EU FP 6 Project
GOCE 037063 with DG Environment

GEO-BENE

Global Earth Observation
-Benefit Estimation: Now, Next and Emerging

STREP

PRIORITY [1.1.6.3]
[Global Change and Ecosystems]

DELIVERABLE D13 (T36)
GEO-BENE FINAL REPORT

Due date of deliverable: T36

Start date of project: 1 July 2006 Duration: 36 Months

Organization name of lead contractor for this deliverable:
International Institute for Applied Systems Analysis (IIASA)

Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Purpose of the Deliverable D13

The purpose of the GEO-BENE Deliverable D13 (T36) "GEO-BENE Final Report" is twofold: 1) to provide a scoping (policy) article on the entire project and to present a summary of selected results of the GEO-BENE project; and 2) to present a compilation of GEO-BENE outputs. The latter will be presented in the form of peer-reviewed articles, as well as working papers and reports that have been conducted and published during the life time of the GEO-BENE Project (2006 – 2009). We will start this presentation with overview posters that were mainly presented at the GEO-BENE Final Meeting in the framework of the ISRSE conference in Stresa, Italy (May 2009). A complete listing of GEO-BENE publications up to the beginning of 2010 is also presented in this report.

Michael Obersteiner
Florian Kraxner

Contents

GEO-BENE FINAL REPORT

1. On the Value of Global Earth Observations

Background

Mankind has never been so populous, technically equipped, economically and culturally integrated as today. In the 21st century we are confronted with a panoply of challenges to manage the Earth System. These global challenges range from multi-hazard disaster management, new infectious diseases, environmental changes triggered by unprecedented interference in the major bio-geochemical cycles and ecosystems all the way to basic food security issues on a warming planet. Preparing for such a massive confluence of potential global-scale failures involves highly complex planning, coordination and international cooperation. The global change challenge can only be tackled effectively and efficiently if plans and decisions are based on reliable information and cutting-edge science. However, at the beginning of the 21st century we lack the basic global observations and information processing infrastructure to at least monitor and document many of the important ongoing global changes with sufficient accuracy. Consequently, the improvement of our basic understanding of the major Earth system processes and process changes are constrained by information paucity. In this decision-making environment, Earth system management is still an erratic business, based on the gut feeling of a few powerful individuals rather than on precise and robust science. Although environmental and security-related international conventions are main drivers of global Earth observations, the space and in-situ observing instruments are far from optimal deployment in view of the value of the decisions that are at stake today. This is because of the large uncertainties involved in the quantification of the benefits from investment in such observing assets, which underlines the importance of ex ante benefit assessments of Earth Observation strategies to resolve at least some of this uncertainty.

The history and ongoing controversy on the interpretation of the United Nations Convention for Climate Change's (UNFCCC) "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" serves as a typical example of potentially incorrect, high-impact decision-making informed by science based on poor data. Although the Global Climate Observing System (GCOS) is considered to be advanced in its implementation, the benefit of reducing uncertainty in climate predictions by better informed models through an improved global climate observing systems appears worth the effort. The incremental annually recurring costs of the planned Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2004) is estimated to be in the range of 600-700 mill. US$, which can be compared to the average annual incremental mitigation cost of some 30 bill. US$ to keep the option open to meet low stabilization targets.

Global Earth Observations and GEO-BENE

At the two Earth Summits in Brazil and Johannesburg, it was realized that complex Earth processes can be adequately measured to support environmental decision-making only by linking and coordinating the current observing systems. Since then, a number of Earth Observation Summits were held, which established the intergovernmental Group on Earth Observations (GEO). GEO provides the platform to coordinate observation strategies and investment for improved decision-making in nine so-called societal benefit areas: Disasters, Health, Energy, Climate, Water, Weather, Ecosystems, Agriculture and Biodiversity.

Prioritization of coordinating actions and investments to build the Global Earth Observation System of Systems (GEOSS), which GEO is mandated to create, necessitates integrated assessment of the economic, social and environmental benefits and costs of improved integration of existing observing assets or investments into new observing systems. The EC project GEO-BENE (Global Earth Observations – Benefit Estimation Now, Next and Emerging) developed methodologies and analytical tools and applied these to assess the societal benefits of actions improving GEOSS in all of its nine societal benefit areas following a benefit chain concept. The basic idea is that the costs incurred by an incremental improvement in the observing system - including data collection, interpretation and information-sharing aspects - will result in benefits through information cost reduction or better informed decisions, which in turn will lead to improved societal outcomes. This incremental value is judged against the incremental cost. Since in many cases there are large uncertainties in the estimation of both the costs and especially the benefits, and it may not be possible to express them in comparable monetary terms, we show how order-of-magnitude approaches and a qualitative understanding of the shape of the cost-benefit relationships can help guide rational investment decisions in Earth Observation Systems.

There are mainly two source categories for cost reductions in information delivery from building GEOSS. The first relates to cost reduction from economies of scale of a global or large observing system vis-à-vis the currently prevailing patchwork system of national or regional observing systems. For example GEO-BENE has shown, that the costs and implicit uncertainty of the sum of individual national forest carbon assessments aimed at policies of avoided deforestation is much larger than the cost of one consistent global forest observatory such as that envisaged by the GEO's forest carbon tracking task. The second source of cost reduction from GEOSS related to economies of scope. GEOSS, as an integrated observing system, will decrease the net cost of observing one object as a result of combining systems designed to observe a number of different objects. MERIS (MEdium Resolution Imaging Spectrometer) was originally designed to observe ocean color without any expectations of benefits from observing terrestrial ecosystems. However, today the most up-to-date land cover product comes from GLOBCOVER based on MERIS observations. In this case, an ocean observing system helped to produce useful information for managing terrestrial ecosystem just at processing costs. Economies of scope are also produced when observing systems are combined. GEO-BENE's Geo-Wiki Project (www.geo-wiki.org) is an observing system of a global network of volunteers (human sensors), who wish to help improve the quality of global land cover maps derived primarily from satellite images. Since large differences occur between existing global land cover maps and current ecosystem and land use science lacks crucial accurate data (e.g., to determine the potential of additional agricultural land available to grow crops in Africa), volunteers are asked to review hotspot maps of global land cover disagreement and determine, based on what they actually see in Google Earth and their local knowledge, if the land cover maps are correct. Their input is recorded in a database, along with uploaded photos, to be used in the future for the creation of a new and improved hybrid global land cover map. GEO-BENE has shown that the value of improved global land resource information is of particular importance for the estimation of indirect land use effects of changes in agriculture, forestry as well as biofuel policies. A major problem in such impact assessments is uncertainty in basic land cover information. According to GEO-BENE's analysis the cost difference of global agriculture, forestry and biomass production for 2030 is estimated to be in the range of 350 billion US$/year depending on the land reserve estimates based on different land cover products.

Economies of scale and scope cannot only be reaped from cost reduction of building GEOSS, but also from increased benefit generation. The simultaneity of challenges from global social and environmental change requires an integrated decision framework that needs to be matched by a global system of systems approach on the observation side and interoperability of data streams. In a case study for South Africa, for example, GEO-BENE investigated the benefits of improved land cover information for biodiversity protection. Decision-making processes are typically supported by integrated land management models identifying priority areas for conservation action (e.g. land acquisition, land stewardship and management, easements, finer scale planning). These models require spatially explicit data on the distribution of biodiversity (species, ecosystems), threats facing biodiversity (e.g. land conversion) and current conservation efforts. Extrapolating the South African experience to global scales from having finer scale data enabling minimum area biodiversity planning, the expected cost for the information system would be 6 times smaller than the expected benefits of some 1.2 billion US$.

Nation states increasingly come to the realization that they can benefit from cooperation when addressing global-scale problems. Global environmental agreements have been major drivers for Earth Observation in the civil sector. Earth Observations do not only establish legitimacy of global environmental agreements, as it was the case for the Montreal protocol, but also help in the planning of collective actions and provide the necessary monitoring and evaluation of implementation success. Under the UNFCCC, international financial transfers are currently discussed to jointly avoid GHG emissions from deforestation and degradation (REDD). One of the major concerns about implementing REDD policies are leakage effects, where conservation measures to protect one forest would lead to the deforestation in an adjacent forest. GEO-BENE results show that leakage effects can either be avoided by payments to conserve all forests in a particular region amounting to a yearly cost of some 30 billion US$ or under appropriate high resolution forest monitoring amounting cost of avoided deforestation would amount to some 4 billion US$ per year.

Conclusion

Earth Observations are key for the management of global scale societal and environmental issues. Investments in Global Earth Observation assets do not keep pace with the requirements stemming from managing the major interacting global challenges ranging from the immediate food and water crisis all the way to more distant risks associated with climate disruptions. According to our calculations, the societal benefits from improved and globally coordinated Earth Observations are in the majority of case studies orders of magnitudes higher than their production costs. With national contributions to build GEOSS coming increasingly under pressure, it is becoming important to be able to quantify their potential benefits and document realized impacts. Thus, benefit assessments such as those conducted by the GEO-BENE project need to be communicated to decision-makers and user communities. Spin-off activities from GEO-BENE acted as boundary organizations interfacing between the data providers and users such as businesses, governmental and non-governmental organizations. More such initiatives need to be created under the supervision of GEO's user interface and capacity building committee.

One such interface, coordinated by GEO's Science and Technology Committee, is that of observation-science-users. Continuous and comprehensive monitoring of the Earth through GEOSS carries the potential for a major development in global change science. Not only will science generate more and more robust knowledge through data assimilation into ever larger and integrated Earth system models, but also new scientific fields will emerge such as the new discipline of energy meteorology. Finally, GEOSS-informed Earth system science tools will become available for use in local and global decision-making. These scientific benefits are among the least visible and predictable today, but they might emerge as the most important and pertinent ones from GEOSS.

Literature

http://www.geo-bene.eu

B. Walker *et al.*, *Science* **325**, 1345-1346 (2009).

S. Rao, "Scaling up low carbon investments - focus on renewable energy in Latin America" (Global Renewable Energy Forum, Working Paper, 18 pp, 2009).

H. Böttcher *et al.*, *Carbon Balance and Management* **4,** 7 (2009).

S. Fritz *et al., Remote Sensing* **1**, 345-354 (2009).

T. D. Searchinger *et al., Science* **325**, 527-528 (2009).

S. Fritz, P. Havlik, U. A. Schneider, E. Schmid, M. Obersteiner, "Uncertainties in global land cover data and its implications for climate change mitigation policies assessment" *Proceedings of International Symposium on Remote Sensing of Environment (ISRSE), Stresa, Italy* (2009).

B. Reyers *et al., Ecology and Society* **14:**1, 38 (2009).

J. A. Bouma, H. J. van der Woerd, O. J. Kuik, *J. Environ. Manage.* **90**, 2, 1280-1288 (2009).

2. GEO-BENE on a Glance

Global Earth Observation

Global Earth Observation offer important societal benefits in a wide range of areas. For example, it can help agri-business boost yields in agriculture, optimize the deployment of energy systems or provide valuable information for immediate help in events of natural disasters.. The GEO-BENE (Global Earth Observation – Benefit Estimation: Now, Next and Emerging) project carried out the world's first systematic study of these benefits which accrue through the use of information from Global Earth Observation Systems. .

GEO-BENE brought together 12 partners from 5 EU countries plus Switzerland, South Africa, and Japan with the aim of developing methods and tools designed to clarify the economic and social benefits of Global Earth Observation.
The project covers all of the nine societal benefit areas of GEO: disasters, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity.

Weather

Even with current technology, we still cannot provide completely accurate weather forecasts, and every year many people die and vast amounts of money are spent as a result. Being able to provide reliable weather forecasts would be a huge advantage for almost every European industry. GEO-BENE researchers have investigated the impact of climate change on weather and crop yields in the future, and developed a tool to quantify the value of weather-related satellite information.

Biodiversity

Global Earth Observation is also a useful tool to survey biodiversity and protect our ecosystems. Ecosystems form the basis of life on Earth. They have evolved over millions of years, giving us food, air, water and energy. But they have been under threat for a number of years from pollution, climate change and intensive agricultural methods. Global Earth Observation can give us state-of-the-art information about the current condition of ecosystems around the world in order to promote sustainability and good resource management.

Analysis of biodiversity in GEO-BENE has focused on the creation of a comprehensive observation system for biodiversity that can be used by natural resource planners, governments, scientists and researchers. Extensive data on biodiversity factors is not widely available in many developing countries, yet these nations are home to most of the world's unprotected biodiversity.

GEO-BENE research in South Africa revealed that poor quality data often led decision makers to overestimate the amount of land needed for conservation areas. Managing this extra land for conservation purposes costs a lot of money. Therefore, investing in the gathering of high quality data will help to make the establishment and management of conservation areas more cost effective and free up more land for other uses.

Agriculture

In the area of agriculture, GEO-BENE's aim is to have a global land use and food distribution information service that can enable sustainable development through wise planning of land resources. For example, research so far has shown that the planned biofuels programmes of Europe, the US, Brazil, China and India may cost billions of euros more than anticipated.

Project results have also shown the benefits of using Global Earth Observation to identify geographic centres of malnutrition to efficiently plan aid operations. Other results from the project include the establishment of a database for global data modelling, establishing an EPIC model (a system that can simulate agricultural ecosystem processes), analysing global nitrogen levels in cropland and a study of the impact of climate change on food production and agricultural water use around the world.

Energy/Water

Energy is vital to our day-to-day lives – in the food we cook, the work we do, our places of entertainment, our homes, and our transport systems. It is also responsible for much of the world's current high pollution levels. GEO-BENE found that more certainty about climate sensitivity through the acquisition of better Global Earth Observation data will lead to better informed climate change and energy policies and more stable CO2 prices. Under these conditions, energy producers' profits would be expected to rise, while CO2 emissions are likely to fall.

Water conservation is becoming more and more important as a result of global warming and desertification in certain parts of the world. The EU needs clear water conservation policies and water resource management. GEO-BENE surveys have highlighted areas of emerging water scarcity and availability using remote sensing information. This technique increases the availability of water quality information such as early warnings of water shortages.

Disasters

The project is also studying a range of natural and man-made hazards such as forest fires and earthquakes to help developing better disaster management policies.

In the health field, GEO-BENE is investigating how Global Earth Observation information on factors such as climate and weather could help health systems detect disease epidemics early on. Global Earth Observation data could then be used to plan vaccination programmes, if necessary. Another GEO-BENE study is looking at whether the season and weather affect the risk of a patient dying from acute myocardial infarction.

Impact

GEO-BENE has had a high public impact with considerable media coverage in journals such as *Nature* and *Science*. It has also had a direct impact on government policies in close collaboration with the Group on Earth Observation (GEO), for example the UK's Gallagher Review on Biofuels, and on World Bank strategies and financing. Special focus has also been put on policy processes under the UNFCCC, such as Avoided Deforestation. Thanks to GEO-BENE's work, the usefulness of benefit assessment has now been recognized by the parties of GEO.

3. Selected GEO-BENE Results

3.1 What are the results of GEO-BENE's analyses of biodiversity within the ecosystems SBA?

When one compares the cost estimate of some 200 million Euros for an improved biodiversity observing system with the foregone benefits of some 1.2 billion euros of better planning based on fine scale data it appears that the benefits of a GEO based biodiversity observing network outweigh the costs by almost an order of magnitude.

Improved data for conservation planning

This case study demonstrates the benefits of replacing commonly available coarse scale global data (the non GEOSS scenario) with finer scale data in conservation decision making. These finer scale data are comparable with those expected from GEOSS and can thus be used to estimate the potential benefits of GEOSS data. We then contrast the benefits of these data improvements with the costs of the improvements.

South Africa, like most countries, is attempting to increase the amount of land and water area under some form of conservation (e.g. national parks, conservancies, easements). The current extent of the formal protected areas network is approximately 6% and biased towards mountainous or tourist areas often with low agricultural potential resulting in large gaps in the national conservation area network. Efforts to reduce these gaps must ensure that new protected areas are optimally located so as to represent a full sample of the country's biodiversity in the most cost efficient manner. A sophisticated set of systematic conservation planning tools is available for this purpose. These tools identify spatially explicit priority areas for conservation action (e.g. land acquisition, land stewardship and management, easements, finer scale planning) and feed into land use decision making processes across the country from local to national scales supported by legislation. These tools require spatially explicit data on the distribution of biodiversity (species, ecosystems), threats facing biodiversity (e.g. land conversion, alien invasive plants) and current conservation efforts. These data are often available at coarse (1:1 000 000) global or continental scales (e.g. WWF ecoregions, African Mammal Databank (http://www.gisbau.uniroma1.it/amd/index.htm). Several authors have highlighted that comprehensive data sets such as point locality data for specific taxa and fine-scale land class and habitat transformation maps are invariably lacking, especially in developing countries which harbor most of the world's unprotected and vulnerable biodiversity. South Africa is fortunate as an exception to this rule in that it is both a "biodiversity-rich" country and has relatively good biodiversity data. These national scale data (1:250 000) were used to conduct a National Spatial Biodiversity Assessment, which identified broad scale priority areas for national conservation action. As part of this assessment, a comparison was made of the outputs of the NSBA (the GEOSS scenario) and the outputs of the same assessment based on the coarse global scale data (the non GEOSS scenario), in an effort to assess the benefits of improved national scale data.

The coarse scale data led to a 9% overestimate of priority areas identified by the national scale data and a 10% underestimate in other areas. Turning these differences into benefit estimates is complex. A simple proxy would be the cost consequences of these over or underestimates. Estimates of conservation costs developed in the Cape Floristic Region of South Africa found that implementing a conservation area network (of protected areas and other off reserve mechanisms) of 2.8 million hectares would result in a once off cost of 627 million Euros with annual costs totaling 29 million Euros [All costs are calculated in Euros for the year 2000 using annual national inflation rates and 2000 exchange rates]. By just applying these costs to the priority areas identified in the NSBA a 9% (or 5 million ha) overestimate would cost over 1.2 billion Euros in once off costs with annual management costs of the overestimated area equivalent to 57 million Euros. It is important to note that the priority areas identified in the NSBA were not intended to become a conservation area network necessarily, but rather to direct future sub-national conservation efforts and finer scale conservation plans. The cost differences are however a useful indication of the potential benefits of improved data. The costs or loss of benefits associated with the underestimates are more complex to assess and are still in progress.

