Existing scenarios and data compilation on integrated scenarios using demographic, climatic, land cover from global and Black Sea Basin studies

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Abstract:

This report presents an overview of different existing scenarios for the territory of the Black Sea Basin. Main sources include the IPCC, GSG and GEO scenarios. They are global scenarios with either country or broader-region calculations of future changes, like plausible changes for Western Europe, Eastern Europe and the Middle East. Consequently, a number of driving forces were extracted and shortly presented in graphs outlining the trajectories of most plausible changes in the Black Sea Basin. Storyline descriptions per group of country were developed following the IPCC approach and applying the existing predictions of future GDP and population density numbers. The report concludes with an overview of integrated tools for environmental scenario development.

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Introduction

Environmental scenario construction and analysis

¨Rather than relying on predictions, scenarios enable a creative and flexible approach to preparing for an uncertain future¨

Mahmoud et al, 2009

Scenario construction and analysis aims to explore the range of uncertainties related to future state of a system that cannot be well characterized by either probabilistic or deterministic predictions. In environmental science, this method builds on a systematic assimilation of the available information from various disciplines, exploring first what can be characterized with relations and predictions to a certain degree, identifying and then describing what is left as uncertainty. This brings the added value of identifying unforeseeable points that may change the future state of the system.

Environmental scenarios are integrated scenarios, as they need to combine a range of themes and subjects. Scenario themes are typically suggested by the cause and effect relationships between the most critical and uncertain variables. The different themes are linked in a coherent story-line narrative. Several unique storylines are typically framed, each storyline being equally likely to occur.

Environmental scenario construction and analysis have not been developed as a standardized method of research. Several scenario families have been developed in the past, e.g. IPCC-SRES, Millennium Ecosystem Assessment scenarios, Global Outlook, Global Scenarios Group scenarios. They all present quite different pictures ("scheme" or "diagram" or "representation" could be used to replace "picture") as well as working methodologies to construct them, however certain common elements can be identified. Recently a ¨Formal framework of scenario definition for environmental decision making¨ was defined and published by a group of 21 authors from 19 institutions from America and Europe and Australia - Mahmoud et al. (2009). They outline the following major points of environmental scenarios:

Aiming to characterize future environmental factors and conditions that consist of threats to natural ecosystems and socio-ecological systems, and have consequences towards land-use addressing some key issues, such as:

- Water resources - representing water's importance for human survival, ecosystems management, economic activities, agriculture, power generation etc. The quantity and quality of water are equally important in assessing present and future demands for the resource.
- Land-use - representing issues related to food security, carbon cycling, and land-management practices
- Technology - representing technological changes that affect societal development and economic growth and environmental conservation.

The authors stress that for most environmental studies, all of these categories are closely interrelated with potential feedbacks; and consideration of each of them in isolation can potentially lead to flawed scenario outcomes. As a result, successful environmental scenario studies usually combine elements of climate, socioeconomic, environmental, and technological factors (Mahmoud et al., 2009).

The formal framework of scenario definition proposes scenario construction on the basis of systematic methods of assimilating the available scientific, technical, and socioeconomic information for the purpose of understanding the risks, impacts and mitigation options resulting from (human-induced) environmental change. This is done in an iterative process with five progressive phases:

1. Scenario definition – defining spatial and temporal scales; defining whether the future state is merely a trend of the present or if there is potential paradigmatic shift; defining critical driving forces. The latter are identified as factors to which the system is responsive and that have a certain degree of predictability. The definition results in *Scenario narratives, a* qualitative description of future issues of interest.

2. Scenario construction – includes the quantification of key drivers (specifying casual relations, variables, datasets and techniques); the description of identified uncertainties and the description of the assumptions about how the system works.

2.1 System conceptualization

2.2 Selection or development of models

2.3 Data collection/processing

Issues to be considered in selecting or developing models and procedures:

- Can the model adequately represent the important behaviours of the system?
- Is the model feasible at the scales and resolutions specified?
- Is a single model applicable to all the scenarios defined or are different models needed for the different scenarios within the spectrum?

2.4 Scenario analysis

Scenario analysis focuses on identifying the consequences of interactions among the:

- Boundary conditions,
- Driving forces,
- System components, through various statistical and other analytical techniques.

It allows the identification of notable system conditions or behaviours, like *trends*, *shift in regimes*, *thresholds and triggers*, *discontinuities and cascading effects*.

3. Scenario assessment - includes identifying risks, benefits, mitigation opportunities and trade-offs; and presenting the results to stakeholders. This phase extracts a set of narratives describing scenario results from the outcomes of the scenario analysis phase, and examines the implications for various purposes that rely on scenario exploration

4. Risks identification and management

¨In a general sense, scenario definition and assessment require extensive interactions and cooperation between scientists and stakeholders; scenario construction and analysis are primarily scientific efforts of researchers; and risk management is mainly the responsibility of stakeholders. However, in most cases, continuously involving stakeholders throughout the entire process can be important and desirable. Further, it is useful to have some feedback among all phases of scenario development¨ (Mahmoud et al, 2009).

1 EnviroGRIDS scenarios

EnviroGRIDS explores a data-driven view for environmental studies. The WP3 aims to construct *contrasting environmental scenarios* for the Black sea basin utilizing available datasets from multiple scales. At least three scenarios shall be constructed – best environmental scenario, worst scenario and a business as usual.

The work on integrated scenario development includes:

a) Instrumental part - exploring tools & models able to link datasets reflecting on diverse factors;

b) Narrative storylines development.

For the instrumental part the rationale is to start working with globally available datasets, applicable over the entire BSB, or with European or local datasets for model testing zones, provided that the same inputs can be supplied using the global datasets. A list of suitable data and sources is presented in *Annex VI*. Following the data-driven approach, integration refers to using different sources of data (triangulation method, Beunen, 2006) for asserting multiple evidence about an issue. In addition, linking different subjects (factors, drivers, impacts etc.) allows for constructing a holistic and comprehensive picture about an environmental situation e.g. best scenario or worst scenario. The different topical subjects should reflect on an environmental situation following the DPSIR framework (EEA). Main purpose of the task 3.4 is to design a framework and tool for diagnosing different environmental situations caused by a range of environmental factors and drivers. Then additional techniques will be applied for contrasting what factors and drivers are contributing respectively to the "best" and "worst" environmental scenario.

Important insight for designing such a diagnostic method can be gained by reviewing similar studies from Europe and elsewhere, for example the outcomes of the DITTY Project (EVK3-CT-2002-00084) which explored ways of supporting the European Water Framework Directive through the ¨*Development of an information technology tool for the management of Southern European lagoons under the influence of river-basin runoff*¨. The environmental situation is outlined as follows (Aliaume et al., 2002)

> At the root of environmental change are economic drivers (as agriculture and aquaculture intensification, industrial intensification, urbanization, tourism development), which in turn will create environmental pressures (as land conversion and reclamation, nutrients emissions, waste disposal). These pressures, along with physical factors such as climate change, will lead to changes in the state of the environment: changes in nutrient concentration leading to increased risks of eutrophication, loss of habitat and species diversity. Such physical changes will in turn have an impact on human welfare, for example trough aquaculture productivity, health impacts or reduced welfare from decreased biodiversity and lower water quality.

For environmental assessments performed in such a comprehensive way, multi-criteria techniques and multivariate analysis are typically applied. One of the best examples, with a thorough overview of the application of multivariate quantitative analysis for comprehensive ecosystem assessment has been published by Jordan and Vaas (2000) reflecting on several-decade efforts to restore, monitor and assess the state of ecosystems in the Chesapeake Bay in the USA. This is one of the first known cases of dead marine zones, due to algal blooms and pollution. It is also one of the cases with the longest running efforts to restore the ecosystem as well as monitor its degradation and restoration while applying all available scientific tools.

In EnviroGRIDS, considering the need to present an environmental situation over the entire Black Sea Basin through looking at climate, demography and land-use changes, the proposal is to start by characterising key long-term processes of land change with agricultural practices and urban/residential transformations. The working processes starts with exploring examples of such situations developed on the basis of the widely & globally available datasets, then organize presentations and discussions with local experts and improvement of the original results. In this way, a multi-scale assessment process will be carried out.

2 Conceptual Model

A conceptual model was discussed and sketched during a two-day workshop in Geneva (Dec. 2009) including researchers involved in WP3 (scenario development) and WP4 (soil and water modelling). Most important issues and relations in WP3 have to be developed in parallel with separate modelling of demography, climate and land cover.

EnviroGRIDS scenario integration proposes as main goal the combination of climate, demography and land use/cover scenarios. The EnviroGRIDS storylines development would be based on global socio-economic development paths such as IPCC- SRES and related scenarios studies. The plausible future changes in each of the three themes, climate, demography and land use will be calculated according to the assumptions specified in these storylines, reflecting on regional patterns i.e. groups of countries within the Black Sea Basin. Having the outputs of the three themes simulated in a spatially-explicit way presents several options for integrated analysis. It has to be underlined however, that simulated future land use per se is a result of integrated multi-criteria analysis of various environmental factors and human-actions related drivers, as explained by Mahmoud et al. (2009). As a starting step, a global environmental model (IMAGE 2.2) is used to define the land use demand for each Black Sea Basin countries. Additionally, population and economic global trends are taken from global trend lines, and included in the Integrated Decision Support System – IDSS called METRONAMICA. At regional scale a dynamic spatial interaction model (White, 1977, 1978 IN Engelen, G., 2003) will manage the allocation of national growth. The attractiveness of a region is determined by it is importance as a center of economic activity and housing, its position relative to the other regions and its position relative to the neighbouring countries. At local scale a cellular automaton land use is used to allocate the regional demands on a Land Use map. Modelling outputs would be generated for 50 years in 25 years time steps. Spatially explicit scenarios outcomes from the model would be used as an input for the Soil and Water Assessment Tool and also for impact assessment (Figure 1).

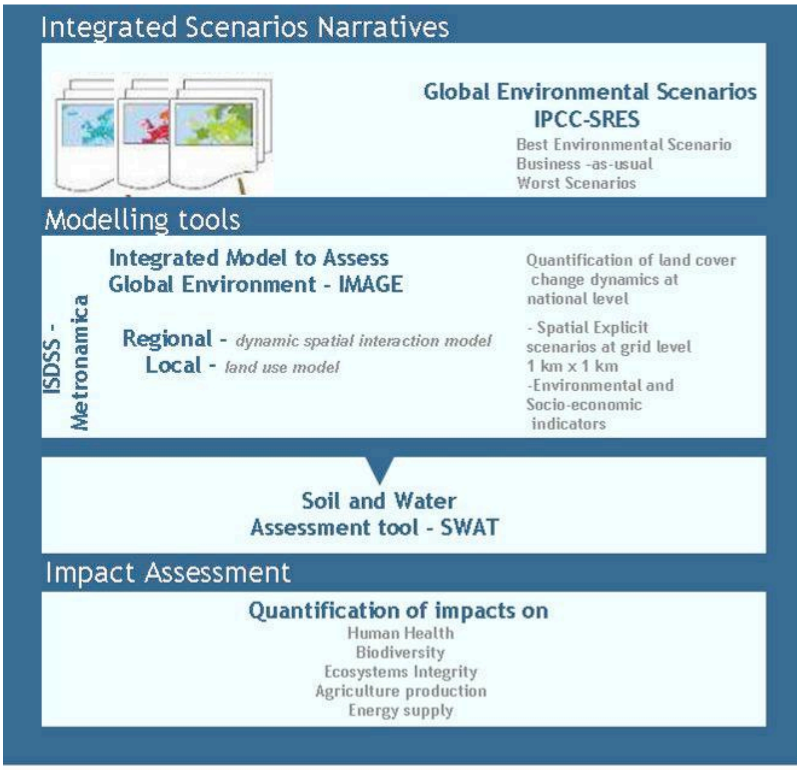


Figure 1: Demography, climate and land use scenarios (WP3) as input for Soil Water and Assessment Tool (WP4).

Therefore, for managing redundancy, the land use scenarios are to be considered as a part of the scenario integration subject. Possible outputs of the same METRONAMICA framework for demographic and climate change indicators assessment will be explored. In addition, other tools will be used to link the three subjects in an open modelling framework as the Bayesian Belief Networks. These networks allow the incorporation of data from various sources including unrelated subjects which are linked in a probabilistic way. The data is normally inserted in categories of already processed information which forces the modellers to have a good understanding of the processes being analyzed and to present a transparent view of the modelled issues.

Many possible links were discussed, but finally it was agreed that the EEA's approach DPSIR (Driver – pressure – State – Impact- Response) will be followed to structure main issues and relations relevant for the Black Sea Basin.

The three modules of scenario development e.g. land use, demography and climate are modelled separately but the future simulations follow common storylines. BSB scenario storylines have been initially sketched during the Geneva Workshops, and in parallel, quantifications of key parameters of climate, land use and demography are being explored.

The IPCC-SRES storylines are followed as the most widely accepted basis for scenario development. The storylines are needed for compiling time-series of observations and future simulations. In addition to climate, demography and land use, a set of available global datasets applicable over the entire BSB and reflecting on main pressure-impact-state spatial indicators are explored.

The objective is not to attempt a complete integration of all parameters into a (deterministic) model but rather to apply loose modelling techniques while incorporating expert opinions. Those expert opinions will allow the assessment framework to address environmental issues related to land degradation, water quantity and quality assessment in time and space perspectives.

3 Driving Forces

For the driving forces description, there is a framework proposed by RIVM (National Institute of Public Health and Environmental Protection) that was used for the development of Integrated Environmental Assessment that distinguishes Driving Forces, Pressures, States, Impacts and Responses. This became well-know as a DSPIR framework and has been more and more adopted by many projects for integrated studies (Kristensen, P., 2004). In EEA (1999), the term driving forces is described as "the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns. Primary driving forces are population growth, increasing needs and activities of individuals. These primary driving forces provoke changes in the overall levels of production and consumption. Through these changes in production and consumption, the driving forces exert pressure on the environment" (EEA, 1999).

In scenarios studies, independently of their type, scenario construction needs a consistent set of assumptions for the driving forces. Lambin (2006) specified the typical driving forces used for land use scenario development (table 1):

Driving Forces	
Demography	- Population Size including migration - Size of urban/rural population
Economic and technology	- Average per capita income - Biofuel demand (Typically used only in global/continental scenarios) - Food demand - Food/crop prices - Food trade - Status of land tenure/farm size (Typically used In regional and local scenarios.)
Biophysical	- Crop yield - Accessibility (infrastructure, travel distance) - Climate - Soil characteristics - Topography
Other factors	-Food preferences -Types of governance (Typically used in regional and local scenarios) -Education level (Typically used in regional and local scenarios)

Table 1: Driving forces for land use scenarios (Adapted from Lambin, 2006)

A driving force is the principal cause, independent and subject to change. A static condition cannot be a driver. For example, the soil type, topography cannot be a driver, because normally they cannot change or if they change the change is so small as to be irrelevant, so they are used for the analyse but they are not considered as a driving forces because they are static factors (Kuhlman, IN Katharina, 2008) (more on static factors in Deliverable 3.3).

For EnviroGRIDS the driving forces specification follows the common strategy for maintaining the internal consistency of driving forces. This process was used in the IPCC-SRES (Nakicenovic, N. et al., 2000) and Environmental Outlook Report (Geo) (UNEP, 2004) and it corresponds to good examples of the storylines descriptions, which provides many different assumptions about future changes in socio-economic development and the biophysical environment.

In this sense, which drivers could be used for integrated scenario development in Black Sea Basin? Part of this is dictated by the modelling approach but apart of this there are some driving forces that cannot be integrated in the model but should be explained. Non-spatial policies like energy demand and production, policy actions (like CAP), among others are explained bellow. The biophysical factors were analysed in the deliverable 3.3 and they were explained for the land use models overview.

In this chapter the driving forces analysed describe the recent trends and the global scenarios assumptions that would be used in the Black Sea Basin integrated scenarios development.

3.1 Demography changes in Black Sea Basin Countries

Demography is an important driving force that reflects in a large impact on land use. For Lambin et al. (2006), the demography changes are not only conducted by fertility and mortality rates, but also associated to the development of households, migration and urbanization. In this sense the demography should reflect the expected growth or decrease of total population and urban/rural population in Black Sea Basin region.

3.1.1 Population – World Population Prospect

The Black Sea Basin experienced a fluctuating population growth over the last five decades. Since 1950 the decline in population growth was visible mainly for the Eastern countries which reached the lowest negative values in 1995, maintaining this trend into the future. The Western Europe countries have been also suffering a declining of population growth over the last decades but in this case this decline was weaker, showing some rises in population, in 1995 and 2005. However, the projections show an even bigger decline in population growth reaching the lowest negatives values in 2030 (Figure 2).

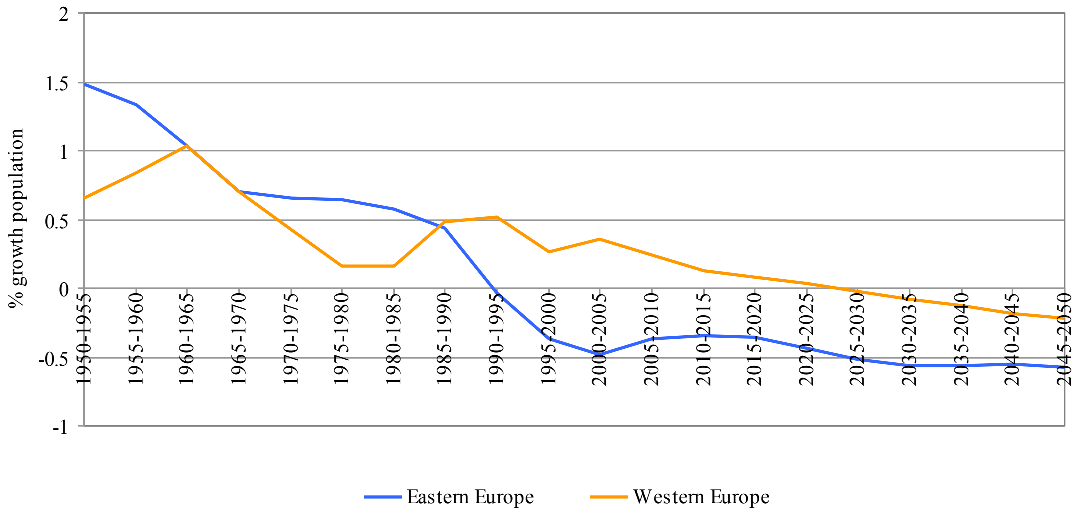


Figure 2: Eastern and Western Europe growth population Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision, http://esa.un.org/unpp, Thursday, September 16, 2010; 10:56:40 AM.

The projections based on the published UN population projections (1998) ranges between 7 and 15 billion people globally by 2100 depending on the speed and extent of the demographic transition. Comparing the WPP with the IPCC scenarios, the projection used in the B2 scenarios was the UN medium variant (UN, 1998). The A1 and B1 scenarios all shared a common, relatively low, population projection from IIASA, while the A2 scenario used a relatively high population projection from IIASA (Lutz et al., 1996) (Richard S.J, 2005).

For 2008, the three variants of the UN long-range population are used to downscale the regional population, providing the population scenarios for all BSB countries. The low variant is used for A1 and B1, the medium variant for B2 and the high variant for A2 (for more information consult D 3.1).

In the Eastern Europe the scenario A1, B1 corresponds to the low population growth scenario, and reveals that the population would decrease between 2005 and 2100. The B2 scenario corresponds to the medium variant and presents a slightly population decrease between 2005 and 2100. The A2 scenario corresponds to the high variant and represents a slow decline population between 2005 and 2100.

In the Western Europe the low scenario had a little decline (A1 and B1), and the medium variant seems to be constant from 2010 to 2050. The high variant (A2) shows a little increase between 2010 and 2100 (table 2).

Population	
Low Scenario A1 and B1	Low population growth -Eastern Europe: Strong decrease -Western Europe: Slightly decline
Medium Variant B2	Moderate population growth -Eastern Europe: Slightly decrease -Western Europe: Constant population
High Variant A2	Fertility patterns across regions converge very slowly, which results in high population growth -Eastern Europe: Slow Decline -Western Europe: Little increase

Table 2: Population scenarios for Western Europe and Eastern Europe

The figure 3 shows that since 1990 the Eastern Europe population is declining. The high variant scenario in Eastern countries represent a slightly decrease. The medium variant and low variant show a stronger decrease. In the Western Europe, the population has been increasing between 1950 and 2010. The highest scenario shows the continuous increase of the population and the medium scenario shows that population will not vary greatly from 2010 to 2050. The lower variant in Western Europe is the scenario that reveals a population decrease.

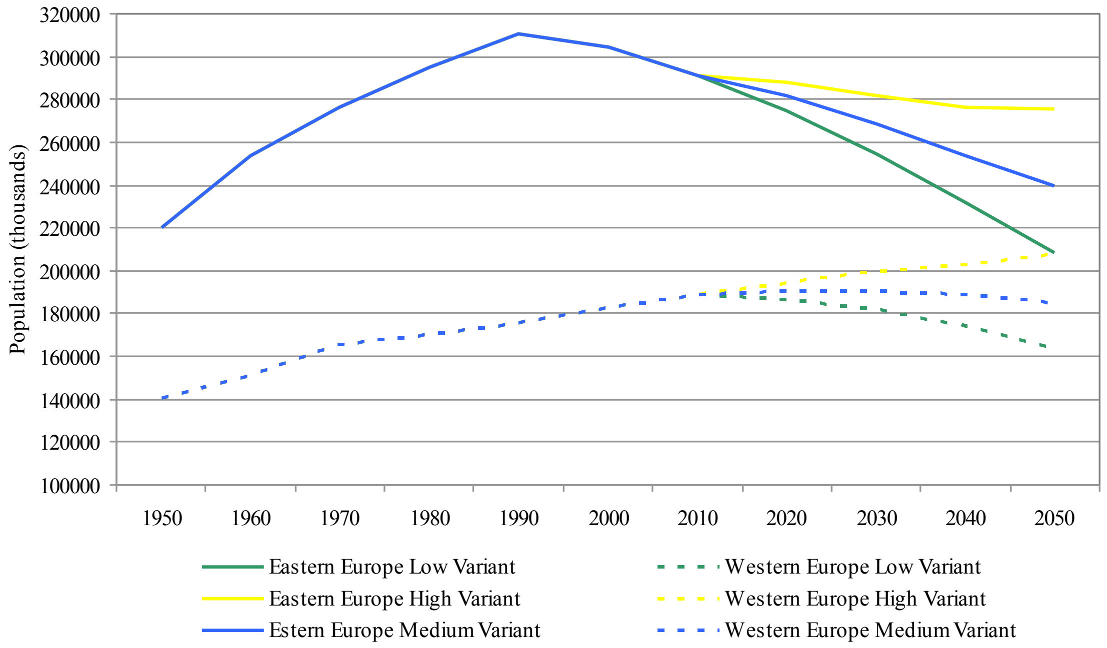


Figure 3: Eastern and Western Europe low, medium and High scenarios Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision, http://esa.un.org/unpp, Thursday, September 16, 2010; 10:56:40 AM.

