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Valuation of Linkages between Climate Change, Biodiversity and Productivity of European Agro-Ecosystems

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Summary

It is clear that climate change involves changes in temperature and precipitation and therefore directly affects land productivity. However, this is not the only channel for climatic change to affect agro-systems. Biodiversity is subject to climatic fluctuations and in turn may alter land productivity too. Firstly, biodiversity is an input into agro-ecosystems. Secondly, biodiversity supports the functioning of these systems (e.g. the balancing of the nutrient cycle). Thirdly, agro-systems also host important wildlife species which, though not always, play a functional role in land productivity, nonetheless constitute important sources of landscape amenities. The present paper illustrates a unique attempt to economically assess this additional effect climate change may imply on agriculture. We first empirically evaluate changes in land productivity due to climatic change effect on temperature, precipitations and biodiversity. Then we estimate the economic cost of biodiversity impact on agro-systems. Our key finding is that climate-change-induced biodiversity impact on European agro-systems measured in terms of GDP change in year 2050 is sufficiently large to deepen the direct climate-change effect in some regions and to reverse it in others. Different economies show different resilience profiles to deal with this effect.

Keywords: Climate Change, Biodiversity, Agro-Ecosystems

JEL Classification: D58, Q54, Q57

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Abstract

It is clear that climate change involves changes in temperature and precipitation and therefore directly affects land productivity. However, this is not the only channel for climatic change to affect agro-systems. Biodiversity is subject to climatic fluctuations and in its tern may alter land productivity too. Firstly, biodiversity is an *input* into agro-ecosystems. Secondly, biodiversity supports the functioning of these systems (e.g. the balancing of the nutrient cycle). Thirdly, agro-systems also host important wildlife species which, though not always, play a functional role in land productivity, nonetheless constitute important sources of landscape amenities. The present paper illustrates a unique attempt to economically assess this additional effect climate change may imply on agriculture. We first empirically evaluate changes in land productivity due to climatic change effect on temperature, precipitations and biodiversity. Then we estimate the economic cost of biodiversity impact on agro-systems. Our key finding is that climate-change-induced biodiversity impact on European agro-systems measured in terms of GDP change in year 2050 is sufficiently large to deepen the direct climate-change effect in some regions and to reverse it in others. Different economies show different resilience profiles to deal with this effect.

Aknowlegments:

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1. Introduction

In the 21st Century, the agricultural sector will be radically altered by both natural disasters and anthropogenic factors, including climate change, changing world economies, and potential changes in the Common Agricultural Policy (CAP) and the subsidies currently paid to farmers and land managers. Both climate change and socio-economic drivers will affect crop productivities and agricultural land use patterns. The work of Rounsevell et al. (2005) shows that climatic impacts on agriculture vary across different climate scenarios and land use changes will also influence future land management scenarios.

Many studies have already coped with the difficulty of projecting variation in land productivity caused by climatic change induced fluctuations in temperature and precipitation. Brown and Rosenberg (1999), Rounsevell et al. (2005) and Kan et al. (2009) are just few representative examples. However, this is not the only channel for climatic change to affect agro-systems. Biodiversity is subject to climatic fluctuations and in its tern may alter land productivity. This research aims at analyzing the potential effects of biodiversity variation due to climatic changes on the agricultural sector in Europe in terms of the changes in land productivity for various crops, agricultural output and ultimately GDP. Our analysis focuses on the depiction of different future scenarios of the agricultural sector in the next 40 years following four IPCC scenarios, i.e. A1FI, A2, B1 and B2. The proposed economic valuation of consequences of climate-change-induced change in biodiversity is anchored in a three step approach. The first step is the determination of the role of biodiversity in creating agro-ecosystems. The second step is empirical evaluation of the reduced quantity and quality of agro-system services. Here, the magnitude of climate change impacts on agricultural productivity is isolated and estimated by an econometric application where biodiversity is tested as being a determinant of agricultural yield. The third step is the (monetary) valuation of that loss employing Computable General Equilibrium (CGE) model. To the best of our knowledge, this study represents an original attempt to uncover climate-change-induced impact of biodiversity on agro-systems.

The paper is organized as follows. Section 2 discusses a roadmap to the monetization of climate change impacts on agro-ecosystem services, exploring the role of the two agro-systems of croplands and grasslands respectively. Section 3 focuses on the assessment of climate change impacts on provisioning services, with particular attention paid to the role of biodiversity. Section 4 provides an economic valuation of regional GDP loss due to climate-change-induced impact of biodiversity on agro-systems. Section 5 concludes.

2. A roadmap to the monetization of climate change impacts on agro-ecosystems

Ecosystem goods and services provided by agro-ecosystems

Natural and modified ecosystems provide many services and goods that are essential for humankind (Matson et al., 1997). Simultaneously, modern agriculture has both substantially changed agro-ecosystems and severely impacted the environment; these impacts include reductions in biodiversity and a degradation of soil quality (Solbrig, 1991). The present study focuses on cultivated ecosystems (also known as agro-ecosystems), their link to biodiversity, and how this is impacted by global climatic changes. Building upon the Millennium Ecosystem Assessment (MEA 2005), we are able to identify the following ecosystem services: food, feed, and fiber; soil erosion control; maintenance of the genetic diversity essential for successful crop and animal breeding; nutrient cycles; biological control of pests and diseases; erosion control and sediment retention; and water regulation. These are the local benefits that agro-ecosystems can provide to local communities. In addition, there are also global benefits to human wellbeing from agro-ecosystems in terms of regulating services such as carbon sequestration (Swift et al., 2004; Allen & Vandever 2003; MEA, 2005). Moreover, we also distinguish between croplands and the grasslands due to the very different types of ecosystem goods and services that these two distinct agro-systems provide.

Croplands and grasslands

We discuss croplands and grasslands in detail for two main reasons. Firstly, croplands and grasslands provide different goods for human consumption. Secondly, these two agricultural systems are characterized by different profiles with respect to the supply of regulating services. In terms of provisioning services, croplands provide three kinds of natural products, including food, non-food, and bio-energy[4] (see Table 1 for examples), whereas grasslands are cultivated primarily for grazing. The distinction between croplands and grasslands is therefore essential to the quantitative projections of ecosystem goods and

[4] *Food* includes crops destined for human consumption, such as sugar crops, nuts, cereals, fruits, oils crops, pulses, root and tubers, vegetables. "non-food" includes provisioning services non-destined for human consumption, such as latex, pharmaceuticals and agro-chemicals product. On the other hand, *bio-energy* includes crops for energy production, such as oilcrop for biodiesel and cereals for ethanol.

services under the climate change scenarios, and ultimately to the economic valuation exercise.

Table 1 – Agricultural ecosystem goods and services

	Cropland Food, Non-Food, Bio-energy	Grassland
Provisioning services	Food, fibre, latex, pharmaceuticals and agro-chemicals. Different crop types for food production, for animal feeding and energy production	Grazing
Supporting services	Genetic library	Genetic library
Cultural services	Agricultural landscape and agri-tourism	Agricultural landscape and agri-tourism
Regulating services	Nutrient cycling, regulation of water flow and storage, regulation of soil and sediment movement, regulation of biological population including diseases and pests	Nutrient cycling, regulation of water flow and storage, regulation of soil and sediment movement, regulation of biological population including diseases and pests

Source: Swift et al. (2004), adapted

Biodiversity indicators in the agriculture system

Multiple dimensions of biodiversity in cultivated systems make it difficult to categorize production systems into ‘‘high’’ or ‘‘low’’ biodiversity systems, especially at spatial and temporal scales. In agro-ecosystems a distinction has been made between ‘planned’ and ‘associated’ diversity (Swift et al., 2004; Walker and Steffen, 1997). ‘Planned’ diversity refers to plants and livestock deliberately, imported, stocked and managed by farmers. The term ‘associated’ refers to the nature of the biota (plant, animal and microbial), associated with the planned diversity and influenced by its composition and diversity. Farmers play a dominant role in the context of agricultural biodiversity by the selection of the present biodiversity stock, by the modification of the abiotic environment and by interventions aimed at the regulation of specific populations (‘weeds’, ‘pests’, ‘diseases’ and their vectors, alternate hosts and antagonists).

It is widely recognized that the relationship between cultivated systems and biodiversity is complex (Macagno and Nunes, 2009). Firstly, biodiversity is an *input* into agro-ecosystems (e.g. genetic resources for food and agriculture). Secondly, biodiversity supports the functioning of agro-ecosystems (e.g. the balancing of the nutrient cycle). Thirdly, agro-ecosystems also host important wildlife species which, though not always, play a functional role in land productivity, nonetheless constitute important sources of landscape amenities. Finally, agro-ecosystems can have an effect on biodiversity in the surrounding areas outside the cultivated fields, for example habitat fragmentation impacts.

More recently, studies of intensive agro-ecosystems have pointed out that permanent grasslands represent "hot spots" of biodiversity (Giardi et al., 2002; Anger et al., 2002; Bignal and McCracken, 1996; de Miguel & de Miguel, 1999; Nagy, 2002; EEA, 2007). Furthermore, the quality of soil is also higher in permanent grasslands with respect to arable lands as confirmed by the many soil quality indicators (organic carbon, aggregate stability). Against this background, the ratio between cropland and grassland can be employed as a *proxy* indicator for the measurement of the levels biodiversity in agro-ecosystems.

This, in turn, can be tested to determine if a significant role is played in the levels of supply of provisioning services. In other words, we can investigate whether this indicator affects the productivity of croplands. Furthermore, we propose to evaluate this link in the context of global climate change through a methodological framework that is discussed in the following section.