Calculating the costs associated with improved datasets presents a challenge as these data have been built up over a number of years by a number of institutions. The datasets are also highly variable in the time and effort taken to collate them. Costs of biodiversity data that are available are provided in the Table 1.

Table 1: The cost of obtaining biodiversity observations.

Database	Cost (in Euros)[1]	Source
Global land cover (GLC)	2 million	Bartholome, 2004
South Africa National Land Cover (SANLC)	1.76 million	M Thompson pers comm
South Africa Local scale land cover	9000 for an area of 20 000km2	Rouget et al 2006
National British bird atlas	1.43 million	www.bto.org/**bird atlas**/fundraising/frbritain.htm
National SA Bird Atlas	222 000	sabap2.adu.org.za/faq.php
Uganda Local scale species data	1.12 million for an area of 15 000km2	(Balmford and Gaston 1999)

The coarse and fine scale analyses described above used the GLC and SANLC datasets described in Table 1, respectively. SANLC covers an area of less than 1% of the Earth's land surface covered by the GLC. Assuming a linear relationship between area covered and cost we extrapolated that the costs of developing a similar data layer to the SANLC at a global scale would be 100 times more than the GLC (approximately 200 million euros). When one compares this cost estimate (200 million euros) with the costs of not having finer scale data (1.2 billion euros) it appears that the benefits of improved data outweigh the costs by almost an order of magnitude.

Land cover data are only one input data layer in conservation decision making processes, and arguably even finer scale data than SANLC would be required for conservation decisions. Table 1 provides estimates of the costs of other finer scale biodiversity datasets. These local scale costs allow us to begin to understand the relationship between costs of data development and the benefits of improved data. It would appear that the benefits of moving from global to national data are large and provide significant savings in land acquisition and management costs of conservation. Work is currently in progress to see if these benefits begin to saturate with increased observational effort in collecting local scale data. The costs of these data improvements are variable and seem to depend on the scale and the type of biodiversity data collected. Simple maps of land cover and vegetation types appear to represent a good investment at all scales, while costs of data on detailed species surveys increase significantly at local scales. Despite these costs, demonstrate that investment in high quality biodiversity inventories at a local scale are a very good conservation investment and help ensure cost efficiency in the implementation of expanded protected areas and their management. Given these findings, there is probably still scope for higher-resolution observational effort to yield net benefits to conservation planning in South Africa.

Ref: Steffen Fritz, Robert J. Scholes, Michael Obersteiner, Jetske Bouma and Belinda Reyers, 2008. A conceptual framework for assessing the benefits of a Global Earth Observation System of Systems. IEEE Transactions on Geoscience and Remote Sensing. In press.

3.2. In the area of agriculture, GEO-BENE's aim was to to assess the benefits of a global land use information system to ensure sustainable development through improved planning of land resources. What are the results here?

a. The current controversy over biofuels versus food security and deforestation is symptomatic for the current uncertainties about our globe´s free land resources. GEOBENE research shows that depending on what land reserve we assume (currently a large unknown due to lack of a proper global land inventory system) the costs of the currently envisaged biofuel programs of the US, EUROPE, BRAZIL, CHINA and INDIA might turn out to be up to 36 billion Euros more expensive than currently anticipated.

b. As a second example GEOBENE research shows the benefit of combining a geographically explicit human observing system (calories intake in Africa) with an agriculture observing system combined with modeling. Using better weather and climate forecasts allows to project geographic hot spots of malnutrition. Ex ante coordination and planning of aid operations or even the implementation of anticipative agricultural management systems would substantially reduce to number of people going hungry in the region.

3.3. What are the conclusions of the survey on the Impact of Climate Change Policy Uncertainty under Energy and Water?

Energy

Climate policy might lead to high adaptation costs in the energy sector. More certainty about climate sensitivity through the acquisition of better earth observation data will lead to better informed climate change policy and thus to lower compliance costs with climate policies and more stable CO2 prices in regional or global carbon markets. This leads to a high value of information according to both criteria used in this study: there are gains for producers/investors and reduced emissions. (See also the corresponding section about the results on http://www.geo-bene.eu/?q=node/1797).

Fuss S, Johansson D, Szolgayova J, Obersteiner M (2009). Impact of climate policy uncertainty on the adoption of electricity generating technologies. Energy Policy, 37(2):733-743.

Water

Virtual water has become an important source of water to mitigate regional water scarcity. GEO-BENE's GEO task on socio-economic data revealed the benefit of trade (data) in the management of natural resources. GEOBENE results show that China has imported an increasing amount of virtual water in recent years. This is partly a result of the emerging water scarcity. Virtual water import may become a mitigation approach to cope with the impact of climate change on water resources in the future. Climate change will affect the global hydrological cycles; hence, it will affect the available water for agriculture, particularly for rainfed agriculture. In regions where local water resources cannot support sufficient food production, virtual water will have to play a key role in guaranteeing the local food security. Otherwise, these regions will remain hunger hot spots in the future.

Refs.:

Liu, J., Savenije, H. H. G., 2008a. Food consumption patterns and their effect on water requirement in China. Hydrology and Earth System Sciences 12 (3) 887.

Liu, J., Savenije, H. H. G., 2008b. Time to break the silence around virtual-water imports. Nature 453 587.

Liu, J., Zehnder, A. J. B., Yang, H., 2007. Historical trends in China's virtual water trade. Water International 32 (1) 78-90.

3.4. What are the conclusions of the Value of Information for Water Quality Management in the North Sea and Satellite-based Information for Great Barrier Reef Management surveys?

"***Since this is less than the costs of establishing and maintaining an early warning system, investing in an information system for preventing potentially harmful algal blooms seems to be an economically efficient investment to make. Outcomes do strongly depend on the assumed accuracy of information (the type II error) and the***

variance of the respondent results. Accounting for the range in respondent perceptions, the 95% confidence interval for the value of information ranges from 34,000-103,000 Euros a week. Given a break-even point of approximately 50,000 Euros a week, there is a 75% probability that benefits exceed costs. However, if the type II error is larger than 10%, this is no longer the case. In fact, with a type II error of 20%, the value of information becomes nil. Hence, for assessing the value of information it is important to account for the accuracy of the information system, and the range in expert perceptions as well."

North Sea Water quality

An example of using expert and stakeholder consultation for assessing the value of information is provided by the North Sea water quality case. At present, water quality monitoring in the North Sea is mostly based on *in situ* measurement. With GEOSS-type integrated remote sensing information, the temporal and geographical availability of water quality information increases and early warning information becomes available with regard to the prediction of excessive algal bloom. To estimate how such information is required to improve the effectiveness of water quality management in the North Sea we developed a questionnaire that we sent to 25 key decision makers, experts and stakeholders. Inspired by we asked decision makers to quantitatively estimate how they expected improved EO information to reduce the uncertainty of their decision-making. The response rate was 80%. Table 2 shows the main results.

Table 2: The added value of Remote Sensing information for water quality in the North Sea

	Eutrophication		Excessive algal bloom		Sea water clarity	
	Present	*With GEOSS*	*Present*	*With GEOSS*	*Present*	*With GEOSS*
Average expectation of water quality being well monitored	63%	75%	50%	73%	26%	69%
Range in answers	50-100%	80-100%	10-90%	50-100%	10-50%	20-90%

Source: Bouma and Van der Woerd (2007)

The large range in answers is partly related to the differences between stakeholders and experts: leaving out the stakeholders strongly reduces the answer range. To assess the value of information we had to link this information to the potential welfare impacts of possible changes in decision making. In the case of eutrophication and sea water clarity, decision makers could basically do little with the additional information and the main welfare impact was a reduction in monitoring costs. For the example of excessive algal bloom, however better information makes it possible to transfer fishing nets preventively at 10% of the damage costs, whereas without preventive action excessive algal bloom is expected to cause economic damage of approximately 20 million euro every 5 years.

To calculate the economic value of an early warning system for preventing potentially harmful algal blooms, we used Bayesian Decision Theory. Taking the information presented in Table 3 as the conditional likelihood of information correctly predicting state 1 (potentially harmful algal bloom) and assuming a type II error of 10% (i.e. the probability that the information system incorrectly predicts potentially harmful algal bloom), we could estimate the value of information. Basically, with a 2% probability per week of having potentially harmful algal blooms (for a critical period of approximately 10 weeks), the value of an early warning system would be 74,000 euro/week. Since this is less than the costs of establishing and maintaining an early warning system, investing in an information system for preventing potentially harmful algal blooms seems to be an economically efficient investment to make.

Outcomes do strongly depend on the assumed accuracy of information (the type II error) and the variance of the respondent results. Accounting for the range in respondent perceptions, the 95% confidence interval for the value of information ranges from 34,000-103,000 Euros a week. Given a break-even point of approximately 50,000 Euros a week, there is a 75% probability that benefits exceed costs. However, if the type II error is larger than 10%, this is no longer the case. In fact, with a type II error of 20%, the value of information becomes nil. Hence, for assessing the value of information it is important to account for the accuracy of the information system, and the range in expert perceptions as well.

Ref: Steffen Fritz, Robert J. Scholes, Michael Obersteiner, Jetske Bouma and Belinda Reyers, 2008. A conceptual framework for assessing the benefits of a Global Earth Observation System of Systems. IEEE Transactions on Geoscience and Remote Sensing. In press.

3.5. What has been the overall impact of the project? Has it had many positive conclusions and results so far?

High Scientific Impact:

GEO-BENE has produced a large number of peer-reviewed journal articles, which were published already during the project. In addition, the number of Journal Articles in Top Science Journals such as Nature, Science, PNAS is worth particular mentioning. These articles have also received considerable media coverage (see Activity Report T36 and GEO-BENE Publication list). There are still a number of publications which are still under review and a few manuscripts are still under preparation indicating that there will be a longer-lasting direct impact of GEOBENE.

Policy Impact

GEOBENE analysis has had direct impact on policies e.g. Galagher review on biofuels, UK Dept. of Transport (GB analysis on uncertainties on land reserves impacted on the decision to keep biofuel targets adaptive), DG ENV's climate policy, DEFRA and World Bank strategies on REDD policy strategies and financing, AND through presentations and participation in the GEO process the relevance of benefit assessment has now been recognized and received special priority even from the level of the executive committee of GEO. GEOBENE members are actively involved in a number of GEO tasks and Committees ensuring a continued impact of GEOBENE.

4. Overview on GEO-BENE Deliverables D1-D13 (T1-T36)

4.1. Deliverable (D1) "Detailed Project Workplan"

By the end of *T8 the first (D1) Deliverable "Detailed Project Workplan"* was due. In accordance with EC in Brussels D1 has been delivered together with D3. The purpose of this deliverable is to augment the description of work document as a supplementary document for detailed planning within the consortium. D1 describes concrete projects and tasks within the GEO-BENE consortium putting special emphasis on the second periodic reporting period. While the first year of GEO-BENE concentrated on the development of methodologies, analytical tools and data compilations suitable to analyse GEO benefits, the second year will be dedicated to concrete applications, and finally the third year will be used to concentrate on integration and aggregation. The framework provided by D1 was developed in order to be dynamically up-dated all the way to the end of the project. Up-dating includes the formulation of new projects and task as well as reporting of final results by up-loading complete papers. It is the intention to write papers for each project which are suitable for submission to peer reviewed journals. These papers will be up-loaded on the GEO-BENE website and be made available to a restricted audience until the paper is accepted for publication.

D1 is delivered in a web-based form in order allow for more transparency and timeliness. To date the GEO-BENE website contains already information (incl. draft papers) on the methodologies and analytical tools which were developed in order to assess the **economic, social and environmental effects of improved quantitative and qualitative information delivered by the Global Earth Observation System of Systems (GEOSS)** for the nine benefit areas of GEO.

Material contained in D1 comprises of inter alia:

1. Theoretical models illustrating general assessment strategies and uncertainty assessments for comprehensive benefit accounting of GEO benefits in economic,

social and environmental terms at the grid (polygon) and aggregate levels using a systematic approach;

2. Elaboration of direct linkages between biophysical models and socio-economic valuation models bridging to full benefit chain of GEOs;
3. Setting up a number of tools for benefit assessments, based on a range of different quantitative and qualitative methods for benefit assessments, developing and applying value of information modelling approaches
4. Synergetic use of all relevant sources of information, to be used in a multitude of competing assessment models, with geographically explicit land information as a nucleus of the approach;
5. Design of the structure of an integrated information system directed towards ecological and environmental assessment under global change, which would meet requirements of international conventions and policy processes.

In order to achieve the operational goals of the overall objective of GEO-BENE and tackle the critical issues the following means have to be considered:

D1 contains information on template type models which were developed during the first year of the GEO-BENE project. Emphasis was put on the investigation of appropriate scientific methodologies as the foundation for the upcoming year. In the second year focus will be directed on carrying out concrete quantification of GEO benefits by carrying out detailed quantification studies within each SBA (see table 1) using the methodologies and assessment tools which were developed and are described by in D1.

These proposed studies are so called **"rifle-studies"** (the "rifle-pathway" is described in detail in the *GEO-BENE Deliverable D3 "Benefit Assessment Framework Report")* which are special selected by GEO-BENE partners. The identified and proposed studies are listed in chapter 2 of this report in more detail.

Benefit Area	Number of Studies	Consortium Partners involved
Health	4	IIASA, PIK, KTL, others…
Disasters	15	IIASA, KTL, UNIBA, CSIR, others…
Energy	7	IIASA, FELIS, BOKU, others…
Climate	4	IIASA, PIK, others…
Water	4	IVM, EAWAG, CSIR, KTL, others…
Weather	As cross-benefit area	All, others…
Ecosystems	4	IIASA, IVM, PIK, others…
Biodiversity	4	CSIR, IVM, others…
Agriculture	4	IIASA, BOKU, EAWAG, SSCRI, NIES, IFPRI, others…
Cross-sectoral	2	IIASA, IVM, FELIS, others…
Total	48	All consortium partners

Table 1: showing the number of "rifle-studies" by benefit area to be carried out within the GEO-BENE framework and indicates the consortium partner involved.

The **aim of the Web-based rifle study** representation is primarily coordination among the GEO-BENE consortium partners and subsequently to identify possibly gaps. Gaps relate to incomplete coverage of SBAs, partial benefit quantification within an assessment study, or incompleteness due to the selection of the scientific tool which can only cover a part of all potential benefits. In a subsequent step these gaps, once identified, will be filled accordingly in the third year of GEO-BENE. For these gap-filling tasks respective rifle-studies will be formulated. Gaps and uncertainties adjoined to the detailed benefit quantification cannot be identified and defined ex-ante. The gap identification and investigation of "missing" benefits will continuously be performed during the course of the GEO-BENE project. The search for new rifle studies will be guided by identifying points of incidence with maximum leverage in terms of GEO benefits.

Taking “flooding” as an example, respective rifle studies will help identifying whether the best benefits can be identified with respect to GEO improved prevention, or e.g. in the establishment of a GEO improved early flooding warning system enabled by better planning with the help of higher resolution digital elevation models, or if the optimal benefit might be reached by a better detection and prioritization of measures in the recovery phase of the disaster cycle. Hence, carrying out the rifle studies is seen as a **screening for the maximum benefit**, going along with a consequent filling of the gaps identified during the screening phase.

Although aggregation and integration are the prime tasks for the third year, some of the defined projects (rifle-studies) are already directed at integration and aggregation. However, the dynamic properties of the sub-systems have to be studied in more details. One typical question with respect to the open questions would be on how to aggregate exogenous and endogenous risks, where the latter are a function of GEOSS.

4.2. Deliverable (D2) “Web Page”

Deliverable (D2) “Web Page” (T6) is no report by its nature according to the deliverable plan of the GEO-BENE project. The inter-active GEO-BENE Web Page (http://www.geo-bene.eu) has been successfully launched at the GEO-BENE Progress Meeting (4-6 June 2006).

All “rifle studies” (see Deliverable 1) are based on the GEO-BENE web page under the section “GEO-BENE benefit assessment database” which are restricted in use for consortium partners only. This will enable the partners and the coordinator to steadily update, report and check on the current state of the respective study. Finished “rifle studies” will be uploaded as a pdf-file to the web page in order to disseminate the results to the consortium partners and possibly to a wider audience. By these means it is also planned that successively new projects will be identified by a wider user community which can then be added to the web-based data collection.

This web-based planning process will be used over all phases of the GEO-BENE project and will function as a direct communication tool between the partners in order to inform about the different activities and progress status of the individual studies and assessment tasks.

The web-based planning process aimes at a "cross-fertilization" between the single partners and user groups. This is seen as essential when dealing with a highly complex project such as GEO-BENE.

Additionally, web-blogs and discussion fora for the different sub-groups (e.g. GEO-BENE geo data info group) are hosted online in order to enhance the exchange of ideas and strengthen the communication by complementary communication tools such as telephone and video conferences.

4.3. Deliverable (D3) "Benefit Assessment Framework Report"

The Deliverable (D3) "Benefit Assessment Framework Report" (T8) has been delivered to Brussels as a product of the GEO-BENE Progress Meeting (4-6 June 2006) together with the Deliverables D2 and D3.