Regarding the scenarios at country level (Annex I) with the exception of a few countries almost all scenarios confirm the decline in population: high, medium and low variants.

Albania, Austria, Czech Republic, Italy, Turkey and Switzerland show an increase in population for the high (A2 IPCC- SRES) and medium variants (B2 IPCC-SRES) however the low variant shows a decline in population.

The others countries show a decline in population, even in the high variant. Countries such as Belarus, Bulgaria, Russia, Serbia and Germany appear to be declining in 2025 and 2050.

3.1.2 Urban/Rural Population - World Urbanization Prospects

The urban population size is one of the driving forces for land use and other environmental changes. However the population growth does not directly influence the expansion of build-up areas. More and more people in Europe regard a new house, ideally localized in the suburban/rural areas outside the city, as the prime investment to be made in their lifetimes (EEA, 2006).

In Eastern Europe the urban population growth has been declining; reaching negative values in 2005. Since 2010 until 2050 the projected urban population growth increases a little, always showing negative values. In the Western Countries for all over the years, also was notice a decline in urban population but intercalated with slightly increases, and always showing positive values, with an exception from 2045 to 2050, that decline to negative values (figure 4).

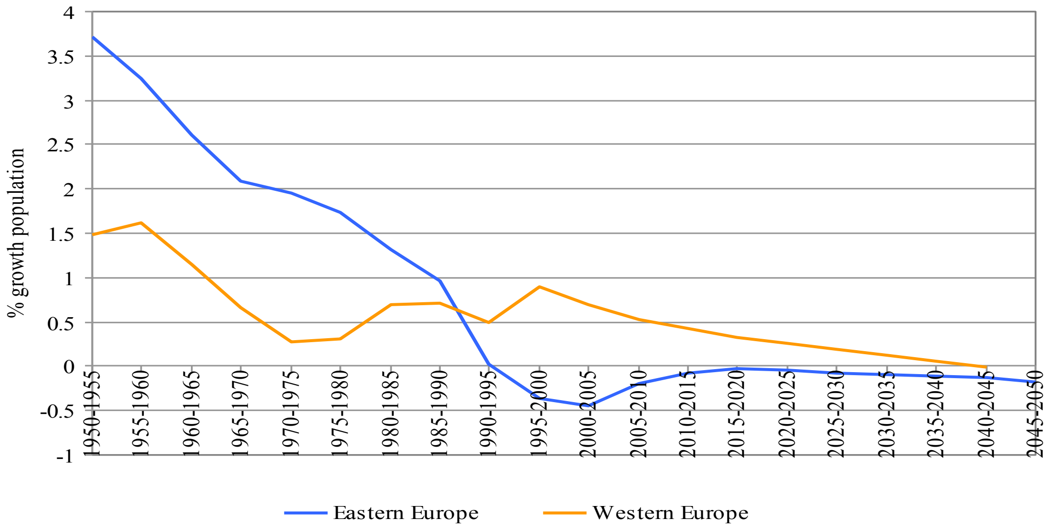


Figure 4: Eastern and Western Europe urban population (Source: World Urbanization Prospects: The 2009 Revision Population Database).

The figure X shows the urban population in the Black Sea Basin Countries between 2000-2025 and 2025 to 2050. Between 2000 and 2025, Albania, Bosnia and Herzgovina and Turkey are the countries that show the highest urban population growth. In contrast, Georgia and Moldova show a decline in urban population. Regarding the urban population growth between 2025 and 2050, almost all countries show an increase including also the countries that in the previous period show a decline. The exception is Belarus, which in the first period is gaining population and from 2025 - 2050 seems to suffer a strong decrease in urban population. Russian and Ukraine, seems to continue losing urban population but this decline is more modest comparing with the previous period (Annex III).

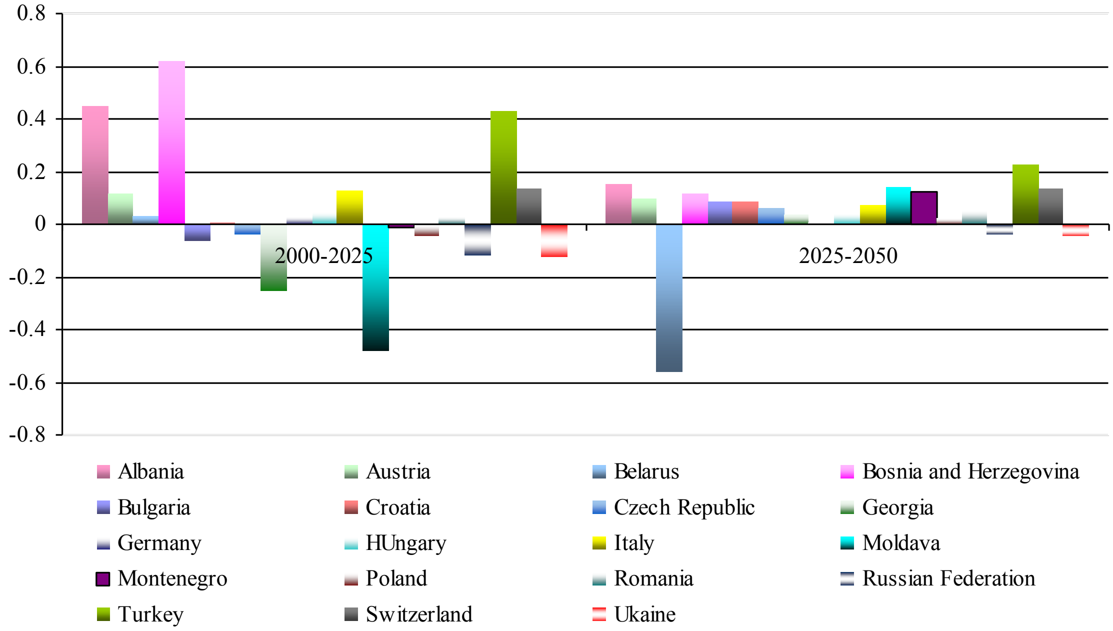


Figure 5: BSB countries urban growth population between 2000-2025 and 2025 to 2050 (Source: World Urbanization Prospects: The 2009 Revision Population Database)

It was said that this decline could be associated to the movement of population to the suburban/rural areas outside the city. However the graphic that represents the rural population growth shows that rural population growth is declining which could be related to the agriculture abandonment or the improvement of agriculture practices. In this sense the decline in urban population could be to other factors, factors such migration, among others.

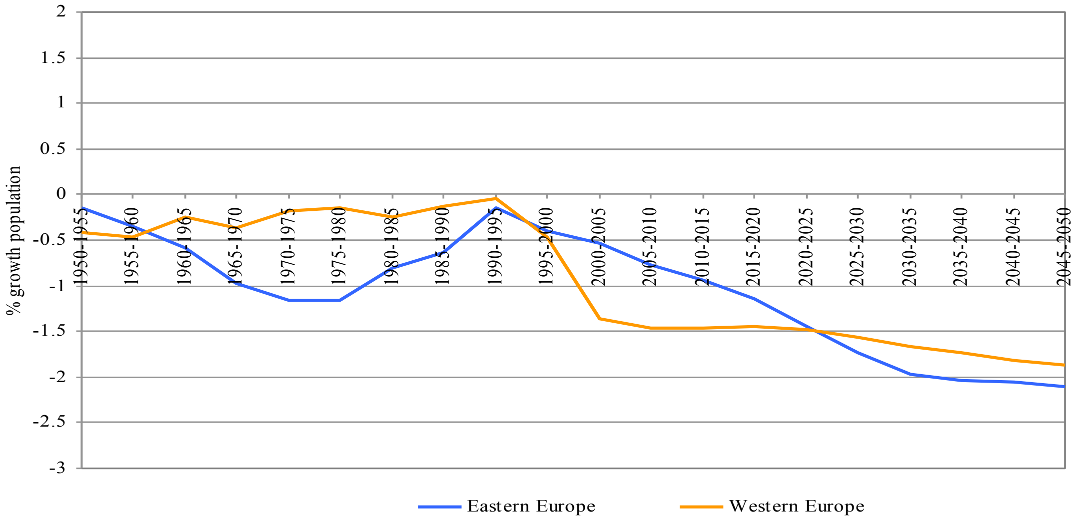


Figure 6: Eastern Europe and Western Europe Rural Population growth from 1950 to 2050 (Source: World Urbanization Prospects: The 2009 Revision Population Database)

The figure 7 shows the rural population growth in the BSB countries. In general the prospect assumes a decline in rural population in almost every country with exception of Austria, Czech Republic, Italy and Switzerland where the rural population increases. This increase could be related with the EU CAP policy. Since 2025 the prospects assumes that all BSB countries will increase in rural population (Annex IV).

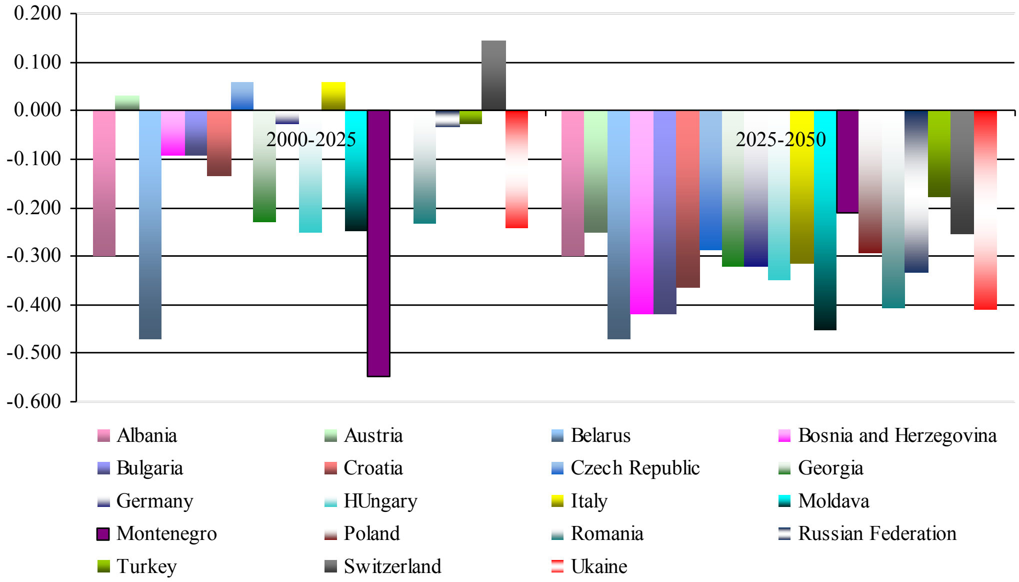


Figure 7: BSB countries rural growth population between 2000-2025 and 2025 to 2050 (Source: World Urbanization Prospects: The 2009 Revision Population Database)

3.1.3 Net Migration rate

The curve of net migration is characterized by consecutive rises and falls. The figure 8 shows two peaks, in 60's and 90's decades that show the population flow into Western European countries. In 80's, 00's and 10's the net migration rate shows a decline. Low variant scenario shows a little increase on the net migration, from 2015 to 2050. Medium scenario reveals that there is no important change to highlight. The high scenario shows a slow descending trend.

Regarding the Eastern Countries, from 1950 to 1970 had been registering negative migration rate. Most probably this decline could be associated to the population migration from Eastern Countries to the Western Countries (Figure 8). Since 1975 the migration rate had converted in to positive values. For this group of countries the high migration rate that they had registered was in between 1990 and 1995 followed by a slightly decline until 2005, which had almost reaching the null migration rate. All the variant scenarios show a small increase in net migration rate from 2020 to 2050.

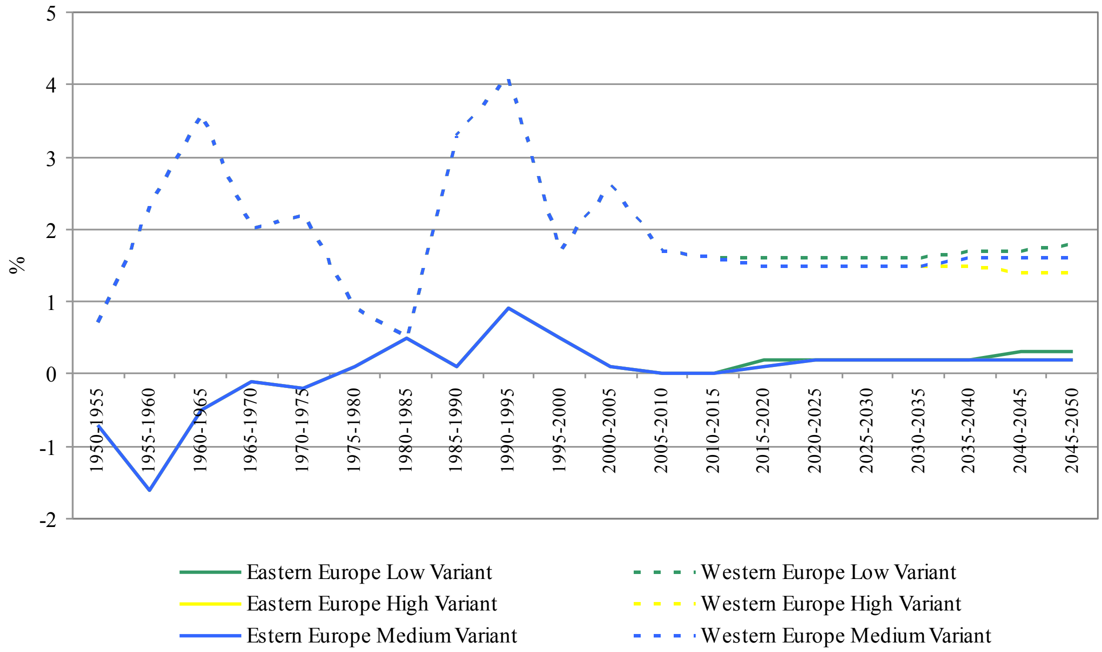


Figure 8: Eastern Europe and Western Europe net migration rate from 1980 to 2050 (Source: World Population Prospects: The 2008 Revision Population Database)

3.1.4 Black Sea Basin Economic Growth

The economic growth is usually expressed by the Gross Domestic Product – GDP. The GDP is considered as an important driver, which influences the technology and science development, the demand for food, and the demand for space for housing, infrastructure and recreation.

According to OECD data, plotted on Figure nº 9 it reveals a slow decreasing trend of the economy growth in Western Countries and Eastern Countries. However the economic growths have been decreasing in different ways. The Eastern Europe country shows an increase until 2009 followed by slow descending trend until 2016. The Western Countries shows a decline in 2008 till 2010 maintaining the trend until 2016 (figure 9).

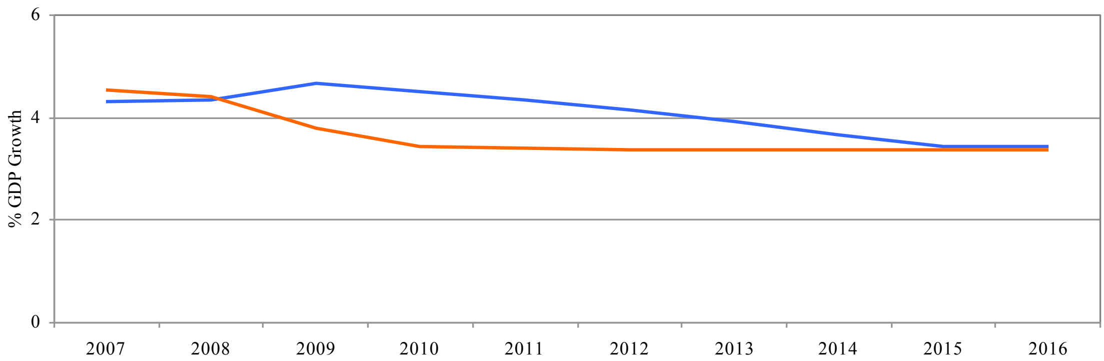


Figure 9: Eastern Europe and Western Europe Economic Growth from 2007 to 2016 (Source: OECD, Macroeconomic data 2007, OECD, Food and Agriculture Organization of the United Nations in OECD-FAO Agricultural Outlook)

Modelled GDP estimates per inhabitant were taken from Netherland Environmental Assessment Agency scenarios study. This study presents a set of algorithms that downscale the IPCC-SRES scenarios for population, GDP and emissions at the national and grid levels. The scenarios are taken from IMAGE 2.2 and the base-year data used was from World Bank (2004)[1] and UNSTAT[2] (2005) for each country and at grid level the base year data on the basis of population map and country data.

The BSB countries that show the highest GDP are Switzerland, Austria and Germany. In contrast the slower GDP appears in the Serbia, Ukraine and Moldava (Annex II).

Comparing the various IPCC-SRES scenarios, the GDP is highest in the global oriented scenarios (table 3): A1 and B1. The richer countries have the lower GDP growth in the regional oriented scenarios: A2 and B2. The poorer countries have the slower rate growth in the regional oriented scenarios between 2000 and 2050.

Economic growth	
A1	Strong globalization with very rapid economic growth
B1	Continuing globalisation and economic growth. Rapid changes in economic structures toward a service and information economy, with reduction in material and intensity
A2	Economic development is primarily regionally oriented and per capita economic growth is more fragmented and slower than other narratives
B2	In which the emphasis is on local solutions to economic, social, and environmental sustainability - intermediate levels of economic development.

Table 3: Economic growth IPCC-SRES scenario assumptions (adapted from Strengers et al., 2004)

3.2 Technology development in potential yield

Technology development is one of the most important drivers related with the crop management and production, for example. The development of the technology could have important consequences on the agriculture patterns such higher production, efficiency and scale increase in farm size.

The actual model of agriculture development is focus in to increase and intensification of the production. In this sense the principal goal consist in to increased productivity and reduced environmental impact. Better farming practices, irrigation, improved varieties, modern inputs, etc. all contributed to the growth of yields that increases the productivity (Bruinsma, 2003).

Future impacts on technological development have been modelled based on historical yield trends. The scenario study used to represent the technological development was presented by Ewert et. al., 2005. This study presents an alternative possibility for productive changes for EU - 15. The IPCC-SRES scenario approach was used to estimate a range of alternative possibilities for productive changes. In this sense, the parameters reflect the future SRES worlds (Table 4).

[1] World Bank's World Development Indicators (WDI) measured in constant 1995US$

[2] Since data is missing from the WDI database for a small number of countries, the set was supplemented with GDP data from the UN Statistics Database.

Technology	
A1	It was assumed that gains in potential yield will gradually decrease, between 80% in 2050 comparing with 2000. Emphasis is on technology development to meet the increasing world food demand. Optimism related to possible advances in biotechnology suggests that further progress in potential yield is possible. however, it is considered that yields will gradually approach a biological limit and rates of yield increase decline even for the global economic scenario
B1	This scenario assumes the introduction of clean and resource - efficient technologies. Also in this scenario the gains in potential yield will decrease gradually between 60% in 2020 and 40% in 2050 comparing with 2000.
A2	Technological change are more fragmented and slower than in other narratives. The yield would increases due the food demand. The gains in potential yield will decrease gradually between 80% in 2020 and 60% in 2050 comparing with 2000.
B2	Less rapid and more diverse technological changes than B1 and A1 narratives. It was assumed that gains in potential yield will gradually decrease depending on the scenario 0% in 2050 comparing with 2000. It is assumed that Food demand in EU 15 + 2 is already met and future increase in food demand is relatively small.

Table 4: Technology on potential yield (adapted from Ewert et. Al, 2005)

3.3 Policies and institutional factors in Black Sea Basin Region

Policies are considered an important driver that explain dynamics controlling and regulating population growth, economic and social development, technology, energy, agriculture and other policies, such as environmental policies and transportation and infrastructure policies (Nakićenović et al., 2000).

The importance of policies in Black Sea Basin scenarios needs to be considered, since governments are one of the main interested groups for the scenarios, also because scenarios are proposed to form a reference for mitigation strategies.

3.3.1 Energy and Co2 Emissions

The energy development is important for the future emissions. The scenarios assumptions were taken from the CPB/RIVM study which uses trends in population and in economy to obtain the energy emission. This study was proposed to deal with the uncertainties that are part of the energy developments and climate. Four Futures for Energy Markets ad Climate Change were developed based on the economic scenarios for Europe: Four Futures of Europe (Strong Europe, Global Economy, Transatlantic Market and Regional Communities) (for more information: Bollen et al., 2004).

Energy demand will be affected by the future climate policies. Climate policy is focused on taking critical measures to reduce the emission of greenhouse gases and consequently the energy system will experience a dramatic change. Measures are: reduce demand and improve efficiency in energy conversion to substitution of fossil energy to non-carbon fuel, such, biomass, solar and wind energy or nuclear power.