3. Assessing the impact of climate change on the provisioning services of agro-ecosystems

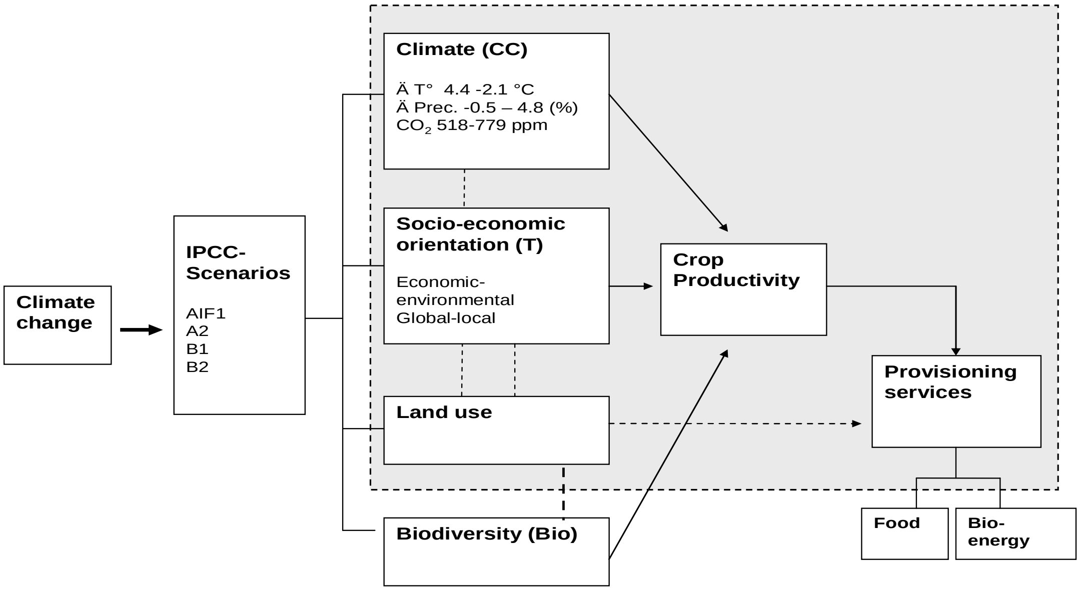
A methodological framework

To understand the interface between climate change and the provisioning services of agro-ecosystems, a graphical presentation is given in Figure 1 below. First of all, land productivity for different crops is affected by physical climatic variables (**CC**) including temperature and precipitation, and by the level of technology (**T**). In turn, both are anchored in the specific IPCC scenario under consideration ranging from AIF1 to B2. In addition, a biodiversity variable (**Bio**) is also assumed to impact land productivity. Formally, we propose to estimate the β 's of the following equation:

(Equation 1): $$CrP = \beta_0 + \underbrace{[\beta_1 Temp + \beta_2 Temp^2 + \beta_3 P + \beta_4 P^2]}_{\textbf{CC}} + \underbrace{[\beta_5 F + \beta_6 Tr]}_{\textbf{T}} + \underbrace{[\beta_7 GR / CL]}_{\textbf{Bio}}$$

Where *CrP* is the land productivity of harvested product, measured in t/ha, β_0 is the intercept, *Temp* is the average annual temperature (°C), *P* denotes the annual precipitation (mm), *F* is the total fertilizer consumption per hectare (Mt), *Tr* refers to the total tractors used per hectare, and *GR/CL* is the ratio of grassland to cropland. As expressed by the equation, land productivity is a function of physical variables (*Temp* and *P*), technological level (*F* and *Tr*) and a proxy of biodiversity (*GR/CL*)[5].

Figure 1 –Methodological framework for the evaluation of IPCC story lines on agricultural provisioning services



This section proceeds with presentation of the data used for estimating equation 1, focusing first on cropland and grassland data and its projections across the different IPCC story lines. We then discuss the results.

The grassland and cropland land-use data

Before entering into a specific discussion on the data, it is important to note that the methodological framework in this study focuses on 33 European countries: Greece, Italy, Portugal, Spain, Albania, Bosnia and Herzegovina, Bulgaria, Serbia and Montenegro, Turkey, TFR of Yugoslav, Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands, Switzerland, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Denmark, United Kingdom, Estonia, Latvia, Lithuania, Finland, Norway and

[5] GR/CL is considered to be a good proxy for biodiversity at the European scale due to the fact that grasslands have been demonstrated to be biodiversity 'hot spots' within the intensive agro-ecosystems and are therefore very important in the maintenance of associated biodiversity values (Baglioni et al 2009a, Baglioni et al 2009b).

Sweden.

Quantitative data of present cropland and grassland areas and the respective crop products in Europe are collected from the FAO 2005 database at national levels. In the present study, we consider over 153 million hectares of croplands in Europe – see first column in Table A1, in the Annex, and 92.5 million hectares of grassland – see first column in Table A2, Annex. A large proportion is dedicated to cereal crops – see Table A3, Annex. With respect to production, crop yields of each of the selected crop categories are derived from the FAO database in terms of weighted average yield (i.e. t/ha, harvested production per hectare) – see Table A4, Annex. By multiplying the weighted average yield of a crop product by each country's cropland area, we can calculate the total harvesting of this specific type of crop for this country, see the first column of Tables A5 to A12, Annex. If for example, the cereals area in Italy, for 2005, was 3.965 million ha and the average yield of 5.4 t/ha, also measured in 2005, then total production of cereals produced by Italy in that year was 3.965 Mha x 5.4 t/ha = 21 million tons, again as reported in the first column of Table A5, Annex.

The calculation of the actual land devoted to bio-energy crops is based on the EEA technical report No 12/2005, which shows that approximately 4.6 million hectares of agricultural land in the EU-25 is directly devoted to biomass production for energy use, see Table A13, Annex. As an illustration, in Italy, the total land area for bio-energy production is estimated to be 355,000 ha in 2005, about 3.6% of total cropland area. The majority of the land area for bio-energy production, about 83 per cent, is devoted to oil crops (used for biodiesel), and the remaining 11 per cent is used to cultivate ethanol crops. Bearing in mind the lack of data at the individual country level on the distribution between these two land uses, we assume the same proportions to calculate the oil crops and cereals used for biodiesel and ethanol production at country level, respectively. With respect to the remaining non-EU countries, the distribution is based on the average estimate of relative area devoted to bio-energy of the EU member states located at the same latitude. Moreover, we assume that the quantity of oil crops and cereals used for bio-energy production equals that of food crops – see last column in Table A4, Annex. This assumption enables us to calculate the total production of bio-energy – see Tables A14 and A15, Annex. Again, taking Italy as an example, our calculation shows that about 1 million tons of oil crops and more than 167,000 tons of cereals are used for bio-energy production. Next, we estimate the agricultural areas assigned for cropland, grassland and bio-energy production in each country in 2050. Here we adopt two approaches. The primary approach is to base our calculation on the land use change results of ATEAM model (Schröter et al. 2004, Schröter et al. 2005), which provides downscaled projections of soil used for the European Agro-ecosystems at country level using IPCC SERS circulation model. The results obtained are consistent with that of the IPCC report. Once again, taking Italy as an example, our estimation shows that the country's cropland area in 2050 will range between 5.9 and 8 Mha depending on the scenario – see last columns of Table A1, Annex. These figures indicate a general contraction of cultivated areas. However, the limitation of the ATEAM model is that it covers only 17 developed European countries. For this reason we referred to an IMAGE 2.2 Integrated Assessment Model (IMAGE team, 2001) to calculate the required information on agro-ecosystem land use patterns for the 16 remaining countries of interest. This is done based on a global projection of land use changes. Final results are presented in Tables 1A and 2A respectively for croplands and grasslands. Projections of land productivities for all four IPCC scenarios are the focus of the next section.

Land productivities under different IPCC scenarios: results

As seen in Figure 1, the estimation of the future crop yield takes into account the impacts of advancements in technology (***T***), direct climate effects (***CC***) and biodiversity contributions (***Bio***). With respect to the technology factor (***T***), the parameter value was derived from Ewert et al. (2005) who provide a mean coefficient for Europe - see Table 2. For instance, in the global economic scenarios (A1 and A2) show higher technological impacts on crop productivity when compared to the B's scenarios. As an illustration, the actual cereals yield in Italy may increase from present 5.4 t/ha to 6.8 t/ha in 2050 in the scenario B2, using the parameters of relative change in crop productivity presented in Table 2.

Table 2 – Estimated relative change in crop productivity due to technology factor on 2050

A1FI	A2	B1	B2
1.87	1.81	1.63	1.28

Source: Ewert et al., (2005)

In addition, with respect to climate change impacts, the coefficient (***CC***) was calculated on the basis of a study developed by Tor (2007), which estimates the relative wheat yield changes in 2050 for the European Environmental Zones under different IPCC scenarios. The information regarding the percentage of each environmental zone within the EU countries is used to calculate a weighted average for an estimation of the relative wheat yield changes for all 33 European countries of interest. Moreover, since wheat is the most cultivated crop in Europe, it is considered the most representative of net primary production (NPP) variation and can therefore be an important crop to be studied in terms of the consequences of changing climatic parameters (such as temperature, precipitation and CO_2). All of the calculated *CC* coefficients are reported in Table 3.

Table 3 – Estimated relative changes in land productivity (2050) as affected by changes in climatic conditions (CC) and biodiversity (Bio) for different IPCC scenarios

	CC				Bio			
Country	**A1FI**	**A2**	**B1**	**B2**	**A1FI**	**A2**	**B1**	**B2**
Greece	0.91	0.93	0.98	0.96	1.14	0.98	1.20	1.00
Italy	0.94	0.95	0.98	0.97	1.00	0.99	0.99	0.99
Portugal	0.91	0.92	0.98	0.96	0.94	0.87	0.90	0.86
Spain	0.92	0.93	0.98	0.96	1.05	0.97	1.09	1.00
Albania	0.95	0.96	0.99	0.98	0.92	0.94	0.92	0.94
Bosnia and Herz.	1.05	1.04	1.01	1.03	0.91	0.93	0.91	0.93
Bulgaria	1.01	1.01	1.00	1.01	0.94	0.96	0.94	0.96
Serbia and Mont.	1.03	1.03	1.01	1.02	0.94	0.96	0.94	0.95
Turkey	1.03	1.03	1.01	1.02	0.91	0.94	0.92	0.94
TFR of Yugoslavia	1.02	1.02	1.01	1.01	0.88	0.91	0.88	0.90
Austria	1.07	1.06	1.02	1.04	0.94	0.92	0.98	0.93
Belgium	0.98	0.98	0.99	0.99	1.00	0.99	1.00	0.99
France	0.95	0.96	0.99	0.98	0.99	0.99	1.00	0.99
Germany	1.01	1.01	1.00	1.01	0.99	0.99	1.00	0.99
Ireland	0.95	0.96	0.99	0.98	0.98	0.99	1.01	0.99
Luxembourg	0.98	0.99	1.00	0.99	1.00	0.99	1.00	0.99
Netherlands	0.96	0.97	0.99	0.98	1.01	0.98	1.00	0.98
Switzerland	1.08	1.07	1.02	1.04	0.92	0.90	0.96	0.92
Croatia	0.99	0.99	1.00	0.99	0.91	0.94	0.92	0.93
Czech Republic	1.05	1.04	1.01	1.02	0.97	0.98	0.98	0.98
Hungary	1.01	1.01	1.00	1.01	0.98	0.98	0.98	0.98
Poland	1.03	1.03	1.01	1.02	0.97	0.97	0.97	0.97
Romania	1.04	1.03	1.01	1.02	0.92	0.94	0.92	0.94
Slovakia	1.03	1.03	1.01	1.02	0.92	0.93	0.92	0.93
Slovenia	1.08	1.07	1.02	1.04	0.93	0.95	0.93	0.94
Denmark	1.00	1.00	1.00	1.00	0.99	0.99	1.00	0.99
United Kingdom	0.97	0.97	0.99	0.98	0.98	0.98	1.01	0.98
Estonia	1.06	1.05	1.02	1.03	0.98	1.00	0.98	0.99
Latvia	1.04	1.04	1.01	1.02	0.92	0.94	0.92	0.94
Lithuania	1.02	1.01	1.00	1.01	0.99	1.00	0.99	1.00
Finland	1.12	1.10	1.03	1.06	1.03	1.02	1.05	1.02
Norway	1.20	1.17	1.05	1.10	1.00	1.00	1.02	1.00
Sweden	1.12	1.10	1.03	1.06	1.00	1.00	1.01	1.00

Again as an example, considering the present Italian cereal productivity (5.4 t/ha) and a CC coefficient value of 0.94 for the scenario A1FI, this country's cereal yield in 2050 will be 5.4 t/ha $\times$ 0.94 = 5.08 t/ha as a result of the future climatic variation.