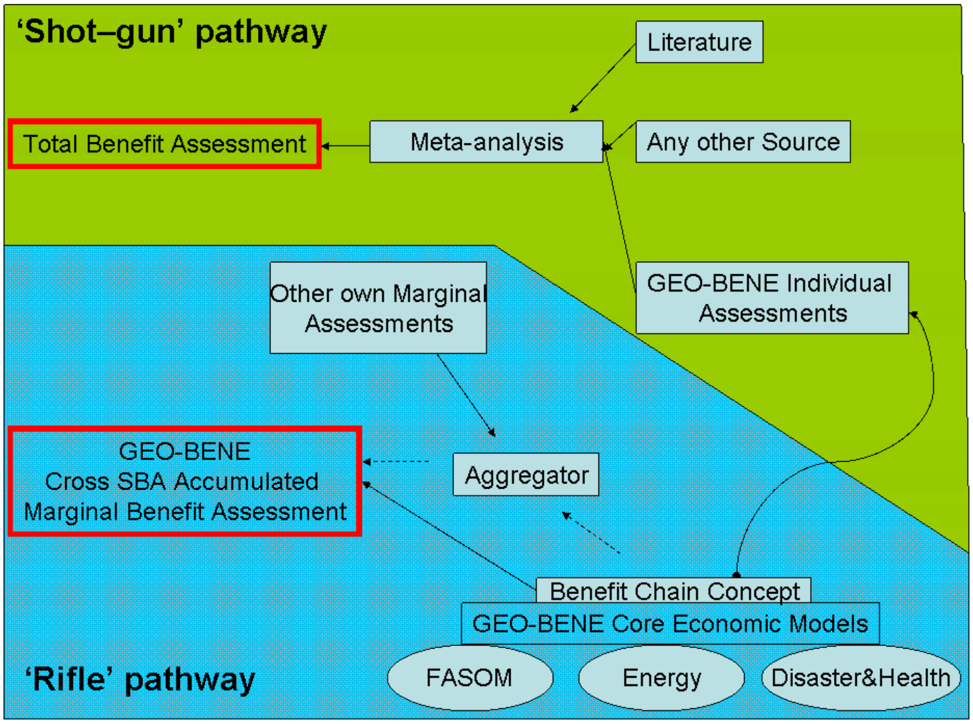
The main goal of this deliverable is to lay out the general framework for benefit assessment within GEO_BENE. The framework shall assure internal consistency of benefit analysis projects which are at this stage either finished, ongoing or planned in the individual work packages of the GEO-BENE project as well as provides a framework on compiling information from the existing literature and other sources. The benefit assessment framework has also been designed to feed directly the final GEO-BENE report which will be of a similar form as the Stern Report on the Climate Change Challenge. It has to be noticed that this document outlines only the framework of analysis. It is understood that the heterogeneity of issues and methodological challenges with the analysis of each sub-socio-economic benefit area are much larger to be covered in one framework. Thus, the framework provides guidelines and provides a roadmap for individual analysis and the integration and aggregation steps.

On the GEO-BENE Progress Meeting GEO-BENE partners agreed to a two tired benefit assessment framework (see Figure 1). Tire 1 called Shot-gun Pathway is based on meta-analysis of already existing assessments published in the peer reviewed and grey literature or from other sources as well as own GEO-BENE assessments. Tire 2 will solely be based on own assessment using GEO-BENE resources aiming at going beyond the assessment of point estimates and ranges of benefits by exploring changes in benefits at the margin and cross margins. Tire 2 type analyses we coined Rifle Pathway.

The final result of Shot-gun pathway type of analysis is the total benefit assessment. In its simplest form the result of total benefit assessment is number and its range in Billions of Euros summing the most credible assessments of GEO benefits net of double accounting (due to multiple reporting in various benefit areas). The aim, however, is that more indicators shall be used such lives saved or changes in biodiversity indices. However, at this stage no final comprehensive list of indicators was developed, although some case studies do compute alternative indicators.

The expected result from Rifle Pathway analysis is a detailed description of the 'in-house' GEO-BENE Marginal Benefit Assessment. Marginal Benefit Assessment refers to exploring the incremental improvement of benefits due to incremental addition of observing capital. It is felt that this additional work will help to mitigate the arbitrariness of baseline setting and provide good information to decision makers based on additional information. This additional information relates to questions of whether in particular SBA marginal returns are expected to be decreasing, i.e. saturation of observing capabilities to solve a particular societal problem, or be of any other shape. The shapes of these marginal benefit schedules will have strong policy implications. The methodology which GEO-BENE has devised will also have substantial potential to be applied for real investment decisions for concrete new missions.

Figure 1: Overview of the two GEO-BENE assessment pathways



The GEOSS process is going to bring improvements in EO which will consequently affect different benefit areas. These improvements can occur in a number of different ways. The improvement can be achieved though technical improvements in the field of satellite observations as well as in-situ measurements. In the field of satellite observations technical improvements such as an increased spatial resolution, an increased temporal resolution or a higher number of spectral bands can be realized. Improved, better interconnected sensors and a denser sin-situ observation network will bring further improvements. On the other hand better and more sophisticated models (e.g. global CGMs) are being developed and continuously improved. The particular emphasis of GEOSS is to foster international collaboration, international standards defined by the Open Geospatial Consortium (OGC). Furthermore, it is the task of GEOSS to identify current data gaps, to encourage model comparison and to contribute to the long term continuous earth observation. Within the Geo-Bene project these different aspects are examined in more detail.

Recommendations given by the Benefit Chain Concept Break-out group to the Geo-bene partners based on the value chain of the observing system

Recommendation 1

- GEOBENE should adopt a shared conceptual model based on marginal cost-benefit analysis
  - All projects need to at least qualitatively describe the pathway by which the increase in information leads to welfare benefit
  - Some projects [a systematically selected set] should attempt to quantify the entire chain [including the cost side], using a range of methodologies
    - System analysis/modeling/optimization
    - Stakeholder survey/expert opinion
    - Meta-analysis
    - Decision theory, value of information
    - Find out if there are any other key approaches?
  - A conceptual paper [and a set of operational rules for participants] must be prepared

Recommendation 2

- The 'topology' of the benefit-effort and the cost-effort curves in the vicinity of the current state are often as useful for policy purposes as actual valuations
  - Will more investment yield *diminishing* net returns or *increasing* returns?
  - This can be done by asking the right 'expert' questions, and should be possible even in cases where valuation is impossible

Recommendation 3

- All SBA's and case studies need to ask the question 'how will *globalization* of this information lead to greater net benefits?'
  - Local or regional case studies are useful, but they must explicitly address the issue of how they are relevant to GEOSS principles
    - How do you upscale them?

- To what extent do they depend on global information?

Recommendation 4

- All studies should undertake some form of sensitivity analysis to help understand in which variables (or which parts of the world) better observations lead to the greatest improvements of welfare [or in accuracy of information for decision-making, as a proxy]
- A ‘technology maturity’ approach may give insights into the investment strategy between SBA’s
  - Where is the learning curve steepest?

The benefit assessment framework has been set up to also deliver the most relevant results and data for the final report of GEO-BENE. The GEO-BENE final report has the aim to be policy relevant and be used for a wider policy community. Currently the benefit assessment framework both for the rifle and on the shot-gun pathway are by design strongly science driven. The communication of the results in relation to the complexities, ambivalences and the many other problems associated with the analysis will require a good strategy and additional thinking. An elaborated communication strategy has not yet been developed and will only be produced in the second half of the project. In order to be directly useful for a wider non-science and non-economic audience a number of simplifications will necessarily have to be performed. As a first step we have outlined the structure of the GEO-BENE report, which is modelled after the Stern Report on Climate Change. It is planned in Part I of the report to present the overall original framework and its simplifications for the report as well as a description of the associated problems with the presentation in a somewhat intellectual disclaimer manner.

Part II and III will present the final results of GEO-BENE first in an integrated manner and then separated by SBA. Special emphasis will be given to the integration externalities such as economies of scope produced by the GEO initiative. Part III follows the framework of the 10 Year implementation Plan. Part IV will focus on the potential policy responses for GEO in a generic manner to provide a strategic view on the issues. To write this part GEO-BENE will organize a series of small workshops – first within the consortium and then with a number of interested stakeholders from the GEO network. Finally Part V will provide the information on the signposts and economic instruments that shall be conduce to convert GEO from a club good to a truly global public good in order to finally materialize on the full potential of global socio-economic benefits.

It is envisaged that the first draft of the final report will be available by the end of 2007 in order to have a basis for additional outside partners and other stakeholders for collaboration and possible joint ownership.

4.4. Deliverable (D4) "Methodology and Tools Report"

By the end of *T20 the fourth (D4) Deliverable* "Methodology and Tools Report" was due. In accordance with EC in Brussels (given the delayed contract issue for GEO-BENE and its deriving complications for some consortium members), D4 has been delivered 1 month later by the end of T21 (March 2008).

The main goal of this deliverable is to describe the different methodologies and tools that were developed for the purposes of assessing the environmental and socio-economic benefits of GEO. GEO-BENE covers a very wide range of methods and methodologies to quantify the value of information from GEOSS. It is important for GEO-BENE to employ a wide selection of approaches to quantify the benefits of GEOSS. Clearly, there is no one silver-bullet methodology to assess benefits in all the different SBAs. In the scholarly literature (Macauley, 2006) summarizes the issues of benefit assessment most pointedly: its economic, environmental or human benefit ranges from values smaller than conventional belief might suggest while in other cases benefits turn out to be so large as to justify nearly infinite amounts of investment. The explanation lies in the characteristics of information (e.g. the SoS), how decision makers use it, and differences in how analysts model this relationship.

It is, thus, the purpose of this deliverable to

(1) Illustrate the methodologies GEO-BENE has developed;

(2) Describe the principle GEO-BENE tools that were developed;

(3) Discuss the methodological implications for decision making.

A comparative study of the different approaches will not be provided since there is already sufficient literature covering the theory of value of information and the specific applications to earth observation (e.g., Macauley, 2006). Furthermore, comparative analysis is highly contextual and can, thus, only yield reasonable insights for particular cases.

4.5. Deliverable (D5) "Status Report Year I"

By *T13 the fifth (D5) Deliverable "Status Report Year I"* was due and has been delivered to EC in Brussels at the end of August 2007, according to the time plan.

The purpose of the GEO-BENE Deliverable D5 (T13) "Status Report Year I" is to augment the description of work document and serve as a summary of the Reports D1 "Detailed Project Workplan", D2 " GEO-BENE Web Page" and D3 "Benefit Assessment Framework Report". By that it is envisaged to provide an overview on the work and studies carried out so far within the GEO-BENE framework and make available the actual status of the project.
Additionally, this report provides an overview on the model cluster that is applied in integrative way within the projects framework. The individual models are listed and the influencing parameters are shortly described. A visualization helps in understanding the interaction between the models used in GEO-BENE.

4.6. Deliverable (D6) "GEO-BENE Database Report"

By *T14 the sixth (D6) Deliverable "GEO-BENE Database Report"* was due and has been delivered to EC in Brussels at the end of September 2007, according to the time plan.

The main objective of workpackage WP4000 has been the analysis of current geomatics standards, the definition of the geodata infrastructure within the GEOBENE project as well as the definition of the interfaces between different system architecture layers. The results of this workpackage will influence the data storage and will give recommendations and definitions to other work packages.
The outcome of this task / recommendations …..

- **OGC and ISO TC211 standards**, a general review of geomatioc standards that are used world wide
- **A review of Metadata standards (like Dcand ISO 19115)** which are obviously vitally important for this project
- **A review of global spatial data infrastructures**, like UN-SDI, INSPIRE initiative etc.
- since GEO's data infrastrucutre is still developing and in discussion we will review this SDI in deliverable D8
- **GEOBENE's system architecture** that we are going to use for our spatial data and model results within our project.

4.7. Deliverable (D7) "Interim Aggregate Benefit Assessment Report"

By *T20 the seventh (D7) Deliverable "Interim Aggregate Benefit Assessment Report"* was due and has been delivered to EC in Brussels at the end of February 2008, according to the time plan.

According to the DOW WP 5000 Aggregate Benefit Assessment is comprised of the following tasks

1. In accordance with information gathered and defined in WP2000, decisions made 3100 and based on the tools build under WP 3200 supported by input data from WP 4000 carry out simulations in the respective benefit areas.
2. Describe the decision tree for the methodological and tool choice and give a precise, mathematical and database reference description of the scenario calculations. Store the simulation results such that they can be analysed for later use or independent outside assessment.
3. Describe quantitatively and qualitatively the results of the simulations for the aggregate (WP 5100) and by benefit area (WP 5200).
4. Describe synergies and trade-offs within sub-benefit areas and between GEO-Benefit areas in the production of geo-benefits.

With respect to **task 1** GEOBENE has developed in WP 2000 the GEOBENE benefit chain concept which is described in D4 deliverable and has been accepted for publication in a special issue on GEOSS with the IEEE journal. GEO-BENE has decided that in the disaster and health SBAs stochastic simulation and optimization approaches were selected to be used for benefit assessment. In the Energy SBA GEOBENE has developed an operational Real Options framework combined with Portfolio models. In the remaining SBAs GEOBENE decided to use a more deterministic framework. A large GEOBENE database was build and is fully coupled with the GEOBENE tools.

In respect to **task 2**: The methodological and tool choices are described for each case study described below. The precise mathematical descriptions and results from the assessment are provided for each case study in the form of an scientific paper to be or already submitted to scientific journals or as book contributions. The drafts of these papers are available via the internal GEO-BENE website. The individual simulation results are not stored in a centaral database, but are available upon request from each research group leader.

In respect to **task 3** GEOBENE has developed the FeliX model (ref. GEO-MACRO the wording of the GEOBENE DOW) for global integrated GEO benefit assessment. FeliX is described below with a simple illustrative example of aggregation of benefit assessment. Aggregation by individual SBAs has not yet been performed and there is ongoing discussion about the sensibility of such an exercise as GEOSS emphasises integration. This discussion links to **task 4** describing and quantifying synergies and trade-offs within sub-benefit areas and between GEO-Benefit areas. The advantage of the FeliX model is that it provides a more visually appealing representation of the interconnectedness of benefit areas.

4.8. Deliverable (D8) "Status Report Year II"

The purpose of the GEO-BENE Deliverable D8 (T25) "Status Report Year II" is to augment the description of work document and serve as a summary of the Reports D6 (T14) "GEO-BENE Database Report" and D7 (T20) "Interim Aggregate Benefit Assessment Report".

- The Deliverable D6 (GEO-BENE Data Base Report) deals with main objective of workpackage WP4000 which is the analysis of current geomatics standards, the definition of the geodata infrastructure within the GEOBENE project as well as the definition of the interfaces between different system architecture layers. The results of this workpackage will influence the data storage and will give recommendations and definitions to other work packages.

- The Deliverable D7 (Interim Aggregate Benefit Assessment Report) - according to the DOW WP 5000 Aggregate Benefit Assessment – comprises tthe following tasks

    5. In accordance with information gathered and defined in WP2000, decisions made 3100 and based on the tools build under WP 3200 supported by input data from WP 4000 carry out simulations in the respective benefit areas.

6. Describe the decision tree for the methodological and tool choice and give a precise, mathematical and database reference description of the scenario calculations. Store the simulation results such that they can be analysed for later use or independent outside assessment.
7. Describe quantitatively and qualitatively the results of the simulations for the aggregate (WP 5100) and by benefit area (WP 5200).
8. Describe synergies and trade-offs within sub-benefit areas and between GEO-Benefit areas in the production of geo-benefits.

Further, the progress of and achievements under the GEO-BENE project since D5 (T13) "Status Report Year I" is documented in this report by a section containing the updated and modified work descriptions by the consortium partners as well as a literature list of papers produced during that review period under the framework of the GEO-BENE project.
Additionally, a selection of the most recent articles and papers is attached as annex to this report.

4.9. Deliverable (D9) "Interim Benefit Assessments Report"

By the end of *T26 the ninth (D9) Deliverable* "Interim Benefit Area Assessments Report" has been delivered in due course to Brussels.

The purpose of the GEOBENE Deliverable D9 (T26) "Interim Benefit Area Assessment Report" is to present and summarize the various work done on gathering information on benefit assessment within the 9 Societal Benefit Areas. The main contributing Workpackages have been WP5000 and precedent WPs.

In order to build up adequately documented data bases on benefit assessment of Earth Observation (EO), the inter-active GEOBENE web page has been used. 2 different data-bases have been established online, aiming at different purposes: the **Public GEOSS** Benefit Assessment Database and the **GEO-BENE** Benefit Assessment Database. In the Public GEOSS Benefit Assessment Database, results of a meta-study from a wide range of GEOSS-related benefit assessment studies (e.g. literature) are compiled for public users for scientific purposes. In the GEOBENE Benefit Assessment Database, a comprehensive benefit assessment on project-internal case studies is conducted and detailed information about case studies is collected for registered consortium members. Both databases are accessible at www.geo-bene.eu

Public GEOSS Benefit Assessment Database

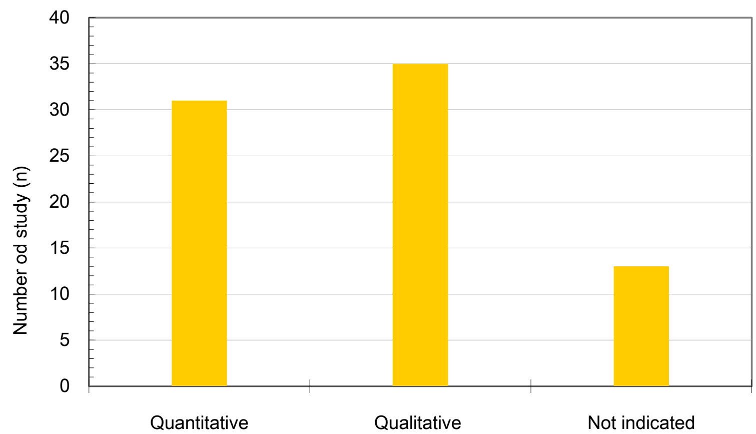
The Public GEOSS Benefit Assessment Database - as a public domain database - provides a collection of EO-related benefit assessment studies available for interested researchers, stakeholders and policy makers. In the meta-study, we collected studies, which looked at measuring qualitative as well as quantitative information on the benefits of EO, illustrating the potential of EO in the different benefit areas, and using satellite observations or in-situ measurements. Every internet user involved in EO is invited to contribute to our database and can submit studies on the above GEOSS-related topics. All papers, reports and projects which currently exist are collected and published in this database after positive review.