Additionally to the climate policy there are others policies that try to secure the supply of energy and they are focused on influencing energy price and production capacity. At present the policy is mainly designed to provide a sufficient and low-cost energy, keeping apart the climate policy main goals. For this reason, it will be a challenge for policy makers to design plans that serve both goals. In addition, the technology goals aim to lower carbon emission and reduce dependency on conventional sources (Bollen, 2004).

The figure 10 shows the energy use per unit in the EU 15 and Eastern Countries[3] for the Four Futures of Energy (REF). The energy use per unit of demand in the Eastern Europe is almost five times higher than in the EU-15. This means there is needs to take strong measures to reduce the energy use in these countries.

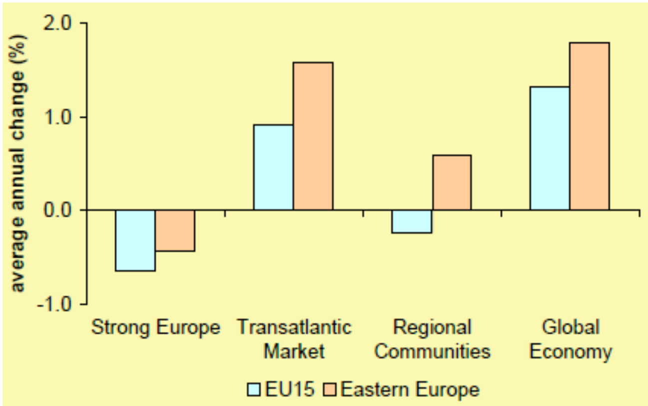


Figure 10: Energy use per unit in the EU-15 and Eastern Countries for the Four Future for Energy between 2000 and 2004 (Bollen et al., 2004)

The scenarios proposed by Four Future for Energy are presented in table 5. In B1 scenario the climate policy tries to prevent the global warming and reach the Kyoto protocol. The economic oriented scenarios (A1 and A2) trust on private firms, which should regulate the energy system.

Energy	
A1	Excellent international relation and efficient organised markets are believed to secure supply of energy. In this scenario the energy system is leaved to the private firms and the competitions policies, production, transport and trade of energy regulation are in there hands.
B1	Is the only scenario which combines the global cooperation with environmental orientation. Climate policy is in harmony with the long-term climate objective that remains to keep the global worming below 2°C. Kyoto Protocol ambitions are reached, in which all regions accept assigned amounts of emissions rights.
A2	Also trusts in the private firms, however, there are more regulation due the geopolitical restrictions on capacity for international transport of energy.
B2	The domestic and regional measures directed to non-climate environmental issues. The security of supply is very important in due the restricted opportunities for international trade and the political distrust in the ability of market forces to arrange a secure supply of energy. Regarding the climate policy, the moderate economic growth and the focus on local environmental problems also leads to some move away from fossil fuel use, and consequently to reduce the GHG emission.

Table 5: Energy scenarios (adapted from Bollen, et al. 2004)

[33] Poland, Czech Republic, Slovakia, Hungary, the Baltic States, Romania and Bulgaria

3.3.2 Agriculture policies

Regarding the agriculture policies for the EU Black Sea Basin Countries, the EURURALIS scenario study was evaluated. The EURURALIS include the reform on the Common Agriculture Policies (CAP) assumptions at European policy level using the four scenarios for global agriculture and liberalization (Eickhout et al., 2004). The general framework of EURURALIS tried to make concrete what a certain scenario specifies for CAP measures in Europe.

Eickhout (2004) used the IPCC-SRES storylines to implement specific trade liberalization and agriculture policies. These policies are in line with the two axes (Globalization – Regionalization and Efficiency - Equality) and are considered possible direction of coming WTO[4] rounds (table 6).

CAP	Export Subsides	Import Tariffs	Domestic Supp	Trade Blocks
A1	Abolished	Abolished	Abolished	Romania, Bulgaria, Former Soviet Union accede EU
B1	Abolished	Abolished	-/- 50% linked to environmental and social targets	Romania, Bulgaria, Former Soviet Union accede EU
A2	No change - 2003 CAP Reform	No change - 2003 CAP Reform	No change - 2003 CAP Reform	EU - USA
B2	Abolished	No change - 2003 CAP Reform	+10% linked to environmental and social targets	Manufacturing: Free Trade Area of the Americas (North + South America), TUR - Middle East and North Africa Rest of Africa, FSU

Table 6: Four scenarios for global agriculture and liberalization (Eickhout et al. (2004, 2008))

In general the expenses for the CAP are connected to the four assumptions varying from abolishment to a continued use of support measure. EURURALIS storylines assumes that the Global Economy (A1), CAP subsides and cohesion policy will decrease gradually by 2030. The Global co-operation (B1) the level of subsidies is reduced with domestic support specially targeted at environmental sustainability and to catalyse rural development (2 pillar of CAP). The Regional Communities (B2) scenario assumes that agricultural markets are protected against competing products to avoid cheap import surges.

3.3.3 Environmental Policies and Nature conservation

The Black Sea Basin countries have various environmental problems. The production of industrial and chemical materials is increasing more than the population causing different kinds of pollution. This situation raises increasing concerns between EU and Black Sea Countries to protect marine environment from further pollution.

Integrated nature conservation as EU´s Natura2000 is also considered in the Black Sea Basin scenarios. In all scenarios the Natura2000 areas are protected. Once more, the scenarios assumption for Natura2000 protected sites was taken from the EURURALIS scenarios study (Eickhout et al., 2008). Following the EURURALIS assumptions, in all scenarios the Natura2000 areas are protected (table 7).

[4] WTO: World Trade Organization

Nature Conservation	
A1	Existing areas within Natura2000 protected
B1	Existing areas protects; abandonment agricultural areas in Natura2000 network managed for nature development
A2	Existing areas protected
B2	Existing areas protected but with 50% of abandoned agricultural areas managed for nature development.

Table 7: Four scenarios for nature conservation (Eickhout et al., 2008)

3.4 Land Use

The land use scenarios should be constructed to support analyses of the vulnerability of the environment and ecosystem (WP 5), to analyse how land use changes respond to a range of future environmental change drivers such demographic and climate changes (WP 3) as well to be integrated in the SWAT model (WP 4) in order to analyses the impact of land use changes scenarios on water availability for BSB countries.

The scenarios should have 2000 as a baseline year and constructed for 2 years 2025 and 2050, covering al BSB countries at a spatial resolution of 1km. The IPCC-SRES (Nakićenović et al., 2000), and relative close approaches such GSG (Kemp-Benedict et al, 2002) and GEO3 (UNEP, 2004) should be used for interpretation of the storyline using the supply/demand model for land use quantities for Black Sea Basin region.

The IPCC-SRES scenarios are one of the well-known approaches used for development of regional scenarios and those quantification. However, the SRES scenarios have some limitations related with the geographical scale because the SRES scenarios are derived for global scale applications and there are no guidelines when downscaled at regional scale. In order to response this problem the UNEP third Global Environmental Outlook (UNEP, 2002) made an effort to give a regional context to the global scenarios through a collaborative process, four GSG scenarios were refined with input from SRES (Carpenter, et al. 2005 IN Zhu, Z. et al. 2010).

Clearly there are many common points regarding the storylines of the different global scenarios. Raskin, (2005), compared various global scenarios studies and wrap up that there is a great variation in the way each exercise was structured. However, the environmental scenarios are established in a common set of standard visions of the future such dominant driving forces, strong policy push for sustainability goals, environmental collapse, and institutional failure, new human values and forms of development emerge.

Models play an important role in the scenarios quantification. There are different options to model land changes; however the approaches that are able to develop the global scenarios are only two. The PoleStar is based in land use accounting (Kemp-Benedict et al., 2002) and the IMAGE model is based on rule-based/cellular automata model (Alcamo et al., 1998; Eickhout et al., 2005; IMAGE-Team 2001 IN Lambin, 2006).

The GEO (UNEP 2002, 2004), SRES (Nakićenović et al, 2000), and the Global Scenario Group (Gallopin et al., 1997; Gallopin and Raskin, 2002; Raskin et al., 2002) used these models approaches to develop the land use changes for the different regions of the world. Both approaches were analysed in order to compare the different scenarios quantification for land use, focusing in agriculture, forest and urban land.

The IMAGE model was developed by Netherlands Environmental Assessment Agency is an ecological-environmental model that simulates the environmental influence of the global human actions such the long-term dynamics of global change as the result of interacting demographic, technological, economic, social, cultural and political factors.

The IMAGE 2.2 was used to elaborate the IPCC-SRES scenarios (Nakicenovic et al., 2000). From this version were released two CD-ROMs (IMAGE-team, 2001a; IMAGE-team, 2001b) that present IMAGE 2.2 and its implementation of the six IPCC-SRES scenarios. Lately the installable version of the User Support System was available on the Netherlands Environmental Assessment Agency ftp site.

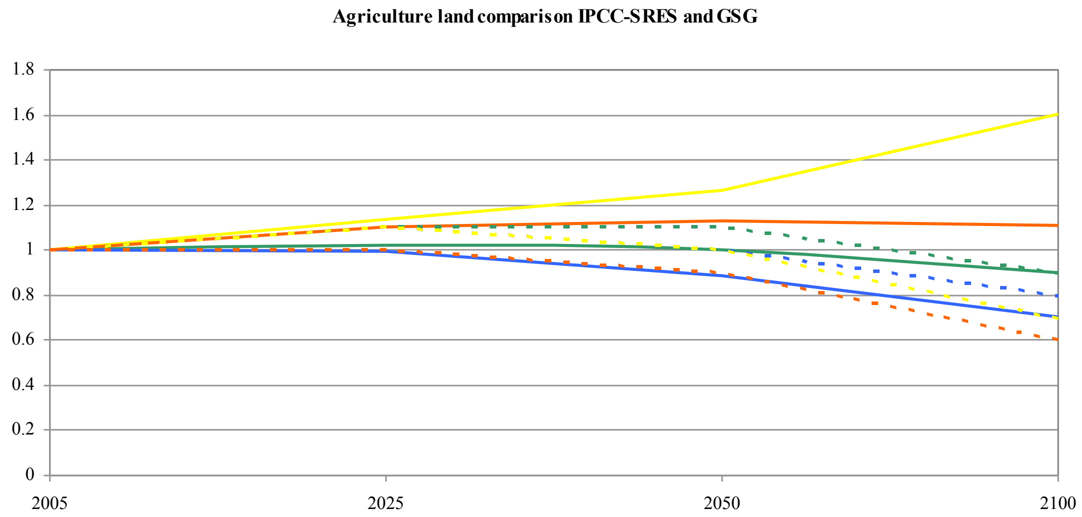
The IMAGE model combines physical and human factors and produce the land use change geographically explicit. The information used is related with the demographic data such density, and historical trend data such FAO data for arable area in each country and FAO data for land productivity.

The PoleStar model[5], was developed by Tellus Institute and the Stockholm Environment Institute under the PoleStar project[6] in 1991. The PoleStar Project explores alternatives futures developing appropriated methods for sustainability assessment that integrates environmental, social and economic dimensions of development, taking into account the future generations at different scales.

This tool was constructed for constructing integrated long-range scenarios providing quantification of scenarios assumptions. The PoleStar Projects was distinguished by the narrative scenarios description and detail in scenario quantification.

The PoleStar model is a comprehensive tool that covers a wide range of economic, social and environmental variable and their interactions at multi scale. The tool offers the possibility to the user to define the data structure, time horizon and spatial boundaries.

The Figure 11 show the outcomes of IPCC-SRES and GSG global scenarios, however, in spite the fact that they are close the quantification of those scenarios were derived from different approaches, methodologies and tools. Also the land use classification and geographical coverage and regions are different (Lambin et al., 2006).



[5] Oficial Web-site PoleStar System (http://www.polestarproject.org/polestar_sys.html)
[6] Oficial web-site PoleStar Project (www.polestarproject.org)

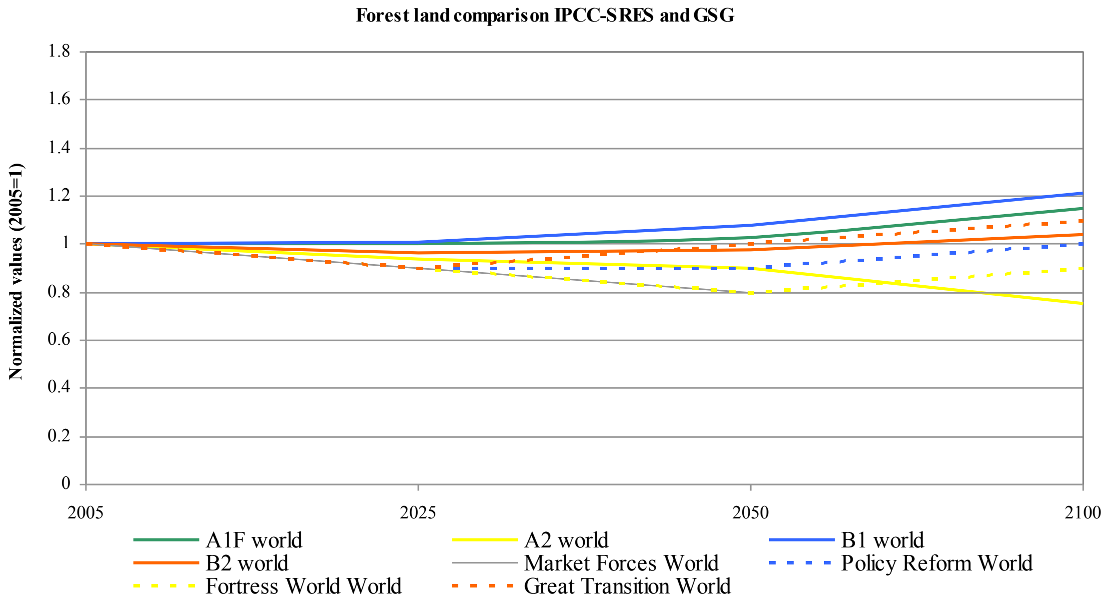


Figure 11: The GSG (Market Forces - Green, Policy Reform - Blue, Fortress World- Yellow and Great Transition - Orange and GEO scenarios were computed by PoleStar model (Kemp-Benedict et al. 2002) and IPCC-SRES scenarios (A1F – Green, A2 - Yellow, B1 – Blue , B2 - Orange) were computed by IMAGE 2.2 model.

In the IMAGE model the agriculture land includes the land use classes Agriculture Land and Extensive Grassland and is the sum of Cropland and Grazing land in the PoleStar model.

In the IMAGE model Forest land is defined as the sum of Carbon Plantations, Regrowth Forest, Boreal Forest, Cool Conifer Forest, Temperate Deciduous Forest, Warm Mixed Forest and Tropical Forest. The PoleStar model the Forest land is the sum of Natural Forest and Plantation.

The agriculture land show very dynamic patterns essentially caused by trade-off between food supply and demand as moderated by the international trade (Figure 8). The table 8 shows the main assumptions for each scenario regarding food demand and supply. Generally the global oriented scenarios (A1 and B1) show high crop intensity growth related with high population assumptions, fast increase in the volume of trade in food and feed and fast increase in food and livestock productivity and new and more technology. In contrast the regional oriented scenarios (A2 and B2) show the moderate increase in the volume of trade of food and feed and livestock productivity decrease and diminish of the technology development and consequently lower demand for agriculture land (Hoogwijk et al., 2005; Strengers et al., 2004).

Crop intensity growth	
A1	In the A1T and A1B the crop land remains stable. In the A1F the crop land decrease due the Energy mix is strongly based on fossil fuels, leading to a smaller increases of demand for biofuel crops.
B1	Crop land area decrease due to rapidly increasing of land productivity world-wide coupled to a lower demand due to less meat-based diets
A2	Crop land increases
B2	Crop land increases

Table 8: Four scenarios for crop area (adapted from Strengers, 2004)

Between 1995 and 2100 apart of A2 scenario which show an increase until the end of the of century, in all scenarios, the agriculture land increase for several decades and then declines even reaches lower levels than 1995 (B1 and A1F).

These changes could have an important consequence on the amount of greenhouse gas emissions, release of nutrients and other trace substances to aquatic ecosystems and other large-scale impact on Earth System (Lambin, 2006).

The forestland is considered in IMAGE 2.2 as a consequence of agriculture changes. In this sense, at global the amount of forest area in the A2 scenario decrease as a consequence of agriculture increase. When there is an expansion of agriculture areas, a part of the forest products such wood fibre and pulp are used to satisfy the demand, the other part it is burnt. When there is no expansion of agriculture areas the forest products are taken from the mature woods and after this they recover again.

The forestation/afforestation trends are thus strongly related with the size, performance and structure of regional and global food markets. The figure 8 shows, during the first half of this century, forestation continues in all scenarios mainly in global oriented scenarios (B1 and A1). In contrast, in A2 scenario deforestation continues throughout this century and the total forest area decrease rapidly. In B2 the forest area and agriculture area remains relatively stable (Strengers, 2004) (Table 9).

Forest land	
A1	Deforestation in half part of this century and then the forest area increase. The larger forest areas in the A1F scenario, compared to A1T and A1B due the lower demand for biofuel crops in the A1F scenario
B1	Deforestation in half part of this century and then the forest area increase.
A2	The deforestation continues throughout this century and the total forest area decreases rapidly.
B2	Deforestation in half part of this century and then the forest area increase but less than A1 and B1.

Table 9: Four scenarios for forest (adapted from Strengers, 2004)

The urban areas visions are published in few global scenarios and these give a limited view of urban developments. The urban areas presented in global scenarios showing a steep increase from 2005 to 2050. The stabilization occurs after 2050 till 2100 (Raskin et al., 2010) (Table 10).

The Market Forces scenario reflects a market centred growth-oriented globalization. As a consequence of population expansion by 40 % in 2050, free trade and deregulation force growth the global economy expands over eightfold by 2100. Consequently the build-up areas show a strong increase from 1.8 in 2050 to 2.7 in 2100.

The Fortress World is even more chaotic in the sense that explores the possibility that powerful world forces, systemic crisis, impose and authoritarian order, leaving impoverished masses outside. The urban areas expansion in the Fortress scenarios is even clearer than the Market Forces scenario. The increase from 1 to 2.2 in 2050 and then increase smoother, from 2.2 to 2.7 in 2100 (figure 12).

The Policy Reform supposes the government intervention to get sustainability without major changes in the state-centric international order. Strong and harmonized policies are applied, by redirecting the world economy, promoting technological innovation, in order to reduce the poverty, climate change stabilization, ecosystem preservation, freshwater protection and pollution control. The urban area does not suffer important changes and the urban expansion occurs smoothly till 2100.

Urban areas	
A1 (Market Forces)	Build-up areas show a strong increase from 1.8 in 2050 to 2.7 in 2100
B1 (Policy Reform)	Does not suffer significant changes and the urban expansion occurs smoothly till 2100.
A2 (Fortress World)	The increase from 1 to 2.2 in 2050 and then increase smoother, from 2.2 to 2.7 in 2100.
B1/B2 (Great Transition)	Increase smoothly till 2050 and after that the trend shows a decrease till 2100.

Table 10: Four scenarios for forest (adapted from Raskin, et al. 2010)

The Great Transition scenario is presented as the more sustainable scenario and values-led change. The population stabilizes more rapidly than in order scenarios as more equal gender roles and universal access to education and health care services lower birth rated, and less consumerist lifestyle. Consequently the urban areas trend to increase smoothly till 2050 and after that the trend shows a decrease till 2100.

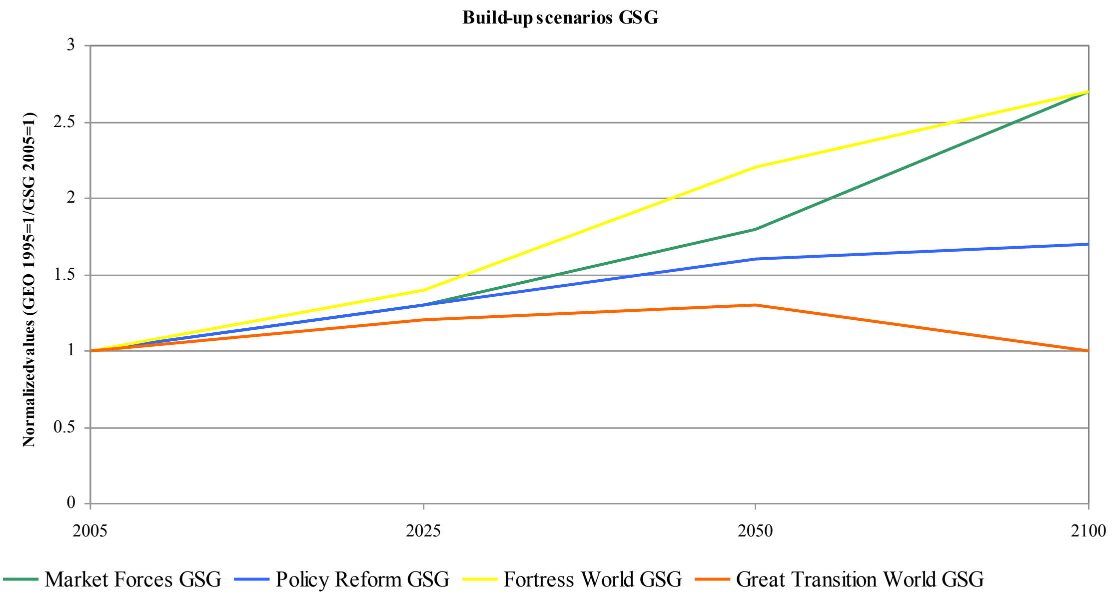


Figure 12: Four scenarios for urban (adapted from Raskin, et al. 2010)

4 Building blocks for Black Sea Basin integrated environmental scenarios

The above sections presented an overview of the broadly available data and tools, as they relate to the objectives and needs of EnviroGRIDS for development of integrated scenarios. The following sections present the first steps in building up the actual scenarios while defining a set of assumptions. First assumption is that Black Sea Basin future environmental states are results of the combined effect of climate change (exogenous factor) and the socio-economic development patterns as a main internal driver, influencing demographic and land use changes. Regarding the latter, first outlining paths of major socio-economic changes expected to happen in the next decades until 2050 was explored. These paths were projected globally by the UN´s Global population prospect and IIASA's on the basis of the trends of population demographic changes and economic development during the last decades. The respective data is available as 5-year step records estimated per country, as well as maps in roughly 50 km grid. Therefore applying the datasets showing the past changes in population numbers and GDP should allow to track the changes on regional level and relate these socio-economic changes to certain environmental changes, as land-use (agricultural extends and crop yields, forestry, urban-industrial areas, residential areas), nitrogen emissions and deposition, soil erosion and carbon content, biodiversity, threatened species etc. To a certain extend some clear relationships should be identifiable between these variables. Where no relationships can be detected, either due to input data quality or non-existing relations, some assumptions of possible relations can be applied on the basis of expert judgments. All these relations will enable a system to be built for simulating the future possible states where socio-economic and environmental links are presented in spatially and temporally explicit way.

