place, it follows that somewhere else or in the future there will be fewer resources available for other people.

7.2 CONSUMPTION

As shown in chapter three - Conceptual Framework -, if all animal feeds were cultivated in Europe, they would occupy most part of the available arable land, which is excessively high. In a few countries, they would even require more land than available. Therefore, should meat consumption be reduced and more available land freed, the most reasonable action to undertake might be to reduce dependence on foreign imports. This would allow for a reduction of pressures on other countries' ecosystems and avoiding the loss of biodiversity elsewhere, which are often exacerbated by lenient environmental regulations. For example, economic growth is given precedence, as demonstrated by various developing nations, where deforestation is considered a less important issue than the sustenance of economic growth.

As argued by Goodland (1997), there are only three ways of compensating for increasing food demands: extension, intensification and change of diet. Applying these considerations to Europe, the lack of land would limit the extension option should it be considered. An intensification of agriculture would entail many impacts at the environmental level, as demonstrated with the LCA in chapter 3. We are therefore left with one option, which is also the most sustainable one. A reduction of meat consumption would allow for lower land use, less environmental impacts, as well as a healthier diet for the consumers.

7.3 NEED FOR CHANGE

The ‘paradigm of growth’ has driven societies to intensify farming practices and produce more in order to offer more products at cheaper prices. It has been possible to reach this state partly thanks to new technologies and chemical developments, which have led to a phenomenal increase in the agricultural output. However, the long term consequences of these advances have long been neglected. As a result, cheap products have reached consumers in industrialized countries, who, over the years, gained access to increasing amounts of meat and other foods. This availability of products has then led to an unsustainable consumption model, harmful to the environment and human health. The first signs of these consequences can be clearly seen today, as water sources dry, soils erode, pollution rises and changes in climate occur.

While consumers in industrialised countries have access to large quantities of cheap meat thanks to grain-feed based diets for livestock, people in developing and emerging nations have trouble even affording grain products due to rising prices. Instead of being part of the ‘paradigm of growth’ this situation has become a ‘paradox of growth’, which should be addressed in order to avoid future humanitarian disasters.

Western societies should rethink their consumption patterns and lifestyle, raising awareness of the consequences for individual dietary choices. However, these kind of changes need to be supported by strong legislation. Educational programmes might prove useful to direct the public attention to the need for individual action to counteract the harmful effects of current consumption trends. Agricultural policies also need to be reformed to propose a more sustainable structure of current agricultural practises. Both individual and collective actions could complement each other.

7.4 AS INDIVIDUALS

A first and major step should be taken by individual choices, like reducing our intake of meat. As shown through the model in chapter 3 - Conceptual Framework -, a reduction of meat consumption could lead to a reduction of land use and environmental hazards, as well as in energy and water use. Another important behavioural aspect is the amount of food thrown away due to the perceived abundance thereof. This awareness for the consequences of dietary choices is the basis on which a more sustainable agriculture system can be built. In other words, people that are aware of the fact that what they buy and consume is a privilege at the cost of others, will consequently demand such a sustainable system themselves.

A second suggestion can be derived from the discrepancy between consumption and exploitation of resources. For example, fuels and energy could be radically reduced by improving management and losses. Looking at current demand, there is no space available to produce enough biofuel. With the calculation in chapter five – Findings-, it was demonstrated that should Europe produce all the biofuel for its transportation needs, an area twice as large as Europe would be needed. Where could we grow our hamburgers then?

7.5 AT A POLITICAL LEVEL

Many directives have been implemented on agricultural matters in the EU such as common agricultural policy (CAP) or biofuel recommendations. However, in this section some general considerations about need of action at political level will be made.

It could be argued that radical reforms at the political level need to be implemented; by suggesting measures that will promote food policies that are healthier for the people and constitute a more sustainable alternative for the environment. To promote a more efficient and eco-friendly agro-environmental policy in Europe; several measures could be considered. For instance; the major polluting sectors should be made financially responsible for their acts. Efficiency taxes should be implemented based on the "polluters pay principle" (Goodland 1997). The least efficient converter of feed, such as cattle should pay high taxes, as well as farms which have an intensives use of fertilisers. Command-and-control regulations for the prevention of pollution should be accompanied by an approach to provide incentive, like financial support only to the most sustainable sectors and to organic farming.

At the global level; agreements need to be drawn; since unregulated free trade has failed to protect Earth's natural resources. All countries should converge on international policies destined to efficiently protect the eco-system which is currently under undue pressures.

7.6 CONCLUSION

It seems evident that production yield can be improved. However, current consumption standards remain as high as ever. The growing population on the one hand and the limits to available arable land and other natural resources on the other hand will not allow current levels of exploitation in the future.