We designed the web-site in a way that with a few clicks and some text you can provide literature and the most relevant information. A bibliographic module of our Content Management System (CMS) makes an advanced user-friendly interface possible. Every internet user can easily navigate the online submission, exploring the database, and searching and exporting relevant information. In addition, with this advanced management system, administrative users can effectively handle various background tasks such as generating confirmation E-mails automatically, forwarding entries to specific reviewers and managing the status (published or unpublished) of submitted studies by reviewers.

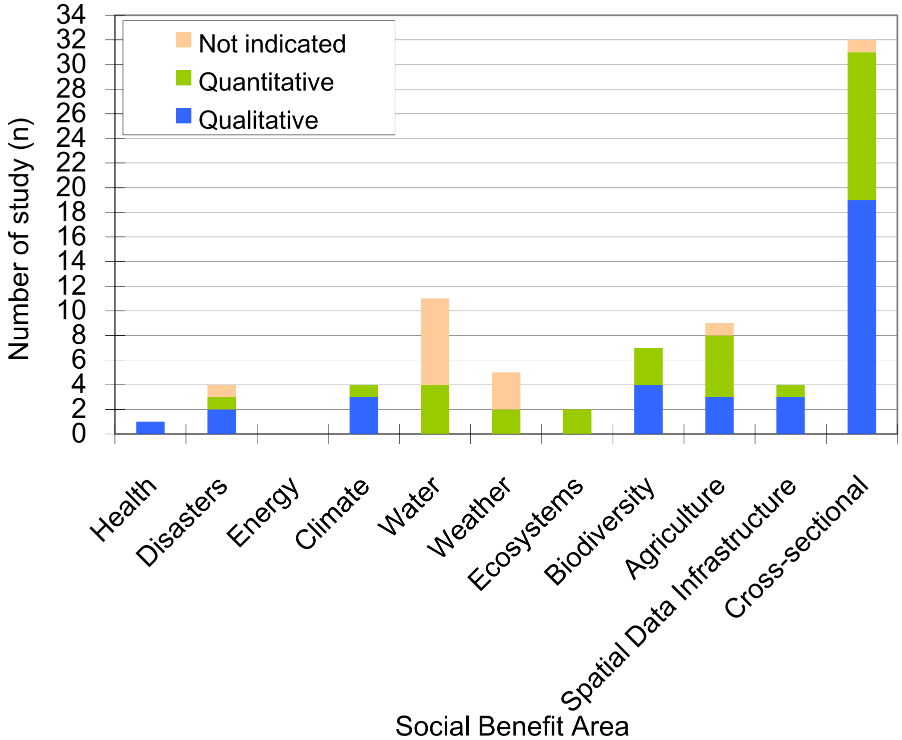
Every internet user can easily get access to the Public GEOSS Benefit Assessment Database (Public GEOSS) from the GEOBENE main page (www.geo-bene.eu). (Special login and application instructions have been provided in the GEO-BENE Deliverable D9: “Interim Benefit Area Assessments Report”.)

Overview Statistics

The overview statistics of the Public GEOSS Benefit Assessment Database is shown below. The number of studies collected in the database is classified by qualitative and quantitative assessment. The studies are also classified with Societal Benefit Area (SBAs) and indicated by assessment types (qualitative and quantitative).



The figure above (updated in T36) indicates that there is a relatively balanced distribution between qualitative and quantitative benefit assessment studies within the Public GEOSS Data Base.



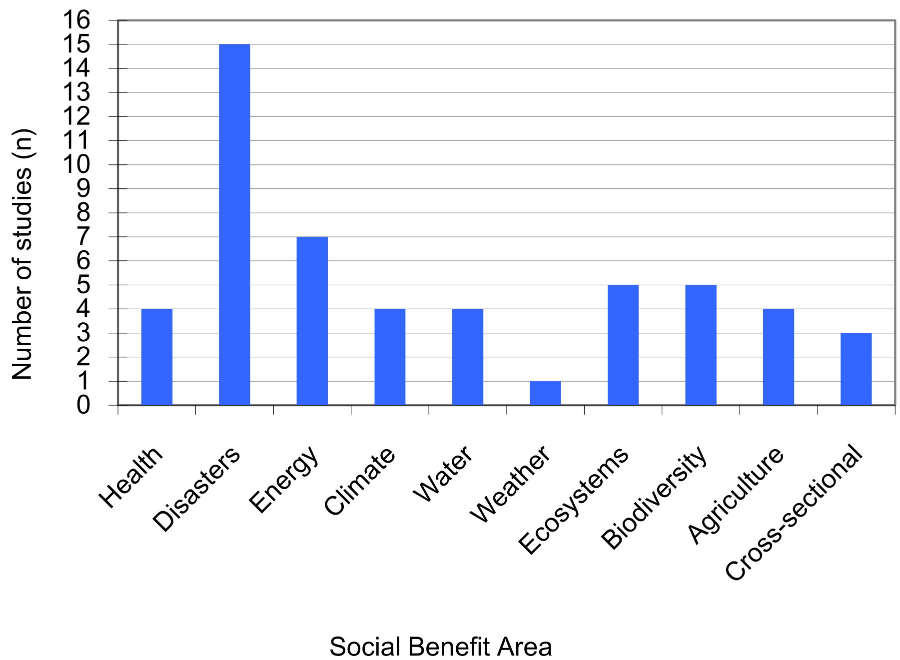
When looking at the distribution between the different SBAs (see figure above, updated in T36) it seems that most studies (qualitatively and quantitatively) are available in the cross-sectional area, not targeting at any specific SBA. Among the special SBAs most uploads to the Public GEOSS Benefit Assessment Data Base were received under Water, Agriculture and Biodiversity, followed by Weather and Climate, as well as Disasters and Spatial Data Infrastructure.

GEOBENE Benefit Assessment Database

Within the GEOBENE consortium we are collecting various project-internal case studies for a benefit assessment of Earth Observation (EO). The GEOBENE Benefit Assessment Database provides consortium members an overview of the different societal benefits from (improved) Earth Observation. Based on the collected comprehensive information on project-internal case studies (e.g. qualitative and quantitative, benefit area etc), consortium partners can effectively obtain, share and exchange knowledge about the current and future benefits of Earth Observation. The GEOBENE Benefit Assessment Database is presented only for consortium partners – the access to the detailed information source is restricted to the registered users in the GEOBENE web page. (Special login and application instructions have been provided in the GEO-BENE Deliverable D9: “Interim Benefit Area Assessments Report”.)

Overview Statistics

The overview statistics of the GEOBENE Benefit Assessment Database are shown below. The number of studies collected in the database is indicated by Societal Benefit Areas (SBAs).



The figure above (updated in T36) clearly indicates that the majority of the benefit assessment studies within the GEO-BENE consortium were carried out within the SBA of Disasters (15 studies), followed by the studies done under the Energy SBA (7) and Ecosystems and Biodiversity (5 studies). On the SBA Weather, only 1 GEO-BENE internal study with respect to benefit assessment could be carried out.

4.10. Deliverable (D10) "Draft GEO-BENE Synthesis Report"

By *T30 the tenth (D10) Deliverable "*Draft GEO-BENE Synthesis Report*"* was due and has been delivered in due course to Brussels.

It is the purpose of this report to respond to the GEO-BENE tasks described in WP 7000. According to WP7220 of the DoW of GEO-BENE **"WP 7220 Synthesis**: The main results of GEO-BENE assessment runs will be synthesized in a main report, destined for publication. …." And "**WP 7230 Review and Feedback Integration:** This WP will be implemented in two separate stages, an internal review of the synthesis report by the GEO-BENE consortium and subsequent feedback integration and a wider review process involving a selected pool of experts for external review and comments. It is proposed that the list of experts to involve in this external review be set up jointly by the European Commission, as the contractor, and GEO-BENE." Thus, the draft GEO-BENE Synthesis report serves the purpose of presenting the methodology of synthesis as well as the describing the baseline model structure allowing for synthesis. In essence we are describing the numerical model, calibrated for all SBAs, which will be used to carry out the integrated ex ante assessment of GEOSS. This document or even better the model per se will be used to carry out the work related to WP 7230. The review process has been finalized for presentation at the Final GEO-BENE Meeting and the ISRSE conference in Stresa.
Since this is the short description of draft "GEO-BENE Synthesis" report, please see next chapter 2.4.3 GEO-BENE Deliverable (D11) for more details and results.

4.11. Deliverable (D11) "GEO-BENE Synthesis Report"

By *T36 the eleventh (D11) Deliverable "GEO-BENE Synthesis Report"* has been delivered to EC in Brussels in due course.

Description of the GEO-BENE models and data

One objective of D11 has been to provide a list of Models to give an overview on the individual models used in an integrated model cluster for GEO-BENE. The model list indicates the objective of each model of the 15 models and is focusing at the key parameters such as input- and output parameters, scope, resolution, and the general modeling process.

The figure below gives a first glance-overview on the models used within the GEO-BENE approach and indicates their interactions.

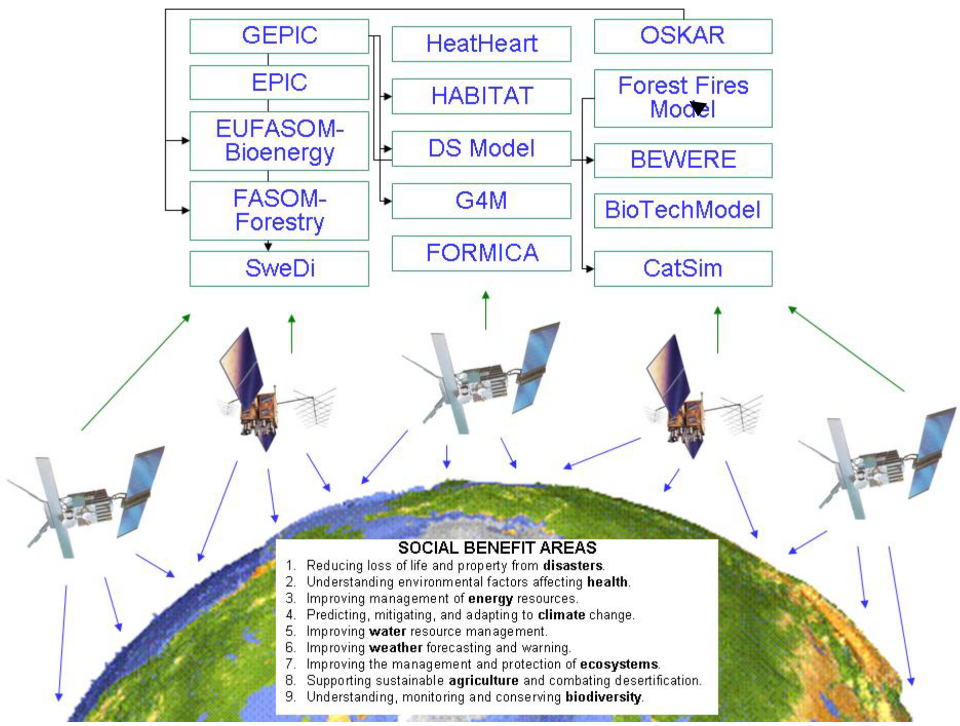


Figure: GEO-BENE Model Cluster and Interactions between the individual models

Overview of the GEO-BENE integration methodology

A second important objective of D11 has been to describe in detail the integration methodology applied in order to derive essential results from benefit assessment studies carried out within and outside the GEO-BENE consortium.

According to the D3 Benefit Assessment Framework Report shot-gun as well as rifle results (Public GEOSS Benefit Assessment Data Base / GEO-BENE Benefit Assessment Data Base, see Deliverable D9) shall be integrated in the synthesis report. The methodology applied in the GEOBENE project assumes use of various quantitative and qualitative methods and data. This includes a number of computer models (shot-gun analysis) focusing on issues in particular Social Benefit Areas and a collection of region specific or global data (also historical) as well as results from other sources such as published literature or even anecdotal evidence. GEOBENE has decided to develop and apply a specialized tool to carry out such type of integrated assessment.

The data as well as the outcome of the computer models – be it simulation scenarios, results of optimization experiments – are used as an input to FeliX (**F**ull of **E**conomic-Environment **L**inkage and **I**ntegration d**X**/dt) system dynamics model. While the particular, detailed model and data focus usually on one specific Social Benefit Area, or specific countries or regions, the main purpose of the FeliX model is to integrate all these information into a global model. FeliX attempts to bring system perspective, where various issues are interconnected and constitute a complex system. A change in one area results in some changes also in other areas – for instance depletion of natural resources being a source of energy may constrain population growth but also put a pressure on agriculture sector in order to produce more energy crops as a substitute of such natural resources as oil or gas. The FeliX model is a dynamic model showing development of certain changes (e.g. depletion of natural resources, carbon dioxide emission) or impact of certain policies (e.g. afforestation, emission reduction) over time allowing for analysis of short and long-term effects. The high level view of the FeliX model main sectors and basic interconnection between the sectors are presented in the figure below. Some of the model sectors and sectors interconnection are still under development. They should be finished by the end of the project.

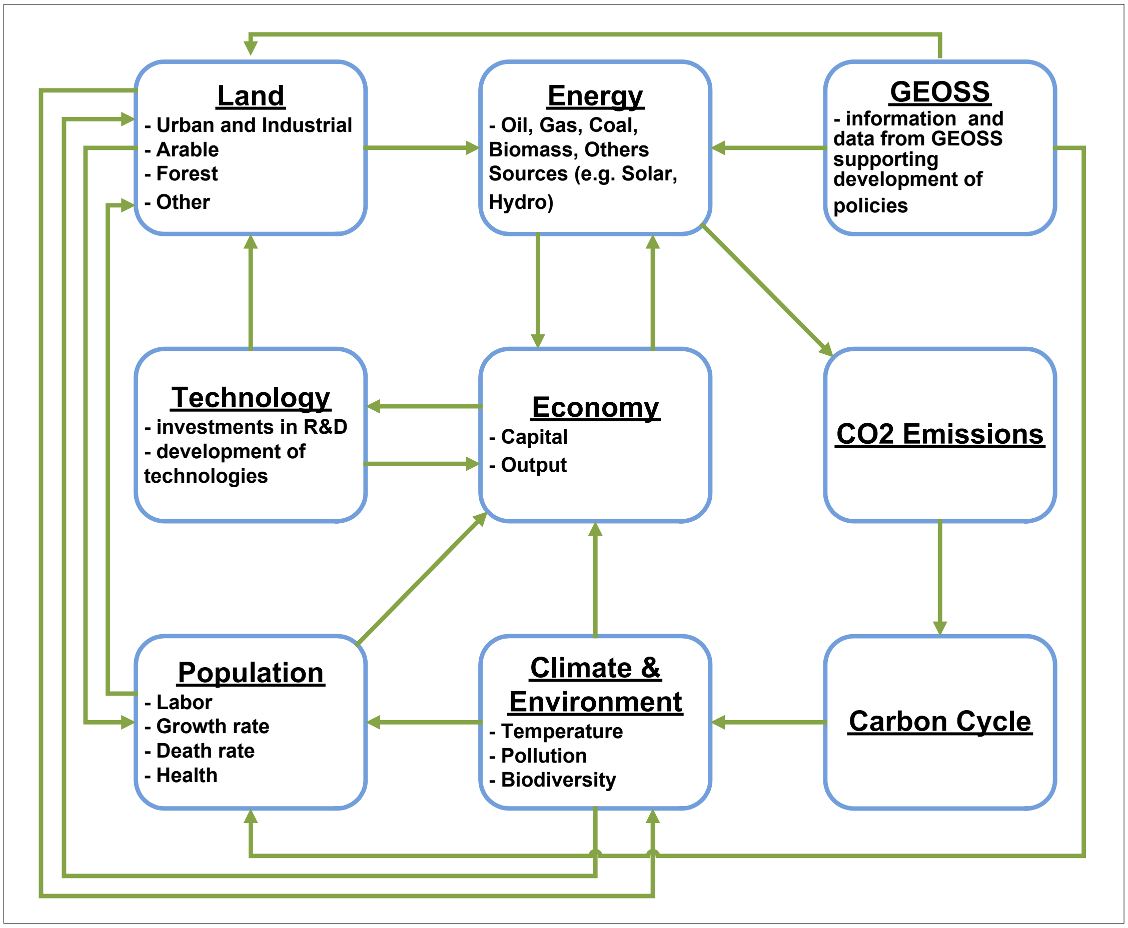


Figure title: High-level view of the FeliX model

Social Benefits Areas (SBA) - Disasters, Health, Energy, Climate, Water, Weather, Ecosystems, Agriculture and Biodiversity – are inherently embedded into the model structure. Some of them are covered by a specific FeliX model sector, e.g. Population sector covers health issues. Others are addressed in a various FeliX model sectors, e.g. disasters are investigated in Land, Population and Energy sectors. If an SBA is covered by one model sector it does not mean that changes or benefits of GEO in that area are constrained only to this particular model sector, however. All model sectors are interrelated and the changes, outcomes of policies, or impact of GEO can propagate across the whole system as it is happening in the real world.

In order to estimate benefits of GEO there are run dynamic scenarios. There is assumed a direct impact of GEO (e.g. early warning systems) or impact of policies supported by data from GEOSS and the results of computer simulations are compared to the model base run. It follows the guidelines specified in Fritz et al. (2008).

Since the FeliX model is trying to integrate some other models and date, very often build using different techniques, there are places where certain issues had to be simplified or modified. Taking this into account there are also available results of benefits analysis in particular SBA's conducted at the level of particular detailed models. The FeliX model constitutes an overview of many thorough researches.

In order to make it easier for policy makers to deal with the FeliX model, allow them to test various policies and observe GEO benefits across various model sectors over time there will be prepared a user-friendly interface and a simulator.

The GEOBENE integration methodology can be illustrated as in the figure below.