In such a way, a combined framework is proposed with three main components to build the integrated scenarios for the Black Sea Basin:

1. Analysis of future socio-economic changes and identifying patterns typical for groups of countries pertaining to the Black Sea Basin according to the IPCC-SRES scenarios;
2. Analysis of past processes of socio-economic changes and environmental changes to establish casual relationships between the two;
3. Simulation of the future state of the environmental changes in relation to the available projections of the socio-economic ones in 2025 and 2050.

For the first, a cluster analysis was applied with SPSS Inc using the Population density data from UN Global population prospect and IIASA's GDP projection. For the second, multivariate analysis are applied using the available datasets, showing quite limited applicability at the present stage, but certain data improvements, harmonization could strengthen the potential to characterize the casual relationships. For the third step a Bayesian Belief Networks (BBN) tool NETICA (Norsys software corp., www.norsys.com) is explored. The progress of the three steps is presented bellow.

4.1 Future development paths of the Black Sea Basin countries according to IPCC-SRES scenarios

The IPCC-SRES overall scenarios emphasise future plausible changes along two axes (figure 13):

- Economy, unrestrained development versus environmentally restrained development;
- Cooperation, globally concerted developments versus local solutions;

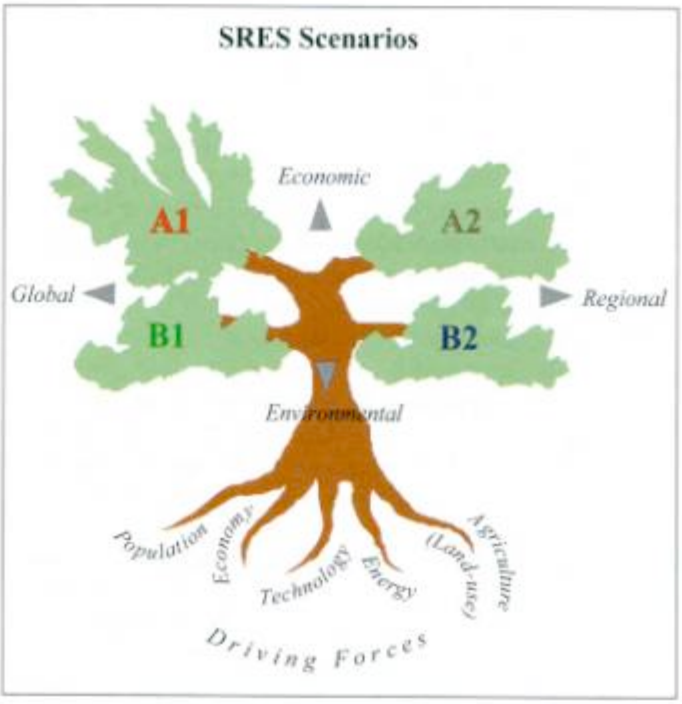


Figure 13: Characteristics of the four main scenario families of the IPCC Special Report on Emission Scenarios (Nakićenović et al., 2000)

Consequently, four scenario possibilities are commonly cited: Environmentally unrestrained and globally concerted strong economic growth (A1); Environmentally unrestrained but locally and regionally driven economies (A2); Far-reaching environmental considerations on global level with adapted economic and technological developments (B1); Locally and regionally driven developments strongly respecting environmental constraints (B2).

In accordance with the four scenarios the following related changes in major drivers of environmental change are estimated on global level (www.ipcc.ch).

Scenarios	CO2 Emissions (ppmc yr 2100)	GDP growth	Population growth	Technology development	Forest	Agriculture	Urban
A1	Highest (1210)	Highest (20)	Low	High	Decrease	Increase or stable	Strong Increase
B1	Low (650)	High (15)	Low	High	Increase	Increase	Increase
A2	High (1020)	Lowest (7)	High	Low	Decrease	Increase	Smoothly Increase
B2	Medium (810)	Medium (11)	Medium	Medium	Decrease	Increase	Smoothly Increase

Table 11: Major driving forces of environmental change

At Black Sea Basin level additionally three main factors have to be addressed:

- The influence of the EU as main factor of political, economic, social and environmental importance

- The existence of geographic, west – east gradient in past and current economic development level as well as population density.
- The existence of historic political factor, namely the break up of socialist system that incurred nearly complete collapse of the economies of many impacted countries, which are currently at different stage of recovery and reorientation towards market economy

According to the EU factor and its extension, four groups of countries can be distinguished covering some part of the BSB as show on Figure 14.

- Group 1: West and old EU states (Germany, Austria and Italy, Switzerland may be attributed to this group even if not part of the EU);
- Group 2: New EU states that joined after year 2000 (Slovenia, Hungary, Slovakia, Czech republic, Romania, Bulgaria, Poland);
- Group 3: EU candidate countries, either current or future, basically all West Balkan states (Albania, Monte Negro, Croatia, Bosnia and Herzegovina, Serbia, FYR Macedonia);
- Group 4: Neighbourhood countries (Turkey, Ukraine, Russian federation, Belarus, Georgia, Moldova) which EU actively involves in major security and economic development issues.

Figure 14: Groups of countries in the Black Sea Basin

This figure already illustrates the west – east gradient in the Economic level of development and affluence, as well as population density. But the latter are explicitly shown in the table bellow as mean values and standard deviations for each group.

Group 1	EU Western states			
	Minimum	Maximum	Mean	Std. Deviation
GDP 2000	20938.1	46815.5	**33517.2**	10579.3
Population 2000	95	230	**172.3**	56.6
Group 2	NEW EU			
	Minimum	Maximum	Mean	Std. Deviation
GDP 2000	1461.5	11668.9	**4775.5**	3445.4
Population 2000	72	130	**104.6**	18.9
Group 3	EU CANDIDATES			
	Minimum	Maximum	Mean	Std. Deviation
GDP 2000	1116.0	5002.9	**2135.6**	1495.6
Population 2000	48	115	**83.3**	24.4
Group 4	EU NEIGHBOURHOOD			
	Minimum	Maximum	Mean	Std. Deviation
GDP 2000	361.5	3047.7	**1634.9**	1173.3
Population 2000	9	121	**68.7**	37.8

Table 12: Mean values of GDP and population density per group of countries

In the outlined global and European context, the following likely changes in the Black Sea Basin were outlined as preliminary markers of the future environmental scenarios:

- Possible agricultural boom and delocalization of EU industries to the EU neighbourhood countries (according to scenario A1);
- Possible further or even complete expansion of EU (A1, B1);
- Good COP15 results, followed by strong and effective global environmental policies that stop the increase of greenhouse gases and stop the climate change (B1);
- Possible break-down of the EU and reinforcement of country-based military and economic and environmental security systems (A2, B2),

4.2 Socio-economic development paths of the BSB countries

Using the UN data on Global population prospect and IIASA's GDP with 5-year temporal projections until year 2050, five general patterns of expected developments in the Black Sea Basin were described (Figure 15):

Past development pattern – current west European states of highest GDP at present, and with the smallest rates of future economic growth according to all scenarios. They are also expected to have certain increase of population growth at last during the first period (2000 – 2025).

Future "hard" development pattern – this pattern outlines the association between future's highest economic growth countries expected to exhibit also the strongest depopulation. Many states come in this cluster in the A1 and B1 scenarios.

Future development pattern – currently states of varying economic status, also expected to undergo substantial future economic growth, but with less depopulation process in the future.

Recent development pattern – includes countries of quite high economic status at present, and expected to have population growth during the first period according to all scenarios.

Delayed development pattern – includes different states expected to reach higher economic prospects in the future, and also with depopulation processes.

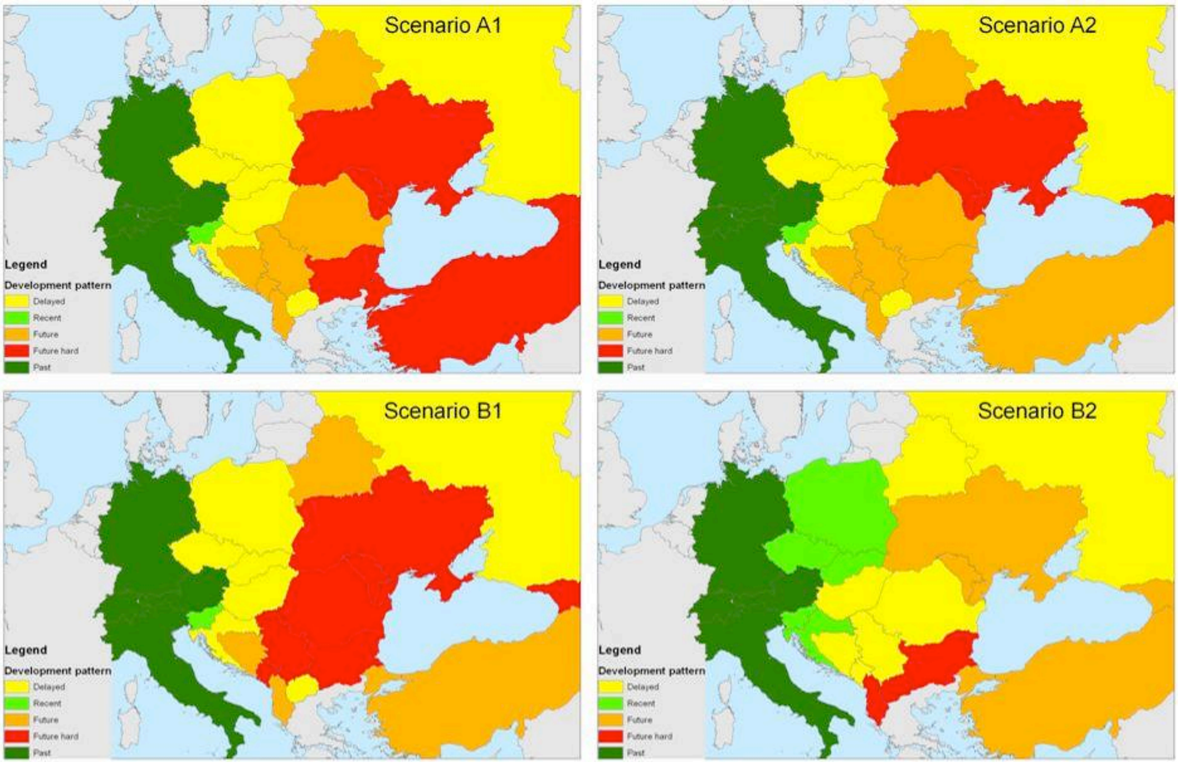


Figure 15: Development patterns of the BSB countries

These patterns include different values of GDP and population density according to the four IPCC-SRES scenarios. The cluster analysis helped to sketch the first version of the storylines describing the possible patterns of future developments of the BSB countries. The typical patterns with their respective values of future GDP and population density and also additional driving forces reviews are explained in the storylines bellow.

Scenario A1

According to the A1 scenario, globally the highest economic growth would be experienced with low population increase and highest increase in Greenhouse gas emissions and consequently global climate change. This implies also highest environmental pressures in the areas of the Black Sea Basin that could be partially alleviated by the fast revealing technological developments.

But will all the Black Sea Basin follow the same global patterns?

On figure 12, the countries in red and orange indicate where most of the expected future growth would be concentrated with 16 – 18% annual increase during the first period and 60 – 80 % in the second. The same group of countries experiences also substantial depopulation (-13%, -14%). The countries developed economically in the past or recently show just a small economic growth and experience some population density increase in the near future while the rest loose population density. All countries experience high rates of depopulation in the second period.

A1					
cluster	I	II	V	IV	III
A1 Development pattern	Past	Recent	Delayed	Future	Hard
GDP annual increment 2000 - 2025	2.4	**7.2**	**11.8**	**18.1**	**16.4**
GDP annual increment 2025 - 2050	3.0	**13.3**	**31.3**	**62.5**	**75.1**
Population density change 2000 - 2025	**7.3**	3.0	-4.1	**-6.8**	**-13.0**
Population density change 2025 - 2050	**-19.3**	**-12.0**	**-14.3**	**-13.5**	**-14.0**

Table 13: A1 cluster centres of future GDP and Population density

According to the above mentioned assumptions for possible agricultural boom and delocalization of EU industries to the EU neighbourhood countries and even possible further or complete expansion of the EU, it can be expected that gains in potential crop yield will gradually decrease, up to 80% in 2050 compared to 2000. Emphasis is on technology development to meet the increasing world food demand. Optimism related to possible advances in biotechnology suggests that further progress in potential yield is possible. However, it is considered that yields will gradually approach a biological limit and rates of yield increase decline even for the global economic scenario. Nature conservation is restricted to the existing protected areas and within Natura2000 network. Forest will increase in all countries during the first period, but afterwards decreases in the western countries and increases in the eastern. Build-up areas show a strong increase. Cropland areas decrease or remain stable. The economic globalization implies complete abolishment of CAP payments in the EU.

Excellent international relation and efficient organised markets are believed to secure supply of energy. In this scenario the energy system is leaved to the private firms and the competitions policies, production, transport and trade of energy regulation are in their hands.

Scenario A2

This scenario contains the projections of smallest economic growth as average globally, but the estimations for the BSB countries indicate mostly future economic growth in the eastern European countries surrounding the Black Sea. While globally the scenario project highest population increase, the same category of countries displays very strong decrease (20 % during the first period and 5% in the second). The rest of the countries follow generally the global scenario patterns, with certain population increase during both periods. The western European countries are however expected to have quite high population increase, nearly 20% during the first period.

A2					
Cluster	II	I	III	IV	V
A2 Development pattern	Past	Recent	Delayed	Future	Hard
GDP annual increment 2000 - 2025	1	2.4	3.6	4.8	**5.3**
GDP annual increment 2025 - 2050	0.7	3.5	**6.8**	**10.4**	**13.2**
Population density change 2000 - 2025	**19**	**10**	2.4	2.8	**-20.7**
Population density change 2025 - 2050	9.5	3	0.6	3.1	-4.7

Table 14: A2 cluster centres of future GDP and Population density

We assumed a possible break-down of the EU and reinforcement of country-based military and economic and environmental security systems (A2, B2).

Technological change is more fragmented and slower than in the other scenarios. In the agricultural sector, crop yield would increases due the food demand and country based production. Crop land areas also increase. The gains in potential yield will decrease gradually between 80% in 2020 and 60% in 2050 comparing with 2000. Nature conservation continues only within the existing protected areas. Urban land increase till 2050. Forest land is expected to decrease during the first period in the western states, and increase during the second one in the eastern states.

Scenario B1

B1 combines high economic development with prospects of low population increase globally, similar as in A1. In B1 however depopulation processes are only prominent during the first period (2000 – 2025) and nearly no further population changes are estimated afterwards. The economic growth rates are certainly smaller than in A1, but with less pronounced differences between the clusters. There is also not so strong growth foreseen during the second period (2025 – 2050). The emphasis is on simultaneous globalization of both economic and environmental considerations, but with no further climate change initiatives.

B1					
Cluster	II	I	III	V	IV
B1 Development pattern	Past	Recent	Delayed	Future	Hard
GDP annual increment 2000 - 2025	2	4.2	**7.2**	**10.1**	**11.9**
GDP annual increment 2025 - 2050	1.7	**6.9**	**17**	**30.2**	**44**
Population density change 2000 - 2025	**5.6**	3.2	**-6.8**	**3.1**	**-17.3**
Population density change 2025 - 2050	-0.1	-0.1	-0.2	-0.1	-0.2

Table 15: B1 cluster centres of future GDP and Population density

Our assumptions defined good COP15 results, followed by strong and effective global environmental policies that stop the increase of greenhouse gases and stop the climate change in the BSB.

This scenario assumes the introduction of clean and resource – efficient technologies. Also in this scenario the gains in potential yield will decrease gradually between 60% in 2020 and 40% in 2050 comparing with 2000. CAP payments kept 50 % for environmental and social purposes (not for production).

Nature conservation relies on the existing protected areas; and abandonment agricultural areas in the Natura2000 network are managed for nature development too. Crop land area decrease due to rapidly increasing land productivity coupled to a lower demand due to less meat-based diets. Urban area does not follow significant changes and the urban expansion occurs smoothly till 2050. Forest areas increase a little in all countries during the first periods and a lot during the second but only in the eastern countries.

B1 is the only scenario which combines the global cooperation with environmental orientation, the climate policy is in harmony with the long-term climate objective that remains to keep the global worming below 2ºC. Kyoto Protocol ambitions are reached, in which all regions accept assigned amounts of emissions rights.

Scenario B2

B2 combines intermediate economic growth with medium population density increase globally. In the BSB however only in the cluster of recent development population numbers are expected increase. Generally this scenario reveals the most heterogeneous patterns of developments in the BSB countries (there are more or less equal number of countries in each cluster). Moderate GDP growth is expected during the second half of the scenario period for the countries where delayed (26%) and future (29%) economic development would occur, and high for the countries in the hard development cluster (51%).

B2					
cluster	*II*	*III*	*V*	*IV*	*I*
Development pattern	Past	Recent	Delayed	Future	Hard
GDP annual increment 2000 - 2025	1.3	4.7	**7.8**	**7.9**	**12.1**
GDP annual increment 2025 - 2050	1.2	**10.9**	**26.2**	**29.2**	**51.5**
Population density change 2000 - 2025	**-8**	**9.2**	-4.4	-1.4	2
Population density change 2025 - 2050	**-7.3**	1.2	**-9.7**	**-7.4**	**-14**

Table 16: B2 cluster centres of future GDP and Population density

Our assumptions determined possible breakdown of the EU and reinforcement of country-based military and economic and environmental security systems. Accordingly there should be less rapid and more diverse technological changes than B1 and A1 narratives. Crop cultivated areas should increase. It is assumed that gains in potential crop yield will gradually decrease depending on the scenario. It is assumed that Food demand is already met and future increase in food demand is relatively small. Forest areas should increase in all countries.

Deforestation is expected during the entire period until 2050. Urban area increases smoothly till 2050. The protected areas remain as the existing ones**.** In the energy sector, the domestic and regional measures directed to non-climate, environmental issues prevail. The security of supply is very important due to the restricted opportunities for international trade and the political distrust in the ability of market forces to arrange a secure supply of energy.

Regarding the climate change policies, the moderate economic growth restricted to local environmental constraints also leads to reduced use of fossil fuels, and consequently to reduced GHG emission.

5 Numerical inputs for multivariate analysis

Spatially explicit time-series datasets in varying spatial resolution were collected on the several relevant subjects to establish casual relationships between past and current socio-economic and environmental changes:

a. GDP from IIASA and Population number from UN Global population prospect (Figure 16).

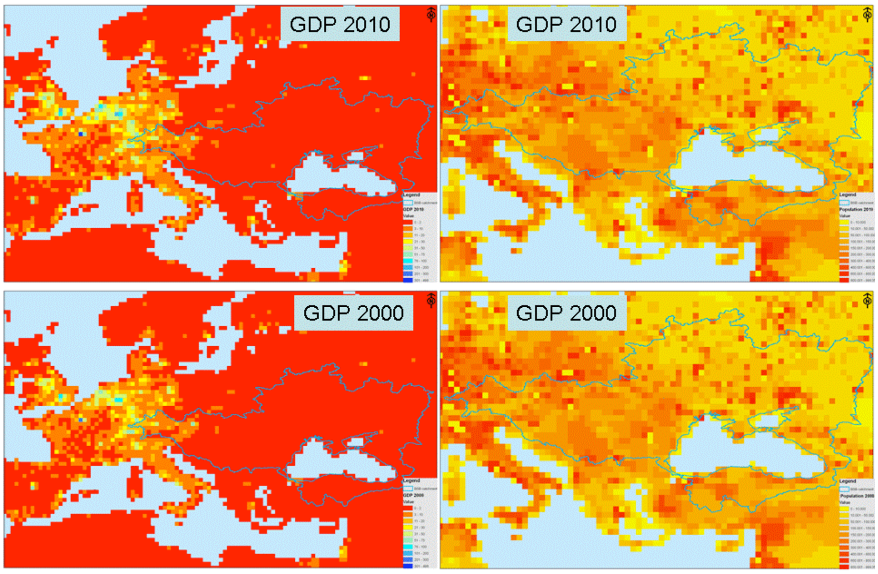


Figure 16: GDP and Population numbers in 50 km grid

b. Remote sensing and modelled estimations (Figure 17):

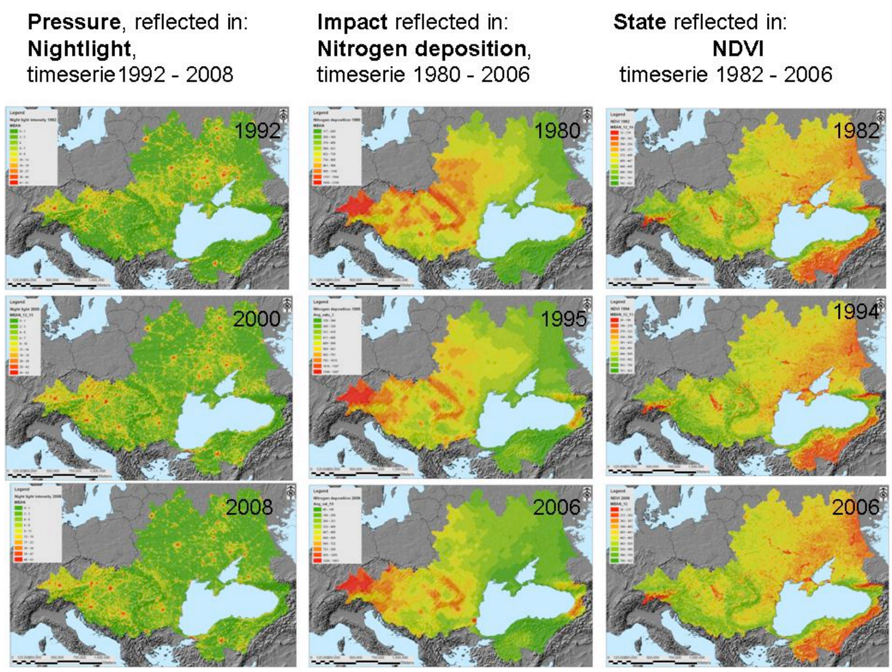


Figure 17: Nightlight intensity, nitrogen deposition and NDVI time series

The above images of annual values were extracted in the European 10 km grid covering the Black Sea Basin. Their spatial relation was studied and no significant correlations was detected (although visually nitrogen deposition and NDVI seem to show similar patterns).