Finally, with respect to biodiversity impacts, the coefficient (***Bio***) was calculated on the basis of an econometric exercise that isolated the marginal impact of biodiversity as modeled by equation 1. We created an *ad hoc* database for the analysis on wheat yields, covering 19 countries over the period 1974 and 2000, see a sample in Table A16, Annex. Moreover, information regarding wheat yield, grassland and cropland areas, total fertilizers used and total tractors is derived from FAO statistics whereas information about temperature and precipitation is derived from the Tyndall database. The regression model results are summarized in Table 4. We can see that the model is statistically significant ($P<0.01$), as are other variables selected. In particular, the GR/CL parameter is significant ($P<0.01$) with a coefficient *g* of 0.549. This implies that, if the actual ratio GR/CL is 0.44 for Italy (from Table A1 and A4, Annex), the contribution of biodiversity to the wheat yield is 0.44 $\times$ 0.549 = 0.24 t/ha.

Table 4 – Crop productivity function for the estimation of the effects of biodiversity on wheat yield

	B	**Std. Err. of B**	**p-level**
Intercept	-0.480	0.518	0.354
Bio(grass/crop)	0.549	0.075	0.000
Avg_T	0.469	0.058	0.000
Avg_T^2	-0.033	0.003	0.000
Prec	0.004	0.001	0.001
$Prec^2$	0.000	0.000	0.006
Fert. (t/ha)	10.002	1.075	0.000
tractor (n/ha)	1.002	2.334	0.668

R= .74 R^2= .55 Adjusted F(7,505)=89.247 p<0.0000 Std.Error of estimate: 1.1959

At this point, it was possible to calculate changes in land productivity due to changes in biodiversity based on the estimated variation (D) of the ratio GR/CL for the IPCC scenarios in 2050 (using data from Table 1 and 4, Annex), as follows:

$$\text{(Equation 2): } (GR/CL)_{scenario} * \beta_7 - (GR/CL)_{2005} * \beta_7 = Yield\_{variation}$$

$$[(GR/CL)_{scenario} - (GR/CL)_{2005}] * \beta_7 = Yield\_{variation}$$

$$\Delta[GR/CL] * \beta_7 = Yield\_{variation}$$

where 'scenario' refers to the A1FI, A2, B1 and B2 scenarios reported by the IPCC. To standardize the wheat yield variation due to biodiversity, we performed the following correction:

$$\text{(Equation 3): } (Yield\_{variation}/Yield\_{2005})*100 = Relative\_variation$$

For example, assuming that the actual wheat yield is 3.2 t/ha, the GR/CL is 0.39 and 0.33 at present, and we operate in the A2 scenario (2050), then the final coefficient will be: [(0.33-0.39)* 0.55]/3.2*100 = -0.9% or 0.99 if expressed as projected final yield values (3.2 t/ha * 0.99 = 3.18 t/ha). The full ranges of the ***Bio*** coefficients calculated for each country are reported in Table 3. At this stage, we are finally able to obtain disaggregated total crop productions (tons) for the different IPCC storylines. The calculation is conducted using the formula below, and the results are reported in Tables A5 -A12, Annex.

(Equation 4):

$$\sum_i \left(estimated\_cropland\_area(ha)_i \times fut.yield(kg/ha)_i \right)$$

As an example, assuming that present cereals yield in Italy is 5.4 t/ha, its predicted value for the B2 scenario will therefore be 6.7 t/ha (5.4 t/ha×1.24 according to Table A16, Annex). Taking into account the estimated cropland area, the total cereals production in 2050 is estimated to be more than 21 Mt for the B2 scenario – see Table A5, Annex. The future trends of the selected indicators are projected individually for the period of 2005 to 2050 based on global circulation models, where greenhouse gas concentration and climatic and socioeconomic factors are the drivers of land use changes (Nakicenovic and Swart 2000; Schöter et al. 2004; Schöter et al. 2005, Ewert 2007). These results are validated by the recent study by carried out by Ferrise in which the authors explore the use of crop simulation model (SIRIUS) and applied to the durum wheat using data from open-field experimental in Florence in 2003-2005, see Ferrise et al., (in press). As a consequence, we are able to present four different development dimensions of agricultural ecosystem goods and services in Europe that are consistent with the four IPCC storylines: A1FI, A2, B1 and B2, as shown in Table 3.

4. Economic valuation of the linkages between Climate change, biodiversity and the productivity of European agro-ecosystems

Most of the economic studies of biodiversity end up with sectoral, partial-equilibrium analysis. However, agricultural products are important market commodities for human consumption. The projection of the agricultural output and respective market prices are therefore subject to standard macro-economic theory, determined by the future supply and demands of these commodities under climate change scenarios. For this reason, the economic valuation of crops in the scenario of climate change shall not be tackled in a partial equilibrium analysis. Instead, we apply the quantitative information obtained from the physical projections in Section 3 to a general equilibrium model. This way we are able to evaluate, in economic terms, the impact of climate-change-induced variation in biodiversity on the productivity of agro-systems.

The Methodological Framework

We employ a static multi-regional CGE model of the world economy called GTAP-EF (Roson, 2003; Bigano et al., 2006). The latter is a modified version of the GTAP-E model (Burniaux and Troung, 2002), which in turn is an extension of the basic GTAP model (Hertel, 1997). It is calibrated to replicate regional GDP growth paths consistent with the A2 IPCC scenario and is then used to assess climate change economic impacts in 2050 with respect to 2000.

Although regional and industrial disaggregation in the model may vary, the results presented here refer to 19 macro-regions in which several European countries appear disaggregated, as distinct economic entities, whereas the rest of the world is aggregated in four major trading blocks. Regional economies are represented by 19 sectors which can be classified in three major industries, where land using industries are presented in broadest disaggregation possible in GTAP database. Table 5 depicts the regional and sectoral disaggregation.

As in all CGE frameworks, the standard GTAP model makes use of the Walrasian perfect competition paradigm to simulate adjustment processes (Ronneberger et al., 2009). Industries are modelled through a representative firm, which maximizes profits in perfectly competitive markets. The production functions are specified via a series of nested Constant Elasticity of Substitution (CES) functions. Domestic and foreign inputs are not perfect substitutes, according to the so-called Armington assumption, which accounts for product heterogeneity. A representative consumer in each region receives income, defined as the service value of national primary factors (natural resources, land, labour and capital). Capital and labour are perfectly mobile domestically, but immobile internationally. Land (imperfectly mobile) and natural resources are industry-specific. The national income is allocated between aggregate household consumption, public consumption and savings. The top level utility function has a Cobb-Douglas specification. Private consumption is split in a series of alternative composite Armington aggregates. The functional specification used at this level is the Constant Difference in Elasticities (CDE) form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods.

Table 5: GTAP-EF Sectoral and Regional Disaggregation

	Regions		Sectors
	Code	Description	Description
1	Italy	Italy	Rice
2	Spain	Spain	Wheat
3	France	France	Cereal Crops
4	Greece	Greece	Vegetable Fruits
5	Malta	Malta	Oil Seeds
6	Cyprus	Cyprus	Sugar Cane
7	Slovenia	Slovenia	Plant-Based Fibers
8	Croatia	Croatia	Other Crops
9	FYug	Bosnia, Montenegro, Serbia	Animals
10	Albania	Albania	Forestry
11	Turkey	Turkey	Fishing
12	Tunisia	Tunisia	Coal
13	Morocco	Morocco	Oil
14	RoNAfrica	Rest of North Africa	Gas
15	RoMdEast	Rest of Middle East	Oil Products
16	RoNME	non-Mediterranean Europe	Electricity
17	RoA1	Other Annex 1 countries	Other industries
18	ChInd	China and India	Market Services
19	ROW	Rest of the World	Non-Market Services

Proposed here economic valuation of consequences of climate-change-induced change in biodiversity is fastened in a two step approach. The first step is creating benchmark data-sets for the world economy "without climate change" at year 2050, using the methodology described in Bosello and Zhang (2005). This entails inserting, in the GTAP-EF model calibration data, forecasted values for some key economic variables, to identify a hypothetical general equilibrium state in the future. Since we are working on the medium-long term, we focused primarily on the supply side: forecasted changes in the national endowments of labour, capital, land, natural resources, as well as variations in factor-specific and multi-factor productivity. We obtained estimates of the regional labour and capital stocks by running the G-Cubed model (McKibbin and Wilcoxen, 1998) and of land endowments and agricultural land productivity from the IMAGE model version 2.2 (IMAGE Team, 2001). By changing the calibration values for these variables, the CGE model has been used to simulate a general equilibrium state for the future world economy.

The second step is imposing over this benchmark equilibrium climate-change-induced temperature and precipitaions (CC), as well as biodiversity (Bio) impacts on land productivity for crops in different regions employing estimations presented in Table 3. For GTAP-EF regions, which absent from analysis in Section 3, we used values from available countries in same geo-climatic category, including latitude groups 35°-45°, 45°-55°, 55°-65° and 65° to 71° as we used before. We run this model for four scenarios about the climate (A1F1, A2, B1, B2). In this way, GTAP-EF generates three sets of results: a baseline growth for the world economy, in which climate change impacts are ignored, and counterfactual scenarios in which temperature and precipitaions, and biodiversity impacts are imposed.

Results

Table 6 presents changes in output of a representative crop, wheat, due to climate-change-induced variations in temperature and precipitations (CC), and biodiversity (Bio) in year 2050 versus baseline projection. Here already evidences for significant effect of biodiversity above direct climatic impact can be observed. For instance, examining percent change in wheat output in Italy under A1F1, A2 and B2 scenarios, it becomes clear that biodiversity added effect reverses direct climatic change impact, so that wheat production is projected to increase with ***Bio*** when compared to benchmark dynamics. The output change is negative when only direct ***CC*** shock is evaluated.

Table 6 – Percentage change in wheat output versus no climate change baseline in 2050

	CC				Bio			
Region	A1F1	A2	B1	B2	A1F1	A2	B1	B2
Italy	-0.067	-0.123	0.150	-0.064	0.333	0.202	0.061	0.108
Spain	-1.683	-1.511	-0.245	-0.821	1.551	-0.522	2.288	0.215
France	-0.436	-0.469	0.478	-0.128	0.609	0.352	0.647	0.173
Greece	-3.331	-2.574	-0.540	-1.432	5.420	-0.536	7.258	0.204
Malta	-1.482	-1.535	0.330	-0.775	2.474	-0.279	3.342	0.468
Cyprus	0.731	0.408	0.775	0.293	1.453	0.577	1.355	0.449
Slovenia	0.419	0.322	0.212	0.198	0.144	0.108	0.026	0.050
Croatia	0.439	0.236	0.432	0.103	-0.595	-0.387	-0.596	-0.615
FYug	0.311	0.255	0.189	0.154	-0.250	-0.193	-0.328	-0.253
Albania	-0.547	-0.443	-0.042	-0.202	-0.703	-0.597	-0.762	-0.594
Turkey	0.317	0.226	0.198	0.146	0.081	0.057	0.024	0.016
Tunisia	0.323	0.235	0.209	0.152	0.101	0.074	0.039	0.035
Morocco	0.322	0.246	0.197	0.156	-0.046	-0.026	-0.072	-0.059
RoNAfrica	0.194	0.145	0.129	0.094	-0.052	-0.030	-0.055	-0.053
RoMdEast	0.984	0.606	0.757	0.396	0.915	0.558	0.708	0.374
RoNME	0.269	0.139	0.209	0.081	0.234	0.145	0.250	0.081
RoA1	0.372	0.250	-0.012	0.159	0.346	0.244	-0.019	0.183
ChInd	-0.612	-0.365	0.184	-0.243	-0.613	-0.366	0.183	-0.243
RoW	-0.630	-0.372	-0.669	-0.251	-0.633	-0.377	-0.666	-0.246

The comparison between climate induced temperature (CC) impact with the combined effect of temperature and biodiversity (Bio) on agricultural output and regional GDP allows us to detect the marginal effect of biodiversity on these economic variables. As illustrates Figure 2, for some regions, the added effect of biodiversity operates in the same direction as temperature change. However, there are regions where this effect is reversed and in some cases it is even larger than temperature and precipitations impact so that the overall effect operates in the opposite direction.