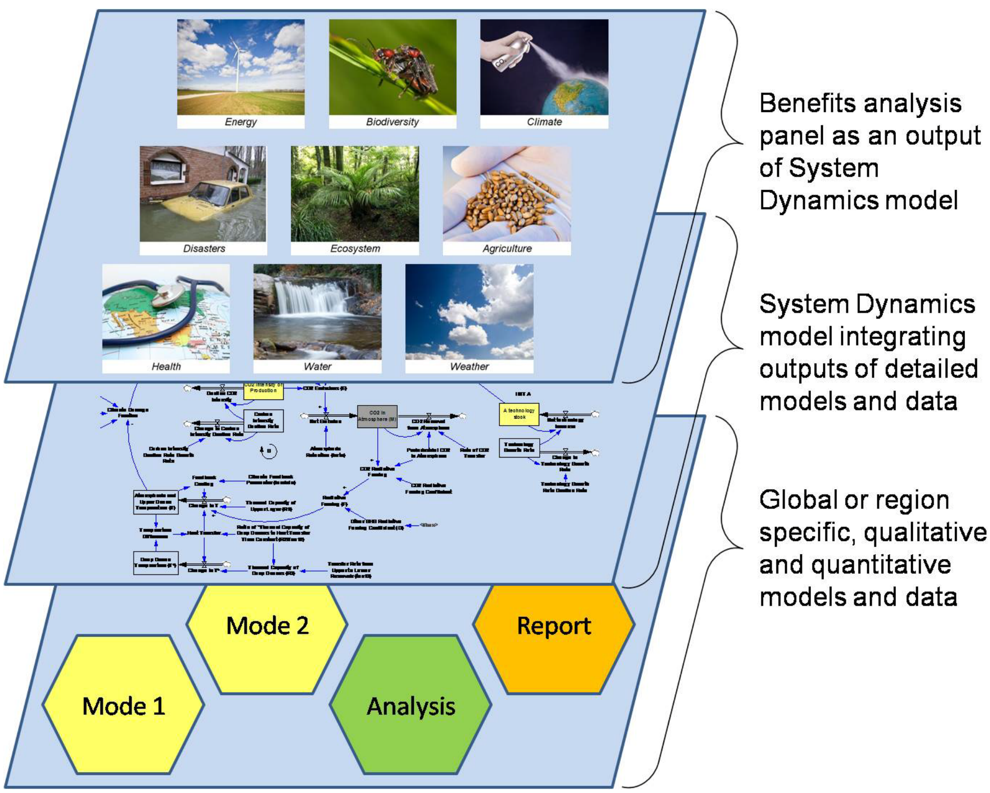


Figure: Overview of the GEOBENE integration methodology

4.12. Deliverable (D12) "GEO-BENE Results Implications Report"

By *T36 the twelfth (D12) Deliverable "GEO-BENE Result Implications Report"* has been delivered to EC in Brussels in due course.

The purpose of the GEO-BENE Deliverable D12 (T36) "GEO-BENE Result Implications Report" is twofold:

1) to review Benefit Assessment results and to analyze implications of Geo-Bene assessment results on technical aspects of GEO and GEOSS, illustrate data gaps and to outline possible low costs solutions; and

2) to analyze implications of Geo-Bene assessment results on policy, especially on international arrangements and conventions.

The first section of the document provides a state of the art documentation of the current public GEOSS benefit assessment implemented on the Geo-Bene website (www.geo-bene.eu).

In the second section of the document, international processes related to GEOSS are analyzed.

The Geo-Bene Results Implications Report demonstrates a selection of the activities which have been undertaken within the Geo-Bene Project, including the GEOSS benefit assessment and the "mail-shot" recently undertaken. Moreover, it shows applications of benefit assessments in the area of ecosystems, agriculture and biodiversity.

The Geo-Bene **Results Implications Report** has demonstrated a selection of the activities which have been undertaken within the Geo-Bene Project, including the GEOSS benefit assessment and the "mail-shot" recently undertaken. Moreover, it has shown applications of benefit assessments in the area of ecosystems, agriculture and biodiversity. All applications shown have demonstrated the need for improved information and the attached benefit to having better information available. In particular, it has highlighted that fact that information on land cover is an essential component for global land use modeling as well as setting biodiversity protection – and that currently available datasets contain large uncertainty (see geo-wiki.org). Societal benefits are manifold if more and better species data and in particular higher quality land cover information is becoming available. Biodiversity conservation can be better targeted, which results in high opportunity cost savings and an improved targeting of the species to be protected. Moreover, the application on land use modeling using different input datasets of land available for agriculture has highlighted the need to move to improve global datasets and to ideally have a Landsat type of global land cover available with high thematic quality. The work has demonstrated that current datasets are not sufficient for some of the land use modeling exercises and that uncertainties about our future development of land use can be reduced if land cover datasets are improved. Moreover, the example of geo-wiki.org has shown that low cost solutions exist and could be further developed and there is the potential to involve the wider public in GEOSS related activities.

International process on the provision of environmental services which resemble a public good have shown that self organization of participants often does not lead to the desired outcome of full participation and cooperation and an external coordinating institution is required. The GEO secretariat can be seen as an external coordinating institution, occupying a facilitating and mediating role to guide the coordination process without offering financial support for the achievement of the tasks' goals, which will definitely impair the success of the secretariat. To support its role, we propose a GEO coordination fund, which is sufficiently large to overcome the well known problems of international and cross-sectoral self organization. We used a game-theoretical approach to model cooperation of independent economies on building a global system aimed at mitigation of future economical losses caused by natural disasters. Our analysis of global partnership shows that partnership naturally emerges among similar economies but uncertainty in environmental risks valuing provides a strong incentive for cooperation for a broader spectrum of economies.

4.13. Deliverable (D13) “GEO-BENE Final Report”

By *T36 the thirteenth (D13) Deliverable “GEO-BENE Final Report”* has been delivered to EC in Brussels in due course.

The objectives of the GEO-BENE Final Report is to provide an overview on what has been achieved by the entire consortium during the lifetime of the project, to present a concise summary of the different scientific papers, reports, meetings and other means of result dissemination that have been produced within the project itself and which implications could be drawn from it for the relevant scientific community.

The GEO-BENE Final Report ended with the over-all conclusions, that Earth Observations are key for the management of global scale societal and environmental issues. Investments in global Earth observation assets do not keep pace with the requirements stemming from managing the major interacting global challenges ranging from the immediate food and water crisis all the way to more distant risks associated with climate disruptions. According to our calculations, the societal benefits from improved and globally coordinated Earth observations are in the majority of case studies orders of magnitudes higher than their production costs. With national contributions to build GEOSS coming increasingly under pressure, it is becoming important to be able to quantify their potential benefits and document realized impacts. Thus, benefit assessments such as those conducted by the GEO-BENE project need to be communicated to decision-makers and user communities. Spin-off activities from GEO-BENE acted as boundary organizations interfacing between the data providers and users such as businesses, governmental and non-governmental organizations. More such initiatives need to be created under the supervision of GEO’s user interface and capacity building committee.
One such interface, coordinated by GEO’s Science and Technology Committee, is that of observation-science-users. Continuous and comprehensive monitoring of the Earth through GEOSS carries the potential for a major development in global change science. Not only will science generate more and more robust knowledge through data assimilation into ever larger and integrated Earth system models, but also new scientific

fields will emerge such as the new discipline of energy meteorology. Finally, GEOSS-informed Earth system science tools will become available for use in local and global decision-making. These scientific benefits are among the least visible and predictable today, but they might emerge as the most important and pertinent ones from GEOSS.

Acknowledgements

We acknowledge the support of the European Commission, i.e. DG Research, DG Environment and DG Agriculture. We highly appreciate the continuing support of Dr. Gilles Ollier, Directorate-General DG Research, and Dr. Florence Béroud, Scientific Officer to the GEO-BENE Project.

We also would like to thankfully acknowledge the kind provision of input data to the GEO-BENE models by the European Commission, DG JRC, i.e. Dr. Max Craglia and his team.

The GEO-BENE Consortium owes a special thanks to the team of the GEO Secretariat in Geneva, i.e. its Director Dr. José Achache, for outstanding support.

Special acknowledgements go to Dr. Lawrence A. Friedl from NASA's Earth Science Division, who facilitated the successful dissemination of GEO-BENE results in the framework of the ISRSE conference in May 2009 in Stresa, Italy.

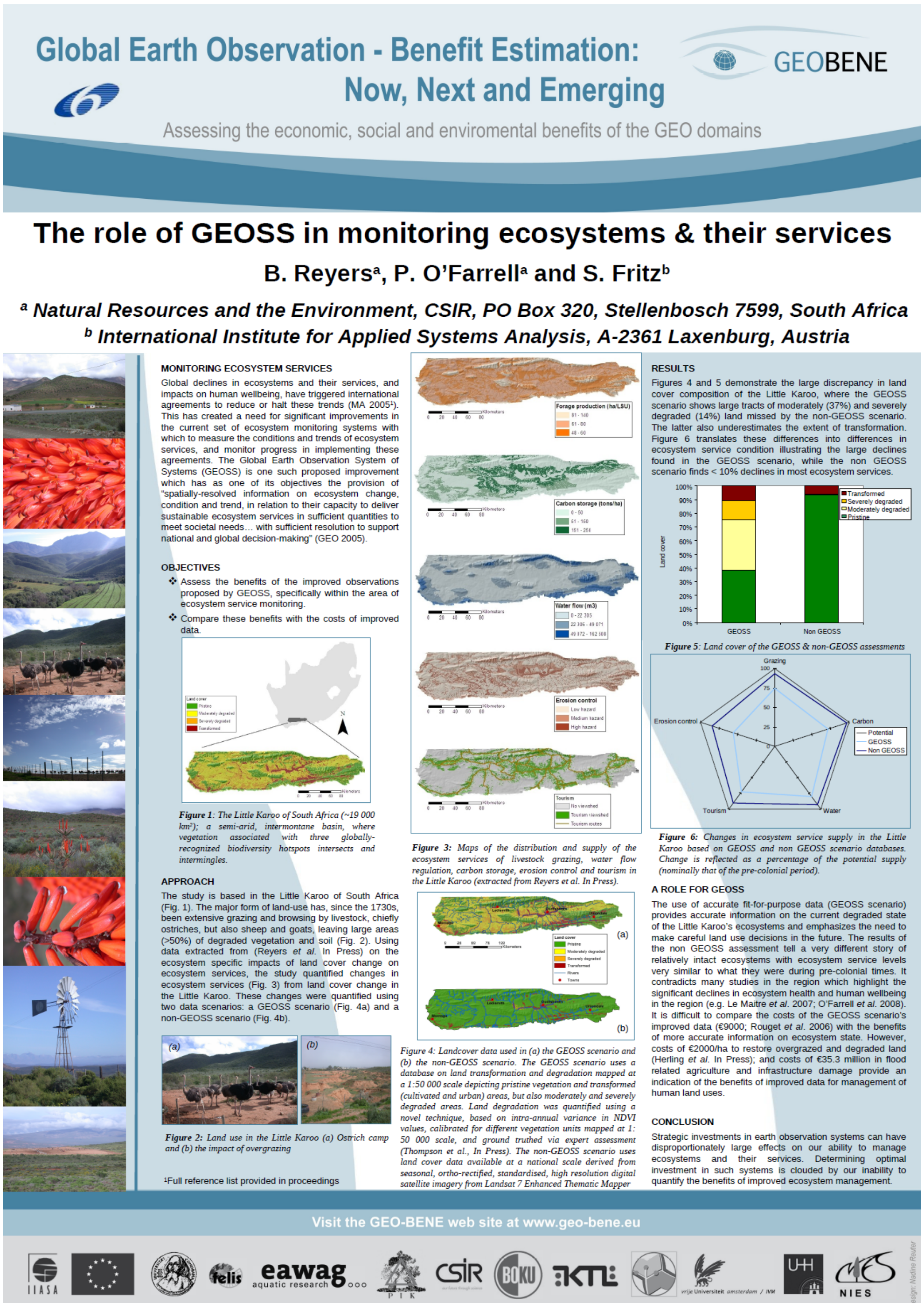
We very much appreciate the valuable contribution by the GEO-BENE - Associated Partner, the National Institute for Environmental Studies (NIES), Center for Global Environmental Research, Japan, i.e. Dr. Yoshiki Yamagata and his team.

Further, we wish to thank Dr. Molly Macauley, Research Director with Resources for the Future (RFF).

Finally we thank all other supporting institutions and persons, especially all participants and contributors to the Public GEOSS Benefit Assessment Data Base created by GEO-BENE.

Annex I Selected GEO-BENE Results Presented at ISRSE as Posters (fully accessible via www.geo-bene.eu)

I.1. SBAs Biodiversity/Ecosystems: The role of GEOSS in monitoring ecosystems & their services



I.2. SBA Health: Modelling of the socio-economic and environmental determinants of subjective happiness and well-being

Global Earth Observation - Benefit Estimation:
Now, Next and Emerging

GEOBENE

Assessing the economic, social and enviromental benefits of the GEO domains

Modelling of the socio-economic and environmental determinants of subjective happiness and well-being

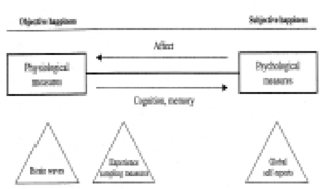
Dimitris Ballas [a], Steffen Fritz [b], Mark Tranmer [c]

[a] Geography Dept., University of Sheffield, UK, *d.ballas@sheffield.ac.uk*
[b] Forestry Program, International Institute for Applied Systems Analysis (IIASA), Austria, *fritz@iiasa.ac.at*
[c] School of Social Sciences, University of Manchester, UK, *Mark.Tranmer@manchester.ac.uk*

Background

In recent years, there have been numerous attempts to define and measure happiness in various contexts pertaining to a wide range of disciplines, ranging from neuroscience and psychology to philosophy, economics and social policy. Our research attempts to extend past work on the perception of happiness by building and analyzing a database of socio-economic and environmental variables at different levels (individual, household, district and region).

There have been several studies suggesting that happiness can be measured subjectively and objectively (see figure below (after Frey & Stutzer, 2002)), and there have been on-going lively debates over how to measure it.

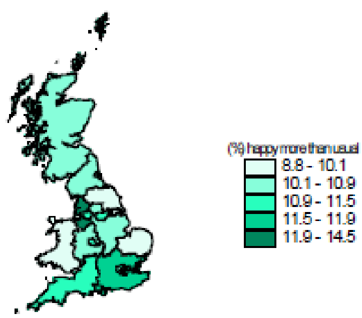


Objectives

This research project aims at developing a comprehensive multi-level framework for the analysis of happiness and well-being by linking socio-economic survey data as well as climate, environmental and wilderness data to determine the extent to which happy or unhappy people congregate in similar places (compositional effects) or whether certain attributes of places cause inhabitants to be happy or unhappy (contextual effects).

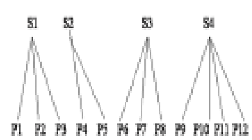
Data and method

Using secondary data it is possible to create maps of subjective happiness and well-being at the geographical levels at which data are available.



The next step in the analysis is to assess the nature and extent of variations in happiness and well-being and to determine the relative importance of the area (district, region), household and individual characteristics.

Multilevel modeling can be used to analyze data at various levels simultaneously, rather than modelling data at a single level.



Socio-economic and demographical determinants

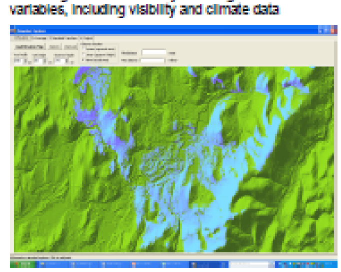
The table below summarises some of the results of multilevel modelling.

Variables, variance component estimates and coefficients (standard error in brackets)	Subjective well-being	General Happiness
Intercept	1.097 (0.117)	0.781 (0.133)
Individual-level variables:		
Age	-0.034 (0.006)	-0.032 (0.006)
Female	-0.195 (0.024)	-0.096 (0.028)
Individual income	-0.002 (0.015)	0.000 (0.017)
Health good (reference = health excellent)	-0.208(0.025)	-0.081 (0.028)
Health fair (reference = health excellent)	-0.506 (0.035)	-0.275 (0.040)
Health poor (reference = health excellent)	-0.725 (0.062)	-0.426 (0.071)
Health very poor (reference = health excellent)	-0846 (0.144)	-0.642 (0.162)
Employment status: unemployed (reference = employed or self employed)	-0.882 (0.234)	-0.690 (0.268)
Employment status: on maternity leave (reference = employed or self employed)	0.312 (0.280)	0.736 (0.321)
Employment status: on maternity leave (reference = employed or self employed)	0.312 (0.280)	0.736 (0.321)
Employment status: other job status (reference = employed or self employed)	-0.295 (0.484)	- 1.256(0.554)
Has lived at current address for more than 5 years (reference = lived at current address for less than 1 year)	0.100(0.036)	0.047(0.040)
Unemployment status (individual level) x unemployment rate (district level)	0.815 (0.235)	0.548(0.270)

The above results pertain to the socio-economic and demographic determinants of well-being and happiness (Ballas & Tranmer, 2008)

The environmental determinants

Our on-going research aims to extend this multi-level modelling framework by adding environmental variables, including visibility and climate data



Conclusions

This poster presents a new framework for the combination of secondary socio-economic data and environmental data sets to provide a powerful database for the geographical analysis of subjective happiness and well-being, building on a rapidly growing body of inter-disciplinary research. Future priorities include extending this framework to inform local debates on issues such as green-spaces and the geographical allocation and extent of geographical features that may be affecting happiness and local well-being.