However Nightlight correlates significantly with urban land use pressures. This relation was tested using a European spatial indicator on urban pressure derived from CORINE LC, by grouping all respective classes and transforming the discrete classes of land use into a probabilistic continuous map.

Correlations	All cases		
		Urban pressure 2000	Nightlight 2000
Urban pressure 2000	Pearson Correlation	1	0.74376
	Sig. (2-tailed)		0
	N	7073	7073
Nightlight 2000	Pearson Correlation	0.74376	1
	Sig. (2-tailed)	0	
	N	7073	7073
**	Correlation is significant at the 0.01 level (2-tailed).		

Table 17: Correlation between nightlight intensity and urban land use

In a similar way, was tested the relation of NDVI with a European indicator called “green background”. The latter was constructed by grouping the following CORINE classes selected as favourable for ecological functions incl.:

- Pastures
- Mosaic farmland
- Standing forest
- Transitional woodland and shrub
- Natural grassland heathland and sclerophyllous vegetation
- Open space with little or no vegetation
- Wetlands
- Water bodies

Correlations	Cell with NDVI above 400		
		NDVI 1998	Green background
NDVI 1998	Pearson Correlation	1.00	0.68
	Sig. (2-tailed)		0.00
	N	5880	5880
green background	Pearson Correlation	0.68	1.00

	Sig. (2-tailed)	0.00	
	N	5880	5880
**	Correlation is significant at the 0.01 level (2-tailed).		

Table 18: Correlation between annual NDVI and the landscape green background

In other words the green background excludes all areas where intensive human pressure is exerted wither urban or agricultural.

Comparing the NDVI annual sum of 1998 with the green background index of year 2000 show no or little correlation generally, but when excluding the areas of small NDVI (bellow 0.4 value) the spatial correlation between the two becomes significant.

Correlation Matrix(a)		Cell with NDVI above 400			
		NDVI 1998	Urban pressure	Green background	Nightlight 2000
Correlation	NDVI 1998	1.00	-0.22	0.68	-0.11
	Urban pressure	-0.22	1.00	-0.38	**0.73**
	Green background	**0.68**	-0.38	1.00	-0.22
	Nightlight 2000	-0.11	0.73	-0.22	1.00

Table 19: Correlation matrix of NDVI, Urban pressure, Nightlight intensity and Green background index

These correlations imply that the time-series of nightlight and NDVI can be applied to register changes of main pressure and state indicators that can be linked with parameters of population and economic growth. Bellow are shown several maps of changes, however no pattern of causal relations could be detected (Figure 18).

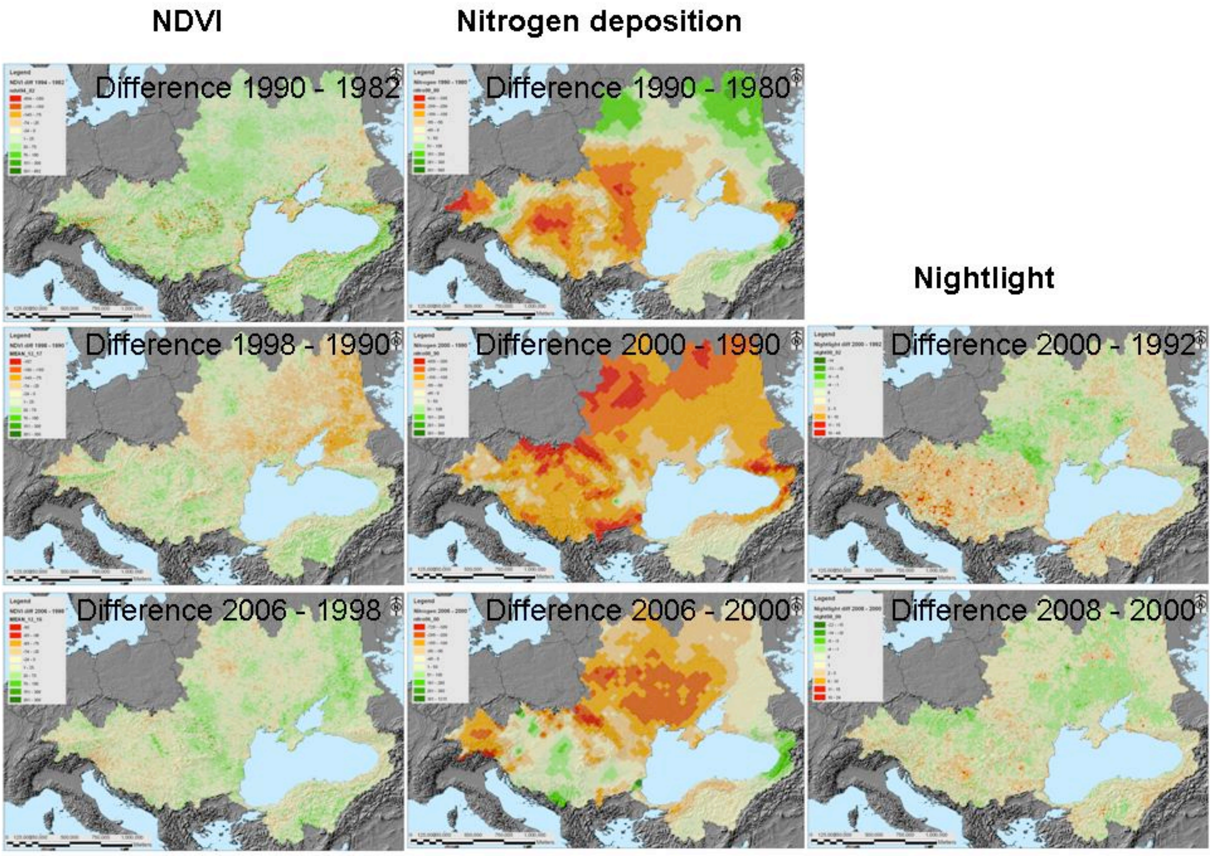


Figure 18: Images of changing decadal changes in NDVI, nitrogen deposition and nightlight

These environmental variables present the main changes and state indicators that can be analysed on harmonized way across the Black Sea Basin. In addition it could be interesting to relate human use of natural resources variables, which in their turn could be related to economic development indicators as GDP, as well as demographic changes, including rural - urban population dynamics.

5.1 Integrating spatial and statistical datasets

A simple technique for downscaling the annual amount of crop and wood harvesting (reported to FAO per country) on the probability to have either cropland or forest land from the CORINE LC was explored. The probability maps are calculated for each CORINE LC map, e.g. 1990, 2000 and 2006 in one km resolution, grouping several classes. The product is called CORILIS, the following land use classes are available (Land accounts of Europe, EEA report):

LEAC groups			CLC classes
1	Artificial surfaces		1.
2A	Arable land and permanent crops		2.1 + 2.2 + 2.4.1
2B	Pastures and mosaic farmland		2.3 + 2.4.2 + 2.4.3 + 2.4.4
	2B1	Pastures	2.3
	2B2	Mosaic farmland	2.4.2 + 2.4.3 + 2.4.4
3A	Forests and transitional woodland shrub		3.1 + 3.2.4
	3A1	Standing forests	3.1
	3A2	Transitional woodland and shrub	3.2.4
3B	Natural grassland, heathland, sclerophylous vegetation		3.2.1 + 3.2.2 + 3.2.3
3C	Open space with little or no vegetation		3.3
4	Wetlands		4.
5	Water bodies		5.

Figure 19: CORILIS classes

For this downscaling exercise first the yields of crops and wood were extracted for year 2000. This was done for each European countries for each the probability map (Figure 20) was available. Then the total amount was divided over the number of cells from the 10 km European grid average yield over the entire territory, and afterwards the average yield was weighted by the probability map to have either crop or wood extracted.

The figure 21 illustrates the inputs of Forestry probability map (light colour – high probability) and a graph of annual amounts of wood extraction in Romania during the last five decades.

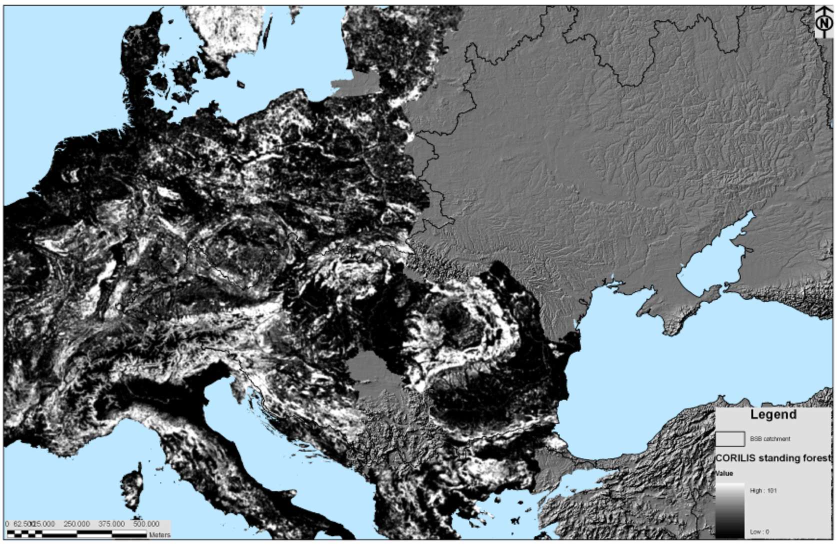


Figure 20: CORILIS of standing forest in EU

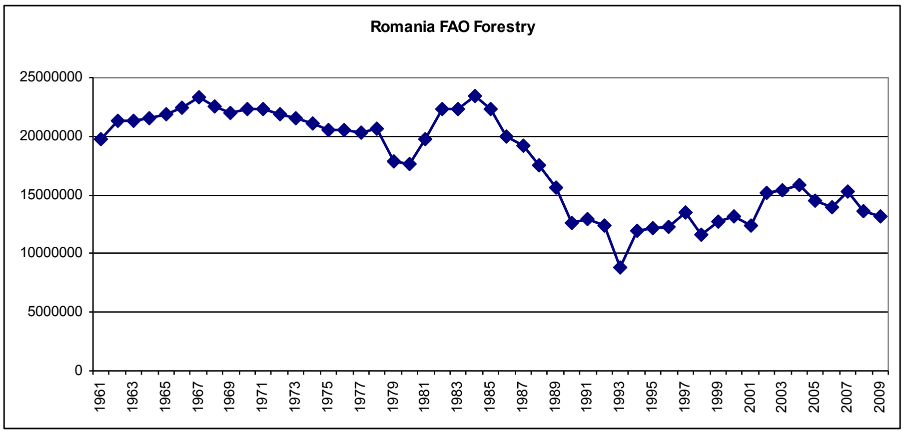


Figure 21: Forest extraction in Romania

Figure 22 shows the result of downscaled wood extraction intensity. This allows the detection of differences between west and east countries, which look all even on the probability maps.

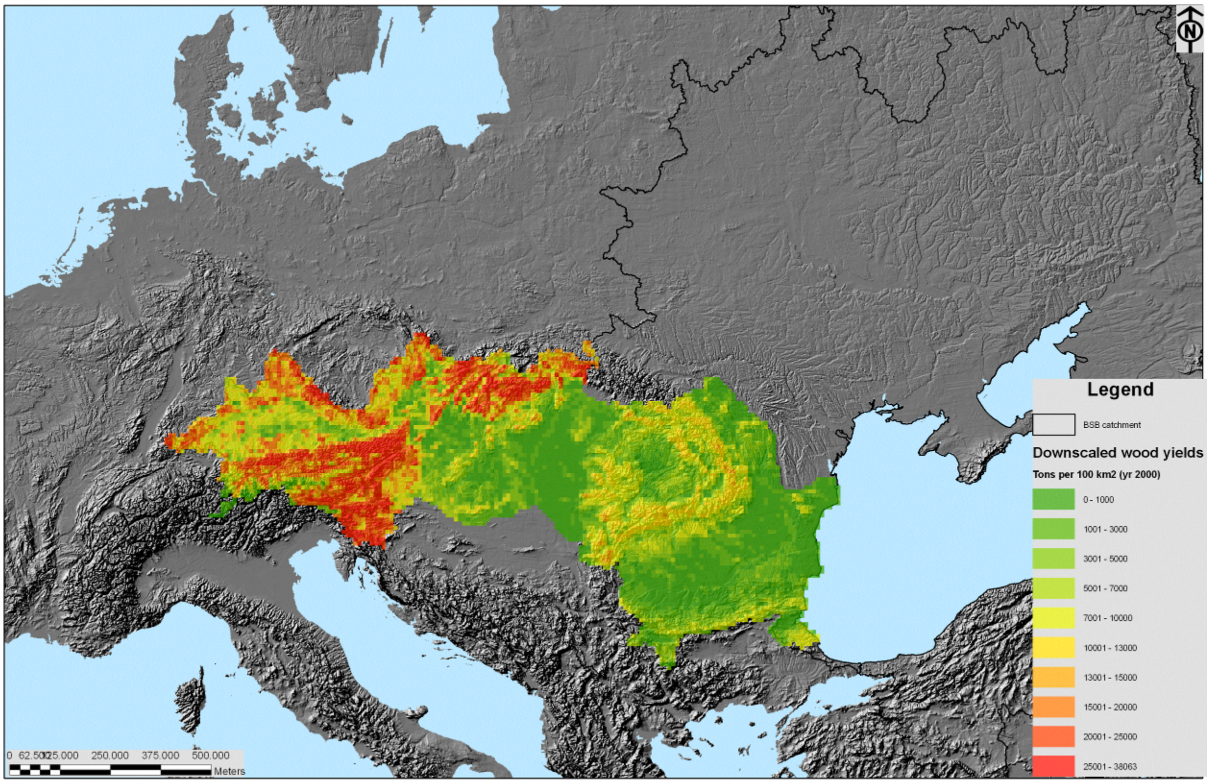


Figure 22: Downscaled wood harvesting intensity.

These maps can be further improved by applying additional factors for defining the hotspots (intensity-wise), as for example – regime of protection. The latter should be very important in influencing wood extraction intensity. For croplands, important additional factors could be soil fertility and inputs of fertilizers and chemicals that are also reported to FAO.

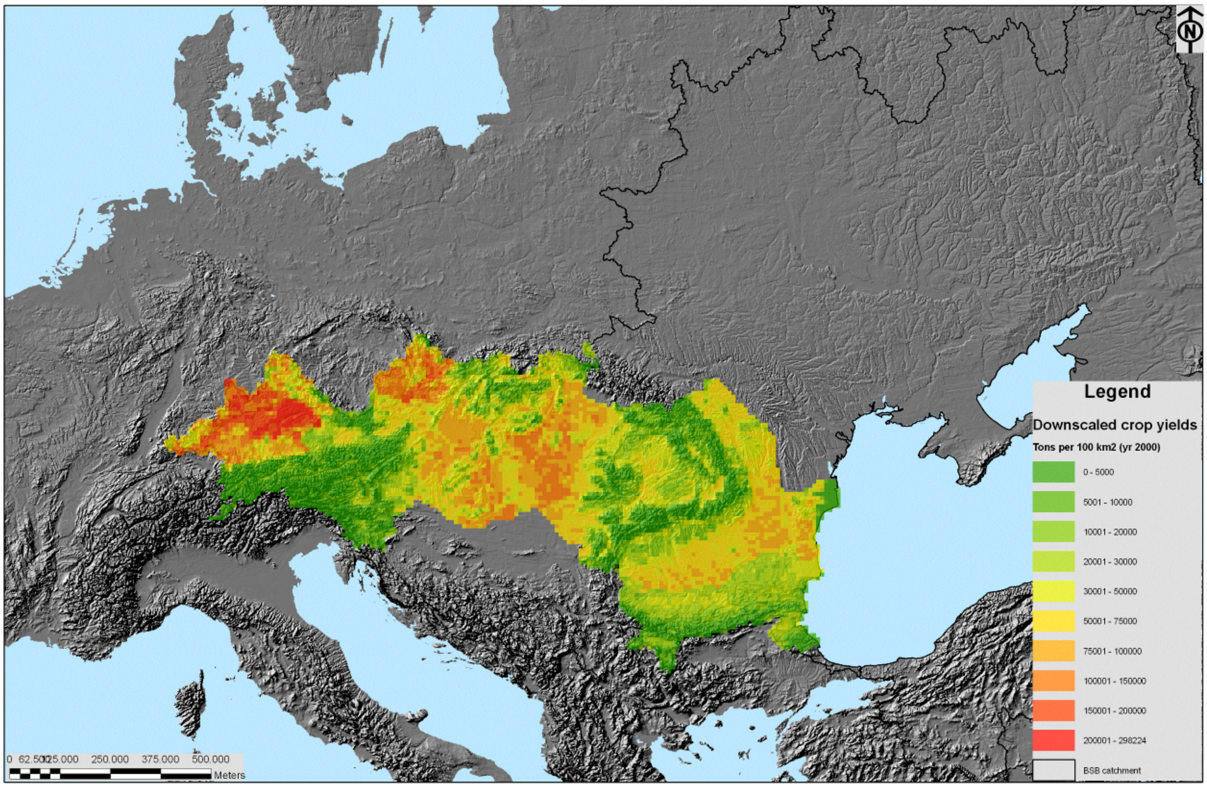


Figure 23: Downscaled crop harvesting intensity

In a similar way probability maps could be calculated from the MODIS Land Cover type dataset to apply the method over the entire Black Sea Basin.

6 Simulation of the future state of the environmental changes

Finally, for completing the application of dynamic integrated simulations a Bayesian Belief Network method is explored, with NETICA BBN software.

The BBN approach looks very promising on one hand for allowing the analyst to make use of all available data, linking many different subjects, each with different type and quality of data inputs and on the other - for forcing the analyst to complete a comprehensive picture of all important subject and links between them. The examples bellow illustrate three sketches of simulating average scenario, worst environmental scenario and best future environmental scenario in the Black Sea Basin (Figure 24, 25, 26).

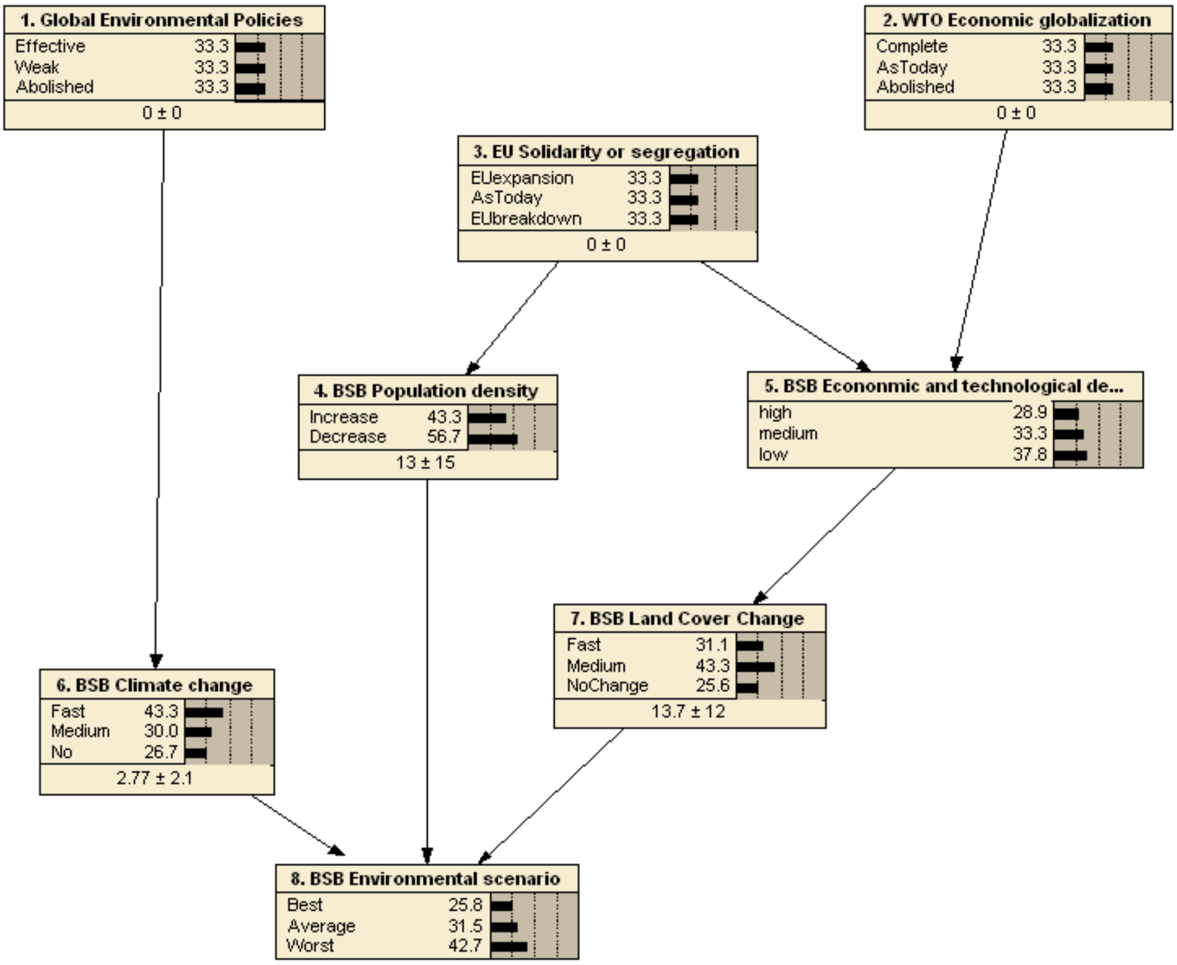


Figure 24: Example of integrated scenario set up

Excluding the global the effect drivers, by setting up equally probable effectiveness of environmental policies, cooperation policies and global economic development, the network indicates that as a whole there should be no population growth in the BSB, no standing out economic and technological development, more likely fast climatic changes and medium speed land use change, which would define more likely the worst environmental situation to follow (42% probability, versus 26 % probability of the best environmental situation).