It could then be suggested that the potential of human behaviour will be the best instrument to avoid possible catastrophic scenarios in the future. The challenge lies not in the lack of solutions, but in convincing people to base their actions on long term living standards and sustainability rather than short term economic gain. For example, through process optimisations, it would be possible to increase the production considerably, resulting in a lower use of resources. Among the sustainable solutions that have been suggested, sustainable agricultural practices like organic production can play an important role in securing a sufficient and healthy diet. They do not require the use of chemical components, which are harmful for the environment if used in excessive amounts as presently done in industrial agriculture. Organic practices have been successfully adopted by humans for centuries; and have allowed the relation between human and nature to remain beneficial for both. Presently, a redefinition of the interaction between man and the environment is necessary in order to positively affect the state of the environment and by extent that of its inhabitants.

8 CONCLUSION

Land use management significantly affects the environment and the amount of land required: both in quality and quantity. This thesis intended to investigate the implications that different scenarios of land use could have on agricultural production and the environment.

The agricultural sector is the principal form of maintenance that man had through history. Over history, agriculture has significantly evolved; it had to meet different types of demands; as the need for food products increases, increasing difficulties have to be dealt with by the agricultural sector.

An increasing world population is greatly preoccupying as people seek to improve their diets by requesting more prestigious food, such as meat and other animal products, which in turn require greater amounts of land;. Although in Europe the majority of the people are not directly seeing all the consequences thereof, these issues are indirectly affecting the entire world. In Europe, the agricultural sector is requested to sustain demand for wholesome products and more eco-friendly farming practices, which in the short term require more land. Simultaneously, an attempt is being made to replace part of the fossil fuels used in transportation with biofuels. All the previously mentioned factors have in common the necessity of using more arable land, which in the light of the worldwide trends, is becoming a limiting factor to growth.

It has been attempted to establish which environmental impacts were the most significant environmental impacts in agriculture. In chapter 3 -Conceptual framework - the main inputs and outputs toward the biosphere have been described by applying a model of screening LCA. Furthermore, in chapter 5 – Findings -, the amount of land used for producing crops for livestock and biofuels have been presented. The livestock sector has been identified as one of the main contributors to GHG emissions; emissions from agriculture practises are proportional to the amount of fertilisers applied in the fields. Additionally, cereals produced and imported are used in greater quantity as ingredients for feedingstuffs on intensive farms, rather than directly by humans. In addition to these harmful factors, the production of biofuels is adding pressure on natural resources as this sector is competing for land use with agriculture. As demonstrated in chapter 5.3 – biofuel scenario -, the arable land required for supplying the total fossil fuels demand for the transportation sector would be twice the total arable land currently available in the EU 15. Although improvements in yields could be possible by adopting more efficient management practices and increasing the use of fertilisers; this alternative scenario is incompatible with attempts to reduce negative pressure on the ecosystem, for instance by preferring organic practices. Furthermore, one of the future challenges that need to be considered by the agricultural sector is the issue of climate change. The scarcity of water and the recurring incidence of higher temperatures will constitute major threats to crop yields in the future.

As shown in chapter 5.2 - livestock scenario -, by reducing meat consumption to 70 g a day in Europe, an area equal to Sweden could be freed for other purposes. Beside the advantages due to increasing land availability, all the consequent impacts related to intensive farming would be reduced, such as CO_2 emissions, water and energy use, etc. Among other options, more sustainable land practices have been proposed; this spare land could be saved for land practices that could try to relieve the impacts caused by the intensive use of land. Chapter 5.4 – organic scenario – calculated the amount of additional land required to render all cereal as well as cattle production organic. Furthermore, some areas could be devoted to the regeneration of endangered species; others could be employed to promote the reforestation of certain areas.

To conclude, significant and complex issues need to be dealt with; such rising challenges will not be easy to solve for now; however, immediate solutions need to be implemented in light of the size and emergency of the problems discussed. Political actions as well as individual initiatives will need to be combined in order to shape a more sustainable future. Solutions do exist; although implementing them will require a conscious decision and a determination. Humans have been living on this planet for millennia, coexisting with nature and its resources to sustain their needs; humans could continue this cohabitation by adopting more sustainable standards of living. In this work it has been shown how much land and resources could be saved only by reducing the meat consumption.