Figure2- Percent change in regional GDP in 2050 due to temperature and biodiversity variation under B1 storyline versus baseline.

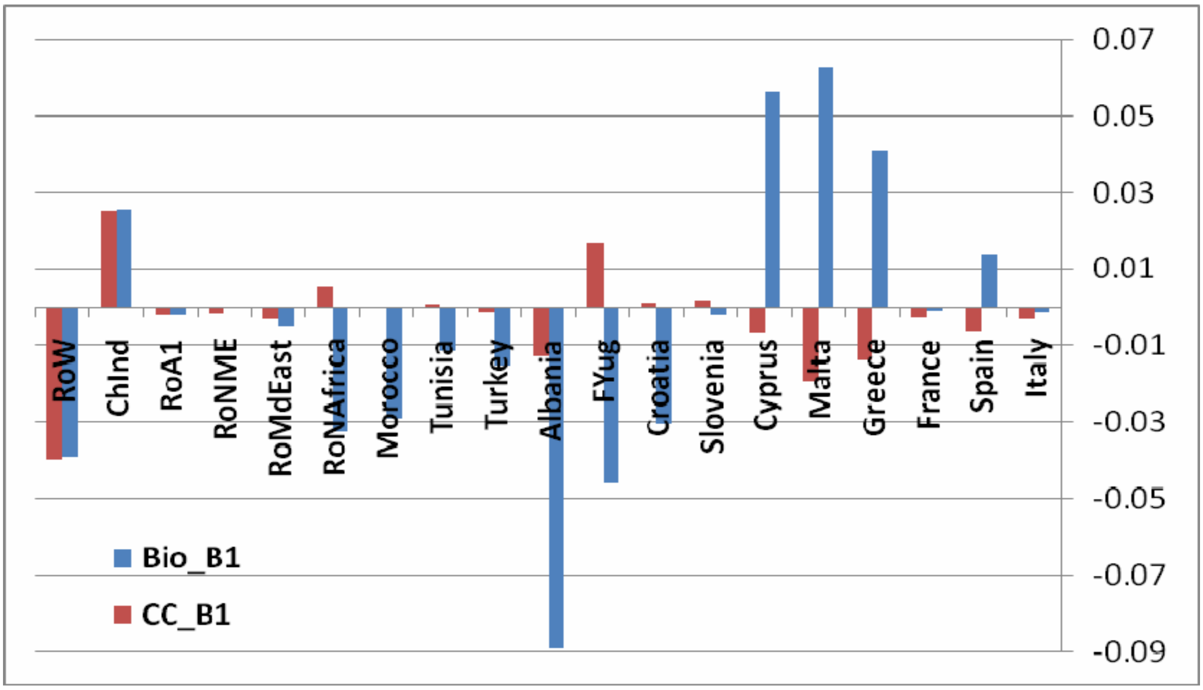


Table 7 reflects that this GDP pattern presents in all storylines. Here, "+" stands for cases where the marginal impact of biodiversity is non-negative, and "-" otherwise. Lighter colors of the cells signal when biodiversity impact on agro-ecosystems reverses direct climatic, CC, effect. Close examination of the outcome illustrated in Table 7 brings to the following conclusions: a) for the European Mediterranean countries, the climate-change-induced effects of biodiversity on agricultural productivity, when measured in terms of changes in GDP, are non-negative; b) in particular, for the majority part of the European Mediterranean countries B1 type of climate change scenario, the inclusion of this valuation transmission mechanism is able to reverse the marginal loss of GDP obtained under climate-change-alone impact evaluation (with the exception of Italy and France); c) for all the rest of the Mediterranean countries as well as for Rest of Middle East region, the climate-change-induced effects of biodiversity on agricultural productivity, when measured in terms of changes in GDP, is negative; i.e. the observed biodiversity impacts will further decrease the level of human welfare of these populations as originally measured by the CGE model; d) for Albania, the Rest of Middle East countries and Turkey (when analyzed at the B1 scenario) the magnitude of the negative impact marginal economic impact of biodiversity above temperature effect on land productivity is such that reverses the original CGE welfare impact; and, finally, e) for all non European countries, including China and

India and the rest of the World, the marginal impact of biodiversity is non-negative, however of low magnitudes.

Table 7- Marginal economic impact of biodiversity above temperature effect on land productivity

Region	A1	A2	B1	B2
Italy	+	+	+	+
Spain	+	+	+	+
France	+	+	+	+
Greece	+	+	+	+
Malta	+	+	+	+
Cyprus	+	+	+	+
Slovenia	-	-	-	-
Croatia	-	-	-	-
FYug	-	-	-	-
Albania	-	-	-	-
Turkey	-	-	-	-
Tunisia	-	-	-	-
Morocco	-	-	-	-
RoNAfrica	-	-	-	-
RoMdEast	-	-	-	-
RoNME	+	+	+	+
RoA1	+	+	-	+
ChInd	+	+	+	+
RoW	+	+	+	+

To summarize, despite the fact that in general we are assisting to a worldwide decrease in the levels of biological diversity, from an economic perspective, which is here approached from the productivity of the agro-ecosystems, this stylized fact is not always corresponding to a similar welfare or GDP change pattern to all. In fact not only European countries will experience diverse impacts. Some countries will more impacted than others, more countries will lose more than others, and some countries will gain, depending on the geographical location, existing markets and profile with respect to biodiversity indicators and land use patterns.

5. Conclusions

We propose to contribute to the ongoing study of the relationship between biodiversity, ecosystem services and human well-being. In particular, this study reports an economic valuation of the economy-wide consequences of climate-change-induced change in biodiversity. This approach depicts the world economy as a system of markets interacting through exchanges of inputs, goods and services responding to changes in relative prices induced by climate shocks. In other words, market-driven or autonomous social-economic adaptation is explicitly described, the mechanisms through which it is likely to operate are highlighted, and the interaction of impacts is stressed. To our knowledge, this exercise constitutes an original procedure, at a global level of analysis, in the economic welfare assessment of biodiversity impacts induced by climate change. First, there is an explicit effort to measure, model and estimate empirically the impact of biodiversity on agriculture. Econometric estimates confirm the presence of a positive and statistically significant magnitude, i.e. biodiversity contributes to explain the land productivity in the agro-ecosystem sector. Second, economic valuation results of the climate-change-caused impacts on biodiversity, agricultural provisioning services and the productivity of European agro-ecosystems are multifaceted. These, in turn, are anchored on the underlying IPCC storyline, that includes both climatic and socio-economic changes, as well as the type of ecosystem services under consideration. All in all, from an aggregate perspective, they do not reveal significant welfare losses. However, estimation results show that respective dimension and its distribution across the different European countries varies significantly. These results reiterate the importance of a welfare analysis of climate-change-caused impacts on biodiversity and ecosystem services that focus on the redistributive aspects involved with these changes: impacts are not distributed in a uniform way across the European countries under consideration; some countries, and respective economies, show to be less resilient than others; and most of the times the welfare changes involved clearly signal the presence of winners and losers. In particular, while developed regions lose slightly, or even gain as in the case of Central and Northern Europe, developing regions can lose considerably more. This highlights their greater vulnerability to climatic change with respect to developed economies, a vulnerability that results from a combination of higher degrees of exposure and sensitivity. Particularly enlightening is the case of Mediterranean Europe where initial negative impacts are eventually turned into gains. There, negative direct impacts are in fact counterbalanced by terms of trade improvements. Even in terms of final impacts on economic activity, the developing world is more severely affected than the developed one. Lastly, we found that studies that don't count for the indirect effect of climate change on agriculture are in danger of providing incorrect results as while counting for biodiversity, the climate change impact is stronger and may even reverse direction comparing to the case when biodiversity impact is ignored.

It is true that in this analysis we are looking at the tip of the iceberg, since welfare impacts of biodiversity are not *restricted to* market/productivity anchored transmission mechanism, and surely the link of biodiversity and human wellbeing is not *limited* to the agro-ecosystem sector and finally that the most efficient way to measure biodiversity may not be to proxy it as the ration between grassland and cropland. Having said that, and since we are not embracing a reductionist approach, we do have the ambition to provide a clear, unique and indisputable reply to the quantification of the biodiversity loss effects on GDP, and therefore on human wellbeing. The crucial point that we raise here is that the economies, which also reflect complex social systems, show different resilience profiles to deal with this type of effects; some economies, and respective social systems, are able to buffer the impacts, others not. Naturally further research is needed to better understand the ecological-social systems interactions and the role of biodiversity as a determinant.

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ANNEX

The crops market by "+" represent aggregated groups. **Cereals +** includes: barley, buckwheat, canary seed, cereals nes, maize, millet, mixed grain, oats, rice paddy, rye, sorghum, triticale, wheat. **Fruits +** includes: apples, apricots, avocados, bananas, carobs, cherries, citrus fruit nes, currants, dates, figs, gooseberries, grapefruit (inc. pomelos), grapes, kiwi fruit, lemons and limes, oranges, peaches and nectarines, pears, persimmons, pineapples, plums and sloes, quinces, sour cherries, stone fruit nes strawberries, tangerines, mandarins, clem. **Oils crops +** includes: castor oil seed, groundnuts, with shell, linseed, melon seed, mustard seed, olives, poppy seed, rape seed, safflower seed, seed cotton, sesame seed, soybeans, sunflower seed. **Pulses +** includes: beans dry, broad beans dry, horse beans dry, chick peas, cow peas dry, lentils, lupins, peas dry, pulses nes, vetches. **Root and tubers +** includes: potatoes, roots and tubersnes, sweet potatoes, yams. **Vegetables +** includes: artichokes, asparagus, beans green, cabbages and other brassicas, carrots and turnips, cauliflowers and broccoli, chillies and peppers green, cucumbers and gherkins, eggplants (aubergines), garlic, leguminous vegetables nes, lettuce and chicory, maize green, mushrooms and truffles, okra, onions (inc. shallots) green, onions dry, other melons (inc. cantaloupes), peas green, pumpkins squash and gourds, spinach, string beans, tomatoes, vegetables fresh nes, watermelons.