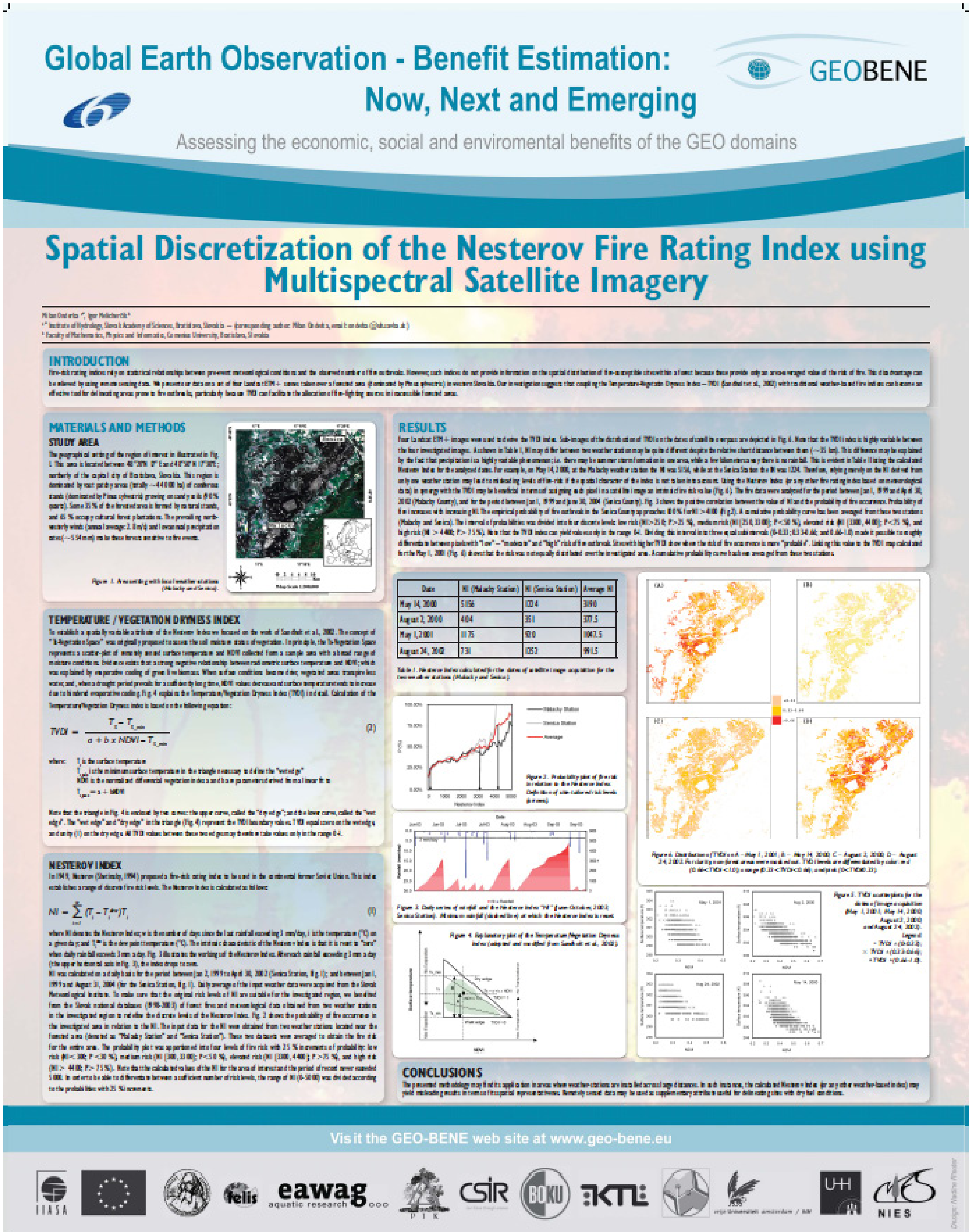
References

Ballas, D, Fritz, S (2008) *Geographical modelling of happiness and well-being using population surveys and remote sensing data*, paper presented at "Studying, Modeling and Sense Making of Planet Earth" UNESCO-sponsored international conference, Department of Geography, University of the Aegean, Greece, 1-6 June 2008
Ballas, D., Tranmer, M. (2008), *Happy people or happy places? A multilevel modelling approach to the analysis of happiness and well-being*, paper deposited at the arXiv e-print archive, http://eprintweb.org/S/article/stat/0808.1001
Frey, B, Stutzer, A (2002), *Happiness and Economics*, Princeton University Press, Princeton.

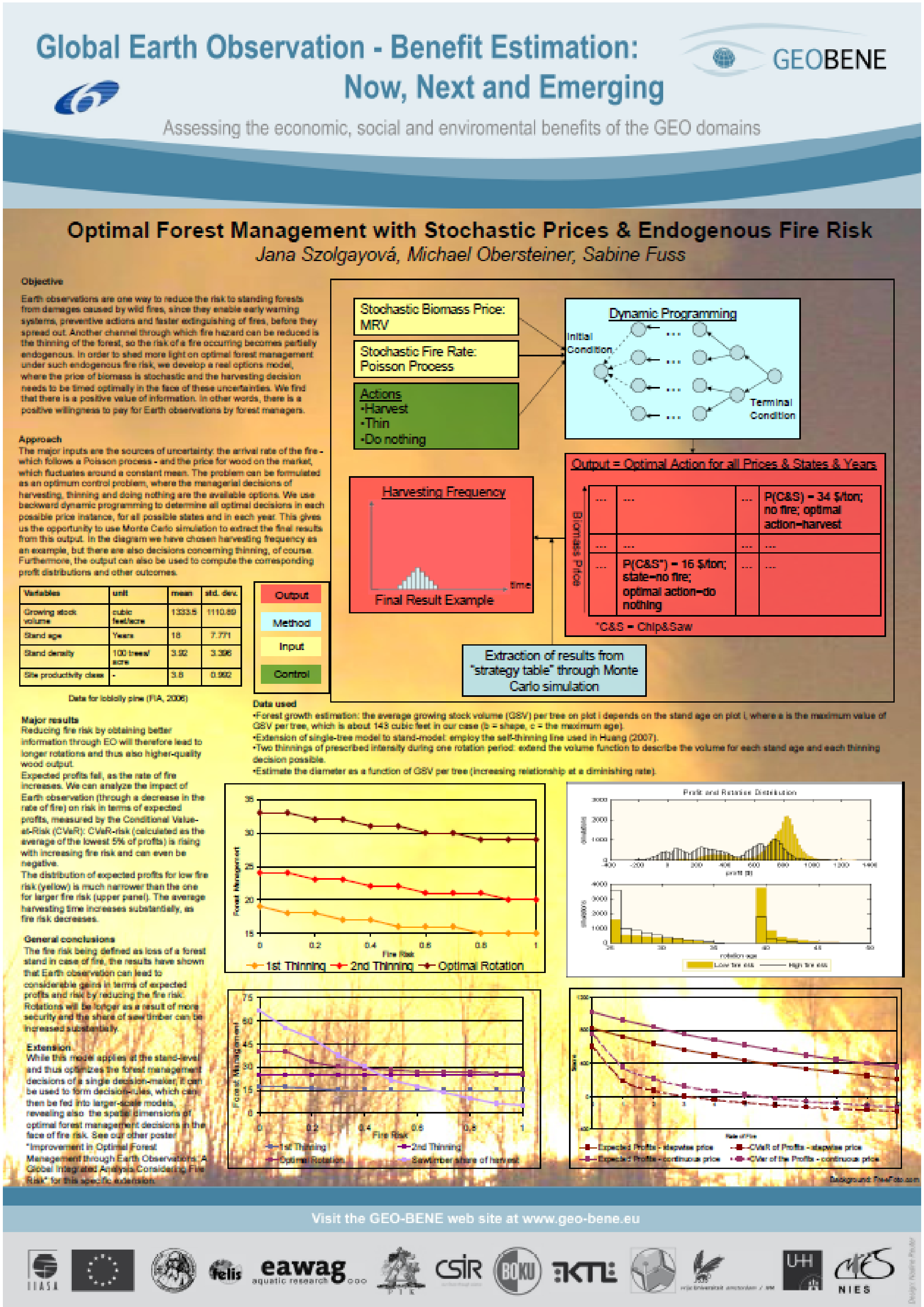
Visit the GEO-BENE web site at www.geo-bene.eu

I.3. Cross-SBA: International cooperation on Earth Observation in the course of GEOSS An evaluation based on game theoretic and economic concepts.

I.4. SBA Disasters: Spatial Discretization of the Nesterov Fire Rating Index using Multispectral Satellite Imagery



I.5. SBA Disasters: Optimal Forest Management with Stochastic Prices & Endogenous Fire Risk



I.6. *SBA Weather/Climate/Disasters: Value of Weather Observations for Reduction of Forest Fire Impact on Population*

Global Earth Observation - Benefit Estimation: Now, Next and Emerging

GEOBENE

Assessing the economic, social and enviromental benefits of the GEO domains

Value of Weather Observations for Reduction of Forest Fire Impact on Population

N. Khabarov [a], E. Moltchanova [b], M. Obersteiner [a]

[a] International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria – (khabarov, oberstei)@iiasa.ac.at

[b] National Institute for Health and Welfare, Helsinki, Finland – elena.moltchanova@thl.fi

33rd International Symposium on Remote Sensing of Environment 4–8 May 2009, Stresa, Lago Maggiore, Italy

In this study we investigate how improvements in the weather observation systems help to reduce forest fires impact on population by targeting and monitoring places where ripe fires are likely to occur. For the purposes of population impact assessment we suggest a relevant index. In our model the air patrolling schedule is determined by the Nesterov index, which is calculated from observed weather data sets at different spatial resolutions. The reduction of fire impact on population, associated with utilization of finer grid/increased number of weather stations, indicates the benefits of more precise weather observations.

Subject of Research – Forest Fires model based on Nesterov index using

- "rough" and "fine" weather data grids
- varying number of weather stations / combining data sets (SoS effect)

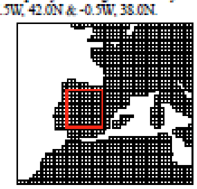
Objectives – Assessment of the incremental value of information in terms of

- saved forest / patrolling costs
- fire impact on population

Weather Dataset – JRC-AGRIFISH / MARS-STAT Data Base

- daily basis, interpolated
- Europe, 50 x 50 km grid for the year 2000 containing:
- maximum/minimum temperature (°C)
- mean daily vapor pressure (hPa)
- mean daily rainfall (mm)

Area and Grids – The area is partly covering the territory of Spain and Portugal located approximately between -7.5W, 42.0N & -0.5W, 38.0N.



- "Fine" grid: 12 x 12 cells, 50 x 50 km each.
- "Rough" grid: 6 x 6 cells, 100 x 100 km each.

Nesterov Index

$$I(t) = \sum_{k=s}^{t} (T_k - T_k^d) \cdot T_k,$$

here t – day number since the start of observations, T_k – daily temperature (°C), T_k^d – dew point temperature (°C) for the day k. For all the days with precipitation greater than 3 mm, the Nesterov index drops to zero and the summation restarts from the next day s.

Fire Impact on Population Index

$$FIPI = B / A \times D,$$

B – yearly burnt area (all parameters per grid cell), A – total area, D – population density (inhabitants per km²).

Fire Danger Classes and Air Patrol Frequency

Nesterov index	Fire danger	Fire danger class	Air patrol frequency
≤ 300	—	I	No patrol
> 300	Low	II	Once in 2–3 days
> 1 000	Medium	III	Once daily
> 4 000	High	IV	Twice daily
> 10 000	Extreme	V	Three times a day

Probabilities Assessment

Probability of a fire in case of ignition:

$$P(I) = 1 - e^{-aI}, \; a = 0.000337.$$

Average number of ignitions during a day:

$$N(D) = (w(D)\, D\, b + l)\, S, \text{ where } b = 0.1,\; w(D) = 6.8\, D^{-0.57},\; l = 0.02,$$

D – population density (habitants/km²), S – area (km²).

The probability of at least one fire in the area:

$$P_f(I, D) = 1 - (1 - P(I))^{N(D)}.$$

Simplifying Assumptions

- Homogeneous forest, no extreme winds
- Constant fire spread velocity $v = 0.3$ m/min
- Maximum fire duration is 24 h

Calculation Methodology

$$FIPI_{total} = \sum_{i,j=1}^{12} \left(D_{ij} \sum_{t=1}^{365} S_{ij}^{t} \right),$$

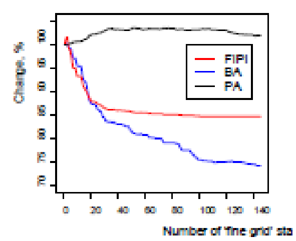
where D_{ij} – population density in the grid cell (i,j), and S_{ij}^t – expected relative burned area in the grid cell in day t implicitly depending on Nesterov index and population density.

Results

Total expected FIPI, burned area (% of total area) and cumulative patrolled area (times of the total area) for rough and fine grids and respective improvement ratios.

	Rough grid	Fine grid	Improvement
FIPI	0.4496	0.3807	15 %
Burned area	0.5261 %	0.3910 %	26 %
Patrolled area	295.2	300.8	-2 %

Dependence of the FIPI, burned (BA) and patrolled (PA) areas on the number of 'added' weather stations.



References

N. Khabarov, E. Moltchanova, M. Obersteiner, Valuing Weather Observation Systems for Forest Fire Management, Systems Journal, IEEE, Volume 2, Issue 3, pp. 349–357, 2008.

S. Venevsky, K. Thonicke, S. Sitch, and W. Cramer, Simulating fire regimes in human-dominated ecosystems: Iberian peninsula case study, Global Change Biology, vol. 8, no. 10, pp. 984–998, 2002.

Visit the GEO-BENE web site at www.geo-bene.eu

I.7. *Cross-SBA: Will GEO/GEOSS Work – An Economist View*

Global Earth Observation - Benefit Estimation: Now, Next and Emerging

GEOBENE

Assessing the economic, social and enviromental benefits of the GEO domains

Will GEO Work? – An Economist View

A. Smirnov [a,b], M. Obersteiner [a]

[a] International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria – (smirnov, oberstei)@iiasa.ac.at
[b] Department of Optimal Control, Moscow State University, Moscow 119991, Russia

33rd International Symposium on Remote Sensing of Environment 4–8 May 2009, Stresa, Lago Maggiore, Italy

We use a game-theoretical approach to model a global partnership in building global earth observation system. Our analysis of possible equilibrium solutions shows that only in the case of similar economies we will observe cooperation behavior (when all invest into global system) and otherwise we will observe free-riding. However uncertainty in environmental risks valuing can provide a strong incentive for free-riders to cooperate.

MODELING FRAMEWORK

- Aggregated macroeconomic model of a society under the threat of extreme events (catastrophes)
- **GEOSS:** Preventive measures to increase society's welfare
- **Global Partnership:** "Investment Game" in multi-society world

MODEL

We consider a stylized neoclassical model of the development of an economy affected by random natural hazards (treated as suggested in [1]).

Capital stock dynamics: $K_{t+1} = ((1-\delta)K_t + I_{t+1}) \cdot D_{t+1}, \quad t = 0,1,\ldots,\infty$

Here K_t is the capital stock, δ is a capital depreciation rate, I_t is investment, and D_t is an extreme event (random variable).

Production output $Y_{t+1} = \alpha K_t$ in period 0 is divided between investment I_0, consumption C_0, and investment z in the development of prevention measures, $Y_t = I_t + C_t + z$; at all other periods (*t>1*) output is divided between investment and consumption, $Y_{t+1} = I_{t+1} + C_{t+1}$

Extreme event occurs with probability q_t causing the loss of fraction d of the capital stock

$$D_t = \begin{cases} 1-d, & \text{with probability } q_t \\ 1 & \text{with probability } 1-q_t \end{cases}$$

Probability q_t endogenously depends on the preventive measures z:

$$q_t = \frac{q_0}{1+\kappa z}, \quad t = 1,2,\ldots$$

Here q_0 is the probability of disasters without any preventive measures, and κ is a given positive coefficient characterizing the efficiency of investment.

Social planner chooses consumption level in order to **maximize** the economy's utility, expected value of the **social welfare** (ρ is a positive social discount rate):

$$W(z) = \max_{C_t} E\left(\sum_{t=0}^{\infty}(1+\rho)^{-t}\log C_t\right).$$

Proposition 1 ([2]). *For every* $z \in [0, \alpha K_0)$, *the optimization problem has the unique solution*

$$W(z) = \log(1-s_0) + \tfrac{1}{\rho}\log((1-\delta)K_0 + s_0(\alpha K_0 - z)) + \log(\alpha K_0 - z) + \tfrac{1}{\rho}\log\rho + \tfrac{1+\rho}{\rho^2}\log\rho\left(\tfrac{\alpha+1-\delta}{1+\rho}\right)$$

where

$$s_0 = \begin{cases} \frac{\alpha K_0 - z - \rho(1-\delta)K_0}{(\alpha K_0 - z)(1+\rho)} & \text{if } z < (\alpha + \rho\delta - \rho)K_0, \\ 0 & \text{otherwise} \end{cases}$$

Optimal investment z in prevention measures:

$$\text{Maximize } W(z) \text{ over all } z \in [0, \alpha K_0).$$

Proposition 2. *Optimal investment problem has the unique solution z*.*
If

$$\kappa K_0 |q_0 \log(1-d)| \le \frac{\rho(1+\rho)}{1+\alpha-\delta},$$

then z=0, otherwise z* is positive (for exact formula see ([?])*

Corollary. Economy refrains from investing in the prevention measures if its ability to cope with natural hazards (κK_0) is low, or the measure of danger, caused by natural hazards ($|q_0 \log(1-d)|$) is not high enough.

INVESTMENT GAME

- Two independent economies both under the threat of natural disasters
- Each of the economies can make an investment (z^1, z^2) in common prevention measures aimed at mitigating the impact of natural hazards on both economies
- Each economy is subject the same dynamics as in the previous section but with its own set of parameters (indicating by corresponding indexes).

Effect of joint investments is achieved by the modification of the rule how probability of the occurrence of natural hazards changes after the implementation of prevention measures

$$q_t = \frac{q_0}{1+\kappa^1 z^1 + \kappa^2 z^2}, \quad t = 1,2,\ldots$$

Each economy is maximizing its own welfare

$$\text{Maximize } W_1(z^1, z^2) \text{ over all } z^1 \in [0, \alpha^1 K_0^1).$$
$$\text{Maximize } W_2(z^1, z^2) \text{ over all } z^2 \in [0, \alpha^2 K_0^2).$$

This is a non-zero-sum game and we can characterize its equilibriums:

Proposition 3. *Investment game problem always has a unique Nash equilibrium solution* (z^{1*}, z^{2*}).