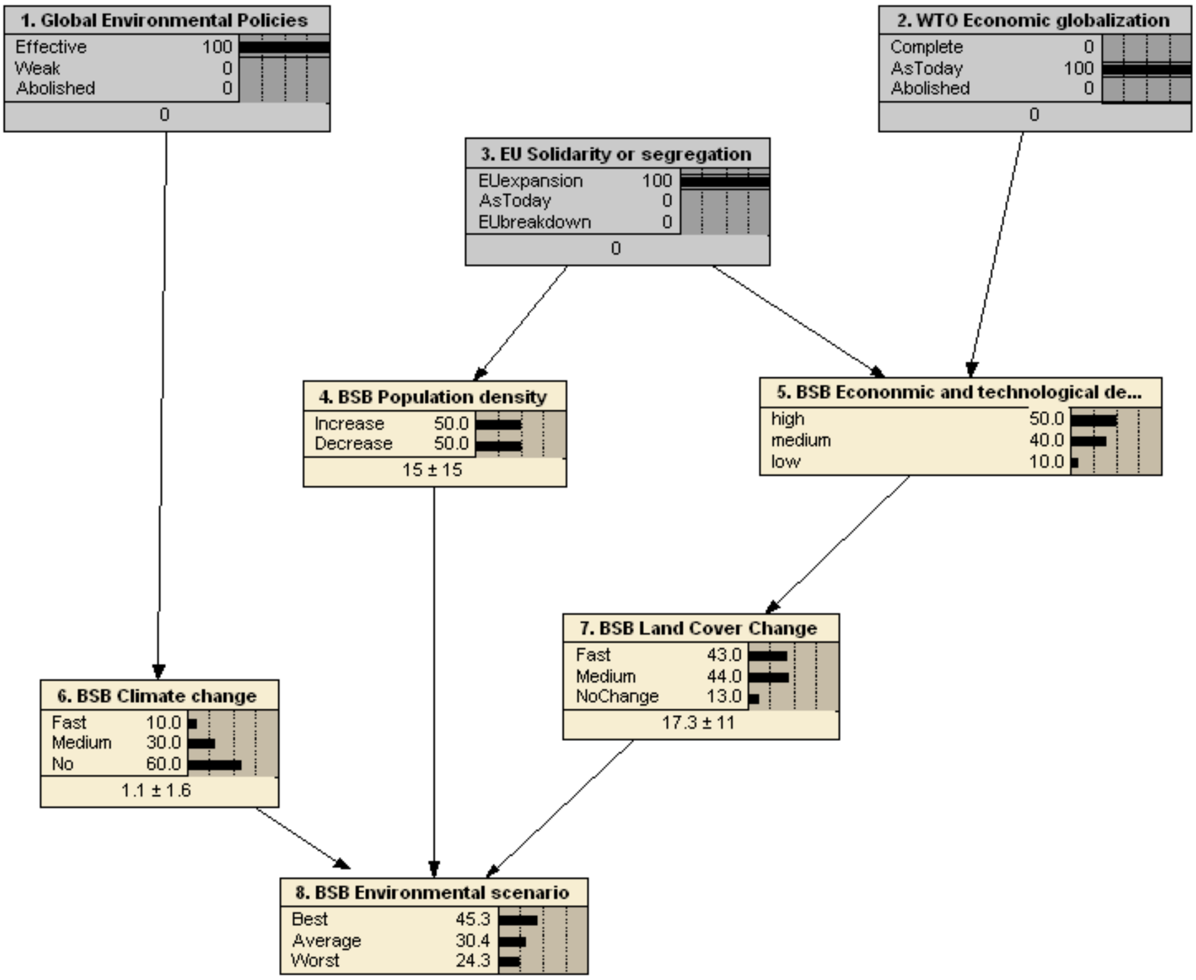


Figure 25: Example of likely achievement of ¨Best environmental scenario¨

If we wish to contrast the effect of the assumptions selecting 100 % probability that effective environmental policies would be realized, as well as 100 % probability that EU would be expanded across the BSB countries guarantying harmonized socio-economic and political conditions and no further economic globalization (than today) the network indicates 45 % probability to end in the ¨best environmental scenario¨ versus 24% for the worst one.

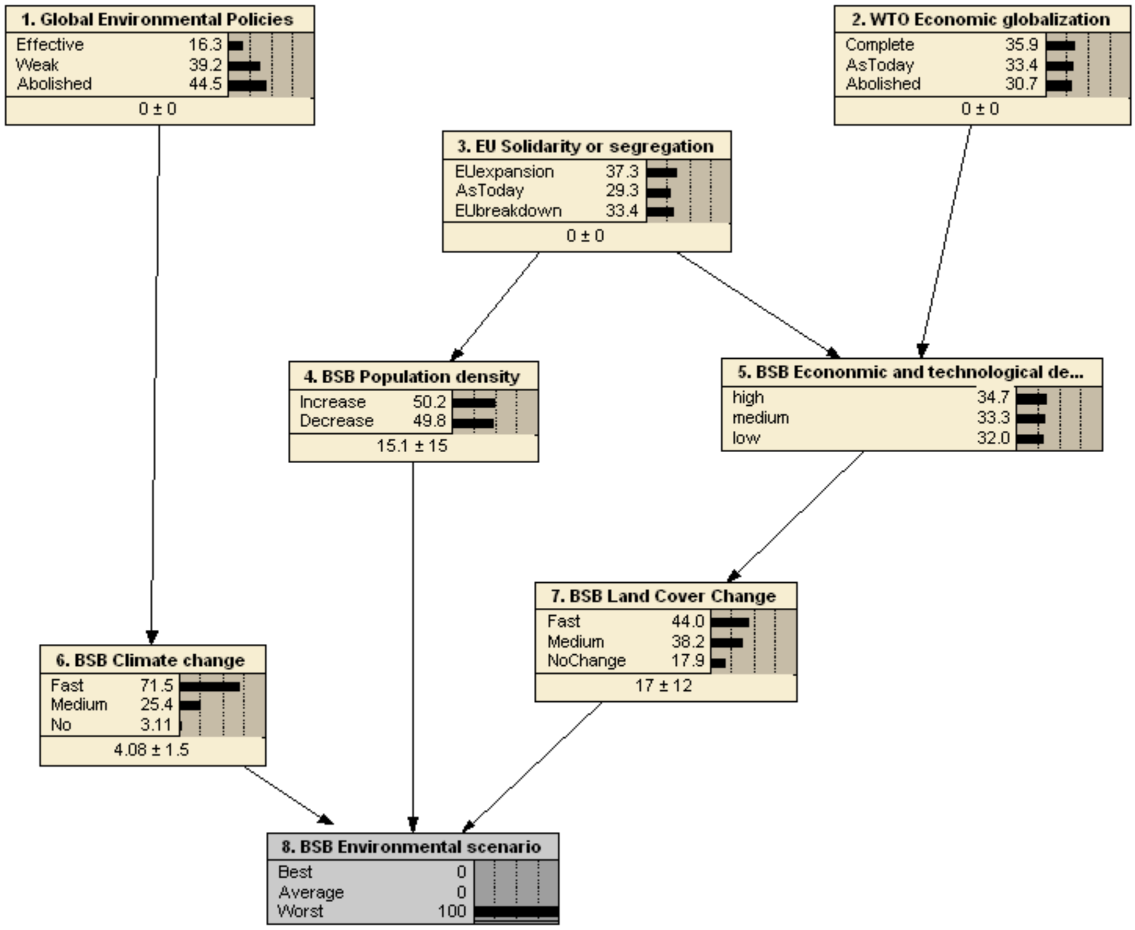


Figure 26: Example of simulating ¨Worst environmental scenario conditions¨

If we fish to check what drivers and factors would cause the realization of 100% worst environmental scenario, this option is selected and the network propagates the corresponding probabilities in the above boxes. With the lookup table set-up with very rough judgements about the casual relationships, one can observe clear prevalence of abolished global climate change policies and slight prevalence of the completed economic globalization, as well as complete EU expansion. Population numbers for example do not appear to have important effect in the chain of casual relations.

7 Integrated modelling framework

Modelling tools play an important role in scenarios integrations at global, regional and local scale The main objective of this chapter is to present the proposed modelling framework which will guide and support the construct contrasting environmental scenarios for Black Sea Basin utilizing available datasets from multiple scales.

Until this moment, there is no single model able to take all key processes essential to explore the environmental processes, assessment of driving forces, policies options and impacts. One of the major focus of LUCC scientific community was the development of the integrated models as well as of prognostic regional and global models – Integrated modelling. These efforts resulted in the emergence of integrated approaches that are able to model at spatially explicit, integrated and multi-scale manner and provide the projection of alternative pathways into the future, for conducting experiments that test our understanding of key processes and for describing the latter in quantitative terms (Lambin et al., 2006).

Integrated models incorporate mostly top-down interactions. At top level, models calculate the quantity of change (the demand) using tools such as non-spatial economic model or global environmental trend analysis at national or regional scales. This demand is followed by spatial allocation assigned based on suitability maps built using selected physical and socio-economic factors. The basis for this approach is the demand-driven nature of land use changes, specially related to commodities (Moreira et al., 2009).

In the last decade have appeared some application of these models combining different approaches at different scales. EURURALIS (Klijn et al., 2005) scenarios used three different models to assess the impact of changes in driving forces such as climate and policy on land use. The models used was LEITAP- GTAP (Purdue University) a macroeconomic model to get the agriculture production per crop and per world region and the industry and services sectors, linked to an environmental model to calculate the effects of land use change and climate change on yield and environmental indicators, finally a land allocation model to downscale the land use changes in a grid level.

The SENSOR (Helming et al., 2008) project also used an econometric model called NEMESIS. Several sub-models with significant importance for land use were modelled individually (forestry, urban, transport, tourism and infrastructure), and linked to the land allocation model to disaggregate land use to grid level.

Also for EnviroGRIDS a global environmental model (IMAGE), will be used to calculate the quantity of land use change at national level. Consequently an ISDSS called METRONAMICA is applied at regional and local level. At a regional scale a dynamic gravity model is applied to calculate attractiveness of a country, based on factors such as population and jobs, then, a land allocation model would be applied to downscale land use to the grid level (Figure 27).

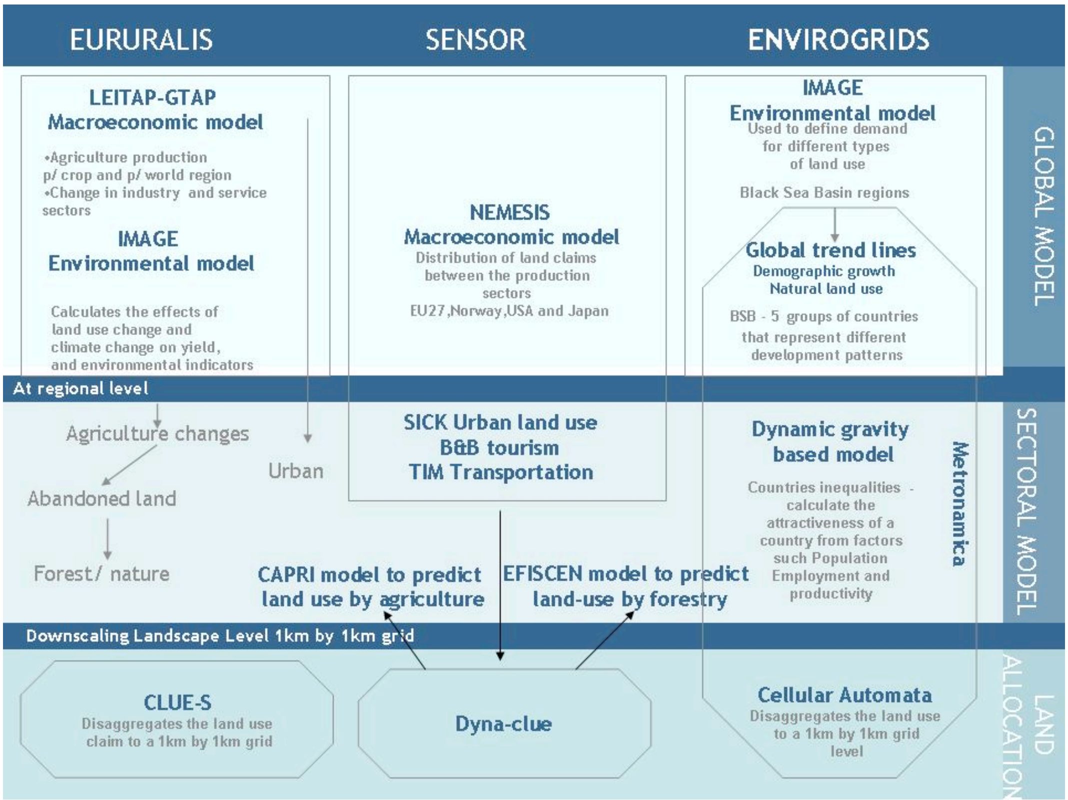


Figure 27: Integrated framework in EURURALIS, Sensor and EnviroGRIDS projects

7.1 EnviroGRIDS modelling framework

Three models were applied to create spatial explicit environmental scenarios for the Black Sea Basin at multi-scale. The IMAGE model (Alcamo et al., 1998) – Integrated Model to Assess Global Environment includes the most detailed, spatially explicit description of global land-use and land-cover dynamics. This model should be used to specify the land use demands for Black Sea Basin countries at global level.

Additionally, population and economic global trends are taken from global trend lines, and included in the Integrated Decision Support System - IDSS called METRONAMICA. METRONAMICA system has been implemented by means of the software framework GEONAMICA®. Currently, there are three versions available: METRONAMICA SL (containing the land use model as a single layer), METRONAMICA ML (contain the land use model but also the regional model as multiple layers) and METRONAMICA LUT (contain the land use and regional interaction model and the transport model) (RIKS, 2009).

The chosen version will be the METRONAMICA ML – Multi-layer, which is structured by two spatial layers. At regional scale a dynamic spatial interaction model (White, 1977, 1978 IN Engelen, G. 2003) manage for the allocation of national growth. The attractiveness of a region is determined by importance as a centre of economic activity and housing, its position relative to the other regions and its position relative to the neighbourhood countries. At local scale a land use model based on *cellular automaton* is used to allocate the regional demands on a land use map. Modelling outputs would be generated for 50 years in 25 years time steps although METRONAMICA runs on annual temporal resolution.
Spatially explicit scenarios outcomes from the model would be used as an input for the Soil and Water Assessment Tool (SWAT, 2007) and also for impact assessment (Figure 1).

7.1.1 Global Environmental Model – IMAGE

The Integrated Model to Assess the Global Environment – IMAGE[7] (Alcamo et al., 1998) main goal is to develop and analyse integrated scenarios of global environmental change. The integrated framework links several sub-models. IMAGE assumes as main driving forces the changes in population and macro-economy, agriculture economy, energy supply and demand. Afterwards those drivers are interacting through land use and emission model with the Earth Systems. Important elements in the biophysical modelling of Land Use/Cover processes are also addressed, contemporaneous and historical land cover, the carbon cycle and nutrients followed by climate and climate variability including the interaction with the land cover (Bouwman et al., 2006).

IMAGE model results have been used in several global studies including IPCC-SRES, the UNEP Third Global Environment Outlook (GEO-3), the Millennium Ecosystem Assessment (MA), but also in European studies such EURURALIS.

The model consists in several modules that interact and are explicitly modelled. IMAGE 2.2 integrated a population model called Phoenix (Hilderink, 1999), a general equilibrium economy model, WorldScan (CPB, 1999) that supply the basic information on economic and demographic development for 17 regions, into three linked subsystems (IMAGE team, 2001):

1. Energy-Industry System (EIS) quantify the regional energy consumption, energy efficiency improvements, fuel substitution supply and trade of fossil fuels and renewable energy technologies taking into account the energy use and industrial production, this module will calculate the emission of GHGs, ozone precursors and acidifying compounds.
2. Terrestrial Environmental System (TES), estimate the land use changes based on the regional consumption, production and trading of food, animal feed, fodder, grass and timber, considering the local climatic and terrain properties. On the other hand, the TES model computes the emissions from

[7] The IMAGE was developed at the National Institute for Public Health and Environment (RVIM) and recently continuing by Netherlands Environmental Assessment Agency (MNP)

land use, natural and agriculture productions systems and the exchange of CO2 between terrestrial ecosystems and the atmosphere.
3. Atmospheric Ocean System (AOS) calculates changes in atmospheric composition using the emissions and other factors in the EIS and TES, taking oceanic CO2 uptake and atmospheric chemistry into considerations. Lastly this model will quantify changes in climate properties by resolving the changes in radioactive forcing caused by greenhouse gases, aerosols and oceanic heat transport.

IMAGE model allows linking the different socio-economic and environmental dimensions and scale levels (Figure 28).

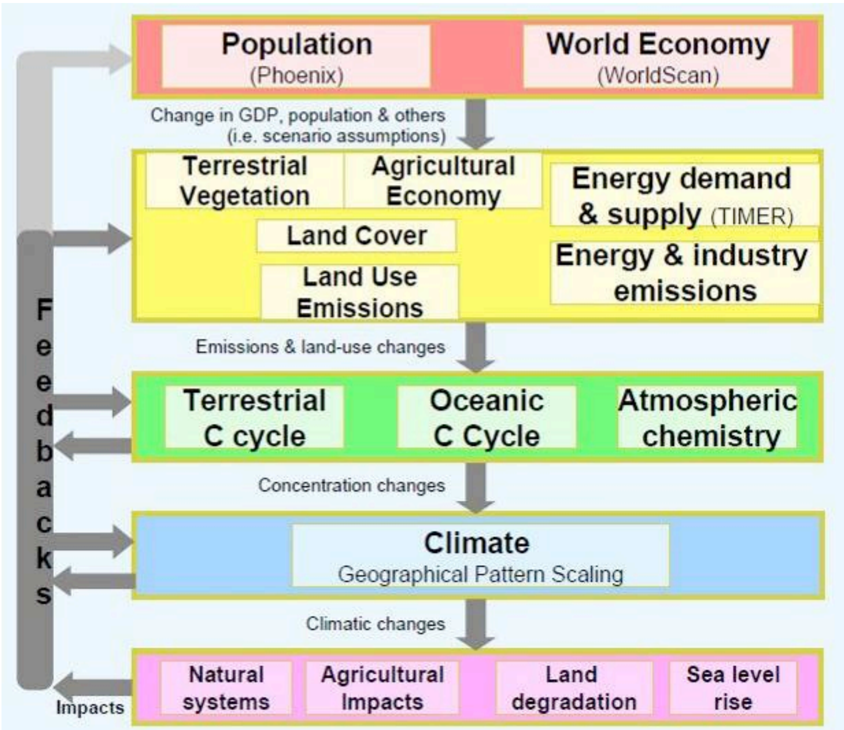


Figure 28: IMAGE 2.2 Model Framework (Source: IMAGE team, 2001)

The version 2.4 (latest version) is not available, however it is accessible in the MNP web-site a User Support System (USS) that enables a comprehensive view on the scenarios data of IMAGE runs. This tool includes scenarios data covering the IPCC-SRES scenarios available on IMAGE version 2.2 (IMAGE team, 2001).

In EnviroGRIDS, the IMAGE 2.2 model results are proposed to be used for scenarios analyse and quantification. All IMAGE 2.2 indicators are hierarchically organized on the basis of the Pressure-State-Impact framework (IMAGE 2.2). The majority of these indicators are presented for the 17 regions, the same that are used for IPCC-SRES, for each A1, A2, B1 and B2 scenarios families, from 1970 to 2100. Bellow, we list some of these indicators (Annex V).

1. Pressure: social, economic and ecological driving forces that are underlying the pressures on human and environmental system – the main drivers are GDP per country, population, primary energy use and demand of agriculture products.
2. State: changes in the state of the biosphere and atmosphere, as well as changes in resource energy – the main states are Global Anthropogenic CO2 emissions, Atmospheric CO2 concentration and land cover
3. Impacts: social-economic and ecological impacts result of disturbances of the system resulting from the pressures on the environmental system – the main impacts are radioactive forcing, global surface

temperature change, rate of temperature change, sea level rise, change of annual temperature and change of annual precipitation.