Table A1 - *Cropland area (1,000 ha) on 2005 and 2050* (*Source: cropland area on 2005 - FAO dataset; cropland area on 2050 - our projections based on ATEAM and IMAGE 2.2 model).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	3,401	1,054	1,740	1,799	2,230
	Italy	9,928	5,920	6,138	7,520	8,002
	Portugal	1,821	662	1,301	1,143	1,577
	Spain	17,863	4,383	8,756	8,601	11,826
	Albania	692	660	585	602	478
	Bosnia and Herzegovina	1,093	1,038	921	948	753
	Bulgaria	3,208	3,565	3,163	3,256	2,585
	Serbia and Montenegro	3,731	3,526	3,128	3,220	2,556
	Turkey	25,952	24,894	22,086	22,737	18,047
	TFR of Yugoslav	608	575	510	525	417
45 to 55	Austria	1,421	1,187	1,272	1,679	1,747
	Belgium	859	1,111	729	1,225	978
	France	19,100	14,688	13,593	18,104	17,889
	Germany	11,730	8,926	9,289	12,567	12,745
	Ireland	1,214	89	115	105	134
	Luxembourg	61	5	11	9	14
	Netherlands	938	931	612	1,014	862
	Switzerland	427	525	476	704	681
	Croatia	1,191	1,497	1,328	1,367	1,085
	Czech Republic	3,183	3,131	2,778	2,860	2,270
	Hungary	4,626	4,533	4,021	4,140	3,286
	Poland	12,325	13,523	11,998	12,352	9,804
	Romania	9,516	9,350	8,296	8,540	6,778
	Slovakia	1,362	1,486	1,319	1,358	1,078
	Slovenia	202	193	171	176	140
55 to 65	Denmark	2,206	2,092	1,328	2,311	1,799
	United Kingdom	5,608	4,778	3,316	5,426	4,557
	Estonia	590	807	716	737	585
	Latvia	1,085	927	822	846	672
	Lithuania	1,913	2,757	2,446	2,518	1,998
65 to 71	Finland	2,213	262	423	329	530
	Norway	863	332	289	344	368
	Sweden	2,677	1,736	1,933	2,203	2,482
	Total	153,615	121,145	115,611	131,270	120,957

Table A2 - *Grassland area (1,000 ha) on 2005 and 2050* (*Source: cropland area on 2005 - FAO dataset; cropland area on 2050 – our projections based on ATEAM and IMAGE 2.2 model).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	4,600	2,017	1,937	3,977	2,665
	Italy	4,411	2207	2,026	2,603	2,768
	Portugal	1,769	315	330	409	374
	Spain	10,400	3,963	3,981	9,679	7,707
	Albania	423	129	179	121	141
	Bosnia and Herzegovina	1,050	319	443	300	351
	Bulgaria	1,891	575	798	540	632
	Serbia and Montenegro	1,768	538	746	505	591
	Turkey	14,617	4,447	6,170	4,176	4,886
	TFR of Yugoslav	630	192	266	180	211
45 to 55	Austria	1,810	944	831	1924	1,277
	Belgium	519	653	355	759	456
	France	9,934	6,539	4,675	9,087	5,900
	Germany	4,929	2,955	2,480	4,570	3,309
	Ireland	3,010	2,000	1,683	4,384	1,893
	Luxembourg	67	24	26	59	34
	Netherlands	980	1,083	441	1,014	708
	Switzerland	1,091	844	631	1,420	1,125
	Croatia	1,469	447	620	420	491
	Czech Republic	974	296	411	278	326
	Hungary	1,057	322	446	302	353
	Poland	3,387	1,030	1,430	968	1,132
	Romania	4,685	1,425	1,978	1,338	1,566
	Slovakia	524	159	221	150	175
	Slovenia	305	93	129	87	102
55 to 65	Denmark	345	181	78	217	102
	United Kingdom	11,180	7,320	5,330	10,897	7,383
	Estonia	231	70	98	66	77
	Latvia	629	191	266	180	210
	Lithuania	891	271	376	255	298
65 to 71	Finland	26	52	48	122	76
	Norway	169	47	42	111	66
	Sweden	513	242	249	568	410
	Total	92,558	69,704	63,130	102,301	76,167

Table A3 - *Cropland area (1,000 ha) on 2005 for the eight selected crop categories* (*Source: FAO dataset).*

Latitude	Country	Cereals +	Fruits (exc melons) +	Nuts +	Pulses +	Roots and Tubers +	Sugarcrops +	Vegetables (inc melons) +	Oil crops +
35 to 45	Greece	1,243	240	41	24	45	41	135	1,191
	Italy	3,965	1,219	184	85	71	253	593	1,106
	Portugal	387	412	90	34	45	9	83	297
	Spain	6,516	1,806	660	565	97	103	395	2,448
	Albania	147	28	2	24	10	0	33	24
	Bosnia and Herz.	315	43	3	14	41	0	142	5
	Bulgaria	1,710	178	11	13	24	1	44	520
	Serbia and Mont.	1,931	352	13	52	95	64	136	258
	Turkey	13,854	1,074	557	1,277	154	336	1,060	1,862
	TFR of Yugoslav	200	46	3	12	13	2	46	8
45 to 55	Austria	792	55	6	43	22	45	13	87
	Belgium	320	18	0	1	65	86	74	19
	France	9,145	990	28	439	164	378	270	1,584
	Germany	6,786	178	4	169	277	420	106	1,085
	Ireland	274	2	0	3	12	31	5	3
	Luxembourg	28	3	0	0	1	0	0	3
	Netherlands	213	21	0	4	156	91	93	6
	Switzerland	166	23	2	5	13	18	14	19
	Croatia	535	72	3	3	19	29	21	105
	Czech Republic	1,604	46	1	35	36	66	15	306
	Hungary	2,911	192	5	22	25	62	85	541
	Poland	8,264	387	5	119	588	286	227	440
	Romania	5,758	380	2	70	285	25	286	912
	Slovakia	788	19	4	17	19	33	29	165
	Slovenia	95	21	0	2	6	5	4	3
55 to 65	Denmark	1,497	7	0	16	40	47	9	89
	United Kingdom	2,895	21	0	219	137	148	132	496
	Estonia	280	12	0	4	14	0	3	36
	Latvia	468	13	0	2	45	14	14	57
	Lithuania	949	33	0	36	74	21	21	86
65 to 71	Finland	1,177	7	0	4	29	31	9	59
	Norway	323	5	0	0	14	0	7	5
	Sweden	1,016	5	0	25	30	49	23	71

Table A4 - *Yield (t/ha) on 2005 for the eight selected crop categories* (*Source: FAO dataset).*

Latitude	Country	Cereals +	Fruits (exc melons) +	Nuts +	Pulses +	Roots and Tubers +	Sugarcrops +	Vegetables (inc melons) +	Oil crops +
35 to 45	Greece	4.1	15.1	2.4	1.8	20.1	63.6	29.1	3.0
	Italy	5.4	14.9	1.5	1.9	24.9	55.9	27.0	3.3
	Portugal	2.0	4.5	0.7	0.6	13.4	70.2	29.0	0.6
	Spain	2.2	8.6	0.4	0.5	26.8	71.4	33.8	1.6
	Albania	3.5	7.9	1.2	1.1	16.7	165.8	20.5	1.1
	Bosnia and Herz.	4.3	5.3	1.2	1.7	11.1	21.0	5.6	2.2
	Bulgaria	3.4	2.1	0.4	1.2	15.6	19.1	12.0	1.5
	Serbia and Mont.	4.9	3.3	1.6	2.7	11.6	48.2	9.2	2.2
	Turkey	2.6	12.1	1.5	1.2	26.5	45.2	24.8	2.3
	TFR of Yugoslav	3.2	9.1	1.7	1.6	14.5	36.4	11.7	1.8
45 to 55	Austria	6.1	18.5	2.8	2.5	34.4	69.0	39.7	2.3
	Belgium	8.6	33.3	2.3	3.4	42.8	70.0	32.9	1.4
	France	7.0	10.0	1.7	4.0	41.6	82.3	22.4	3.1
	Germany	6.7	14.5	4.0	2.4	42.0	60.2	29.7	3.7
	Ireland	7.0	14.4	0.0	5.2	34.7	45.0	41.0	3.8
	Luxembourg	5.6	7.2	1.8	3.2	31.8	0.0	41.0	3.6
	Netherlands	8.3	29.1	0.0	3.8	43.4	65.2	44.5	1.7
	Switzerland	6.3	19.1	0.8	3.7	38.8	77.2	22.2	3.2
	Croatia	5.6	4.5	3.9	3.1	14.5	45.5	13.4	2.0
	Czech Republic	4.7	8.4	4.9	2.5	28.1	53.3	19.6	2.4
	Hungary	5.5	6.6	0.8	2.4	25.9	57.0	18.3	2.1
	Poland	3.2	7.6	1.8	2.1	17.6	41.6	24.7	2.6
	Romania	3.3	5.7	22.9	1.2	13.1	29.2	13.4	1.5
	Slovakia	4.5	5.1	0.3	2.1	15.8	52.2	11.8	2.1
	Slovenia	6.0	12.5	15.2	2.8	22.9	51.4	24.6	2.6
55 to 65	Denmark	6.2	10.7	1.2	3.3	39.4	58.8	27.7	3.0
	United Kingdom	7.2	16.9	0.0	3.6	43.4	58.7	21.1	3.1
	Estonia	2.7	1.4	0.0	1.3	15.1	0.0	18.5	1.8
	Latvia	2.8	4.1	0.0	1.6	14.6	38.5	12.6	2.0
	Lithuania	2.9	3.7	0.0	1.6	12.1	38.1	16.2	1.8
65 to 71	Finland	3.4	2.3	0.0	2.2	25.7	37.9	28.0	1.4
	Norway	4.0	5.4	0.0	0.0	23.1	0.0	26.5	1.7
	Sweden	4.9	6.3	0.0	2.7	31.1	48.4	14.1	2.3