It can be shown that in the context of perfect knowledge about model's parameters the case when both economies invest (z^i*>0*) into preventing measures (we call this **cooperative behavior**) happens only among similar economies. Figure 1 shows the example how narrow is the "cooperation zone" (economies' initial capitals must belong to the black area to reveal the cooperative behavior).

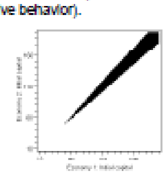


Figure 1.

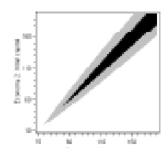


Figure 2.

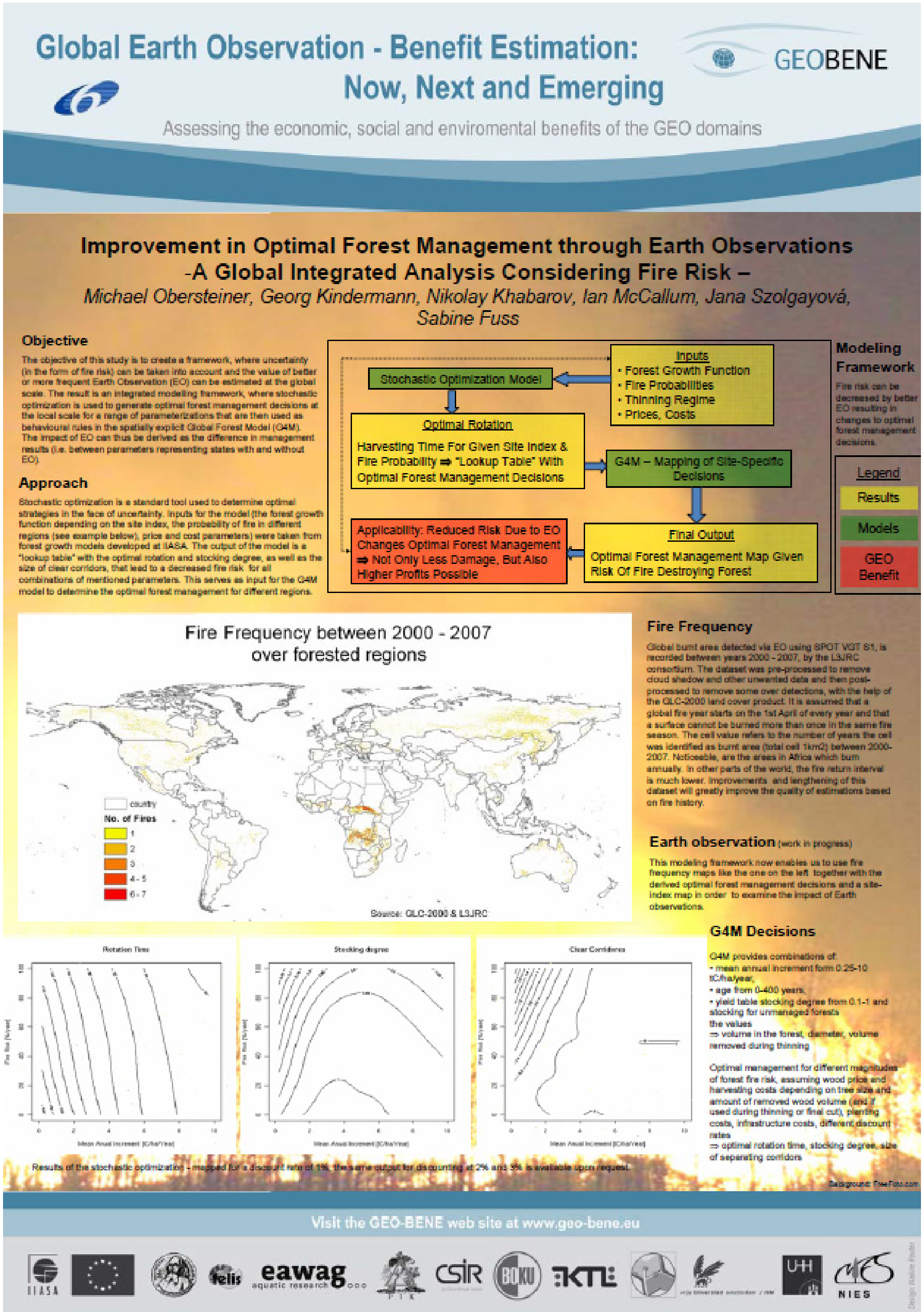
However if we take into account uncertainties naturally existing in the model (parameters like probability of natural disasters, q_0 and their impact on capital stock, d) we found that for some of previously non-cooperative economies there will appear additional cooperative solutions. Figure 2 shows that 10% uncertainty in the probability (q_0) of occurring of natural disaster leads to the increasing of "cooperation zone" of Figure 1 more than twice. Grey area on the figure describes the economies where cooperation becomes an option.

CONCLUSIONS

- Emergence of a joint GEOSS infrastructure as a Global Partnership is unlikely to materialize basing only on economical interests:
  - "Rich" always pays in its own interest;
  - Involving "Poor" only under special cases;
  - Free-rider problem to establish global infrastructure;
- Uncertainty in risk valuing provides an incentive for cooperation;
- Arising non-uniqueness of equilibrium solutions leads to necessity of additional negotiations between countries to set appropriate investments level.

[1] Z. Chladna, E. Moltchanova, and M. Obersteiner, "Prevention of Surprise", in: S. Albeverio, V. Jentsch, H. Kantz (Eds.), Extreme Events in Nature and Society, Springer, vol. 352, pp. 295–318, 2006.
[2] A. Kryazhimskiy, M. Obersteiner, and A. Smirnov, "Infinite horizon dynamic programming and application to management of economies effected by random hazards", Appl. Math. Comput., 205, pp. 609–620, (doi:10.1016/j.amc.2008.05.042), 2008.

I.8. SBA Disasters: Improvement in Optimal Forest Management through Earth Observations - A Global Integrated Analysis Considering Fire Risk



Annex II GEO-BENE Publications List (T1-T36)

Partner	SBA	Publication Title	Published (citation)	Status (submitted/in the pipeline/planned)
IIASA	Energy, Climate, Ecosystem	A global forest growing stock, biomass and carbon map based on FAO statistics	Georg E. Kindermann, Ian McCallum, Steffen Fritz & Michael Obersteiner: A global forest growing stock, biomass and carbon map based on FAO statistics, Silva Fennica, 2008, vol.42(3), p. 387-396	Published
IIASA	Climate, Ecosystem	Predicting the deforestation trend under different carbon-prices. Carbon Balance and Management	Kindermann G.E., Obersteiner M., Rametsteiner E., McCallum I. (2006): Predicting the deforestation trend under different carbon-prices. Carbon Balance and Management, 1 (15), 1-17; ISSN 1750-0680	Published
IIASA	Climate, Ecosystem	lobal cost estimates of reducing carbon emissions through avoided deforestation	Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrasko, K., Rametsteiner, E., Schlamadinger, B., Wunder, S., Beach, R. (2008): Global cost estimates of reducing carbon emissions through avoided deforestation. Proceedings of the National Academy of Sciences of the United States of America, 105 (30), pp. 10302-10307.	Published

IIASA / NIES	Energy	Attitudes towards forest, biomass and certification -- A case study approach to integrate public opinion in Japan.	Kraxner F, Yang J, Yamagata Y (2009). Attitudes towards forest, biomass and certification -- A case study approach to integrate public opinion in Japan. Bioresource Technology, 100(17):4058-4061	published
GEO-BENE Consortium	Cross-SBAs	The Value of Global Earth Observations. Societal benefits from improved earth observations outweigh their production costs by orders of magnitude.	The Value of Global Earth Observations. Societal benefits from improved earth observations outweigh their production costs by orders of magnitude. Michael Obersteiner, Juraj Balkovič, Hannes Böttcher, Jetske A. Bouma, Steffen Fritz, Sabina Fuss, Peter Havlik, Christine Heumesser, Stefan Hochrainer, Kerstin Jantke, Nikolay Khabarov, Barbara Koch, Florian Kraxner, Onno J. Kuik, Sylvain Leduc, Junguo Liu, Wolfgang Lucht, Ian McCallum, Reinhard Mechler, Elena Moltchanova, Belinda Reyers, Felicjan Rydzak, Christine Schleupner, Erwin Schmid, Uwe A. Schneider, Robert J. Scholes, Rastislav Skalský, Alexey Smirnov, Jana Szolgayova, Zuzana Tarasovičová, Hong Yang	Submitted to *SCIENCE (1) and PNAS (2)*
IIASA	Ecosystems	On fair, effective and efficient REDD mechanism design.	Obersteiner M, Huettner M, Kraxner F, McCallum I, Aoki K, Bottcher H, Fritz S, Gusti M, Havlik P, Kindermann G, Rametsteiner E, Reyers B (2009). On fair, effective and efficient REDD mechanism design. Carbon Balance and Management, 4:11 (27 November 2009).	published

IIASA	Ecosystems	An analysis of monitoring requirements and costs of Reduced Emissions from Deforestation and Degradation	Carbon Balance and Management	published
IIASA	Ecosystems	Reducing Emissions from Deforestation and Forest Degradation: A Systematic Approach	IIASA Policy Brief Series	Published (IIASA web, www.iiasa.ac.at)
IIASA	Ecosystems	Satellite-based terrestrial production efficiency modeling.	McCallum I, Wagner W, Schmullius C, Shvidenko A, Obersteiner M, Fritz S, Nilsson S (2009). Carbon Balance and Management, 4:8 (18 September 2009).	Published
IIASA, FELIS	Ecosystems/Cross-SBAs	Geo-Wiki.org: Harnessing the power of volunteers, the Internet and Google Earth to collect and validate global spatial information.	McCallum I, Fritz S, Schill C, Perger C, Achard F, Grillmayer R, Koch B, Kraxner F, Obersteiner M, Quinten M (2010). Geo-Wiki.org: Harnessing the power of volunteers, the Internet and Google Earth to collect and validate global spatial information. Earthzine.	published
The GEO-BENE Consortium	Cross-SBAs	Global earth Observation – a new tool for sustainable development	GEO-BENE selected as success story by the European Commission: Research for Europe	http://ec.europa.eu/research/research-for-europe/environment-geo-bene_en.html
IIASA/FELIS/GEO	Ecosystems/Cross-SBAs	Geo-Wiki.Org: The use of crowdsourcing to improve global land cover.	Fritz S, McCallum I, Schill C, Perger C, Grillmayer R, Achard F, Kraxner F, Obersteiner M (2009). Remote Sensing, 1(3):345-354 (3 August 2009).	published
IIASA/GEO-BENE Consortium	Cross-SBAs	GEO-BENE	European Commission Fact Sheet: Earth Observation	published

IIASA	Cross-SBAs	Global Earth Observation System of Systems (GEOSS).	Fritz S, McCallum I, Williams M, Kraxner F, Obersteiner M (2010). Global Earth Observation System of Systems (GEOSS). In: Encyclopedia of Remote Sensing, E. Njoku (ed.), Springer-Verlag, New York, USA.	Submitted
IVM	Water	Assessing the value of information for water quality management in the North Sea	Bouma, J.A., Woerd, H.van der & Kuik, O.J. (2009).. *Journal of Environmental Management,* 90 (2) 1280-1288.	published
IVM	Water/Ecosystems	The Value Of Earth Observation For Managing The Great Barrier Reef		Planned Submissions to IVM Working Paper Series and *Ecological Economics*
UHH	Biodiversity	Potential impacts on bird habitats in Eiderstedt (Schleswig-Holstein) caused by agricultural land use changes.	C. Schleupner & P.M. Link (2008) Applied Geography 28 (4), 237-247.	published
UHH	Biodiversity	Agricultural land use changes in Eiderstedt: historic developments and future plans.	P.M. Link & C. Schleupner (2008) Coastline Reports 9, 197-206.	published
UHH	Biodiversity	Eiderstedt im Spannungsfeld zwischen Naturschutz- und Agrarpolitik - Entwicklung eines methodischen Anstatzes für ein nachhaltiges Ressourcenmanagement.	C. Schleupner & P.M. Link (2009) Marburger Geographische Schriften, 145, pp. 33-49.	published
UHH	Biodiversity	GIS as integrating tool in sustainability and global change	C. Schleupner (Dissertation) Berichte zur Erdsystemforschung 62. Max Planck Institut für Meteorologie 2009, Hamburg, Germany, 268 pp.	published

UHH	Biodiversity	GIS-based estimation of wetland conservation potentials in Europe.	C. Schleupner & U.A. Schneider	submitted
UHH	Biodiversity	Effects of bioenergy policies and targets on European wetland restoration options.	C. Schleupner & U.A. Schneider	submitted
UHH	Biodiversity	Spatial allocation of European wetland restoration potentials under different agricultural policy scenarios.	C. Schleupner & U.A. Schneider	submitted
UHH	Biodiversity	Benefits of increased data resolution for European conservation planning.	K. Jantke, C. Schleupner & U.A. Schneider	in the pipeline
UHH	Biodiversity	Multiple-species conservation planning with different degrees of coordination: Quantifying area requirements using mixed integer programming.	K. Jantke & U.A. Schneider	in the pipeline
UHH	Biodiversity	Opportunity costs in conservation planning - in the case of European wetland species.	K. Jantke & U.A. Schneider	in the pipeline
UHH	Biodiversity	Gap analysis of European wetland species: Priority regions for expanding the Natura 2000 network.	K. Jantke, C. Schleupner & U.A. Schneider	planned
UHH, BOKU, IIASA, UB	Agriculture, Water, Ecosystems, Climate, Energy, Health, Spatial Data Infrastructure	The European Forest and Agricultural Sector Optimization Model - EUFASOM	U.A. Schneider, J. Balkovic, S. De Cara, O. Franklin, S. Fritz, P. Havlik, I. Huck, K. Jantke, A.M.I. Kallio, F. Kraxner, A. Moiseyev, M. Obersteiner, C.I. Ramos, C. Schleupner, E. Schmid, D.	published

			Schwab, R. Skalsky FNU-156, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg	
UHH, BOKU, IIASA	Agriculture, Water, Energy, Spatial Data Infrastructure	Agricultural adaptation to climate policies under technical change	U.A. Schneider, B.A. McCarl, M. Obersteiner, E. Schmid	submitted
UHH, JRC	Agriculture, Biodiversity, Health, Energy, Climate, Water	Potential synergies between existing multilateral environmental agreements in the implementation of Land Use, Land Use Change and Forestry activities	A. Cowie, U.A. Schneider, and L. Montanarella Environmental Science & Policy 10(4):335-352	published
UHH, BOKU, IIASA, UB	Agriculture, Health, Energy, Ecosystems, Climate, Water	Global interdependencies between population, water, food, and environmental policies	U.A. Schneider, P. Havlik, E. Schmid, I. Huck, M. Obersteiner, T. Sauer, C. Llull, R. Skalsky, J. Balkovic, S. Fritz, B. Dorin, S. Leduc FNU-161, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg	available from authors upon request
UHH, BOKU, IIASA, UB	Agriculture, Water, Energy, Ecosystems, Health	Food production impacts of alternative global development scenarios	U.A. Schneider, P. Havlík, E. Schmid, M. Obersteiner, C. Llull, R. Skalsky, T. Sauer, S. Fritz	submitted
UHH, BOKU, IIASA, UB	Agriculture, Energy	The interdependencies between food and biofuel production in European agriculture – an application of EUFASOM	P.M. Link, C.I. Ramos, U.A. Schneider, E. Schmid, J. Balkovic. R. Skalsky	submitted
UHH, BOKU, IIASA	Agriculture, Water	Agriculture, population, and resource availability in a changing world – the role of irrigation water use for integrated large-scale assessments	T. Sauer, P. Havlík, U.A. Schneider, G. Kindermann, and M. Obersteiner	submitted

UHH, BOKU, IIASA	Agriculture, Energy	Benefits of spatial data for European biomass energy assessments	U.A. Schneider et al.	in pipeline
UHH	Spatial Data Infrastructure	Improved Downscaling of Optimization Model Solutions through Goal Programming	U.A. Schneider	in pipeline
FELIS	Solar/Renewable Energy	A new thinking for renewable energy model: Remote sensing-based renewable energy model	International Journal of Energy Research, 33,778-786	published
FELIS	Solar/Renewable Energy	Improved Spatial Trend Model and Application to Biomass Consumption	Economic Energy	Submitted
THL	Health	”Effect of weather on the incidence of acute myocardial infarction in Finland”	Moltchanova E, Schreier N, Karvonen M. ”Effect of weather on the incidence of acute myocardial infarction in Finland” (abstract accepted for the 6th International Conference on Health Economics, Management & Policy, June 4-6, 2007, Athens, Greece;)	The full paper to be published in the proceedings
THL	Health	“Temporal variation in case fatality of acute myocardial infarction in Finland”.	Schreier NK, Moltchanova EV, Lammi NM, Karvonen ML, Eriksson JG. “Temporal variation in case fatality of acute myocardial infarction in Finland”. Ann Med 2008 Oct 14: 1-8	published
THL	Health	“Seasonal variation of diagnosis of Type 1 diabetes mellitus in children worldwide.”	Moltchanova E, Schreier N, Lammi N, Karvonen M. “Seasonal variation of diagnosis of Type 1 diabetes mellitus in children worldwide”. Diab Med, in press	in press