7.1.2 Regional /local land use model

The demand for different types of land uses as agriculture and forests are calculated by IMAGE model and disaggregated to country level.

In EnviroGRIDS the METRONAMICA (White and Engelen, 1997) was the land allocation model chosen for various reasons. METRONAMICA is based on the Geonamica framework. Geonamica supports the development of Integrated Spatial Decision Support System (ISDSS) based on spatial modelling and (geo) simulation. It is able to link model components with spatial and temporal resolutions into a single integrated dynamic system, by linking all input ports of a model block to output ports of other model blocks. The entire model could be represented by model blocks hierarchically. In addition, Geonamica offers a rich class library of user interface components, for example, map display, editing tools, table views, among others, supporting the development of graphical user interfaces for such integrated models. The Geonamica framework is widely used for the development of ISDSS (Hurkens et al., 2008). Good examples of ISDSS based on this approach are the DeSurvey IAM (Van Delden et al., 2009), (EC – IP - 6th Fram6ework Program, 2005), LUMOCAP (Van Delden et al. 2010), PRELUDE (EEA, 2005 and Van Delden et al., 2009), MOLAND (Barredo et al., 2003) and MedAction PSS (Van Delden, 2005). Consequently, these experiences are very useful for EnviroGRIDS integrated scenarios

METRONAMICA is an ISDSS based on very flexible framework with a standard user interface, a scenario manager and incorporates several simulation-coupled models, which work at different scales to represent different processes. Taking into account the past historical data referring to the land use data, driving forces and policies, the models will simulate various scenarios assumptions based on expertise decisions.

In LUMOCAP, DeSurvey and PRELUDE projects, the climate scenarios were integrated in the model to assess the impact from different climate scenarios changes on the suitability of the land for different land use types. The impacts caused by temperature and precipitation changes are reflected in the flood risk, expansion or decline of wetlands and changes in the suitability of agriculture yield.

In general the ISDSS presented above aims to assess the impact of different scenarios incorporating a set of dynamically linked models depending on the aim of the study. For example, Xplorah is a IDSS that integrated a set of dynamically linked models working at different scales and incorporating knowledge from numerous disciplines, such as climate, economy, demography, transport and land use (Figure 29) (van Delden, et al. 2008).

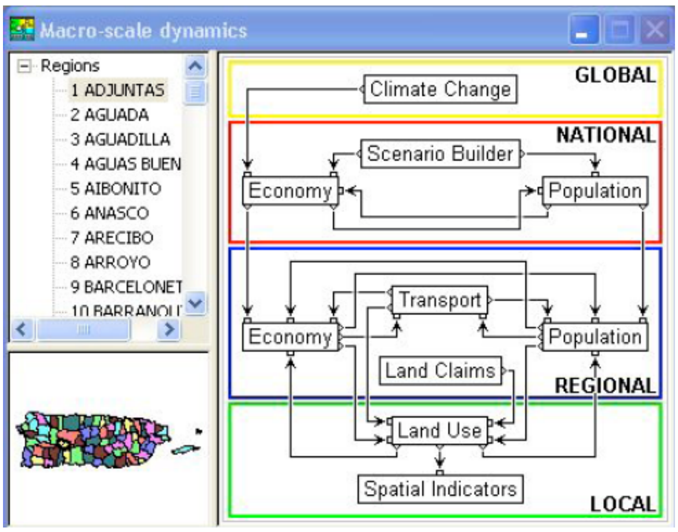


Figure 29: Example of a ISDSS based on Geonamica - System diagram of the Xplorah SDSS (van Delden et al., 2008)

In that project, the impact of global climate change was incorporated as a set of relations that affect different sectors of the economy in the Puerto Rico Island. The demographic model spread the population over the whole area and then uses the regional interaction model to divide the total population amongst different regions.

For EnviroGRIDS the METRONAMICA (White and Engelen, 1997) will be used to simulate the spatial pattern of land use changes taking into account the demography and climate changes scenarios. The climate scenarios can be linked to the land use model through physical suitability component and demographic scenarios can be linked to spatial demands that then are linked to the regional interaction model[8].

Based on the demanded areas for the different land use types, and the conditions specified in the scenarios, METRONAMICA is expected to allocate the changes in land use requirements to specific location and visualize the effect of those scenarios.

METRONAMICA Multi-Layer – ML

The driving forces of the spatial changes regard the economic and demographics developments operating at different scales.

In order to represent the processes that make and change the spatial configuration of the area, it features a layered model representing processes operation at three geographical levels: the global (1 region, typically representing a group of countries, one country or an administrative or physical region within a country), the regional ("n" administrative regions, typically representing NUTS2, NUTS3 or NUTS4 regions) and the local (N cellular units) (Figure 30).

The BSB "global level" is presented in total by the entire area. At this scale, the entire area is modelled integrating data taken from economic, demographic and environmental growth scenarios. The global trend lines for demographic population projections are taken from the WPP, and GDP projection are taken from IIASA's GDP annual projections until 2050. In case of METRONAMICA ML the input data is the population number and jobs in main activities sectors for each country and the land use demands (provided from actual land cover and IMAGE model scenarios) for sectors such as agriculture, forestry, etc. at regional level.

Taking into account that the population growth will not equally spread over the countries since some countries are more attractive that the others, a dynamic spatial interaction based model, will allocate and relocate new residents and new economic activities influenced by these regional inequalities.

[8] Internal Communication between EnviroGRIDS team and RIKS company.

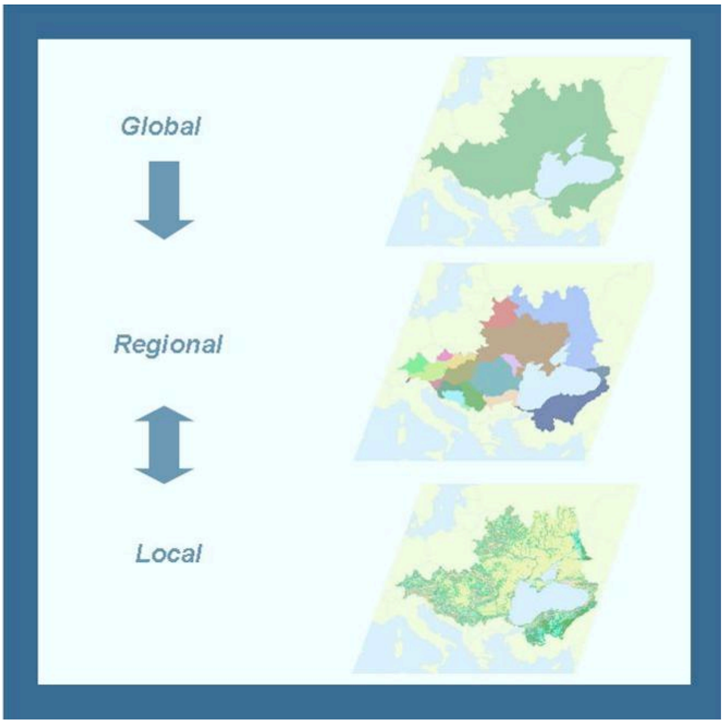


Figure 30: METRONAMICA hierarchical model represent processes at three spatial levels: Global, Regional and local. Black Sea Basin.

The Information provided from the regional interaction model, will determine the spatial allocation of population and land use as a surface area demanded for the different land uses at local scale. Each cell will be modelled dynamically by means of a spatial allocation model based on cellular automata represented by a grid of cells of 1000m per 1000m (Figure 31). Each cell would represent the dominant land use in that area.

The land use is classified by 32 classes maximum and separated by three different states (van Delden et al., 2008):

1. Features States – fixed land uses that do not changes dynamically
2. Functions States – changes dynamically as the result of the local and regional dynamics.
3. Vacant States – changes dynamically due the local dynamics

This model is driven by the demands for land for the total area of each BSB group generated at global level, by means the IMAGE model.

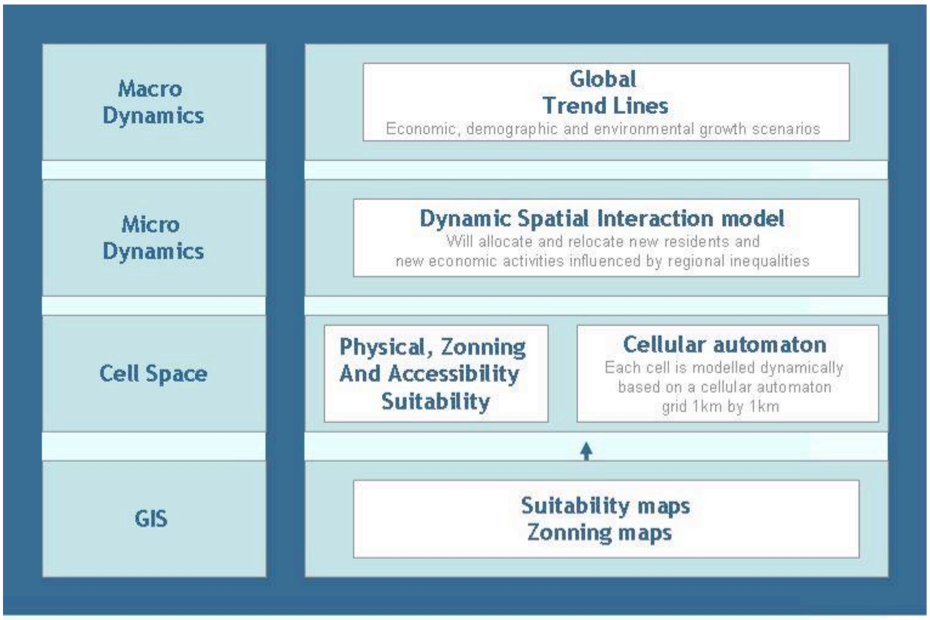


Figure 31: Role of cellular automata land-use models as core elements in linking socio-economic and environmental models at different scales (adapted from Lavalle et al., 2004).

The land use pattern is defined by four elements which determine if the land uses function is taken or not. The three first elements regard the location suitability, expressing how well the cell is positioned in relation to its capacity to support competing activities. The suitability can change the spatial regulation. For example, the suitability can change during a simulation, due either to user intervention referring to a policy measure or to changes in environmental or physical conditions (e.g. flooded by rising sea) (Van Delden et al., 2008 and Engelen et al., 1994):

1. Physical Suitability: The suitability map represents the suitability of the location for a specific land use based on the physical, ecological and environmental factors that influence the allocation of the land use type (for more information D 3.3). In this model each land use function needs a suitability map. Usually the factors used are: elevation, soil quality, water bodies and climate factors such precipitation and temperature.

2. Institutional suitability: the zoning and intuitional suitability represents the master plans and planning figures available at national and regional scale. For EnviroGRIDS BSB, the institutional maps should represent protected figures such as Natura 2000 and Protected Areas (for more information D 3.3). The institutional suitability is represented by one map per land use function and each cell specifies what can or cannot be taken by a land use type. Once the Institutional factors are man made legal instruments for imposing constraints and stimulations trends they are an important figure for policies scenarios that support the decision–making process. In this sense, the institutions factors represent different alternatives decision and they should take into account the planning periods that could be determined by the user: 2000-2005, 2005-2010, etc.

3. Accessibility: the transport infrastructure as roads, railways and settlements infrastructures are important factors determining the spatial location of land use changes. METRONAMICA model calculates the accessibility for each land use function relative to the transportation system which includes the roads (major roads and roads) and link roads, railways and railways stations. The accessibility measures take in to consideration the distance of the cell (which represents a land use function) to the nearest road link or rail station.

4. Dynamics at the local level: The dynamics at local level are developed on a cellular grid where each cell represents a parcel of the land which dynamically changes by means a cellular automata transition rules. A cellular automaton is defined as an array of cells in which each cell can assume one of K discrete states at any one time. Time progress by steps in all cells change state simultaneously as a function of

their own state, and the cells in their neighbourhood, based on a specific set of transition rules either qualitative, quantitative or both. (Engelen, et al. 1994).

The land use dynamic are determined by the physical, institutional suitability and accessibility potential which express the spatial location of a land use function in relation to supporting or competing activities. Apart of these elements the land use dynamic is also influenced by the dynamic impact of land uses in the area immediately surrounding a location. A set of transitional rules is determined for each land use function, deciding the degree to which it is attracted or repelled by the other land use types that exist in the immediate surroundings of a location. Transitional rules, should express the power of the interactions as a function of the distance separating the different functions within the neighbourhood. If the attractiveness is high, the function will try to occupy the location, if not it will try to found a more attractive place. New activities and land uses start spreading by the neighbourhood over the time, changing its attractiveness for activities already present and others searching for space. Van Delden et al. (2008) exemplify this process explaining the decay of the residential neighbourhood due to the invasion by industrial or commercial activities or the revival of a neighbourhood due the arrival of new type of residents, new economic activities, new parks, offices building, among others high quality functions. The rules that determined the interaction between different functions or land uses are defined as part of the calibration of the cellular automata model (Figure 32).

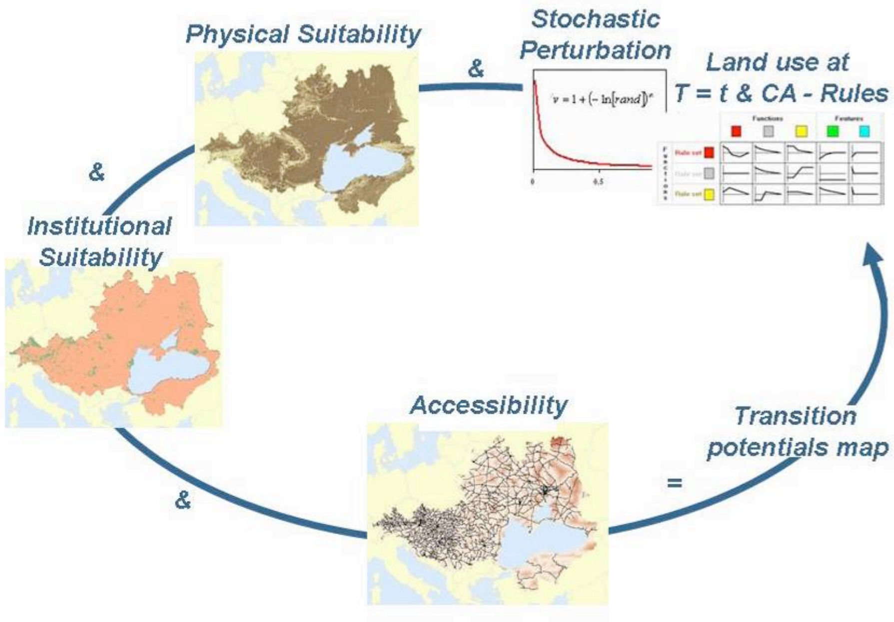


Figure 32: Spatial allocation model elements - land use changes at local level: Physical suitability, institutional factors, and accessibility and transition rules. Black Sea Basin modelling area.

Conclusions

This document presented the state of progress in integrated environmental scenario development for the Black Sea Basin.

First an extensive overview of the future state and trends in major driving forces was presented. The figures were derived from the existing scenarios covering the Black Sea Basin.

Then a framework for building the actual scenarios was proposed by applying the available data, information and selected tools.

The main achievement in this work was the drafting of first version of storylines about the possible changes in the Basin. Analysing and defining the future development paths by clustering the projected values of future economic and population density parameters for each country facilitated the storyline definition.

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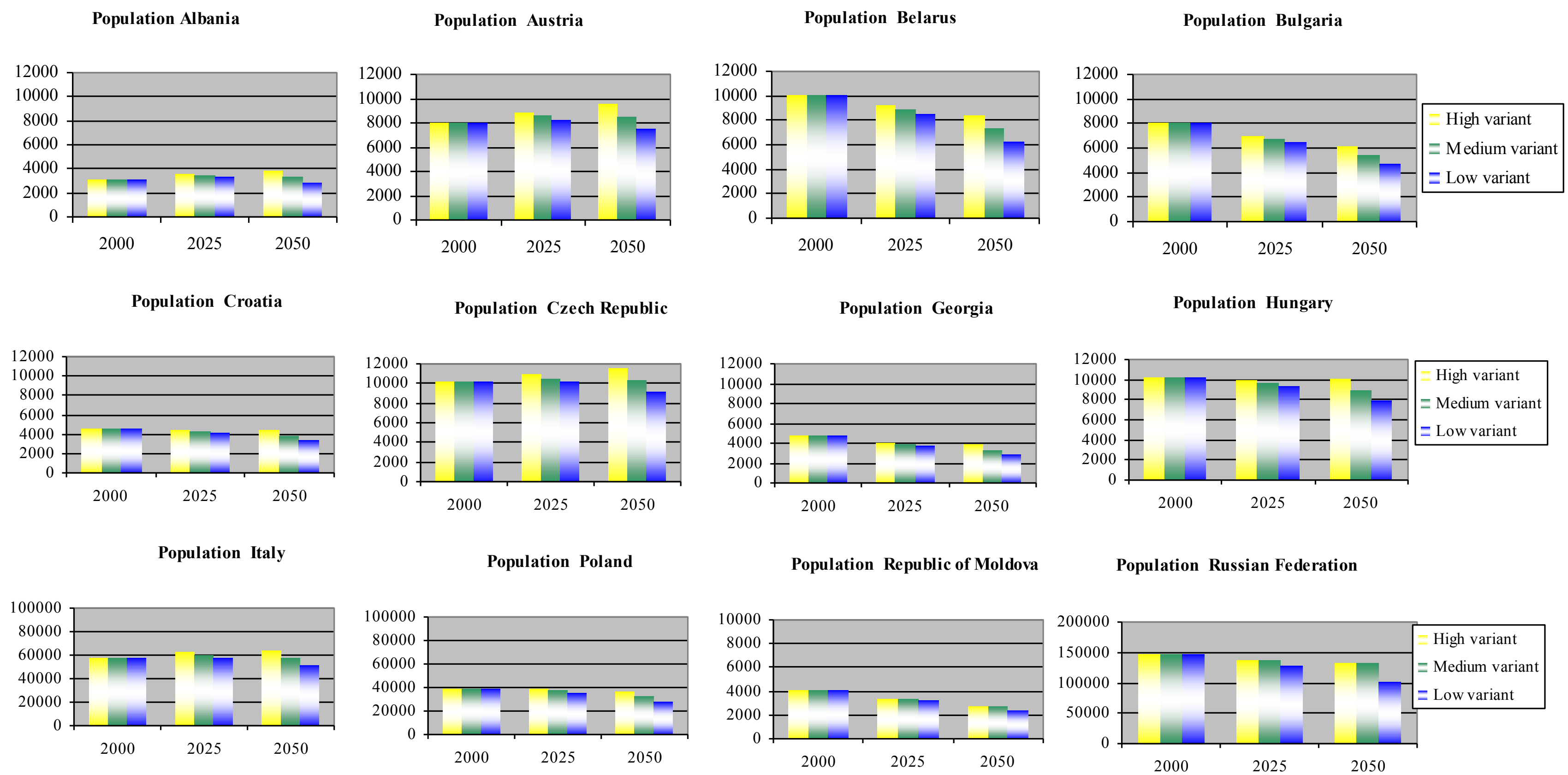
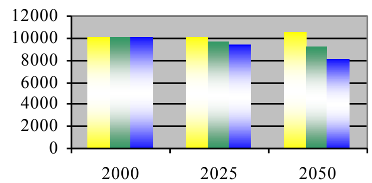
Abbreviations and Acronyms

BBN	Bayesian Belief Networks
BSB	Black Sea Basin
CAP	Common Agriculture Policies
CORILIS	CORIne and LISsage
CPB	Netherlands Bureau for Economic Policy Analysis
DITTY	Development of an Information Technology Tool
DPSIR	Driver – pressure – State – Impact- Response
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEO	Global Environmental Outlook
GSG	Global Scenario Group
IIASA	International Institute for Applied Systems Analysis
IMAGE	Integrated Model to Assess the Global Environment
IPCC-SRES	Intergovernmental Panel on Climate Change - Special Report Emission Scenarios
ISDSS	Integrated Spatial Decision Support Systems
LUCC	Land-Use and Land-Cover Change
ML	Multi-layer
NDVI	Normalized Difference Vegetation Index
NEAA	Netherland Environmental Assessment Agency
NUTS	Nomenclature of Units for Territorial Statistics
OECD	Organization for Economic Co-operation and Development
PRELUDE	PRospective Environmental analysis of Land Use Development in Europe.
RIVM	National Institute for Public Health and the Environment
SWAT	Soil and Water Assessment Tool
UN	United Nations
WDI	World Bank's World Development Indicators
WPP	World Population Prospects
WUP	World Urbanization Prospects
WTO	World Trade Organization

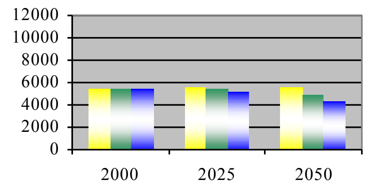
Annex I: Population (thousand) scenarios (WPP) for Black Sea Basin Countries