Table A5 – *Cereal + production (t) on 2005 and 2050* (*Source: 2005 data - FAO dataset; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	5,044,447	3,002,842	4,439,562	4,831,054	4,101,528
	Italy	21,255,971	22,942,046	22,996,953	25,760,869	21,245,161
	Portugal	779,322	487,601	890,875	738,476	742,122
	Spain	14,251,846	6,434,496	11,946,148	11,666,387	11,700,083
	Albania	507,211	841,525	733,718	680,257	420,722
	Bosnia and Herzegovina	1,339,237	2,327,477	2,008,488	1,800,531	1,143,279
	Bulgaria	5,793,514	11,717,549	10,167,172	9,232,081	5,834,069
	Serbia and Montenegro	9,459,464	16,445,808	14,273,310	12,898,199	8,099,227
	Turkey	36,102,256	62,681,762	54,688,677	49,342,575	31,130,096
	TFR of Yugoslav	639,607	1,069,689	932,928	839,001	521,347
45 to 55	Austria	4,864,818	7,638,847	7,793,751	9,366,151	7,475,584
	Belgium	2,764,826	6,617,013	4,177,512	6,388,125	3,967,729
	France	63,730,919	88,706,630	79,827,340	97,860,886	74,615,112
	Germany	45,621,294	64,916,294	65,387,024	79,669,794	63,448,351
	Ireland	1,925,117	253,699	321,133	272,481	266,318
	Luxembourg	159,316	25,939	51,414	40,050	46,653
	Netherlands	1,761,320	3,217,507	2,021,857	3,086,582	2,008,815
	Switzerland	1,048,253	2,408,068	2,080,775	2,779,618	2,071,451
	Croatia	3,003,263	6,680,578	5,826,461	5,343,270	3,283,358
	Czech Republic	7,608,004	14,146,527	12,152,172	11,074,844	6,945,350
	Hungary	16,085,918	29,317,246	25,170,829	23,177,719	14,511,427
	Poland	26,717,757	54,819,895	47,074,960	43,107,919	26,989,602
	Romania	19,199,423	34,523,638	29,792,041	26,879,715	16,958,339
	Slovakia	3,557,271	7,062,926	6,093,984	5,529,329	3,460,306
	Slovenia	571,789	1,026,958	886,871	788,291	498,955
55 to 65	Denmark	9,210,550	16,249,014	9,976,598	15,725,737	9,536,770
	United Kingdom	20,833,615	32,300,961	21,683,385	32,854,422	20,993,243
	Estonia	754,142	1,969,217	1,701,328	1,534,908	971,627
	Latvia	1,312,874	2,052,742	1,781,357	1,598,241	1,008,326
	Lithuania	2,789,156	7,554,512	6,488,357	5,945,634	3,757,807
65 to 71	Finland	4,027,219	962,763	1,486,763	1,023,504	1,311,468
	Norway	1,288,314	1,025,030	854,532	872,704	758,585
	Sweden	5,011,178	6,464,826	6,909,040	6,887,382	6,226,207
	Total	339,019,210	517,891,625	462,617,315	499,596,739	356,049,017

Table A6 – *Fruits + production (t) on 2005 and 2050 (Source: 2005 data - FAO dataset; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	3,614,623	2,151,701	3,181,190	3,461,715	2,938,970
	Italy	18,133,975	19,572,406	19,619,248	21,977,211	18,124,753
	Portugal	1,844,808	1,154,247	2,108,878	1,748,120	1,756,749
	Spain	15,536,631	7,014,557	13,023,078	12,718,097	12,754,830
	Albania	218,490	362,502	316,062	293,033	181,233
	Bosnia and Herzegovina	227,443	395,276	341,102	305,785	194,164
	Bulgaria	369,124	746,565	647,785	588,207	371,708
	Serbia and Montenegro	1,162,487	2,021,050	1,754,068	1,585,079	995,326
	Turkey	12,997,760	22,567,079	19,689,359	17,764,622	11,207,652
	TFR of Yugoslav	415,394	694,711	605,892	544,891	338,590
45 to 55	Austria	1,024,542	1,608,759	1,641,382	1,972,533	1,574,376
	Belgium	589,623	1,411,135	890,891	1,362,323	846,153
	France	9,906,640	13,788,985	12,408,745	15,211,966	11,598,532
	Germany	2,577,952	3,668,268	3,694,867	4,501,953	3,585,318
	Ireland	22,781	3,002	3,800	3,224	3,151
	Luxembourg	24,274	3,952	7,834	6,102	7,108
	Netherlands	605,541	1,106,177	695,113	1,061,165	690,630
	Switzerland	431,847	992,048	857,213	1,145,114	853,372
	Croatia	326,522	726,328	633,467	580,933	356,974
	Czech Republic	389,475	724,201	622,104	566,953	355,552
	Hungary	1,268,110	2,311,183	1,984,306	1,827,182	1,143,987
	Poland	2,920,439	5,992,201	5,145,625	4,712,000	2,950,154
	Romania	2,156,667	3,878,033	3,346,534	3,019,393	1,904,927
	Slovakia	99,270	197,100	170,060	154,303	96,564
	Slovenia	259,975	466,926	403,233	358,412	226,860
55 to 65	Denmark	72,988	128,764	79,058	124,617	75,573
	United Kingdom	354,916	550,271	369,393	559,699	357,636
	Estonia	16,798	43,863	37,896	34,189	21,642
	Latvia	55,039	86,056	74,679	67,002	42,272
	Lithuania	123,961	335,752	288,368	264,247	167,012
65 to 71	Finland	16,577	3,963	6,120	4,213	5,398
	Norway	26,403	21,007	17,513	17,885	15,547
	Sweden	32,573	42,022	44,909	44,768	40,471
	Total	77,823,651	94,770,090	94,709,772	98,586,938	75,783,181

Table A7 – *Nuts production (t) on 2005 and 2050* (*Source: 2005 data - FAO dataset; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	100,803	60,006	88,716	96,539	81,961
	Italy	279,442	301,608	302,330	338,666	279,300
	Portugal	61,699	38,603	70,531	58,465	58,754
	Spain	263,526	118,978	220,892	215,719	216,342
	Albania	2,883	4,783	4,170	3,867	2,391
	Bosnia and Herzegovina	3,024	5,255	4,535	4,066	2,582
	Bulgaria	4,572	9,247	8,024	7,286	4,604
	Serbia and Montenegro	21,766	37,841	32,843	29,678	18,636
	Turkey	837,000	1,453,223	1,267,910	1,143,966	721,725
	TFR of Yugoslav	5,447	9,110	7,945	7,145	4,440
45 to 55	Austria	17,031	26,742	27,285	32,789	26,171
	Belgium	500	1,197	755	1,155	718
	France	47,456	66,054	59,442	72,870	55,561
	Germany	17,661	25,131	25,313	30,842	24,562
	Ireland	0	0	0	0	0
	Luxembourg	140	23	45	35	41
	Netherlands	0	0	0	0	0
	Switzerland	1,483	3,407	2,944	3,932	2,931
	Croatia	10,079	22,420	19,554	17,932	11,019
	Czech Republic	4,903	9,117	7,832	7,137	4,476
	Hungary	4,133	7,533	6,467	5,955	3,728
	Poland	9,005	18,477	15,866	14,529	9,097
	Romania	47,889	86,112	74,310	67,046	42,299
	Slovakia	1,197	2,377	2,051	1,861	1,164
	Slovenia	3,109	5,584	4,822	4,286	2,713
55 to 65	Denmark	7	12	8	12	7
	United Kingdom	0	0	0	0	0
	Estonia	0	0	0	0	0
	Latvia	0	0	0	0	0
	Lithuania	0	0	0	0	0
65 to 71	Finland	0	0	0	0	0
	Norway	0	0	0	0	0
	Sweden	0	0	0	0	0
	Total	1,744,755	2,312,839	2,254,589	2,165,779	1,575,221

Table A8 – *Pulses + production (t) on 2005 and 2050 (Source: 2005 data - FAO dataset; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	44,224	26,326	38,921	42,353	35,958
	Italy	160,639	173,382	173,796	194,684	160,558
	Portugal	20,071	12,558	22,944	19,019	19,113
	Spain	288,495	130,251	241,822	236,159	236,841
	Albania	25,959	43,069	37,552	34,816	21,533
	Bosnia and Herzegovina	24,330	42,284	36,488	32,710	20,770
	Bulgaria	16,183	32,731	28,400	25,788	16,296
	Serbia and Montenegro	140,788	244,768	212,434	191,968	120,543
	Turkey	1,565,367	2,717,835	2,371,260	2,139,457	1,349,778
	TFR of Yugoslav	19,285	32,253	28,129	25,297	15,719
45 to 55	Austria	107,479	168,766	172,188	206,927	165,159
	Belgium	5,078	12,153	7,673	11,733	7,287
	France	1,754,077	2,441,488	2,197,102	2,693,442	2,053,645
	Germany	405,900	577,571	581,759	708,835	564,510
	Ireland	14,000	1,845	2,335	1,982	1,937
	Luxembourg	1,489	242	481	374	436
	Netherlands	14,703	26,859	16,878	25,766	16,769
	Switzerland	17,888	41,093	35,508	47,433	35,348
	Croatia	9,753	21,695	18,921	17,352	10,663
	Czech Republic	86,031	159,968	137,416	125,234	78,538
	Hungary	54,519	99,363	85,310	78,555	49,183
	Poland	254,601	522,394	448,590	410,787	257,191
	Romania	80,913	145,495	125,555	113,281	71,469
	Slovakia	35,045	69,581	60,036	54,473	34,090
	Slovenia	5,540	9,950	8,593	7,638	4,834
55 to 65	Denmark	53,000	93,501	57,408	90,490	54,877
	United Kingdom	791,403	1,227,010	823,683	1,248,035	797,466
	Estonia	5,690	14,858	12,837	11,581	7,331
	Latvia	3,540	5,535	4,803	4,309	2,719
	Lithuania	58,900	159,532	137,018	125,557	79,355
65 to 71	Finland	8,100	1,936	2,990	2,059	2,638
	Norway	0	0	0	0	0
	Sweden	66,280	85,506	91,382	91,095	82,350
	Total	6,139,271	9,341,798	8,220,211	9,019,189	6,374,904

Table A9 – *Roots and tubers + production (t) on 2005 and 2050 (Source: 2005 data - FAO data-set; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	895,936	533,330	788,504	858,036	728,466
	Italy	1,773,777	1,914,477	1,919,059	2,149,703	1,772,875
	Portugal	600,580	375,767	686,548	569,103	571,912
	Spain	2,595,018	1,171,612	2,175,190	2,124,250	2,130,386
	Albania	169,300	280,890	244,905	227,061	140,431
	Bosnia and Herzegovina	458,615	797,033	687,797	616,583	391,510
	Bulgaria	375,459	759,377	658,902	598,302	378,087
	Serbia and Montenegro	1,102,392	1,916,571	1,663,391	1,503,138	943,872
	Turkey	4,090,200	7,101,521	6,195,946	5,590,260	3,526,880
	TFR of Yugoslav	186,653	312,161	272,251	244,841	152,142
45 to 55	Austria	763,165	1,198,339	1,222,640	1,469,309	1,172,727
	Belgium	2,780,865	6,655,401	4,201,748	6,425,185	3,990,747
	France	6,838,112	9,517,921	8,565,203	10,500,141	8,005,949
	Germany	11,624,201	16,540,523	16,660,464	20,299,681	16,166,494
	Ireland	409,200	53,926	68,260	57,918	56,608
	Luxembourg	19,329	3,147	6,238	4,859	5,660
	Netherlands	6,777,000	12,379,946	7,779,462	11,876,186	7,729,283
	Switzerland	485,000	1,114,152	962,721	1,286,058	958,407
	Croatia	273,409	608,182	530,425	486,437	298,908
	Czech Republic	1,013,000	1,883,599	1,618,052	1,474,607	924,768
	Hungary	656,721	1,196,901	1,027,620	946,250	592,441
	Poland	10,377,542	21,292,797	18,284,558	16,743,705	10,483,130
	Romania	3,738,594	6,722,592	5,801,235	5,234,134	3,302,201
	Slovakia	301,169	597,968	515,935	468,129	292,960
	Slovenia	144,714	259,913	224,458	199,508	126,280
55 to 65	Denmark	1,576,400	2,781,044	1,707,510	2,691,484	1,632,233
	United Kingdom	5,961,000	9,242,085	6,204,140	9,400,443	6,006,674
	Estonia	212,902	555,930	480,302	433,320	274,300
	Latvia	658,200	1,029,127	893,071	801,267	505,517
	Lithuania	894,700	2,423,323	2,081,323	1,907,230	1,205,422
65 to 71	Finland	742,700	177,553	274,189	188,755	241,861
	Norway	316,617	251,912	210,011	214,476	186,430
	Sweden	947,300	1,222,094	1,306,067	1,301,973	1,176,986
	Total	69,773,572	112,871,112	95,918,124	108,892,333	76,072,549