THL	Health	"Seasonal variation of the onset of type 1 diabetes among children worldwide".	Moltchanova E, Schreier N, Lammi N, Karvonen M. "Seasonal variation of the onset of type 1 diabetes among children worldwide". Diabetologia 2008, 51,S157 (Abstract volume for the 44th Annual Meeting of the European Association for the Study of Diabetes, Rome, 8-11 September, 2008)	published
THL + UBR		'The Value of Observations in Determination of Optimal Vaccination Timing and Threshold'		in progress
Eawag	Water	Time to break the silence around virtual-water imports	Liu J. and Savenije, 2008. H.H.G., 2008. *NATURE* 453 (7195) : 587	published
Eawag	Water	China's move to higher-diet hits water security	Liu J., Yang H., Savenije H.H.G., 2008. *NATURE* 454 (7203): 397	published
Eawag	Water	Global consumptive water use for crop production: The `importance of green water and virtual water	Liu, J., A. J. B. Zehnder, and H. Yang, 2009. Water Resources Research, 45, W05428	published
Eawag	Water	Using MODAWEC to generate daily weather data for the EPIC model	Liu J., Williams J.R., Wang X., Yang H., 2009. Environmental Modelling & Software 24(5): 655-664	published
Eawag	Water	A GIS-based tool for modelling large-scale crop-water relations	Liu J., 2009. Environmental Modelling & Software 24(3): 411-422.	published

Eawag	Water	A spatial explicit assessment of current and future hotspots of hunger in Sub-Saharan Africa in the context of global change	Liu J., Fritz S., van Wesenbeeck C.F.A., Fuchs M., Obersteiner M., Yang H., 2008. Global and Planetary Change 64 (3-4): 222-235.	published
Eawag	Water	Food consumption patterns and their effect on water requirement in China	Liu J., Savenije H.H.G., 2008. Hydrology and Earth System Sciences 12: 887-898.	published
IIASA	Energy	Optimizing biodiesel production in India	Applied Energy	published
IIASA	Energy	A new thinking for renewable energy model: Remote sensing-based renewable energy model	International Journal of Energy Research	published
IIASA	Energy	Optimal Location of Ethanol Ligno-Cellulosic Biorefineries with Polygeneration in Sweden	Energy (Just accepted)	published
IIASA	Weather	Fuss, S., Szolgayova, J. & Obersteiner, M., “A Real Options approach to satellite mission planning,” 2008.	Space Policy	published
IIASA	Energy	Fuss, S., Khabarov, N., Szolgayova, J. & Obersteiner, M., “ The effects of climate policy on the energy technology mix: An integrated CVaR and Real Options approach,” 2008.	In: Golub A & Markandya A (eds), Modeling Environment-Improving Technological Innovations under Uncertainty. Routledge, London, UK, [ISBN: 978-0-415-46376-8].	published

IIASA	Energy	Fuss, S., Szolgayova, J. "Fuel Price & Technological Uncertainty in a Real Options Model for Electricity Planning," 2009.	Applied Energy	published
IIASA	Disasters	J. Szolgayova, M. Obersteiner , S. Fuss, "Optimal Forest Management with Stochastic Prices & Endogenous Fire Risk," 2009.	Conference Proceedings of the 33rd International Symposium on Remote Sensing of Environment, Stresa, May 2009	published
IIASA	Energy	S. Fuss , N. Khabarov , J. Szolgayova , M. Obersteiner, "Valuing Climate Change Uncertainty Reductions for Robust Energy Portfolios," 2009.	Conference Proceedings of the 33rd International Symposium on Remote Sensing of Environment, Stresa, May 2009	published
IIASA	Energy	Fuss, S., Johansson, D., Szolgayova, J. & Obersteiner, M., "Impact of climate policy uncertainty on the adoption of electricity generating technologies," 2009.	Energy Policy	published
IIASA	Energy	N. Khabarov , S. Fuss , J. Szolgayova , M. Obersteiner, Extension of: "Valuing Climate Change Uncertainty Reductions for Robust Energy Portfolios,"		planned
IIASA	Energy	The Effects of Climate Policy on the Energy Technology Mix: An integrated CVaR and Real Options Approach.	Fuss S., Khabarov N., Szolgayova J., Obersteiner M., The Effects of Climate Policy on the Energy Technology Mix: An integrated CVaR and Real Options Approach. In: Modeling Environment-Improving Technological Innovations under Uncertainty, A. Golub and A. Markandya (eds), Routledge, London, UK, 2008.	published

IIASA	Energy	Valuing Climate Change Uncertainty Reductions for Robust Energy Portfolios.	Fuss S., Khabarov N., Szolgayova J., Obersteiner M., Valuing Climate Change Uncertainty Reductions for Robust Energy Portfolios. Proceedings of the 33rd International Symposium on Remote Sensing of Environment, Stresa, May 2009.	published
IIASA	Disasters	Valuing Weather Observation Systems for Forest Fire Management.	Khabarov N., Moltchanova E., Obersteiner M., Valuing Weather Observation Systems for Forest Fire Management. Systems Journal, IEEE, 2(3):349-357, 2008.	published
IIASA	Disasters	Value of Weather Observations for Reduction of Forest Fire Impact on Population.	Khabarov N., Moltchanova E., Obersteiner M., Value of Weather Observations for Reduction of Forest Fire Impact on Population. Proceedings of the 33rd International Symposium on Remote Sensing of Environment, Stresa, May 2009.	published
IIASA	Disasters	The Value of Observations for Reduction of Earthquake-Induced Loss of Life on a Global Scale.	Khabarov N., Bun A., Obersteiner M., The Value of Observations for Reduction of Earthquake-Induced Loss of Life on a Global Scale. Proceedings of the 33rd International Symposium on Remote Sensing of Environment, Stresa, May 2009.	published
IIASA	Disasters	Implementation and integrated numerical modeling of a landslide early warning system: a pilot study in Colombia.	Huggel C., Khabarov N., Obersteiner M., Ramirez J.-M., Implementation and integrated numerical modeling of a landslide early warning system: a pilot study in Colombia. Natural Hazards, Springer, April 2009, DOI 10.1007/s11069-009-9393-0	published

IIASA/THL	Disasters	The Value of Observations for Earthquake Rapid Response Systems	Elena Moltchanova, Nikolay Khabarov, Michael Obersteiner	submitted to the International Journal of Applied Earth Observation and Geoinformation
IIASA	Disasters	On Optimal Placement of Tsunami Detectors and Importance of Detector's Network Density for Tsunami Early Warning Systems	Nikolay Khabarov, Michael Obersteiner	In the pipeline (draft is available)
IIASA	Disasters	GEO Information For Disaster Recovery -- Case Study: The Use of Orthophotos in Aceh, Indonesia.	Kidd R, McCallum I, Fritz S, Kraxner F, Obersteiner M (2009). IIASA Interim Report IR-09-011 [September 2009, 49 pp].	published
IIASA	Disasters	Banda Aceh-The Value of Earth Observation Data in Disaster Recovery and Reconstruction: A Case Study.	McCallum I, Kidd R, Fritz S, Kraxner F, Obersteiner M (2008). IIASA Interim Report IR-08-048 [November 2008, 24 pp].	published
UBR	Climate Water	Long-term Danube monthly discharge prognosis for the Bratislava station using stochastic models	Meteorological l Journal. Slovakia, ISSN 1335-339X 10 (2007), 211-218.	published
UBR	Climate Water	Analyzing temporal changes in maximum runoff volume series of the Danube River.	In IOP Conference Series: Earth and Environmental Science: IOP Electronic Journal 4 (2008), p. 12007	Published
UBR	Climate Water		Acta Hydrologica Slovaca. 9(2008), 77-88.	Published
UBR	Climate Water	Analysis of statistical characteristics of daily precipitation at Hurbanovo in different periods: Part II Frequency analysis	Acta Hydrologica Slovaca, 2009, vol. 10, No. 1, 134–140.	Published
		Supplementation of the mean		

		monthly water temperatures in the Danube at Bratislava station in period 1901–1925		
UBR	Health Disasters	Socio-economic impacts of pandemic influenza mitigation scenarios in Slovakia	Journal of Economics 57(2009), 113-132	Published
UBR	Disasters Weather Climate	Risks due to variability of K-day extreme precipitation totals and other K-day extreme events	Journal of Hydrology and Hydormechanics	Under revision following the referees' comments
UBR	General	Quantifying benefits of information and knowledge		Planned
UBR	Disasters Climate Water	Hydrologic scenarios for the Danube River at Bratislava	KEY Publishing ISBN 978-80-87071-51-9	Published
UBR	Disaster Weather	Spatial Discretization of the Nesterov Fire Rating Index	Meteorological Journal	Under revision following referees' comments
UBR	Disaster Weather	Toward Spatially Variable Fire Risk Indices Based on Weather Data and Satellite Observations	ISRSE 33 Proceedings	published
URB	Water Climate	Statistical evaluation of runoff volume frequencies of the Danube at Bratislava	XXIV-th Conference of the Danubian Countries, Bled, Slovenia	published

UBR	Disasters	A Markov chain model for observation dependent disaster risk decision making		planned
UBR	Health	Towards a dynamic stochastic model of pandemic influenza		planned
PIK	Climate	"Climate Targets in an Uncertain World"		submitted
PIK	Climate	"The Implications of Future Information for Climate Policy"		in the pipeline
BOKU / KTL	Climate Change / Agriculture	Strauss, F., Schmid, E., Formayer, H., Moltchanova, E., and X. Wang (2009): Climate Change and Likely Near Future Development of Ecological Indicators in the Marchfeld Region of Lower Austria.	Working paper	In progress
BOKU / KTL	Climate Change / Agriculture	Strauss, F., Schmid, E., Formayer, H., and E. Moltchanova (2009): Simulation of climate scenarios and sensitivity analysis with the bio-physical process model EPIC.	Proceedings of the 33rd International Symposium on Remote Sensing of Environment (ISRSE): Sustaining the Millennium Development Goals. Stresa, Lago Maggiore, Italy. 4-8 May 2009. http://isrse-33.jrc.ec.europa.eu/	published
BOKU / KTL	Climate Change / Agriculture	Strauss, F., Schmid, E., and E. Moltchanova (2009): Simulation von Klimaszenarien und die ökonomische und ökologische Bewertung verschiedener Pflanzenproduktionsverfahren im	In: H. Peyerl (eds). Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie. Band 18/3, Facultas, Wien, 107-116.	published

		Marchfeld.		
BOKU / KTL	Climate Change / Agriculture	Strauss, F., Schmid, E., and E. Moltchanova (2009): Simulation of climate scenarios and the bio-economic assessment of different agricultural management systems in the Marchfeld region.	In: van Ittersum, M.; et al. (Eds.), Integrated Assessment of Agriculture and Sustainable Development; Setting the Agenda for Science and Policy. Proceedings of the AgSAP Conference, Egmond aan Zee, The Netherlands, 10-12 March, 2009. pp. 428-429. http://www.conference-agsap.org/	published
BOKU / KTL	Climate Change / Agriculture	Strauss, F., Schmid, E., and E. Moltchanova (2008): Simulation von Klimaszenarien und Auswirkungen auf Pflanzenertrag und Bodenkohlenstoff im Marchfeld.	Klimaforschungsinitiative AustroClim (Hrsg.), Klima, Klimawandel und Auswirkungen, Tagungsband 2008	published
BOKU / KTL	Climate Change / Agriculture	Strauss F., E. Schmid, und E. Moltchanova (2008): Simulation von Klimaszenarien und die ökonomische und ökologische Bewertung verschiedener Pflanzenproduktionsverfahren im Marchfeld.	Tagungsband der 18. Jahrestagung der Österreichischen Gesellschaft für Agrarökonomie. Universität für Bodenkultur Wien, Wien 18. – 19. September 2008. 37-38.	published
BOKU / IIASA	all	Heumesser, C., and M. Obersteiner (2009): Identifying challenges in the provision of GEOSS. An evaluation based on game theoretic and economic concepts.	Proceedings of the 33rd International Symposium on Remote Sensing of Environment (ISRSE): Sustaining the Millennium Development Goals. Stresa, Lago Maggiore, Italy. 4-8 May 2009. http://isrse-33.jrc.ec.europa.eu/	published

BOKU / SSCRI	Agriculture	Heumesser, C., Schmid, E., and R. Skalsky (2009): Evaluating the efficiencies of crop production systems within an Integrated Data Envelope Framework for the European Union.	Proceedings of the 33rd International Symposium on Remote Sensing of Environment (ISRSE): Sustaining the Millennium Development Goals. Stresa, Lago Maggiore, Italy. 4-8 May 2009. http://isrse-33.jrc.ec.europa.eu/	published
BOKU / SSCRI	all	Heumesser, C. (2008): Designing of research coalitions in promoting GEOSS. An overview of the literature.	Discussion paper, DP-40-2008; BOKU University, Institute for sustainable economic development	published
BOKU / SSCRI	Agriculture	Heumesser, C., Schmid, E., and R. Skalsky (2009): Evaluating the efficiencies of crop production systems within an Integrated Data Envelope Framework.	Working paper	In progress
BOKU	Agriculture / Climate Change	Schwab, D.E., R.C. Izaurralde, W.B. McGill, J.R. Williams, and E. Schmid (2009): A stoichiometric model of nitrification in soils and the production of nitrous oxide under partly anaerobic conditions.	Global Biogeochemical Cycles	submitted
BOKU / UHH	Agriculture / Biodiversity	Schönhart, M., E. Schmid, and U.A. Schneider (2009): Crop Rotation Modelling for Integrated Environmental Assessment using Field and Farm Land Use Data.	Agricultural Systems	submitted
BOKU / IIASA	Energy	Schmidt, Jh., S. Leduc, E. Dotzauer, G. Kindermann, and E. Schmid (2009): Potentials for biomass fired combined heat and power plants in Austria considering the spatial distribution of biomass supply and heat	International Journal of Energy Research	submitted

		demand.		
BOKU/UHH/IIASA	Agriculture	Schneider, U.A., E. Schmid, B.A. McCarl, and M. Obersteiner (2009). Agricultural adaptation to climate policies under technical change.	Environmental Management	submitted
BOKU/UHH/IIASA	Agriculture	Schneider, U.A., P. Havlík, E. Schmid, M. Obersteiner, Ch. Llull, R. Skalsky, T. Sauer, and St. Fritz (2009). Food production impacts of alternative global development scenarios.	Population and Environment	submitted
BOKU/UHH/IIASA	Agriculture / Energy	Havlík P., A.U. Schneider, E. Schmid, H. Böttcher, St. Fritz, R. Skalský, K. Aoki, St. de Cara, G. Kindermann, F. Kraxner, S. Leduc, I. McCallum, A. Mosnier, T. Sauer, and M. Obersteiner (2009). Global land-use implications of first and second generation biofuel targets.	Energy Policy	submitted
BOKU/UHH/SSCRI	Agriculture / Energy	Link, P.M., C.I. Ramos, U.A. Schneider, E. Schmid, J. Balkovič and R. Skalský (2008), The interdependencies between food and biofuel production in European agriculture - an application of EUFASOM.	Biomass and Bioenergy	submitted
BOKU/IIASA	Energy	Leduc, S., E. Dotzauer, E. Schmid, and M. Obersteiner (2009). Methanol from Gasification: A	Energy Economics	submitted

		Facility Location Problem.		
BOKU	Agriculture	Schönhart, M., M. Penker, and E. Schmid (2009). Sustainable Local Food Production and Consumption – Challenges for Implementation and Research.	Outlook of Agriculture. 38/2, 175 - 182.	published
BOKU/IIASA	Energy	Leduc, S., E. Schmid, M. Obersteiner, and K. Riahi (2009). Methanol production by gasification using a geographically explicit model.	Biomass and Bioenergy. 33/3, 745-751.	published
BOKU/IIASA	Energy	Leduc, S., D.E. Schwab, E. Dotzauer, E. Schmid, and M. Obersteiner (2008). Optimal Location of Wood Gasification Plants under Poly-Production.	International Journal of Energy Research. 32, 1080-1091.	published
BOKU/UHH	Agriculture / Climate	Schneider, U.A., B.A. McCarl, and E. Schmid (2007): Agricultural Sector Analysis on Greenhouse Gas Mitigation in U.S. Agriculture and Forestry.	Agricultural Systems. 92, 128-140.	published
BOKU	Agriculture Biodiversity	Schönhart, M., Th. Schauppenlehner, and E. Schmid (2009): Integration of biophysical and economic models for spatially explicit land use and landscape analysis at farm level.	In: van Ittersum, M.; et al. (Eds.), Integrated Assessment of Agriculture and Sustainable Development; Setting the Agenda for Science and Policy. Proceedings of the AgSAP Conference, Egmond aan Zee, The Netherlands, 10-12 March, 2009. pp. 274-275. http://www.conference-agsap.org/	published

BOKU/UHH/IIASA	Agriculture	Havlik, P., U.A. Schneider, E. Schmid, H. Böttcher, G. Kindermann, S. Leduc, M. Obersteiner (2009): GHG mitigation through bio-energy production versus avoided deforestation and afforestation: A quantitative analysis.	In: van Ittersum, M.; et al. (Eds.), Integrated Assessment of Agriculture and Sustainable Development; Setting the Agenda for Science and Policy. Proceedings of the AgSAP Conference, Egmond aan Zee, The Netherlands, 10-12 March, 2009. pp. 416-417. http://www.conference-agsap.org/	published
BOKU/UHH/IIASA	Agriculture / Climate Change	Fritz, S. P. Havlík, U.A. Schneider, E. Schmid, R. Skalský and M. Obersteiner (2009). Uncertainties in global land cover data and its implications for climate change mitigation policies assessment	Proceedings of the 33rd International Symposium on Remote Sensing of Environment (ISRSE): Sustaining the Millennium Development Goals. Stresa, Lago Maggiore, Italy. 4-8 May 2009. http://isrse-33.jrc.ec.europa.eu/	published

Annex III Selected GEO-BENE Publications by SBA

III.1. CROSS-SBA Publications by GEO-BENE Consortium Partners

III.2. SBA AGRICULTURE Publications by GEO-BENE Consortium Partners

III.3. SBA BIODIVERSITY Publications by GEO-BENE Consortium Partners

III.4. SBA CLIMATE by GEO-BENE Consortium Partners

III.5. SBA DISASTERS by GEO-BENE Consortium Partners

III.6. SBA ECOSYSTEMS by GEO-BENE Consortium Partners

III.7. SBA ENERGY by GEO-BENE Consortium Partners

III.8. SBA HEALTH by GEO-BENE Consortium Partners

III.9. SBA WATER by GEO-BENE Consortium Partners

III.10 SBA WEATHER by GEO-BENE Consortium Partners