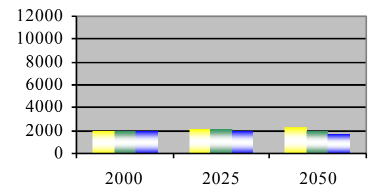
Population Serbia



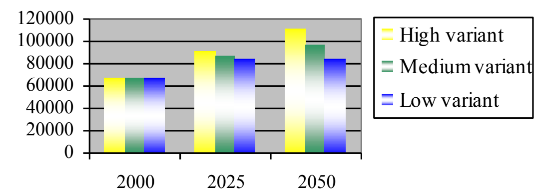
Population Slovakia



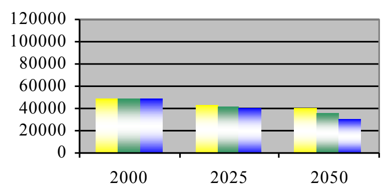
Population Slovenia



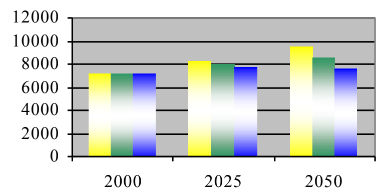
Population Turkey



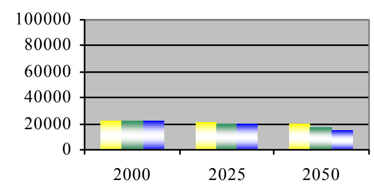
Population Ukraine



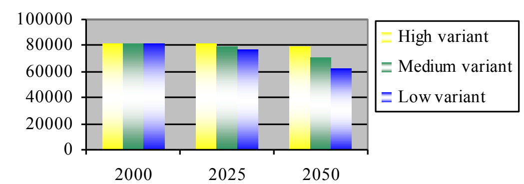
Population Switzerland



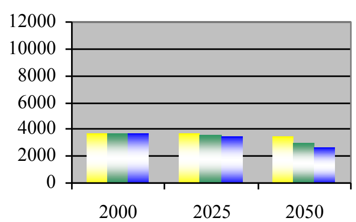
Population Romania



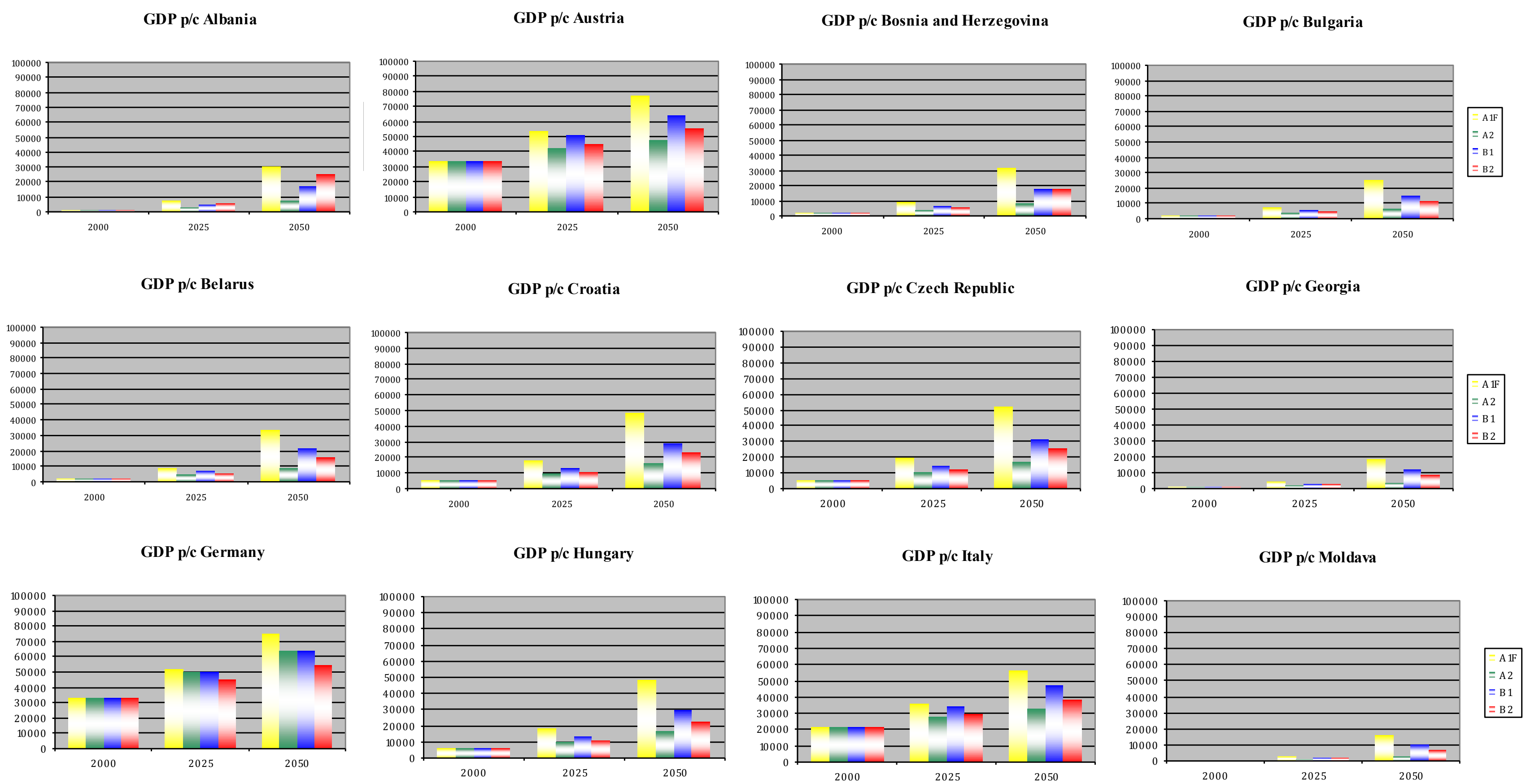
Population Germany



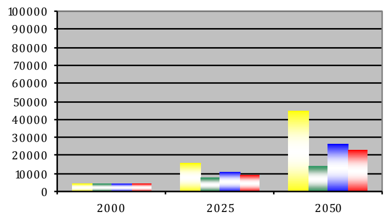
Population Bosnia and Herzegovinana



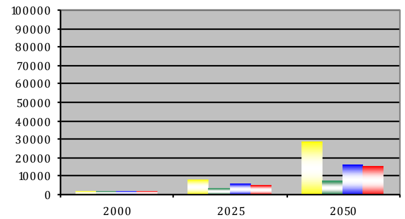
Annex II: GDP scenarios (IPCC- SRES) per inhabitant by Black Sea Basin Countries



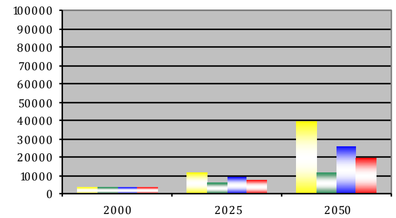
GDP p/c Poland



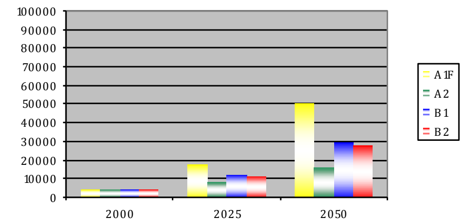
GDP p/c Romania



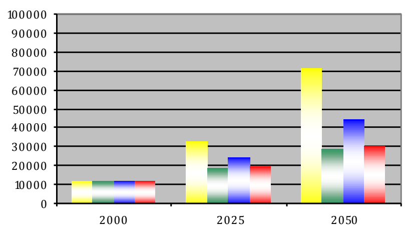
GDP p/c Russian Federation



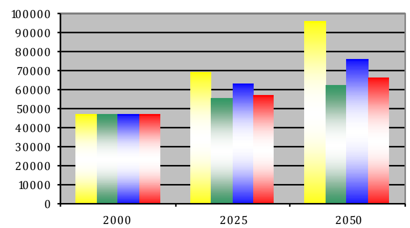
GDP p/c Slovak Republic



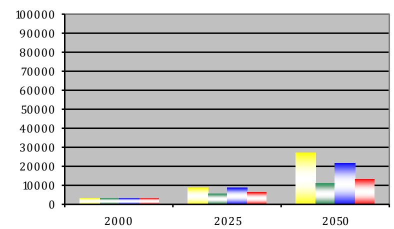
GDP p/c Slovenia



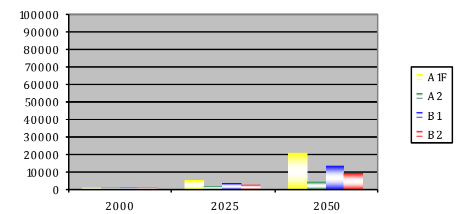
GDP p/c Switzerland



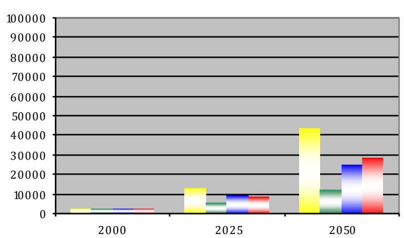
GDP p/c Turkey



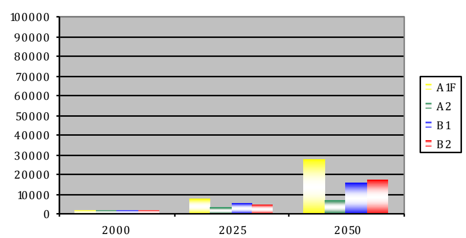
GDP p/c Ukraine



GDP p/c Macedonia



GDP p/c Serbia and Montenegro



Annex III: Urban population growth: 2000-2025 and 2025 - 2050

		Medium variant
Albania	2000-2025	0.45
	2025-2050	0.154
Austria	2000-2025	0.12
	2025-2050	0.1
Belarus	2000-2025	0.03
	2025-2050	-0.56
Bosnia and Herzegovina	2000-2025	0.62
	2025-2050	0.116
Bulgaria	2000-2025	-0.062
	2025-2050	0.088
Croatia	2000-2025	0.006
	2025-2050	0.084
Czech Republic	2000-2025	-0.038
	2025-2050	0.06
Georgia	2000-2025	-0.25
	2025-2050	0.04
Germany	2000-2025	0.032
	2025-2050	0.008
HUngary	2000-2025	0.05
	2025-2050	0.042
Italy	2000-2025	0.128

	2025-2050	0.072
Moldava	2000-2025	-0.478
	2025-2050	0.14
Montenegro	2000-2025	-0.01
	2025-2050	0.122
Poland	2000-2025	-0.042
	2025-2050	0.026
Romania	2000-2025	0.028
	2025-2050	0.058
Russian Federation	2000-2025	-0.12
	2025-2050	-0.036
Turkey	2000-2025	0.428
	2025-2050	0.23
Switzerland	2000-2025	0.138
	2025-2050	0.136
Ukaine	2000-2025	-0.124
	2025-2050	-0.046

Annex IV: Rural population growth: 2000-2025 and 2025 - 2050

		Medium variant
Albania	2000-2025	-0.300
	2025-2050	-0.300
Austria	2000-2025	0.030
	2025-2050	-0.250
Belarus	2000-2025	-0.470
	2025-2050	-0.470
Bosnia and Herzegovina	2000-2025	-0.090
	2025-2050	-0.420
Bulgaria	2000-2025	0.300
	2025-2050	0.450
Croatia	2000-2025	-0.134
	2025-2050	-0.364
Czech Republic	2000-2025	0.060
	2025-2050	-0.288
Georgia	2000-2025	-0.230
	2025-2050	-0.320
Germany	2000-2025	-0.026
	2025-2050	-0.320
HUngary	2000-2025	-0.252
	2025-2050	-0.350
Italy	2000-2025	0.058
	2025-2050	-0.315

Moldava	2000-2025	-0.246
	2025-2050	-0.452
Montenegro	2000-2025	-0.548
	2025-2050	-0.212
Poland	2000-2025	0.002
	2025-2050	-0.294
Romania	2000-2025	-0.232
	2025-2050	-0.406
Russian Federation	2000-2025	-0.034
	2025-2050	-0.332
Turkey	2000-2025	-0.026
	2025-2050	-0.178
Switzerland	2000-2025	0.146
	2025-2050	-0.254
Ukaine	2000-2025	-0.240
	2025-2050	-0.410

Annex V – IMAGE 2.2 Indicators

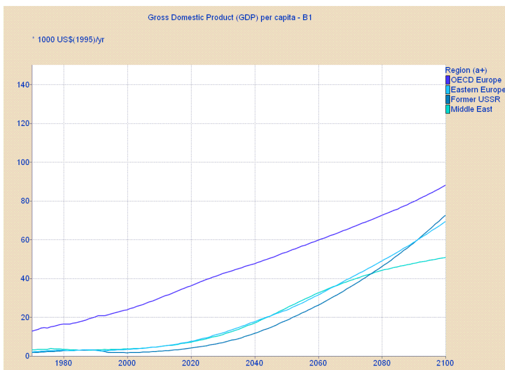


Figure X: GDP p/c, B1 IPCC-SRES between 1970 and 2100, OECD Europe, Eastern Europe, Former USSR, Middle East and World Source: IMAGE 2.2

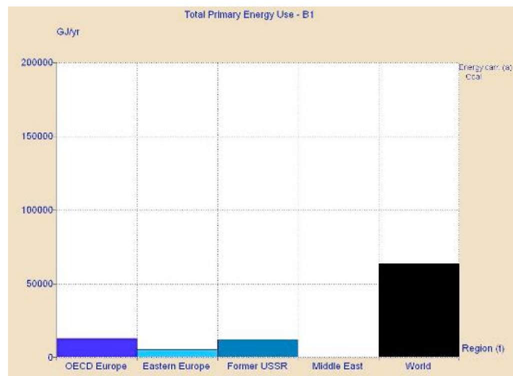


Figure X: Total primary energy, B1 IPCC-SRES between 1970 and 2100, OECD Europe, Eastern Europe, Former USSR, Middle East and World. Source: IMAGE 2.2

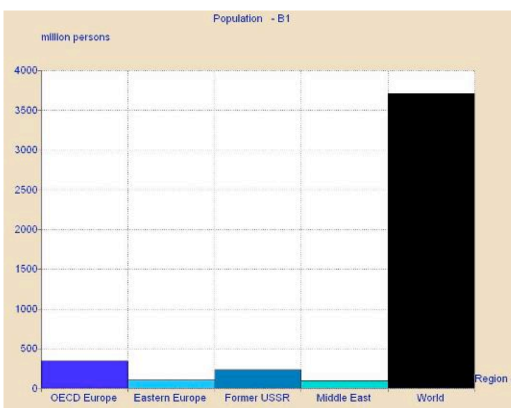


Figure X: Population, B1 IPCC-SRES between 1970 and 2100, OECD Europe, Eastern Europe, Former USSR, Middle East and World Source: IMAGE 2.2

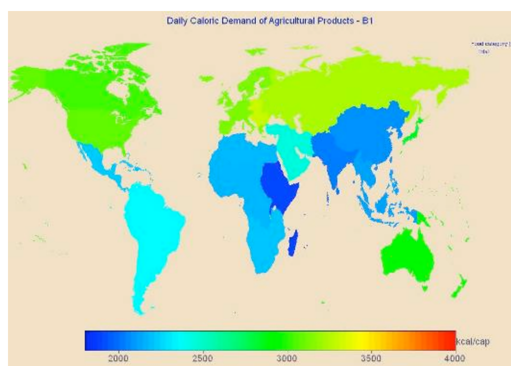


Figure X: Daily caloric demand of agriculture products, B1 IPCC-SRES between 1970 and 2100, world. Source: IMAGE 2.2

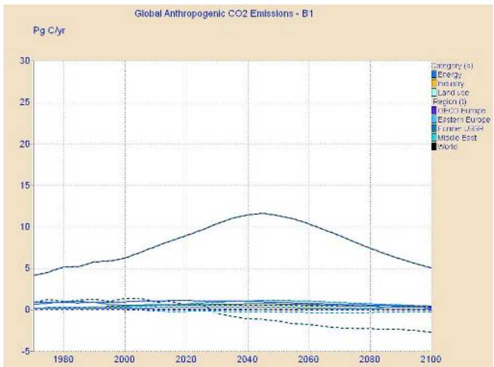


Figure X: Global Anthropogenic CO2 Emissions B1 IPCC-SRES between 1970 and 2100, OECD Europe, Eastern Europe, Former USSR, Middle East and World Source: IMAGE 2.2

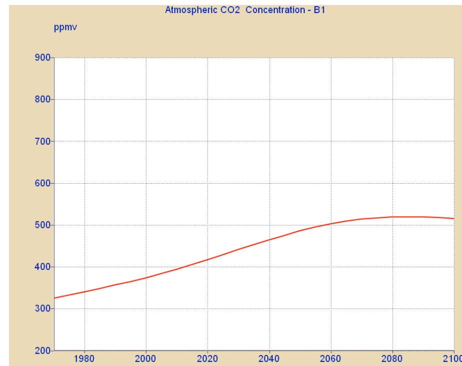


Figure X: Atmospheric CO2 Emissions B1 IPCC-SRES between 1970 and 2100, OECD Europe, Eastern Europe, Former USSR, Middle East and World Source: IMAGE 2.2

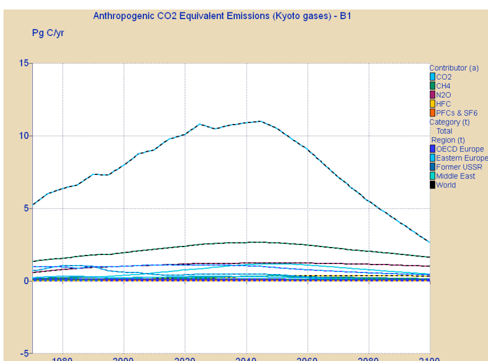


Figure X: Anthropogenic CO2 Equivalent Emissions (Kyoto gases) B1 IPCC-SRES between 1970 and 2100, OECD Europe, Eastern Europe, Former USSR, Middle East and World Source: IMAGE 2.2

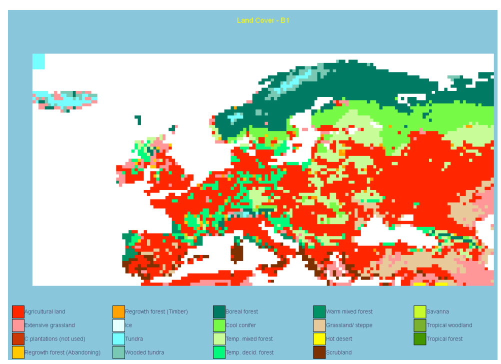


Figure X: Land cover, B1 IPCC-SRES between 1970 and 2100, OECD Europe, Eastern Europe, Former USSR, Middle East and World Source: IMAGE 2.2

Figure X: Rate temperature change, B1 IPCC-SRES between 2000 and 2100 World Source: IMAGE 2.2

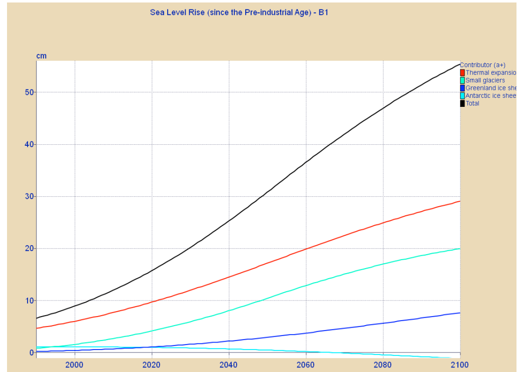


Figure X: Sea Level Rise, B1 IPCC-SRES between 2000 and 2100 World Source: IMAGE 2.2

Annex VI. Inputs for T3.4 Integrated scenario development

I. Global datasets

- *applicable over the entire BlackSea Basin*
- *See also EG Deliverable on Remote sending ¨enviroGRIDS_D24.pdf¨*

1. FAO:

FAOSTAT agricultural and forestry statistics: http://faostat.fao.org/default.aspx

1.1 FAOSTAT data source: http://faostat.fao.org/site/567/default.aspx#ancor

2. NASA, MODIS – land cover products

Land Cover Type Yearly L3 Global 500 m overview: https://lpdaac.usgs.gov/lpdaac/products/modis_products_table/land_cover/yearly_l3_global_500_m/mcd12q1

2.1 Land Cover Type Yearly download data: https://wist.echo.nasa.gov/

3. NASA, MODIS – NPP, vegetation

NPP DAAC http://daac.ornl.gov/NPP/npp_home.html

NPP DAAC Webserver: http://webmap.ornl.gov/daac/viewer.htm?SOURCE=NPP

3.1 Annual MODIS NPP download improved data: http://images.ntsg.umt.edu/

Eight-day NPP download data: https://wist.echo.nasa.gov/

3.2 Global land cover dynamics (vegetation phenology) download: https://wist.echo.nasa.gov/

4. **NASA, OceanColour**

Images on chlorophyll content in sea water (might be relevant, but not at present) http://oceancolor.gsfc.nasa.gov/cgi/browse.pl?per=MO&day=11900&sub=level3&prm=CHL&set=10&ndx=0&mon=12234&sen=am&rad=0&frc=0&dnm=D@M

5. NOAA

NightLight imagery

5.1 Download data http://www.ngdc.noaa.gov/dmsp/global_composites_v2.html

6. ESA,

6.1 GlobCover 2005

6.2 GlobCorine 2009 (latest version)

7. STRM DEM

8. UNEP World database on protected areas

8.1 Global Protected areas download annually updated data: http://www.wdpa.org/AnnualRelDownloads.aspx

9. TeleAtlas

9.1 Roads and railways. http://www.teleatlas.com/index.htm Data has to be paid.

9.2 Product, Effective mesh size should be available through EEA

II. EEA/European datasets

- *Data useful for model-testing*
- *Also for certain region-specific drivers*

1. EUROSTAT

2. EEA CorineLC products

2.1 CORILIS

3. EEA River networks …

4. JRC Soil

5. DEM

6. EEA NATURA2000

6.1 NATURILIS

III. Documents and articles

1. Global scenarios covering Black Sea Basin

1.1 IPCC-SRESS scenarios (our main input for scenario markers to follow) http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=434

1.2 Global Scenario group ¨Great transition scenarios¨ (possible inputs on macro-scale e.g. west versus east Europe) http://www.gsg.org/

1.3 Millennium ecosystem assessment scenarios (possible inputs)

1.4 Global outlook scenarios (possible inputs)

2. European scenarios covering (part) of Black Sea Basin

2.1 SENSOR http://www.sensor-ip.org/

2.2 SEAMLESS http://www.seamless-ip.org/

3. Regional scenarios covering (part) of Black Sea Basin

2.1 CLAVIER FP6 project climate change in Danube, high resolution http://www.clavier-eu.org/

2.2 Balaton lake scenarios