Table A10 – *Sugar-crop production (t) on 2005 and 2050 (Source: 2005 data - FAO dataset; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	2,596,312	1,545,524	2,284,985	2,486,481	2,111,004
	Italy	14,155,683	15,278,547	15,315,112	17,155,777	14,148,484
	Portugal	609,129	381,116	696,321	577,204	580,053
	Spain	7,334,497	3,311,416	6,147,904	6,003,930	6,021,271
	Albania	21,223	35,212	30,701	28,464	17,604
	Bosnia and Herzegovina	21	36	31	28	18
	Bulgaria	24,731	50,019	43,401	39,409	24,904
	Serbia and Montenegro	3,101,176	5,391,568	4,679,339	4,228,525	2,655,238
	Turkey	15,181,248	26,358,114	22,996,966	20,748,893	13,090,420
	TFR of Yugoslav	57,836	96,726	84,359	75,866	47,142
45 to 55	Austria	3,083,792	4,842,239	4,940,433	5,937,172	4,738,748
	Belgium	5,983,173	14,319,433	9,040,273	13,824,112	8,586,295
	France	31,149,554	43,356,851	39,016,949	47,831,147	36,469,385
	Germany	25,284,702	35,978,574	36,239,467	44,155,410	35,164,996
	Ireland	1,395,000	183,838	232,703	197,448	192,983
	Luxembourg	0	0	0	0	0
	Netherlands	5,931,000	10,834,506	6,808,320	10,393,633	6,764,404
	Switzerland	1,409,357	3,237,603	2,797,563	3,737,144	2,785,027
	Croatia	1,337,750	2,975,744	2,595,293	2,380,064	1,462,513
	Czech Republic	3,495,611	6,499,832	5,583,496	5,088,502	3,191,144
	Hungary	3,515,865	6,407,809	5,501,535	5,065,905	3,171,732
	Poland	11,912,444	24,442,131	20,988,955	19,220,201	12,033,649
	Romania	729,658	1,312,042	1,132,221	1,021,541	644,487
	Slovakia	1,732,612	3,440,084	2,968,149	2,693,127	1,685,384
	Slovenia	260,095	467,142	403,420	358,577	226,964
55 to 65	Denmark	2,762,600	4,873,707	2,992,367	4,716,756	2,860,446
	United Kingdom	8,687,001	13,468,545	9,041,330	13,699,321	8,753,561
	Estonia	0	0	0	0	0
	Latvia	519,900	812,888	705,420	632,906	399,299
	Lithuania	798,500	2,162,761	1,857,534	1,702,160	1,075,812
65 to 71	Finland	1,181,300	282,406	436,111	300,223	384,692
	Norway	0	0	0	0	0
	Sweden	2,381,200	3,071,941	3,283,022	3,272,731	2,958,555
	Total	156,632,968	235,418,354	208,843,683	237,572,659	172,246,215

Table A11 – *Vegetables + production (t) on 2005 and 2050* (*Source: 2005 data - FAO dataset; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	3,938,829	2,344,693	3,466,520	3,772,207	3,202,575
	Italy	15,994,285	17,262,990	17,304,306	19,384,044	15,986,151
	Portugal	2,419,883	1,514,056	2,766,269	2,293,054	2,304,373
	Spain	13,355,750	6,029,922	11,195,025	10,932,855	10,964,431
	Albania	685,991	1,138,144	992,336	920,032	569,017
	Bosnia and Herzegovina	798,455	1,387,645	1,197,463	1,073,479	681,624
	Bulgaria	522,125	1,056,013	916,290	832,017	525,780
	Serbia and Montenegro	1,251,848	2,176,408	1,888,904	1,706,924	1,071,837
	Turkey	26,290,250	45,645,878	39,825,183	35,932,065	22,669,442
	TFR of Yugoslav	541,992	906,436	790,547	710,955	441,781
45 to 55	Austria	511,614	803,348	819,639	985,002	786,178
	Belgium	2,419,267	5,789,993	3,655,391	5,589,713	3,471,827
	France	6,037,846	8,404,037	7,562,816	9,271,308	7,069,011
	Germany	3,157,823	4,493,388	4,525,971	5,514,599	4,391,780
	Ireland	209,974	27,671	35,026	29,720	29,048
	Luxembourg	983	160	317	247	288
	Netherlands	4,149,347	7,579,857	4,763,124	7,271,421	4,732,400
	Switzerland	312,702	718,345	620,711	829,181	617,930
	Croatia	286,753	637,865	556,313	510,178	313,497
	Czech Republic	295,227	548,953	471,563	429,757	269,513
	Hungary	1,547,425	2,820,245	2,421,370	2,229,638	1,395,963
	Poland	5,620,855	11,532,955	9,903,583	9,069,001	5,678,046
	Romania	3,826,612	6,880,862	5,937,814	5,357,362	3,379,945
	Slovakia	338,906	672,895	580,582	526,787	329,668
	Slovenia	89,076	159,984	138,161	122,804	77,730
55 to 65	Denmark	252,701	445,809	273,718	431,452	261,651
	United Kingdom	2,772,139	4,297,995	2,885,211	4,371,639	2,793,380
	Estonia	63,521	165,866	143,302	129,285	81,840
	Latvia	172,706	270,034	234,334	210,246	132,643
	Lithuania	338,042	915,597	786,380	720,603	455,441
65 to 71	Finland	250,532	59,893	92,491	63,672	81,586
	Norway	184,121	146,493	122,127	124,724	108,414
	Sweden	327,131	422,026	451,024	449,610	406,449
	Total	98,968,536	137,256,457	127,323,811	131,795,578	95,281,236

Table A12 – *Oil crops production (t)(bio-energy excluded) on 2005 and 2050* (*Source: 2005 data - FAO dataset; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	3,565,820	2,122,649	3,138,238	3,414,976	2,899,289
	Italy	3,653,632	3,943,447	3,952,885	4,427,967	3,651,774
	Portugal	184,356	115,347	210,745	174,694	175,556
	Spain	3,799,369	1,715,358	3,184,698	3,110,117	3,119,100
	Albania	26,220	43,502	37,929	35,165	21,749
	Bosnia and Herzegovina	10,537	18,312	15,803	14,166	8,995
	Bulgaria	755,987	1,529,005	1,326,698	1,204,680	761,279
	Serbia and Montenegro	559,942	973,491	844,892	763,494	479,425
	Turkey	4,276,058	7,424,214	6,477,489	5,844,281	3,687,141
	TFR of Yugoslav	14,336	23,977	20,911	18,806	11,686
45 to 55	Austria	203,333	319,278	325,753	391,474	312,455
	Belgium	26,513	63,453	40,060	61,258	38,048
	France	4,855,802	6,758,758	6,082,224	7,456,241	5,685,093
	Germany	3,987,661	5,674,196	5,715,341	6,963,768	5,545,886
	Ireland	10,986	1,448	1,833	1,555	1,520
	Luxembourg	11,376	1,852	3,671	2,860	3,331
	Netherlands	9,808	17,916	11,258	17,187	11,186
	Switzerland	60,267	138,447	119,630	159,808	119,094
	Croatia	213,163	474,168	413,546	379,250	233,043
	Czech Republic	739,110	1,374,320	1,180,571	1,075,910	674,734
	Hungary	1,153,081	2,101,538	1,804,312	1,661,440	1,040,218
	Poland	1,140,066	2,339,204	2,008,722	1,839,445	1,151,665
	Romania	1,396,026	2,510,279	2,166,235	1,954,475	1,233,073
	Slovakia	350,808	696,527	600,972	545,287	341,246
	Slovenia	6,546	11,757	10,153	9,024	5,712
55 to 65	Denmark	266,133	469,505	288,267	454,385	275,559
	United Kingdom	1,540,409	2,388,288	1,603,240	2,429,211	1,552,211
	Estonia	64,426	168,230	145,344	131,127	83,006
	Latvia	113,690	177,759	154,258	138,401	87,317
	Lithuania	157,785	427,365	367,052	336,349	212,582
65 to 71	Finland	81,697	19,531	30,161	20,763	26,605
	Norway	8,686	6,911	5,761	5,884	5,114
	Sweden	165,483	213,486	228,155	227,440	205,606
	Total	33,409,109	44,263,515	42,516,806	45,270,888	33,660,295

Table A13 - *Cropland area for bio-energy (1,000 ha) on 2005 and 2050* (*Source: 2005 data* - EEA Technical - report No 12/2007; *cropland area on 2050 - our projections based on ATEAM and IMAGE 2.2 model).*

Latitude	**Country**	**2005**	**2050 A1FI**	**2050 A2**	**2050 B1**	**2050 B2**
35 to 45	Greece	358	526	477	249	435
	Italy	355	2,569	2,520	1,520	1,209
	Portugal	90	758	603	589	277
	Spain	767	1,686	1,247	911	962
	Albania	8	168	146	105	85
	Bosnia and Herzegovina	4	313	273	197	159
	Bulgaria	166	665	580	417	338
	Serbia and Montenegro	91	624	544	392	317
	Turkey	654	4,710	4,108	2,957	2,392
	TFR of Yugoslav	4	155	136	98	79
45 to 55	Austria	32	457	444	217	189
	Belgium	8	289	429	66	309
	France	535	6,101	6,541	3,488	4,273
	Germany	371	4,309	4,057	1,908	1,919
	Ireland	3	888	921	30	1,562
	Luxembourg	1	39	33	4	45
	Netherlands	3	217	403	43	353
	Switzerland	7	143	180	19	100
	Croatia	35	534	599	141	550
	Czech Republic	102	738	828	195	760
	Hungary	181	856	960	226	881
	Poland	194	2,926	3,282	774	3,013
	Romania	312	2,197	2,464	581	2,262
	Slovakia	55	459	515	122	473
	Slovenia	1	192	215	51	198
55 to 65	Denmark	38	392	533	86	177
	United Kingdom	168	1,775	2,426	234	1,982
	Estonia	13	351	479	64	262
	Latvia	20	516	704	93	385
	Lithuania	33	520	708	94	388
65 to 71	Finland	27	1,210	923	151	1,279
	Norway	4	1,703	1,717	51	2,822
	Sweden	29	2,003	1,642	505	1,343
	Total	4,668	41,474	42,061	16,641	32,339