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Appendix A

Consumption of meat by country (kg/capita/year) in 2002. Source: FAOSTAT 2008

Denmark	145.9	*46*	Papua New Guinea	73	*91*	Dominican Rep	37.8	*136*	Haiti	15.3
New Zealand	142.1	*47*	Switzerland	72.9	*92*	Macedonia, FYR	35.4	*137*	Zimbabwe	15.2
Luxembourg	141.7	*48*	Singapore	71.1	*93*	Peru	34.5	*138*	Lao People's Dem Rep	15
Cyprus	131.3	*49*	Bahrain	70.7	*94*	Swaziland	34.2	*139*	Nicaragua	14.9
United States	124.8	*50*	Paraguay	70.3	*95*	Namibia	34	*140*	Yemen	14.7
St. Lucia	124.1	*51*	Bulgaria	69.4	*96*	Colombia	33.9	*141*	Cameroon	14.4
Bahamas	123.6	*52*	Estonia	67.4	*97*	Vanuatu	32.6	*142*	Chad	14.3
Spain	118.6	*53*	Finland	67.4	*98*	Ukraine	32.3	*143*	Kenya	14.3
Greenland	113.8	*54*	Slovakia	67.4	*99*	Cuba	32.2	*144*	Cambodia	13.9
French Polynesia	112.2	*55*	Dominica	67.1	*100*	Guyana	31.8	*145*	Martinique	13.9
Mongolia	108.8	*56*	Chile	66.4	*101*	Philippines	31.1	*146*	Congo	13.3
Canada	108.1	*57*	Lebanon	63.1	*102*	Mauritania	29.9	*147*	French Guiana	13.2
Ireland	106.3	*58*	Norway	61.7	*103*	Jordan	29.8	*148*	Guinea-Bissau	13
France	101.1	*59*	Kuwait	60.2	*104*	Libyan Arab Jamahiriya	28.6	*149*	Guadeloupe	12.7
Hungary	100.7	*60*	Belarus	58.6	*105*	Viet Nam	28.6	*150*	Pakistan	12.3
Saint Kitts and Nevis	99.3	*61*	Mexico	58.6	*106*	Central African Rep	28	*151*	Zambia	11.9
Uruguay	98.6	*62*	Trinidad and Tobago	57.8	*107*	Thailand	27.9	*152*	Uganda	11.7
Argentina	97.6	*63*	Jamaica	56.8	*108*	Armenia	27.7	*153*	Côte d'Ivoire	11.3
Israel	97.1	*64*	Venezuela	56.6	*109*	Botswana	27.3	*154*	Burkina Faso	11.2
Grenada	97	*65*	Brunei Darussalam	56.4	*110*	Cape Verde	26.3	*155*	Niger	11.2
Austria	94.1	*66*	Antigua and Barbuda	56	*111*	Georgia	26	*156*	Korea, Dem People's Rep	10.8
Portugal	91.1	*67*	Panama	54.5	*112*	Tunisia	25.5	*157*	Myanmar	10.7
Qatar	90.5	*68*	Romania	54.5	*113*	American Samoa	24.9	*158*	Nepal	10
Italy	90.4	*69*	Guam	52.6	*114*	Honduras	24.7	*159*	Tanzania	10
Netherlands	89.3	*70*	China	52.4	*115*	Guatemala	23.8	*160*	Ghana	9.9
Barbados	88.7	*71*	Seychelles	51.1	*116*	Iran, Islamic Rep	23.1	*161*	Tajikistan	8.7
Slovenia	88	*72*	Russian Federation	51	*117*	Moldova, Rep	22.7	*162*	Nigeria	8.6
Malta	86.9	*73*	Malaysia	50.9	*118*	Egypt	22.5	*163*	Togo	8.5
Faeroe Islands	86.4	*74*	Bolivia	50	*119*	Bosnia and Herzegovina	21.4	*164*	Indonesia	8.3
Belgium	86.1	*75*	Croatia	49.9	*120*	El Salvador	21.4	*165*	Ethiopia	7.9
Iceland	84.8	*76*	Oman	49.8	*121*	Syrian Arab Rep	21.2	*166*	Liberia	7.9
Samoa	82.6	*77*	Lithuania	49.5	*122*	Sudan	21	*167*	Comoros	7.6
Brazil	82.4	*78*	Korea, Rep	48	*123*	Uzbekistan	20.7	*168*	Sri Lanka	6.6
Germany	82.1	*79*	Réunion	46.8	*124*	Morocco	20.6	*169*	Virgin Islands	6.6
United Kingdom	79.6	*80*	Gabon	46	*125*	Turkey	19.3	*170*	Guinea	6.5
St. Vincent & Grenadines	79.1	*81*	Latvia	45.7	*126*	Angola	19	*171*	Sierra Leone	6.1
Greece	78.7	*82*	Ecuador	45	*127*	Mali	19	*172*	Mozambique	5.6
Poland	78.1	*83*	Kazakhstan	44.8	*128*	Algeria	18.3	*173*	Gambia	5.2
Serbia and Montenegro	77.6	*84*	Saudi Arabia	44.6	*129*	Senegal	17.7	*174*	India	5.2
Czech Rep	77.3	*85*	Japan	43.9	*130*	Madagascar	17.6	*175*	Malawi	5.1
New Caledonia	76.6	*86*	Costa Rica	40.4	*131*	Djibouti	17.1	*176*	Congo, Dem Rep	4.8
Sweden	76.1	*87*	Fiji	39.1	*132*	Maldives	16.6	*177*	Rwanda	4.4
Belize	74.7	*88*	Kyrgyzstan	39	*133*	Benin	16.2	*178*	Burundi	3.5
United Arab Emirates	74.4	*89*	South Africa	39	*134*	Azerbaijan	15.9	*179*	Bangladesh	3.1
Netherlands Antilles	73.3	*90*	Albania	38.2	*135*	Lesotho	15.4	*180*	Bhutan	3