Table A14 – *Oils crop for biodiesel production (t) on 2005 and 2050* (*Source: 2005 data* - EEA Technical - report No 12/2007*; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	1,043,292	2,663,088	2,161,313	1,189,159	1,419,990
	Italy	1,068,984	13,512,377	12,816,176	7,068,330	4,357,778
	Portugal	53,939	712,621	527,009	486,488	166,331
	Spain	1,111,624	4,238,045	2,912,572	2,115,436	1,630,110
	Albania	7,671	280,092	240,089	155,641	98,118
	Bosnia and Herzegovina	3,083	1,090,007	924,747	579,645	375,161
	Bulgaria	221,187	1,546,916	1,319,593	837,813	539,663
	Serbia and Montenegro	163,829	2,197,404	1,874,947	1,184,680	758,262
	Turkey	1,251,094	17,223,540	14,773,670	9,320,096	5,993,530
	TFR of Yugoslav	4,195	444,752	381,346	239,795	151,883
45 to 55	Austria	59,491	1,772,204	1,638,327	728,608	487,496
	Belgium	7,757	646,340	924,663	129,050	470,690
	France	1,420,717	29,793,704	31,057,732	15,243,317	14,411,011
	Germany	1,166,715	26,054,602	23,746,706	10,056,465	7,941,856
	Ireland	3,214	5,400,686	5,474,385	162,717	6,594,311
	Luxembourg	3,328	229,891	190,300	19,134	180,927
	Netherlands	2,870	597,447	1,063,922	104,660	654,923
	Switzerland	17,633	757,779	903,850	87,196	350,926
	Croatia	62,368	1,682,511	1,855,159	389,748	1,174,630
	Czech Republic	216,250	2,962,588	3,217,419	671,726	2,066,116
	Hungary	337,370	2,986,249	3,241,401	683,765	2,099,675
	Poland	333,562	12,464,383	13,531,781	2,838,723	8,717,022
	Romania	408,451	5,416,937	5,909,761	1,221,505	3,779,720
	Slovakia	102,640	1,562,806	1,704,724	354,345	1,087,612
	Slovenia	1,915	826,167	902,004	183,669	570,185
55 to 65	Denmark	77,865	1,911,410	2,515,438	368,106	590,417
	United Kingdom	450,695	8,835,003	11,678,074	1,042,730	6,720,000
	Estonia	18,850	1,051,059	1,395,057	162,192	533,860
	Latvia	33,263	1,661,166	2,214,627	256,055	839,990
	Lithuania	46,165	1,577,179	2,081,037	245,745	807,613
65 to 71	Finland	23,903	2,968,012	2,163,072	312,753	2,112,998
	Norway	2,541	5,202,472	5,016,294	129,032	5,747,883
	Sweden	48,417	8,156,854	6,414,825	1,724,267	3,681,575
	Total	9,774,878	168,426,293	166,772,021	60,292,590	87,112,262

Table A15 – *Cereals for ethanol production (t) on 2005 and 2050* (*Source: 2005 data* - EEA Technical - report No 12/2007*; 2050 data – our projection).*

Latitude	Country	2005	2050 A1FI	2050 A2	2050 B1	2050 B2
35 to 45	Greece	39,682	492,262	399,510	219,811	262,480
	Italy	167,208	2,991,548	2,837,414	1,564,880	964,782
	Portugal	6,130	315,193	233,097	215,174	73,568
	Spain	112,111	814,325	559,640	406,474	313,220
	Albania	3,990	121,215	103,903	67,357	42,463
	Bosnia and Herzegovina	10,535	292,656	248,286	155,629	100,727
	Bulgaria	45,574	491,626	419,381	266,266	171,511
	Serbia and Montenegro	74,412	675,306	576,209	364,076	233,029
	Turkey	283,995	2,665,690	2,286,523	1,442,473	927,620
	TFR of Yugoslav	5,031	105,816	90,730	57,053	36,136
45 to 55	Austria	38,269	633,068	585,245	260,274	174,144
	Belgium	21,749	554,440	793,189	110,701	403,764
	France	501,333	9,234,565	9,626,351	4,724,670	4,466,696
	Germany	358,876	6,500,545	5,924,731	2,509,058	1,981,469
	Ireland	15,144	1,346,171	1,364,541	40,559	1,643,693
	Luxembourg	1,253	48,786	40,384	4,061	38,395
	Netherlands	13,855	396,281	705,689	69,420	434,404
	Switzerland	8,246	202,682	241,751	23,322	93,862
	Croatia	23,625	636,787	702,130	147,510	444,567
	Czech Republic	59,848	794,381	862,710	180,115	554,003
	Hungary	126,538	1,055,732	1,145,936	241,732	742,301
	Poland	210,173	2,122,654	2,304,430	483,428	1,484,488
	Romania	151,030	1,608,593	1,754,940	362,733	1,122,411
	Slovakia	27,983	452,736	493,849	102,652	315,075
	Slovenia	4,498	261,247	285,228	58,079	180,301
55 to 65	Denmark	72,454	538,196	708,272	103,648	166,244
	United Kingdom	163,886	2,789,738	3,687,465	329,252	2,121,905
	Estonia	5,932	217,069	288,113	33,496	110,255
	Latvia	10,328	317,883	423,794	48,999	160,742
	Lithuania	21,941	344,773	454,917	53,720	176,545
65 to 71	Finland	31,680	1,003,597	731,416	105,753	714,484
	Norway	10,134	1,688,843	1,628,405	41,887	1,865,896
	Sweden	39,420	2,359,802	1,855,828	498,835	1,065,091
	Total	2,666,862	44,074,205	44,364,007	15,293,094	23,586,269

Table A16 – *Example of the database built for the biodiversity estimation approach*

COUNTRY	anno	wheat_(t/ha)	potato_(t/ha)	cropland	grassland	grass/crop	avg_T	avg_T2	prec	prec2	prec A-S	prec A-S2	fert (t/ha)	tractor (n/ha)
Albania	1974	2.06	6.71	652	470	0.72	11.3	127.69	1091.1	1190499.21	447.2	199987.84	0.06	0.01
Austria	1974	4.09	24.26	1612	2181	1.35	6.8	46.24	1169.8	1368432.04	659.9	435468.01	0.09	0.07
Bulgaria	1974	3.36	10.98	4488	1550	0.35	10.5	110.25	583.7	340705.69	318.8	101633.44	0.09	0.01
Denmark	1974	5.35	27.96	2655	277	0.10	8.3	68.89	730.1	533046.01	310.6	96472.36	0.20	0.06
Finland	1974	2.73	11.06	2480	158	0.06	3.6	12.96	658	432964	388.8	151165.44	0.22	0.07
France	1974	4.58	23.87	18887	13555	0.72	10.8	116.64	920.7	847688.49	412.5	170156.25	0.14	0.04
Germany	1974	4.63	25.35	12479	6342	0.51	9	81	760.7	578664.49	360.2	129744.04	0.27	0.08
Greece	1974	2.35	13.89	3891	5250	1.35	15.2	231.04	673.5	453602.25	152.8	23347.84	0.05	0.01
Hungary	1974	3.75	12.59	5503	1279	0.23	10.2	104.04	652.6	425886.76	398.1	158483.61	0.20	0.01
Ireland	1974	4.30	27.81	1255	4437	3.54	9.2	84.64	1172	1373584	522.7	273215.29	0.06	0.02
Italy	1974	2.58	15.70	12288	5214	0.42	13.3	176.89	800.1	640160.01	345.5	119370.25	0.07	0.04
Norway	1974	4.38	28.50	793	108	0.14	2.8	7.84	996.5	993012.25	520.6	271024.36	0.26	0.11
Poland	1974	3.20	18.08	15078	4179	0.28	8.7	75.69	712	506944	412	169744	0.18	0.02
Portugal	1974	1.18	9.88	3113	838	0.27	14.8	219.04	712.6	507798.76	232.5	54056.25	0.05	0.01
Romania	1974	2.09	13.27	10469	4460	0.43	8.9	79.21	718.6	516385.96	525.1	275730.01	0.06	0.01
Spain	1974	1.43	13.98	20885	11193	0.54	12.9	166.41	588.5	346332.25	257.1	66100.41	0.05	0.01
Sweden	1974	5.30	27.00	3023	716	0.24	3.5	12.25	678.1	459819.61	358.2	128307.24	0.13	0.05
Switzerland	1974	4.64	38.70	387	1633	4.22	5.8	33.64	1595	2544025	831	690561	0.07	0.04
United Kingdom	1974	4.97	31.67	7154	11484	1.61	8.6	73.96	1283.6	1647628.96	489.2	239316.64	0.09	0.03
Albania	1975	1.94	6.97	662	418	0.63	11.3	127.69	676.1	457111.21	294.8	86907.04	0.06	0.01
Austria	1975	3.51	22.85	1609	2181	1.36	6.8	46.24	1138.8	1296865.44	752.1	565654.41	0.08	0.08
Bulgaria	1975	3.29	10.59	4343	1612	0.37	11.1	123.21	669	447561	401.3	161041.69	0.11	0.01
Denmark	1975	5.10	22.27	2660	277	0.10	8.8	77.44	532.1	283130.41	267.9	71770.41	0.22	0.06
Finland	1975	2.84	14.01	2453	160	0.07	3.1	9.61	503.7	253713.69	306.7	94064.89	0.20	0.07
France	1975	3.87	23.07	18954	13403	0.71	10.8	116.64	846.7	716900.89	428	183184	0.14	0.04
Germany	1975	4.32	18.72	12510	6282	0.50	9.2	84.64	600.2	360240.04	364	132496	0.26	0.08
Greece	1975	2.29	15.32	3867	5251	1.36	15.3	234.09	630.8	397908.64	174.2	30345.64	0.05	0.01
Hungary	1975	3.20	12.54	5495	1275	0.23	10.4	108.16	633.8	401702.44	461	212521	0.22	0.01
Ireland	1975	4.37	25.09	1236	4479	3.62	9.7	94.09	912.7	833021.29	377.8	142732.84	0.08	0.02
Italy	1975	2.67	16.23	12313	5204	0.42	13.4	179.56	846.2	716054.44	336.5	113232.25	0.09	0.05
Norway	1975	3.31	19.02	792	106	0.13	2.2	4.84	1319.1	1740024.81	549.9	302390.01	0.26	0.12
Poland	1975	2.83	17.99	15099	4125	0.27	8.9	79.21	514.7	264916.09	320.1	102464.01	0.19	0.02
Portugal	1975	1.30	9.48	3118	838	0.27	14.9	222.01	697.9	487064.41	176.6	31187.56	0.06	0.01
Romania	1975	2.07	8.90	10500	4446	0.42	9.5	90.25	647	418609	473.9	224581.21	0.08	0.01
Spain	1975	1.62	13.87	20833	11088	0.53	12.9	166.41	617.4	381182.76	283.5	80372.25	0.04	0.01
Sweden	1975	4.83	19.91	3010	720	0.24	3.7	13.69	559.2	312704.64	314.5	98910.25	0.14	0.05
Switzerland	1975	3.96	36.58	395	1625	4.11	5.8	33.64	1451.1	2105691.21	917.2	841255.84	0.07	0.04
United Kingdom	1975	4.33	23.47	6954	11629	1.67	8.9	79.21	1050.8	1104180.64	476.7	227242.89	0.10	0.03
Albania	1976	2.55	7.42	685	390	0.57	10.6	112.36	1091.7	1191808.89	449.3	201870.49	0.07	0.01

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